

Identifying social transformations and crisis during the pre-Monastic to post-Viking era on Iona: new insights from a palynological and palaeoentomological perspective

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Abstract

The island of Iona is renowned for its early monastery, founded following the arrival of Columba in AD 563. Our knowledge for this period is improved by the availability of written records produced during the first 200 years of the establishment's life; however, between the late 8th and 12th centuries, northern Britain experienced severe political and social upheavals, and a decline in written records. This paper uses palaeoecological data to provide additional insights into the social and environmental transformations that influenced the landscape of Iona in the prehistoric and historic periods. Notwithstanding age inversions in the prehistoric sequences, the identification of cereal pollen suggests that some arable farming occurred during the Bronze-Age. Evidence of arable farming is inconclusive for the Iron-Age, although there is some indication that pastoral farming was practiced. A gap in the palaeoecological record means that it remains unclear as to whether there were people living on the island at the time of the monastic community's arrival. A more secure palaeoecological sequence is recorded during the early monastic period. Between AD 630 and 1100, the monastic community was involved in woodland clearance, and pastoral and arable farming, but within this period there were two phases of woodland regeneration and agricultural decline. The first phase coincides with a prolonged period of Viking raids and may have witnessed a decline in population. The second phase occurred at a time of increased Scandinavian influence and political restructuring in the wider region; however, small-scale farming continued. After ~AD 1000, there was renewed intensification of landscape management prior to the arrival of Benedictine monks and Augustinian nuns ~AD 1200, which may be linked to climatic amelioration during the Medieval Warm Period and economic growth in the Hebrides.

Keywords: Iona, Scotland, Early Medieval, Bronze Age, Iron Age, pollen, insect, Coleoptera, landscape management, Viking raids, Monastic

1. Introduction

The island of Iona is renowned for formerly being an ecclesiastical power centre, and for its role in the spread of Christianity throughout Scotland and northern England during the Early Medieval period. The island has undergone numerous social transformations since prehistoric times although very little is known about its early inhabitants. Very few prehistoric sites have been excavated and

those that have lack a secure radiocarbon chronology. Based predominantly on lithic finds, the earliest archaeological evidence of human activity on Iona dates to the Mesolithic and Neolithic ~6500-3500 BC (Barber, 1981; RCAHMS, 1982, Ellis 2017). Other finds include prehistoric pottery from Glebe Field just to the south of Iona Abbey (Will, 2014), and at least one stone axe and a carved stone ball believed to be Neolithic in age. None of this prehistoric evidence is well contextualised (RCAHMS, 1982). Iona's Bronze Age record is equally sparse. A burial cairn at Blàr Buidhe is the only potential Bronze Age monument on the island (RCAHMS, 1982), although a late Bronze Age midden deposit has been identified on the west side of the island south-east of Dùn Cùl Bhuirg fort and near to Port Bàn (Alexander, 2008a & b, Fig. 1), dated between 930 and 810 BC. Excavations of the midden revealed a coarse stone tool, small friable fragments of pottery, numerous limpet shells, and burnt and unburnt bone of domesticates and wild animals (Alexander, 2008a). The best-known prehistoric site on Iona is the Iron Age fort at Dùn Cùl Bhuirg (Fig. 1). Excavations between 1957 and 1969 discovered extensive occupation debris including pottery sherds, two yellow glass beads, animal bones (mainly cattle, but also sheep, pig, deer and seal) and a small roundhouse with a central stone-built hearth on the east side of the fort (Ritchie and Lane, 1978-80). Renewed analysis of the pottery (Topping, 1985; MacKie 2007) identified the sherds as Everted Rim Ware, and while there is no absolute chronology for this site, the morphology of the two yellow glass beads, together with the pottery sherds, suggests occupation between 100 BC and AD 300. On the east of the island, south of Iona Abbey, excavations identified a midden deposit which produced prehistoric and historic artefacts. Pottery sherds were predominantly undiagnostic, although a fragment of one vessel may belong to the early monastic period, whilst a few of the pottery sherds also recovered from an upper layer of the buried soil appear to date from the mid-first century AD. A date of AD 980-1060 was obtained from a piece of carbonised hazel recovered from a basal buried soil (Ellis, 2009 & WoSAS, 2018).

An archaeological hiatus occurs across the 3rd-6th centuries AD. What became of the Iron Age community, or whether a lay community could have been present on the island at the arrival of the monastic community, is uncertain. The precise arrival of the monastic community on Iona is also uncertain, although the monastery was probably founded sometime shortly after St Columba and his fellow monks set sail to Scotland from Ireland in AD 563. Iona became a spiritual powerhouse, establishing daughter monastic houses in Ireland and Britain (Herbert, 1988; Fraser, 2009). It played a significant role in the spread of Christianity among the English, and probably also amongst the Picts, and in some areas was involved in organising lay worship through its bishops and priests (Fraser, 2009). Iona was not just a spiritual centre and exemplar of Christian life, but it was also a focus of culture, legal knowledge, literature, art, and learning with important works produced in Latin and Gaelic, ranging from poetry to chronicles, saints' lives, legal texts (Herbert, 1988; Clancy, 1998, p.95-117; Fraser, 2009, 69-83), and perhaps the lavishly decorated gospel book known as the Book of Kells (Meehan 2012).

Peace and presumably prosperity prevailed until the AD 790s, when a series of Viking attacks over a thirty-year period had a potentially devastating impact on the monastic community. Many monks were slaughtered, and others fled (as recorded in the *Annals of Ulster* and *Annals of Inisfallen*: Yeoman and Scott, 2016, p.60-61, Jennings, 1998, p.37-39, Woolf, 2007, p.57-59). Iona had been part of Gaelic-speaking Dál Riata, which from the AD 730s was also often under the control of the Pictish kingdom based in eastern Scotland (Woolf, 2007). However, in the period from about AD 800

to 1100 the western seaboard and isles of Scotland were settled and conquered by Scandinavians, a process reflected in the Scandinavian place-names found throughout the region (Jennings and Kruse 2009a & b), although gradually, Gaelic language and culture re-established their dominance in the area (Clancy, 2011b). From the twelfth-century onwards the Gaelic elites of the area were influenced by the Scandinavian world, Ireland, the expanding kingdom of the Scots, and by European developments, such as reformed monasticism, which made an impact on Iona when a Benedictine monastery and a nunnery of the Augustinian order were established there around AD 1200 (RCAHMS 1982, 49, 143, 178).

These later foundations were to a considerable extent a continuation of the pre-existing monastic community on Iona, but its history from AD 800 to the twelfth century is poorly understood. In the ninth century, the movement of relics of Columba to and from Ireland and to Dunkeld in Perthshire are recorded, and in the early part of the same century a new Columban monastery was founded at Kells in Ireland (Herbert, 1988). It has been suggested that these events, regarded as a result of the Viking raids, meant that the monastery of Iona was no longer the head of the Columban monastic federation, with its leadership divided into Irish and Scottish branches based at Kells and Dunkeld respectively (Smyth 1984, 147; Bannerman 1993). However, it has been argued that Iona maintained its pre-eminent position in the Columban *familia* of monasteries until perhaps the early tenth century (Herbert 1988) or the late tenth or early eleventh century (Clancy 2011a). Opinion has been divided on the impact of Scandinavian raids on Iona. Some scholars have proposed that Iona ceased to have a monastery, with only maybe a skeleton community from AD 807 to 814 (Jennings 1998) or until sometime after the raid of AD 825 (Smyth 1984, 147), while another view is that Iona's monastic community remained substantial throughout the ninth century (Herbert 1988; Clancy 2011a). What is likely, from the continued use of the title 'Abbot of Iona' (Jennings 1998), is that any near-abandonment would not have been very long, so it is likely that a monastic community was present on the island by AD 900, considerably before the mid-tenth century, when there is evidence indicating that it had by then Christianised Scandinavian rulers based in Dublin and the Hebrides as patrons (Clancy 2011a).

While the documentary sources provide some evidence for the history of Iona, especially across the period from AD 563 to 740, the socio-environmental impacts of Viking attacks on Iona and other ecclesiastical and political upheavals between the 8th-13th centuries are unclear. The purpose of this current investigation, through the integration of historical, archaeological and palaeoenvironmental analyses (an examination of pollen, non-pollen palynomorphs [NPPs], beetles and ¹⁴C dating of sediments extracted adjacent to and from recent archaeological excavations of the monastic banks and ditch), is to better understand the social transformations that took place during the prehistoric and historic periods. In particular, the research aims to fill in some of the gaps in knowledge regarding early monastic settlement and the socio-environmental impacts of Viking raids and Scandinavian influence, as well as providing some wider context for these findings.

2. Site details

The island of Iona lies within the Inner Hebrides of western Scotland, 1 km to the west of the island of Mull (Fig. 1). It has a relatively low-lying topography with the highest peak at 101 m above sea level. The island is 5.5 km in length and varies in width from 1.5-2.5 km (RCAHMS, 1982). The geology mainly consists of granitic Lewisian gneiss, but also includes Torridonian sandstone and

basic Lewisian gneiss (Balaam in Reece, 1981; Geological Survey of Scotland, 1925). The main vegetation today comprises herbaceous grass and heathland, which includes *Salix repens* (creeping willow) and *Juniperus* (juniper). Today, there are very few trees on Iona, although some *Corylus avellana* (hazel), *Alnus* (alder) and *Quercus* (oak) can be found in more sheltered coastal gullies (Iona Community Council, 2018).

Previous palynological work (Fig. 1) has been undertaken on Iona by: Balaam (in Reece, 1981) – on buried peat beneath the vallum banks; Bohnke (in Barber, 1981) – from the base of the vallum ditch and Lochan Mòr; Tipping (in McCormick, 1993) – again on buried peat beneath the vallum bank; and by Scaife & Dimbleby (1990) – at a peat basin less than a kilometre northwest of the Abbey. Scaife and Dimbleby (ibid.) present palynological data from a shallow peat which they suggest is representative of the full Holocene period. Unfortunately, the record does not have a radiocarbon chronology. Tipping (1993) argues that there are grounds to believe that this is not a complete stratigraphic record due to the absence of distinctive mid-Holocene marker horizons, e.g. the *Alnus* rise. The pollen records from the vallum banks and ditch are thought to represent the early and pre-monastic periods, although identification of taxa has produced some contrasting results. For example, birch is poorly represented in the record produced by Balaam (1981) but is well represented in the sequences of Tipping (1993), Scaife and Dimbleby (1990), and Bohnke (1981; notably zone IOF 4). Oak and ash representation also vary between publications. Balaam (1981) analysed pollen from the western ditch, and Tipping (1993) analysed pollen from the inner vallum bank. Both authors found no evidence for *Fraxinus* (ash trees) and only rare representation of *Quercus* (oak). Bohnke (1981) on the other hand, identified high representation of oak and ash pollen from the southern ditch prior to AD 600 (zone IOF2), suggesting that ash-oak woodland was present on the island at the time of the monastery's foundation. The previous palynological work is constrained by a lack of robust chronologies and incomplete stratigraphic records. Despite this, pastoral farming is supported in all the previous pollen investigations, whilst arable farming appears to be represented in the pollen records generated by Bohnke (1981), and Scaife and Dimbleby (1990).

There have been no studies of insect remains from previous archaeological excavations on the island. The present-day beetle fauna has been little investigated, although a list of 937 beetle species occurring on the Inner Hebrides compiled by Welch (1983) includes a limited number of records for Iona.

3. Materials and Methods

3.1 Sample selection

The sampling was designed to include both on-site and off-site material. In 2017 a trench cut across the enclosure banks and ditch, originally excavated in 1956 by Charles Thomas, was re-opened at Site A on the western edge of the monastic enclosure (Campbell & Maldonado 2016; Campbell and MacIver, 2017) (Fig. 1). Two monolith tins were used to extract sediments for supporting environmental analysis (centred on NGR NM 28670 24517) within and adjacent to the trench (Fig. 1). Monolith one (Context 109, sample numbers SY112, SY111 & SY110) was taken from trench A, sampling well-humified dark black peat located under the inner monastic bank (Fig. 2). Micromorphological analysis of this sequence was undertaken by Elliot (2019). The base of SY110

was identified as being an *in situ*, very thin and compact buried soil. The rest of the sequence between SY110-SY112 consists of layers of turves and sediments, none of which appear to have formed *in situ*, except for a burnt horizon in SY111 and a thin accumulation in SY112. Elliot (2019) suggests that these were probably removed from different areas of the site and may account for the inverted nature of some of the radiocarbon ages (discussed below). Monolith two (Contexts 126-124; sample number HY17A129) was extracted from the lower levels of the ditch in trench A (Fig 2). Despite the potential risks posed by erosion and redeposited turves, it was hoped that some of the samples from the ditch would be undisturbed and exhibit relatively good microfossil preservation, to provide palaeoenvironmental evidence from a landscape dating to the period before the establishment of the monastery and during the initial monastic construction period. Analysing pollen from archaeological contexts in undisturbed sediments (preservation permitting) allows direct comparison with the archaeology, which in this case aimed to better understand the timing and phases of the vallum construction. Due to the absence of a chronology from Tipping's buried peat profile, and contrasting findings arising from the previous pollen-base studies (Scaife and Dimbleby, 1990; Bohncke, 1981; Tipping, 1993; and Balaam, 1979), it was hoped that additional pollen analyses with a better chronology would clear up some of these discrepancies and support one or other of the earlier interpretations.

In addition to the monolith tins, a 1.05 m core (Core 1, Context 141) was collected using a Russian corer immediately south of the Benedictine Abbey church, adjacent to trench one of Site A (Fig 1, C, C1). It was hoped that this would provide a continuous sequence to fill in any gaps displayed in the monolith sequences, and improve understanding of environmental changes associated with social change and crisis spanning the pre-monastic to post-Viking era on Iona up until the Benedictine period. The location of the coring site was chosen such that it was beyond the direct impact of any construction or slope wash. To minimise the risk of secondary deposition from the slopes of the monastic banks, the core was extracted from the middle of a small peat-filled depression. The pollen source area is described by Tipping (1993) and by Bohncke (1981) as probably predominantly local. This is important as it means a more concentrated representation of social-environmental indicators is likely within the samples, and thus a more robust understanding of the impacts of social change can be developed.

All of the sites analysed have been sampled for non-pollen palynomorphs (NPPs) (Van Geel, 1976) and a single sample, adjacent to monolith two was also extracted for insect analysis from context 124 (sample <123>), from the basal fill of the ditch in trench A (Fig. 2). These proxies have not been previously analysed on Iona. A multi-proxy approach helps to fill in gaps or uncertainties by providing additional or supporting information regarding human habitation, landscape management and social change. After extracting the sediments, the stratigraphy was described briefly in the field and in more detail in the laboratory using the nomenclature of Troels Smith (1955).

3.2 Laboratory preparation and analyses

3.2.1 Pollen

Pollen samples were prepared using the conventional methods outlined in Fægri *et al.* (1989), including the additional step of density separation (Nakagawa *et al.* 1998). A representative minimum sum of 300 to 500 total land pollen (TLP) (cf. Birks and Birks, 1980) was counted for all sub-

samples where possible. Identification was aided by reference keys in Fægri *et al.* (1989), Moore, *et al.* (1991), Beug (2004) and Reille (1999), and supported by a modern type-slide reference collection housed at the University of Aberdeen. As *Myrica* and *Corylus* pollen are difficult to separate (Edwards, 1981), these species have been grouped as *Corylus avellana*-type. *Cereal*-type are classified as grains greater than 38 μm in diameter and with an annulus size greater than 8 μm (Moore *et al.*, 1991, Anderson, 1979, Beug, 2004). All of the grains identified were circular in shape and thus most likely to belong to either *Hordeum*, *Triticum* or *Avena*, although it should be acknowledged that some wild grasses are also incorporated into this group (Tweddle *et al.*, 2005).

Standards of pollen preservation were assessed in order to better understand the taphonomic processes influencing pollen representation. Damaged pollen grains have been divided into four main categories, adapted from Cushing, (1967), Delcourt and Delcourt (1980) and Tipping (1987). Categories include broken, crumpled, corroded/degraded-identifiable and corroded/degraded-unidentifiable. Broken and crumpled categories would have been influenced by mechanical processes, such as breakage during transport, whilst corroded/degraded grains would have been subject to chemical weathering, such as oxidation (Cushing, 1967; Delcourt and Delcourt, 1980). The pollen and spore data are expressed as a percentage of total land pollen (TLP), with spores and aquatic taxa excluded from the sum. NPPs were also counted during routine pollen analysis and were identified using information presented in Bakker and van Smeerdijk (1982), van Geel (1976, 1978), van Geel *et al.* (1980-81, 1983, 1986, 2003), Haaster (1984), Kuhry (1985, 1997), Pals *et al.* (1980) and van der Wiel (1983). NPPs are expressed as a percentage of total NPPs. Microscopic charcoal particles greater than 10 μm in length were counted and are represented as total frequency. The pollen diagrams were constructed and delineated using CONISS software as part of the Tilia and Tilia.graph version 1.7.16 package (Grimm, 2011).

3.2.2 Insects

Insect remains were extracted by paraffin flotation (Kenward *et al.* 1980), with recovery on 0.3 mm mesh. Beetle (Coleoptera) and bug (Hemiptera) sclerites were subsequently removed from the paraffin flot onto moist filter paper for examination under a low-power stereoscopic zoom microscope (x10–45). Identification was assisted by comparison with modern insect material and with reference to standard published works. Taxa were divided into broad ecological groups with interpretation based on Kenward *et al.* (1986) and Kenward (1997). Aquatics were subtracted from the rest of the assemblage to calculate percentages for the terrestrial fauna. Nomenclature follows Duff (2012) for Coleoptera, and the British Bugs website for Hemiptera (Bantock and Botting 2018). Information on host plants of plant-feeding species has been obtained from the British Bugs website, Harde (1984), Hodkinson and White (1979), Le Quesne (1960), Morris (1997, 2008, 2012), Nau (2004) and Southwood and Leston (1959), unless otherwise stated. The sample produced a large, generally well-preserved assemblage of beetles and bugs (a minimum of 324 individuals of 152 taxa, an estimated concentration of 108 individuals/litre of sediment). Fragmentation was low but a proportion of the remains showed signs of degradation in the form of surface erosion, thinning and colour loss, and some sclerites were wrinkled or pitted.

3.2.3 Loss-on-ignition

Loss-on-ignition (LOI) was conducted on core 1 between 90-0 cm following the conventional methods outlined in Heiri *et al.* (2001). Due to small sample sizes, LOI could not be completed for sediments deeper than 90 cm.

3.2.4 Radiocarbon analyses

Twelve samples were extracted for AMS ^{14}C dating; one birch twig and 11 bulk peat, from which the humic acid fraction was measured (Table 1). These analyses were undertaken at the SUERC Radiocarbon Laboratory in East Kilbride, Scotland. This includes four samples from each monolith and core one. Sediments were screened for macro-fossils but only a single macrofossil (a birch twig) was identified as suitable for dating; this was taken from monolith two. The birch twig was extracted at the same depth and context as one of the bulk peat samples in order to compare any potential age differences between the bulk samples and macro-remains. A peat sample was also dated between contexts 125 and 124 as part of the 2017 archaeological excavations. This has been included in Table 1 because it is located directly above the peat and birch samples extracted from monolith two. Dates were calibrated using the OxCal Bayesian modelling program version 4.3 (Bronk Ramsey, 2009, 2013) and the InCal13 calibration curve (Reimer *et al.* 2013). The Poisson-process deposition model: P_Sequence was used to produce an age-depth model for core 1 (Fig. 3). This model was chosen on the assumption that sediment accumulation is unlikely to have been uniform over time. The basal and top ages of the model were determined based on the top and bottom depths of the sediment sequence and are therefore open to some error, given that no radiocarbon ages were available at these depths. The extrapolated ages produced by the model should therefore only be considered as an estimate of the potential age and not as a precise measurement.

4. Results

4.1 Chronology

The radiocarbon dates are shown in Table 1. Calibrated ages are expressed as AD/BC ages at 95% probability. Both monoliths produced inverted ages towards the top of the sequences. The bottom of monolith one (Figure 4; vallum bank, context 110-109, sample 112) dates to the Bronze Age (~1610-1430 BC) and represents the buried soil described in Elliot (2019). The upper sequence (context 109, samples 111 and 110) produced inverted Iron Age and Early Medieval ages, probably caused by upturned turves or the slumping of turves during the construction of the banks (Campbell and Maclver, 2017; Elliot, 2019). Monolith two (Figures 5-7; the vallum ditch) produced three radiocarbon ages from bulk sediment and one from a birch twig. The lowest radiocarbon dates from context 124 suggest that peat accumulation either began between AD 580-660 (SUERC-75763, peat) or AD 680-770 (SUERC-77872, birch twig). The birch twig is much younger than the peat sample and is also similar in age to a peat sample dated directly above between contexts 125-124 (SUERC-75764, AD 660-800; extracted from excavated peat). This would suggest that the birch twig has been reworked. The older peat deposit (SUERC-75763) is similar in age to Barber's (1981) radiocarbon age from the base of ditch 1 (AD 585 ± 55 ; AD 600-635 when calibrated) and is thus probably more reliable. The age range however, does not represent the initial monastic period but as proposed by Barber (1981) is likely to be representative of a later construction period, for ditch 1 and the vallum banks in the Trench A location. The ^{14}C ages produced from monolith two at 2 cm (385-204 BC) and at 23 cm (160 BC-AD 20) are inverted (both from context 126); a distinct transition in the stratigraphy and pollen/NPP record suggests the reversal probably begins between 42-36 cm

(context 125). It is quite plausible that eroded sediments fell into the ditch from the monastic banks of the vallum. Although the age inversions from both monoliths prevent a continuous chronology, it has been possible to gain brief chronological snapshots of environmental information spanning this period (discussed further in sections 3.3 and 4).

The radiocarbon dates from core 1 appear to be in chronological order and modelled ages range from AD ~630 to ~1600. An abrupt transition observed in the pollen diagram (Figure 8) occurs at 90 cm and may signify a hiatus. If so, the modelled ages might be slightly younger than actual ages, particularly between zones 1-3 where the two bottom age ranges are very similar. Rapid sediment accumulation is also suggested by the age-depth model between ~AD 630-1000 which begins well before a drop in LOI around ~AD 830 (80 cm). The LOI results point to peat at the base of the core (Fig. 8); however, some mineral matter has been identified in the stratigraphy (section 3.2) and these changes might reflect mineral in-wash during the nearby construction and maintenance of the vallum banks and ditch. The two basal ages are statistically not possible to separate; justification that these are separate ages is based on the pollen record which highlights distinctly different environments. SUERC-77861 is located in zone 2, where a gradual increase and then dominance in birch trees is represented, whilst SUERC-75772 is located in zone 3, which shows a significant decline in birch and a rise in herbaceous taxa and willow.

4.2 Stratigraphy

The stratigraphy is represented in Table 2 for monolith 1, monolith 2 and core 1

4.3 Beetles, pollen and non-pollen palynomorphs

Beetle and bug results are presented in Table 3 and Figures 6-7. Summary curves for trees, shrubs (constituting arboreal pollen, AP), dwarf shrubs and herbs (non-arboreal pollen, NAP) are shown in Figures 4, 5 & 8. NPP terminology follows van Geel (1978) using the prefix (HdV-) followed by the type number.

4.3.1 Monolith one

Monolith one does not represent a continuous sequence of events, but rather two independent archaeological units which can be treated as 'snapshots' of time. The lower unit (110-109, <112>) is likely to represent the buried soil described in Elliot (2019), and Campbell and Maclver (2017), and produced a Bronze Age date (~1610-1430 BC). The overlying unit (109, <111-110>) produced inverted Early Medieval to Iron Age dates (Table 1) caused by the redeposition of turves during the construction of the Early Medieval monastic banks. The pollen sequence from the buried soil (110-109, <112>) is reliable as this has formed in situ; however, the sediments above (109, <111-110>) have potentially been mixed.

General vegetation components

In both archaeological units, tree and shrub pollen comprise approximately 25-65% TLP with *Betula* and *Corylus avellana*-type well represented, suggesting that deciduous woodland/scrub was present on Iona in each of the time periods. *Betula* is a pioneer species (Hynynen *et al.* 2010) which may have been able to better tolerate Iona's exposed hyper-oceanic conditions than other deciduous tree taxa, such as *Quercus* and *Ulmus*, which may have been restricted to less exposed locations. Other tree and shrub taxa recorded include *Salix* and *Alnus*, indicative of moist ground/wet

woodland (Brown *et al.*, 2007). However, *Salix repens* has been reported on the moorland of Iona today (Iona Community Council, 2018) and is often associated with drier conditions and tends to be common on sand dunes (JNCC, 2018). *Pinus* and *Fraxinus* are also recorded in mainly trace amounts. *Pinus* is an abundant pollen producer which can travel long distances, and probably represents a more regional component, perhaps from the neighbouring island of Mull and/or mainland Scotland. Local pine representation can vary greatly, and some authors have demonstrated that pine pollen percentages can occasionally fall below 5% TLP even in instances where the tree is locally present (e.g. Lageard *et al.*, 1999; Bennett, 1984, 1995; Fossitt, 1994; Brown, 1991). *Fraxinus* is known to be a poor pollen producer, and thus very low representation could still indicate a local presence. As well as the tree-shrub components, wet grassland/marsh is suggested by the frequent occurrence of high Poaceae, Cyperaceae and Rubiaceae pollen. *Filipendula* is also frequently present. This plant is often associated with marshes, or can be found alongside streams, rivers and ditches (Brown *et al.*, 2007). Dry heathland taxa also form part of the vegetation communities on Iona, and *Calluna vulgaris* is well-represented.

Archaeological Unit (110-109), <112>, ~1610-1430 BC

This unit displays potential evidence of human activity during the Bronze Age in both the pollen and NPP records. This includes *Glomus cf. fasciculatum chlamydospores* (HdV-207, >5% TNPP), which is often associated with erosion, although Kolaczek *et al.* (2013) suggest that it can also be naturally present on host plants growing on bogs. Herbaceous pollen taxa often associated with disturbance and/or pastoral activities are also recorded, including Apiaceae, *Artemisia*, Asteraceae, *Plantago lanceolata* and *Potentilla*-type (Brown *et al.*, 2007). With the exception of *Sordaria* (HdV-55A/B), coprophilous dung fungi are not recorded during this time. This might reflect a limited amount of pasture close to the sampling location, although *Sordaria* may also be indicative of decayed wood. After ~1370 BC, cereal-type pollen grains are absent from the record.

Archaeological Unit (109) <111-110>, inverted AD 420-345 BC

A more pronounced human signature is potentially represented within this time period despite the inverted ages. This is suggested by a stronger representation of herbaceous taxa associated with disturbance (e.g. *Artemisia*, *Potentilla*-type and *Plantago lanceolata*), pastoral activity (including higher Poaceae values), and trace amounts of Caryophyllaceae, Lactuceae, *Plantago undiff.*, and Ranunculaceae pollen (Brown *et al.*, 2007). There are higher amounts of microscopic charcoal in the Iron Age deposits, but these may originate from the *Calluna*-dominated moorlands (e.g. Legg *et al.*, 1992) as *Calluna* percentages are also higher in the upper part of the pollen diagram. Cereal-type pollen grains are not represented except for a single occurrence at the top of the sequence.

4.3.2 Monolith two

Monolith two (Fig. 5) is subject to taphonomic issues (which are also reflected by age inversion). It has therefore been divided into two archaeological units: 1) Unit (124) <129>, the lower ditch sediments, which are believed to date to AD 580-660 (see section 3.1); and, 2) Unit (125-126) <129>, which produced inverted Early Medieval to Iron Age dates (AD 20-560 BC), most probably caused by human-induced erosion. Elliot (2017) suggests the organic rich deposits at the base of the ditch (context 124) may have formed soon after the ditch was cut, whilst in context 125 an increase in silt is likely to have been caused by erosion. Burnt bone fragments were also identified in this unit.

Archaeological Unit (124) <129>, AD 580-770

This unit is characterised by >50 TLP% arboreal pollen, indicative of woodland close to the sampling location; an interpretation supported by the beetle record (see below). The most prominent arboreal taxa are *Betula* and *Salix*. *Alnus* and *Salix* may have been growing close to, or in, the ditch and/or may have formed wet woodland. The presence of grassland is reflected by Poaceae pollen percentages of approximately 20% TLP. A variety of herbs often associated with pasture and/or disturbance are recorded (e.g. *Rumex*, *Plantago lanceolata*, *Ranunculaceae*, *Asteraceae*, *Apiaceae*, and *Potentilla*-type; cf. Behre, 1981; Brown *et al.*, 2007). To a lesser extent, pollen and spores from plants of wetter substrates are notable, these plants perhaps being associated with the ditch itself. They include Cyperaceae, Rubiaceae, *Filipendula*, *Sphagnum* and Pteropsida monolete undiff. Taxa typical of heathland (e.g. *Calluna* and *Pteridium*) are also present.

Archaeological Unit (125-126) <129>, inverted 560 BC- AD 20 (\pm 275)

The radiocarbon dates show an age reversal in this unit. Based on the change in stratigraphy and in microfossil assemblages, there appear to be clear differences in the pollen and NPP record which provide a suitable change to place a boundary (between 42 cm and 36 cm) between the suggested earlier and later deposits e.g. characterised by lower *Betula*, *Salix*, microscopic charcoal, Tracheids, *Spirogyra* and higher *Corylus avellana*-type, Poaceae, *Calluna* and *Glomus cf. fasciculatum chlamydospores* (HdV-207).

This unit is characterised by open moist/wet woodland, although *Salix* (2-5% TLP) representation is lower than in context (124). Deciduous woodland was present, despite a decrease in *Betula* (20-30% TLP), with the occasional presence of *Quercus*, *Ulmus*, *Corylus avellana*-type and *Fraxinus* is recorded at 10 cm. Both grassland and heathland expand with sizeable increases in Poaceae (20-45 % TLP) and *Calluna* (15-25% TLP) pollen. A rise in other herbaceous taxa (10-20% TLP), particularly *Plantago lanceolata* and undiff., and *Asteraceae*, *Chenopodiaceae*, *Lactuceae*, *Potentilla*-type, and *Rumex* is indicative of an intensification in anthropogenic disturbance and pastoral activities compared to Zone 1. Cereal-type pollen are consistent in this zone. *Sordaria* (HdV55A/B), a possible coprophilous fungi (van Geel *et al.*, 2003), was also recorded at 36 cm and is a further indication of grazing. At the same time microscopic charcoal shows a notable increase. Minor occurrences of *Spirogyra*, *Mougeotia*, HdV'-66 and HdV-128 indicate the presence of shallow eutrophic to mesotrophic water, possibly in the ditch.

Insect results from the base of the ditch (context 124), <123>, Tables 3 & 4:

The insect remains were extracted from the same context as the pollen samples analysed in unit (124), <129>. A nearby woodland component is supported by the insect fauna with at least 12% of the terrestrial taxa associated with the foliage of living shrubs and trees. These include *Oncopsis* planthoppers (consistent with several closely similar species found on birch) and the shield bug *Elasmotethus interstinctus*, which principally feeds on birch (see Table 3). Other woodland/scrub indicators included *Drymus brunneus*, a ground bug (Lygaeidae); *Dalopius marginatus*, a small click beetle (Elateridae); *Ocys harpaloides*, a ground beetle (Carabidae) (Luff 2007, 75); and *Grynobius planus*, a member of the woodworm beetle family (Ptinidae). Over a quarter of the beetle and bug assemblage indicates aquatic conditions in the ditch. *Hydroporus incognitus*, the most numerous

water beetle, is typically found amongst dead leaves in small, shaded, often temporary, water bodies (Foster and Friday 2011, 84; Foster *et al*, 2016, 220). Other aquatics noted were larvae of caddis flies (Trichoptera) and non-biting midges (Chironomidae), ostracod carapaces and water flea ephippia (Cladocera: resting eggs). Damp ground/waterside taxa accounted for 9% of terrestrial beetles and bugs, the majority being *Cyphon* species found in marshy places with shallow standing water that are probably indicative of conditions within the ditch. *Conomelus anceps* (a leafhopper) is found on rushes (*Juncus*). Heathland and grassland components are also supported in the insect record: *Micrelus ericae*, *Scolopostethus decoratus* and *Strophingia ericae*, together accounting for 2% of the terrestrial fauna, are associated with heathers, and the spiked shield bug (*Picromerus bidens*) is often associated with heathland; the brown chafer (*Serica brunnea*), orchid beetle (*Dascillus cervinus*) and coprophilous beetles Geotrupinae and *Aphodius* spp. are all characteristic of grassland. Coprophiles accounted for 4% of the terrestrial taxa. Decomposers other than coprophilous beetles accounted for 14% of the terrestrial fauna, and around a third of these are regarded as being synanthropic to some degree. A small but distinctive group of beetles (3% of terrestrial insects) suggests that some of this material came from within buildings: *Ptinus* cf *fur*, *Lathridius minutus* group, *Mycetaea subterranea*, and *Atomaria* are all typical members of an ancient 'building fauna' (Hall and Kenward 1990; Kenward and Hall 1995; Carrott and Kenward 2001). A flea (Siphonaptera) represented by partial male genitalia could not be identified since the identifiable parts were missing and the surviving portion was not illustrated in identification guides (Smit 1957; Whitaker 2007). As this material must have been deposited in the ditch from outside the monastic enclosure, this is the first confirmation that there were ancillary buildings outside the enclosure, though this had been suspected from literary references to barns and other buildings (MacDonald 1997, 41).

4.3.3 Core one (141): AD ~640 to ~1600 (Fig.8)

Zone 1: AD > 600 (105-96 cm)

This zone is characterised by low percentages of *Betula* and *Corylus avellana*-type with *Quercus*, *Fraxinus*, *Ulmus*, *Crataegus/Sorbus*-type and *Sambucus* as minor constituents indicative of deciduous woodland. Trees and shrubs associated with wetter substrates primarily consisted of *Salix* although its representation declined throughout the zone (from 20 to 5% TLP) as *Betula* increased simultaneously (from 8 to 25 %TLP). The dominant land use was grassland, some of which may have been used for pasture. This is suggested by high percentages (35-40%TLP) of Poaceae and the presence of herbaceous taxa (~20 %), commonly associated with disturbance or pasture, such as *Artemisia*, Apiaceae, Asteraceae, Brassicaceae, *Potentilla*-type, Lactuceae, *Plantago lanceolata*, *Rumex* and Ranunculaceae (Brown *et al.*, 2007). Coprophilous fungi, notably *Sordaria* (HdV-55A/B), *Cercophora* (HdV-112), *Sporormiella* (HdV-113) and *Tripterospora* (HdV-169) are consistently recorded (van Geel *et al.*, 2003) and, together with the herbaceous pollen taxa, provide evidence for pastoral activities close to the monastic site. A constant, low representation of cereal-type pollen suggests arable farming was practised locally. Evidence for wetter grassland and marsh is provided by the recording of Cyperaceae, *Filipendula*, *Iris*, cf. *Lotus*, *Urtica*, *Equisetum* and Rubiaceae (although certain species are regarded as arable weeds) Low levels of heathland, perhaps on higher ground, may have surrounded the vicinity of the monastic enclosure as *Calluna*, the presence of *Viola* and *Pteridium* are recorded Bracken is often the dominant plant on heathland but also represents a pioneer plant, able to colonize open land quickly (MoorPLANTS, 2012). Aquatic pollen

such as *Potamogeton*, *Callitriche* (pondweeds/water-starworts) and *Isoetes* (quillworts) indicate the continued presence of standing water, perhaps associated with the nearby ditch.

Zone 2: AD > 690-870 (96-90 cm)

This zone represents a marked rise in deciduous woodland taxa, notably *Betula* (55-80 TLP%). Other deciduous and wet tree and shrub taxa are present including *Quercus*, *Ulmus*, *Fraxinus* and *Alnus*, although *Salix* declines to below 10 % TLP). A downturn in human activity is suggested by the decline in NAP taxa indicative of grassland, heathland, marsh, pasture and cultivated land. The zone is characterised by the absence or lower amounts of cereal-type pollen and the recording of less Poaceae, Cyperaceae, *Calluna*. Most of the other NAP, aquatic and spore taxa also decline. These changes are most likely to be the result of changing land use/practices and pollen taphonomic effects as the presence of *Betula* very close to the sampling site could filter out other local and regional pollen components due to the over representation of *Betula*, especially those taxa known to be poor pollen producers and dispersers such as cereal pollen (cf. Heide and Bradshaw, 1982). The absence of the coprophilous fungi *Sordaria* (HdV-55A/B) and *Sporormiella* (HdV-113) indicates a reduction in the amount of grazing.

Zone 3: ~AD 680-880 (90-77 cm)

This zone begins with an abrupt change in pollen and NPP percentages, e.g. *Betula*, *Salix*, Poaceae and *Equisetum* (horsetails), which might indicate a hiatus. A large reduction in total arboreal pollen is represented by a pronounced decline in *Betula* (to below 25 % TLP) and less frequent occurrence of other tree taxa except for *Salix*. Initially *Salix* increases (to > 20 % TLP) but then declines throughout the zone (to 5 %TLP), suggesting a short-lived phase of regeneration of wet woodland. Increased representation of grassland is suggested by higher Poaceae percentages (35-45 % TLP, and a suite of NAP and NPP taxa, suggestive of arable and pastoral farming. This includes the reappearance and consistent presence of cereal-type pollen, the occasional presence of coprophilous fungi (*Sporormiella* (HdV-113), *Sordaria* (HdV-55A/B), *Cercophora* (HdV-112) and *Podospora* (HdV-368)) and by a rise/presence in herbaceous pollen taxa with cultural affinities (e.g. *Artemisia*, Lactuceae, Asteraceae, Chenopodiaceae *Plantago* undiff., *Plantago lanceolata*, *Potentilla*-type, Ranunculaceae, *Rumex*). Evidence of burning is indicated by sporadic occurrences of *Gelasinospora* (HdV-1/2) and by a slight increase in micro-charcoal (0-10 counts). Heathland persists although *Calluna* percentages are low, ~5 % TLP and *Pteridium* is regularly recorded. The presence of open water is suggested by aquatic pollen such as *Callitriche*, *Nuphar*, *Typha*, *Potamogeton* and by the eutrophic algae *Spirogyra*. Marsh/wet grassland seems to have formed around the sampling site, with Cyperaceae, *Pteropsida* monolete undiff., trace amounts of *Iris*-type, *Filipendula*, Apiaceae, Rubiaceae and high percentages of *Equisetum*.

Zone 4: AD ~880-1100 (77-57 cm)

An increase in woodland is indicated by higher amounts of *Betula* (25-45 %TLP), *Quercus* (2-5 %TLP), *Corylus avellana*-type (15-20 %TLP) and by a more consistent presence of *Ulmus* and *Fraxinus*. Wet woodland is indicated by consistent percentages of *Alnus* (2-5 %TLP) and *Salix* (1-7 %TLP). Coincident with the increase in trees and shrubs, NAP taxa percentages decrease, although grassland remains with Poaceae prominent with percentages exceeding 20 %TLP. A less intensive farming regime is suggested by a decline in herbaceous taxa commonly associated with pastoral farming (notably *Plantago lanceolata* and Ranunculaceae; Brown *et al.*, 2007). *Sporormiella* (HdV-113) and other coprophilous fungi percentages also remain very low (below 2 %TNPP) but still occur more

sporadically. Arable farming is also represented by the presence of cereal-type pollen. Despite the increase in deciduous tree cover, *Calluna* shows a pronounced increase (10-20 %TLP) suggesting an expansion of heathland, which could also support *Betula* and *Corylus avellana*-type. It is quite tempting to associate these changes with reduced grazing (Gwynne *et al.*, 1974; Gimingham, 1972). *Calluna* and *Corylus avellana*-type appear to increase simultaneously with micro-charcoal (50-110 counts) and corroded/degraded pollen grains (5-55 %TLP), as LOI decreases. These changes may reflect people using fire as a tool to manage the local heathland (e.g. Gimingham, 1972; Hobbs *et al.*, 1984). In the latter part of the zone *Plantago lanceolata* slightly increases and other NAPs also display a wider diversity and/or increase. This includes the Asteraceae, Chenopodiaceae, Caryophyllaceae, Fabaceae and the NPP *Sporormiella* (HdV-113). More land was possibly devoted to farming at the expense of woodland as the total tree pollen percentage falls towards the end of the zone ~ AD 900-1025.

Open water persists, possibly in the ditch at the site, with aquatic algae more consistently recorded in this zone, including *Botryococcus*, *Nuphar*, *Pediastrum* and *Spirogyra*; Type HdV-128 is occasionally present. Aquatic plants are also more regularly represented (e.g. *Myriophyllum*, *Callitriche* and *Potamogeton*).

Zone 5: ~AD 1000-1600 (57-26 cm)

This zone is marked by a pronounced but gradual decrease in woodland and a strong increase in human activity marking the lowest representation of total tree taxa in the pollen record, especially *Betula*, which declines across the zone 4/5 boundary (from 12 to 3 % TLP). An expansion of grassland is suggested by increased Poaceae pollen. Pastoral activities and disturbance are represented by a strong increase in herbaceous taxa, notably Apiaceae, Asteraceae, Lactuceae, *Plantago lanceolata*, *Plantago* undiff., Fabaceae, *Polygonum*, Caryophyllaceae, Ranunculaceae and *Rumex*, and are further supported by a marked rise in *Sordaria* (HdV-55A/B), *Sporormiella* (HdV-113) and *Cercophora* (HdV-112). *Sordaria* however, can also be associated with dead wood (van Geel 1980-1981). Arable farming probably still persists, represented by low but consistent values of cereal-type pollen. An increase in *Glomus cf. fasciculatum chlamydospores* (HdV-207) may be associated with increased erosion, particularly given the rise in herbaceous taxa, low LOI and high micro-charcoal counts, but it could equally have been naturally growing on host plants (Kolaczek *et al.*, 2013). Whilst there is also a decline in the marsh and aquatic pollen (such as *Potamogeton*), other aquatic pollen are present, including *Callitriche* and *Myriophyllum*, as well as the algae *Zygnema* and *Spirogyra*, which suggest the continued presence of shallow eutrophic water.

5. Discussion

5.1 Bronze-Iron Age

Monolith one (Inner monastic bank) contains the oldest sediments of the three sites investigated, spanning the mid-Bronze Age. Unfortunately these sediments also produced inverted Early Medieval-Iron Age ages but despite the chronological limitations it has been possible to obtain some environmental information from the monoliths. During both the Bronze Age and inverted Early Medieval-Iron Age the Iona landscape likely consisted of woodland, heathland (dominated by *Calluna*) and grassland. *Betula* and *Corylus avellana*-type seem to have been the dominant tree/shrub taxa but other deciduous and wet woodland taxa, such as oak, elm, willow and alder,

probably existed in the more sheltered and on wetter substrates. Including the environment surrounding and within the vallum banks and ditch.

To date there are no confirmed archaeological sites on Iona spanning the early to mid Bronze Age, but a potential Bronze Age burial cairn has been recorded at Blàr Buidhe (RCAHMS, 1982). Low percentages of cereal pollen are represented in monolith one (~1670-1370 BC, {110-109} <112> unit), which may signify small scale arable farming nearby, and supports the existence of a community living on Iona during at least part of the mid-Bronze Age. Pastoral activities are also represented by *Plantago lanceolata*, *Rumex* and Apiaceae, and by a strong representation of grassland (Behre, 1981; Brown *et al.*, 2007), although supporting evidence in the coprophilous fungi record is scarce. Archaeological evidence for later Bronze Age occupation (~930-810 BC) is also provided by the Port Bàn midden deposit (Alexander 2008 a,b).

Dùn Cùl Bhuirg (100 BC - AD 300), slightly north-west of Port Bàn, provides evidence for a later Iron Age occupation, based around a pastoral economy. This is inferred from the zooarchaeology remains (mainly cattle, but also pig, sheep/goat) but wild animals, including deer and seal, were also important (Ritchie and Lane, 1978-80). Arable farming may have been practised as well, at/near to Dùn Cùl Bhuirg since two pottery sherds were identified with glume incursions similar in appearance to barley. Some caution should however be applied with the interpretation of glume incursions, as these could equally have originated from imported pottery. No pollen or NPP analysis has been carried out on the west of the island; however, farmsteads, enclosures and cultivation ridges have been identified on numerous surveys of Iona and may in future provide stronger evidence for arable farming, but currently these are of undefined age (CANMORE, 2018). Unfortunately, no cereal grains were identified in the inverted Iron Age sediment deposits from monolith one (unit: (109), <111-110>), although monolith two does show a weak but continuous presence of cereal-type pollen in the inverted sediments (unit: (125-126), <129>). Scaife and Dimbleby (1990) have identified cereal pollen as well which may span the Iron Age; but this evidence lacks an absolute chronology.

Despite the limited evidence of cereals, further late Iron Age activity has been identified during archaeological excavations on the east of the island. McCormick (1993) for example, recorded an early date of 40 BC-AD 220 from underneath the western enclosing bank of the monastic enclosure, which indicates some sort of burning event substantially prior to the establishment of the monastic settlement. Higher amounts of microscopic charcoal were identified in the inverted sediments of monolith one (unit: (109), <111-110>) but could equally be representative of natural or human-induced fires. One of the sediment samples in this unit (AD ~25-130) however, also contained coprophilous dung fungi, perhaps indicative of low intensity pastoral activity. In addition to these findings Roman pottery, found during excavations at the monastic site, has been dated to the 2nd century AD by Dore (1992, 212), whilst Ellis (2009; Wosas, 2018) tentatively identified some pottery sherds dating from the mid-first century AD during the excavation at Oran cottage, to the south of the monastic site.

4.3 Early – Late Medieval (AD <580 – 1600)

4.3.1 Early Monastic Period

The archaeological evidence described above, supported to some extent by the palaeoecological record, demonstrates that people were living on Iona at least until the 2nd or 3rd century AD, in the west at Dùn Cùl Bhuirg and on the east of the island. What is less clear is whether there was a community still living on Iona at the time of St. Columba's arrival in the 6th century AD. Scaife and Dimbleby (1990) argue the pollen record shows continuity of agriculture during the first half of the first millennium AD, through to the monastic period, but the evidence is unreliable due to the absence of a ¹⁴C chronology. Chronological gaps in this current investigation means the question remains unresolved. It is also unlikely that the initial arrival of the monastic community is represented in this current palaeoecological sequence. However, the early life of the monastery including a slightly later construction period for the vallum bank and ditch (Barber, 1981; Campbell and MacIver, 2017 from the Trench A location) is likely represented by monolith two, in the sediment unit of context (124), <129> (Figure 5). Despite an age-inversion in the upper sediment unit (contexts (125-126), <129>), the chronology of context (124), <129> probably falls between AD 580-630, which is comparable with the AD 600-635 age proposed by Bohncke (1981). The pollen record in monolith two, unit (124), <129> (124), <129>, indicates the presence of woodland dominated by willow and birch during the early stages of monastic settlement. This seems to reflect no or only limited woodland scrub clearance compared to after ~AD 630 (see core 1; Fig. 8) although these results are not comparable with Bohncke's ditch 1 pollen profile (1981) and may simply reflect local trees-shrubs growing close to the ditch of the sample location. The insect assemblage also supports the presence of nearby woodland/scrub vegetation growing close to the ditch. Away from the immediate vicinity of the ditch, the environment appears to have been relatively open dominated by grassland and heathland (identified in both the insect and pollen records). Apart from possible increased evidence for fire, which may not necessarily be anthropogenic, there is very limited evidence of human activity in the pollen record of monolith two, unit (124), <129> (AD 580-630), compared to monolith two, unit (125-126), <129> (AD 20-385 BC), although some of these signals have perhaps been suppressed by the high representation of birch pollen. This is in contrast to the insect record which does provide some evidence of human occupation and activity during the initial monastic period. For example, coprophilous scarabaeoid beetles account for 4% of the terrestrial taxa, a proportion that modern studies suggest would indicate low-level 'naturalistic' grazing (Smith *et al.* 2010; 2014), or perhaps grazing more distant from the sampling site. The presence of synanthropic decomposers also provides a hint that limited amounts of waste from human occupation had entered the ditch and that some of this material may have originated within buildings (e.g. *Ptinus cf fur*, *Lathridius minutus* group, *Mycetaea subterranea*, and *Atomaria*). *Mycetaea subterranea* is strongly synanthropic with 20th century records mainly from decaying straw and wood in dry cellars, barns and stables and in association with the dry rot fungus *Merulius lacrymans* (Hinton 1945, Palm 1959).

A more continuous sequence is represented by Core 1 (Fig. 8) which spans the period from ~ AD >640 until AD 1600. The monks living on Iona from AD 563 onwards would likely have brought with them new knowledge and agricultural innovations to improve agricultural production; this included the use of horizontal mills (although a much later innovation), which were in use by at least the 8th century AD (RCAHMS, 1982, p.25; and Sharpe, 1995 book iii 23: p.227 & no. 406, p.373). This current investigation suggests that by AD ~640 the monastic community were having a discernible impact on the landscape compared to the Bronze and Iron Ages in terms of woodland clearance and arable and pastoral farming. Woodland clearance is generally represented by a much lower representation of

arboreal taxa, notably birch, and strong representation of open ground taxa, indicated by a higher representation of grass and herbs compared to monolith one. Episodes in the *'Life of Columba'*, written by Adomnán, Iona's abbot from AD 678 to 705, describe the monastery transporting by boat bundles of withies (for building a guest-house), and during Adomnán's abbacy oak and pine (to construct a long ship, a 'great house', and for repairs) from the western mainland using multiple vessels, indicating that the main construction/building resources had to be obtained from elsewhere (Sharpe 1995: II.3, p.155; II.45, p.201; n.213, p. 318). However, it is highly likely that the monastic community made use of the remaining wood resources in the locality as well as importing, particularly birch, hazel, willow and alder. Barber (1981) for example identified several wooden products from ditch 1 of the monastic site. This included wooden bowls made out of willow and alder, as well as a variety of worked wood, stakes, pegs and pins belonging to hazel, oak, birch, alder, poplar, ash and pine.

The microscopic charcoal record (Figure 8) from core 1 suggests that fire was not a prominent occurrence (deliberate or natural) and had little influence on the vegetation. Arable farming is represented by small and consistent increases in cereal-type pollen, and supports the previous findings of Bohncke (1981) and Scaife and Dimbleby (1990). These results also compare favourably with Adomnán's accounts (Sharpe, 1995) who frequently mentions the use and production of cereal grain. For example, the text refers to barley being grown by the Columba community (II 3: p.115-116; I 37, p.139-140); the presence of a baker and a bakery (III 10: p.213); a corn kiln for drying and threshing corn (I 45: p.148); and a barn containing two heaps of grain that could provide enough bread for a year (III 23, p.226). These sources show that most of this arable activity took place on the western side of the island, where there is a large area of machair grassland, at some distance from the core sites reported here. The historical evidence together with the palaeoecological records highlight the importance and success of arable farming during the early monastic period.

Pastoral farming is suggested (AD >640) by the presence of coprophilous fungal spores commonly associated with herbivores (van Geel, 1978), the earlier occurrence of scarabaeoid coprophilous beetle fauna AD <580 and by the presence of NAP taxa strongly associated with pasture (Behre, 1981; Brown *et al.*, 2007) including Ranunculaceae, *Plantago lanceolata*, Asteraceae, Lactuceae, Brassicaceae, *Potentilla*-type and *Rumex*. Despite the lack of reliable chronologies, pastoral farming appears to be supported in all the previous pollen investigations on Iona (Scaife and Dimbleby, 1990; Bohncke, 1981; Tipping, 1993; and Balaam, 1979). The pollen and NPP data also compliment zooarchaeological records conducted by McCormick (in Barber, 1981 and McCormick, 1993) and Noddle (in Reece, 1981). These studies suggest that cattle made up the main bulk of domesticated livestock, although pig, sheep/goat, horse and domesticated fowl were also present as well as a range of wild resources. This evidence is further supported in Adomnán's *'Life of Columba'* (Sharpe, 1995) where a number of references are made to the milking of cows: (II 16, p.166-167; III 23, p.227; II 38 p.187-188; no. 406, p.373), the killing of cows (II 29: p.178) and the keeping of cows on Iona (II 16: p.166 (by implication); II 28: p.177; II 29: p.177-178) as well as to the use of a number of other wild and domesticated resources.

4.3.3 Crisis AD 690-870

Marked changes in vegetation occur in core 1, zone 2, which may fall around AD 750; however, it is difficult to pinpoint the exact timing of this transition given that the radiocarbon ages could range between AD 690 and 870. This includes a pronounced increase in *Betula*-dominated woodland. A similar trend in *Betula* is represented in Bohncke's ditch record (1981), which he notes as a peculiar denticulated curve on his pollen graph and suggests this phenomena might be associated with coppicing. This is certainly a possibility although coppicing is difficult to detect from pollen records

alone with any degree of confidence (Waller *et al.*, 2012). Here it is proposed that Viking raids would have impacted woodland cover. By the late 8th century Iona would have been one of the wealthiest and most prestigious centres in the Hebrides but being an island adjacent to important maritime routes made it particularly susceptible to Viking attacks. The Irish annals (described in Jennings, 1998 & Yeoman and Scott, 2016) record a number of attacks on Iona spanning a 30-year period. The first took place in AD 795, again in AD 802, in AD 806 (when 68 members of the community were killed) and in AD 825 (Blathmac son of Flann, a rather distinguished Irish monk, met a violent death in this incident). The pronounced increase in *Betula* spans this time-frame; percentages may have recovered as the monastic population decreased after successive Viking raids until AD 825. Other marked changes in the pollen record include the absence of cereal-type pollen, coprophilous dung fungi and a sharp decline in herbaceous pollen (Fig. 8; zone 2). According to Jennings (1998), the impacts of Viking raids must have been psychologically devastating on the monastic community. The slaughter of monks and fleeing of some of the remaining monks would also have severely reduced available man-power. Indeed, the pronounced changes represented in the pollen record may signify a severe impact on the farming community; arable farming (although cereal representation may be partly masked by the high *Betula* percentages) seems to have been at least temporarily abandoned or severely diminished, with open conditions dramatically reduced, allowing the recovery of birch woodland/scrub. *Betula* is a fast grower, but it would still take at least 5-10 years to reach sexual maturity (Stace, 1991) and thus 5-10 years to produce pollen. Four samples show increased levels of *Betula* pollen, and therefore could potentially represent 20-40 years of severely reduced agricultural activity. The evidence of Core 1 therefore could support the view that the monastery of Iona was largely abandoned for a period as a result of Viking raids, with Kells and other places acting as refuges for its remaining monks. However, as Viking raids on Iona continued throughout this period, there must have been some occupation, perhaps sustained by food resources from other land holdings of the Iona community, which were extensive in the region. There are no other known events which can explain the sustained reduction in settlement on Iona; the Irish chronicles, whose focus was on Ireland after ca. AD 740, contains references to plagues, scarcity and bad snows from AD 740 to 820, but such notices were frequent in the preceding period too, when we have an 'Iona Chronicle' as a source, without any noticeable environmental impact, presumably because the Columban community could relocate monks from other monasteries to Iona.

4.3.4 Recovery AD 680-880

The eventual return of a monastic community is potentially represented in the Iona pollen record by an abrupt decline in *Betula* to below 20% TLP (zone 3, Figure 8), an increase in cereal-type, grassland, coprophilous fungi (*Podospora* (HdV-368), *Cercophora* (HdV-112), *Sporormiella* (HdV-113), *Sordaria* (HdV-55A/B)) and by a variety of herbs often associated with pasture (Asteraceae, Lactuceae, Brassicaceae, *Plantago lanceolata*, *Potentilla*-type, Ranunculaceae, Rubiaceae, *Rumex*, Apiaceae; Brown *et al.*, 2007). A slight increase in micro-charcoal and the presence of *Gelasinospora* (HdV1/2) also suggests a slight rise in burning, which given the rise in other anthropogenic indicators could well indicate deliberate burning as part of land management on the island. While Scandinavian or lay Gaelic settlement cannot be ruled out, the most likely explanation for the abrupt environmental changes is the return of the monastic community. In the ninth century there are references to movements of abbots of Iona and of Columba's relics in Britain and Ireland (Herbert, 1988, pp. 70–3; Clancy, 2003-4), probably as a means of maintaining their network of monasteries at a time when being focused on one centre was too risky. However, the continued use of the title 'Abbot of Iona' (Jennings 1998, p.42; Clancy 2003-4, pp.221–2) indicates that Iona was still regarded

as crucial to the Columban community, so the re-establishment of a monastery there would have been a necessity, even after the massacre of Blathmac and other monks on the island in AD 825 (Jennings 1998, p.39–41).

4.3.5 Agricultural decline AD >880-1000

Our understanding of the surrounding political and cultural context for the period from AD 800 to 1000 is still very uncertain, making it very difficult to connect social and political events taking place in Scotland with the palaeoenvironmental record. Iona was in the Gaelic cultural zone of Dál Riata in about AD 800 but had been incorporated into the Pictish kingdom located to its east and north (Woolf, 2007). By the mid-tenth century the Hebrides were dominated by Scandinavian rulers and settlers, whose elite was increasingly Christian, and Iona was their most prominent ecclesiastical centre (Clancy 2011a). Archaeologists currently tend towards a mid-ninth century date for Scandinavian settlement (Barrett, 2003), but the evidence is not conclusive, and there could have been periods of Viking political domination from the AD 790s onwards (Woolf 2007). Different islands could have had very different experiences of the Scandinavian impact. We do not know when Iona passed into Scandinavian hands, but presumably after then the monks of Iona had to find an accommodation with them in order to survive.

Vegetation changes represented in the pollen record between AD 880 and 1000 (Fig 8), suggest both a regional decline in human activity and a local increase in human activity, and these changes may reflect social changes within the Iona community. The most notable change in the pollen record in this zone is the expansion of deciduous and wet woodland taxa, particularly *Betula*, *Quercus* and *Alnus*. A reduction in pastoral activities also seems to have occurred with a decline in herbs and NPPs associated with pasture including *Plantago lanceolata*, Ranunculaceae and *Sporormiella* (HdV-113), until some recovery by the ~10th century AD. A slight increase in cereal-type pollen (2.3-3.6 TLP%) reflects the continued practice of arable farming; perhaps signifying a more local focus on resource management in response to population decline, with arable farming relocated closer to the abbey. Bohncke's (1981) ditch sequence also identifies a slight increase in cereal pollen in zone IoF4, which may be of the same time period. Other potential anthropogenic signatures include a rise in both *Calluna* (heather) and *Corylus avellana*-type. The fact that microcharcoal increases at the same time, whilst LOI decreases significantly might suggest people were using fire as a tool to manage the local heathland, rather than indicating a reduction in grazing animals (e.g. Gimingham, 1972; Hobbs *et al.*, 1984;). The fires could on the other hand be natural. Overall, the evidence indicates a decline in activity, rather than abandonment. The changes, which date to between AD 880 and 900, may reflect problems faced by Iona's inhabitants. In AD 878, a terse item in the Irish chronicles describing the relics and shrine of Columba being taken to Ireland in flight from the Vikings (Herbert, 1988, p.73), could, refer to relics moved from Iona to Kells and/or Dunkeld. Certainly, the AD 860s and 870s represent a peak period of Viking activity in Britain, so it is plausible that Iona would have been affected adversely. The increase in woodland is most likely simply a result of a reduced population, but there is a chance that, if the monastery thought sufficiently long-term, it might have intentionally allowed useful woodland species to grow on the island, since it presumably had less reliable access to its former supplies in its regional hinterland given the continued risk of sea crossings to Viking attacks.

By AD 900, *Plantago lanceolata* representation increases slightly, whilst the Asteraceae, Chenopodiaceae, Caryophyllaceae, Fabaceae, *Sporormiella* (HdV-113) and *Sordaria* (HdV-55A/B) show increases, likely associated with increased disturbance and a recovery in pastoral farming. This might reflect a policy of enhancing the monastery during the abbacy of Máel Brigte mac Tornáin

(891–927) or simply a less planned recovery of the pre-existing island community. There is however, no way of knowing if these signals are purely due to the activities of the monastic community or whether a lay population of local or Scandinavian descent. By the late tenth century AD most Scandinavian arrivals to the Hebrides had converted to Christianity and the continued religious importance of Iona is demonstrated through runic inscriptions on grave stones, representing Christian burials of people of likely Scandinavian descent (Jennings, 1998). The repentance and pilgrimage of the Viking king of Dublin (Amlaíb, son of Sihtric) to Iona in AD 980 after losing the battle of Tara suggests that Iona remained a significant centre; indeed, Amlaíb later died on Iona (recorded in the *Annals of Tigernach*; Woolf, 2007). Moreover, the importance of the island is also indicated by the Scandinavian raid on Iona of AD 986, that resulted in the death of the abbot and 15 senior clerics (Clancy 2013) [i.e. his Christmas Raid article]. The Norwegian king, Magnus Barelegs, also visited Iona in AD 1098 coming to the church of Columcille as referenced in the saga account of his Hebridean expedition (RCAHMS, 1982. P.42). In terms of potential evidence of Norse settlement, archaeological work conducted at Glebe Field (Will, 2014) just south of the Abbey has uncovered a large number of Norse period artefacts, supporting the view that Norse influence was prominent on Iona in this period which all likely date between the 9th and 12th centuries AD, including a copper alloy pin, the rim from a steatite carved stone bowl and a small whetstone. The Norse pin may date between the 9th and 10th centuries AD (WOSAS, 2019).

4.3.6 AD >1000

After AD 900-1025, more pronounced clearance, pastoral and arable farming is represented in the pollen record (zone 5; Fig 8). These changes occurred before the arrival of Benedictine monks and Augustinian nuns on the island in about AD 1200. Evidence is provided through a decline in tree taxa, notably *Betula*, but also *Salix*, subtle decreases in heathland and shrubs, subtle increases in Poaceae and significant increases in herbs, notably of Asteraceae but Caryophyllaceae, *Plantago lanceolata* and undiff., *Rumex* and Apiaceae also show increases. NPPs indicative of erosion (e.g. *Glomus cf. fasciculatum chlamydospores* (HdV-207)), and grazing *Sordaria*-type (HdV-55A/B) and *Sporormiella*-type-type (HdV-113) increase. Agricultural expansion could potentially be associated with relative prosperity in Norse-dominated Hebrides from the tenth century onwards (Williams 2004; Sharples and Smith 2009). This may have assisted in the development of the Gaelic-led monastery on Iona; however, it may also reflect increased agriculture and population found across Europe during the climatic optimal of the Medieval Warm Period (MWP- AD 800-1300) (Bartlett, 1993, p.106–66). Based on oxygen isotope ratios from limpet shells, Mobililia (2009) suggests that the MWP, at least in northern Scotland (Quaygre, Orkney Islands), experienced greater seasonality with warmer summer temperatures than today but colder winters. Drier conditions during the summer would have allowed an increase in agricultural productivity. The impact of the later climatic deterioration of the Little Ice Age, beginning after AD 1300, is not evident in this sequence.

5. Conclusion

Iona has been inhabited since prehistoric times, but our knowledge for this period is limited due to a lack of published archaeological research and secure radiocarbon chronologies from the Mesolithic to the early Medieval period. This current investigation focusses on the period between 1600 BC and AD 1600, and demonstrates how combining palaeoecological, archaeological and historical evidence can produce a clearer understanding of past societies, social transformations and the impacts of crisis that occurred on a small but important island in western Scotland. The identification of cereal

pollen ~1670-1370 BC as well as herbaceous taxa often associated with pasture or disturbance, suggests small-scale arable and pastoral farming was being practiced during the Bronze Age. Despite a number of age inversions and a gap in the palaeoecological record, clearance and potential pastoral indicators are represented in the Iron Age which support previous archaeological findings at Dùn Cùl Bhuirg. Evidence for arable farming during this period however, remains inconclusive. It also remains unclear if there were still inhabitants on the island at the time of St. Columba's arrival.

Despite lacking the initial monastic period this study provides evidence from both pollen and beetle analysis of early monastic activity and likely confirms Barber's proposal for the later construction period for the vallum banks and ditch 1 between AD 580 and 630 after the monks had become established. The insect remains include a small element associated with human occupation and activity, including a 'building fauna', and coprophilous beetles relating to the presence of grazing animals. During the early monastic period from AD ~640 there is evidence of woodland clearance, arable and pastoral farming. Historical records document more than 200 years of peace and prosperity and the environmental evidence indicates a successful arable and pastoral economy. However, a series of violent Viking raids beginning in the late 8th century, spanning almost a thirty-year period are documented in the annals and these appear to have had a dramatic effect on land use. The island may have been either temporarily abandoned or activities of the monastic population were dramatically curtailed. This period of crisis and relocation of at least part of the monastic community is reflected in the pollen record by a pronounced rise in birch woodland and brief disappearance of anthropogenic indicators including cereal pollen, with farming either briefly abandoned or severely reduced. Evidence from historical sources suggests an eventual return of the monastic community in the first half of the ninth century but it may have taken a substantial period of time for settlement and agriculture to recover. Recovery is associated with a decline in tree taxa (suggesting clearance) and the return of arable and pastoral indicators. We propose a slightly later rise in birch pollen is associated with another decline in human population, and could be a result of increased instability related to Scandinavian activities in the region; however, the pollen record suggests the island was not abandoned completely. A slight increase in cereal pollen together with a continued pronounced representation of grassland may signify a more local focus on resource management in response to population decline, with arable farming relocating closer to the abbey. After AD 900 anthropogenic activity gradually increased once more and by AD 1000 intense land management (in terms of clearance, pastoral farming and disturbance) is represented in the environmental record, well before the arrival of the Benedictine and Augustinian communities in about AD 1200. This may reflect a period of prosperity after Scandinavian settlement and conversion to Christianity in the Hebrides, and/or associated with more favourable climatic conditions during the Medieval Warm Period, which would have increased productivity encouraging a larger population and economic growth on the island.

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List of Tables:

1. Radiocarbon dates and their respective calibrated ages (BC/AD) from monoliths 1, 2 and from core one. One radiocarbon sample is also included from the 2017 archaeological excavation between contexts 124 and 125 as reference is made to this date in the text. Uncalibrated radiocarbon ages are quoted in conventional years BP. Calibrated ages were calibrated using the OxCal Bayesian modelling program version 4.3 (Bronk Ramsey, 2009, 2013) and the InCal13 calibration curve (Reimer et al. 2013) and are to two sigma calibration (95.4 % probability). $\delta^{13}\text{C}$ values are relative to VPDB. Detailed descriptions of the methods employed by the SUERC Radiocarbon Laboratory can be found in Dunbar et al. (2016)
2. Stratigraphy for monolith one, monolith two and core 1
3. Habitat and food preferences of strongly plant-associated beetles and bugs

Lab No.	Depth (cm)	Thickness (cm)	{Context No.} & <Sample No.>	Material Type	$\delta^{13}\text{C}$ values	Conventional uncalibrated age (^{14}C yr BP)	Calibrated Age AD/BC
SUERC-75765 Monolith one	3-4 cm	2 cm	{109} <110>	Bulk sediment Peat - humic acid	-29.8 ‰	3226 ± 31	1610-1430 BC
SUERC-84823 Monolith one	7-8 cm	2 cm	{109} <111a>	Bulk sediment Peat - humic acid	-29.4 ‰	1915 ± 26	AD 25-130
SUERC-84824	9-10	2 cm	{109} <111b>	Bulk sediment	-29.2 ‰	1679 ± 26	AD 260-420

Monolith one	cm			Peat - humic acid			
SUERC-75766 Monolith one	12-13 cm	2 cm	{109} <112>	Bulk sediment Peat - humic acid	-29.5 ‰	2117 ± 31	345-50 BC
SUERC-75761 Monolith two	0-2 cm	2 cm	{126} <HY17129 a>	Bulk sediment Peat - humic acid	-29.4 ‰	2231 ± 31	385-204 BC
SUERC-77865 Monolith2	23 cm	1 cm	{126} <HY17129 c>	Bulk sediment Peat - humic acid	-29.7 ‰	2042 ± 23	160 BC-AD 20
SUERC-75764 Excavated sample	40 cm	2 cm	Junction between {124- 125} <130>	Bulk sediment Peat - humic acid	-29.2 ‰	1278 ± 31	AD 660-800
SUERC-77872 Monolith two	45 cm	Na	{124} <HY17125>	Birch twig	-28.2 ‰	1268 ± 22	AD 680-770
SUERC-75763 Monolith two	45 cm	1 cm	{124} <HY17129 b>	Bulk sediment Peat - humic acid	-29.3 ‰	1420 ± 31	AD 580-660
SUERC-77862 Core 1	40 cm	1 cm	{141} <140>	Bulk sediment Peat - humic acid	-30.8 ‰	418 ± 22	AD 1430- 1610
SUERC-75771 Core 1	56-60 cm	3,5 cm	{141} <135>	Bulk sediment Peat - humic acid	-30.1 ‰	1058 ± 31	AD 900-1025
SUERC-75772 Core 1	83-84 cm	2 cm	{141} <136>	Bulk sediment Peat - humic acid	-29.2 ‰	1245 ± 31	AD 680-875
SUERC-77861 Core 1	95-96 cm	2 cm	{141} <139>	Bulk sediment Peat - humic acid	-29.5 ‰	1238 ± 23	AD 690-870

Table 1: Radiocarbon dates and their respective calibrated ages (BC/AD) from monoliths 1, 2 and from core one. One radiocarbon sample is also included from the 2017 archaeological excavation between contexts 124 and 125 as reference is made to this date in the text. Uncalibrated radiocarbon ages are quoted in conventional years BP. Calibrated ages were calibrated using the OxCal Bayesian modelling program version 4.3 (Bronk Ramsey, 2009, 2013) and the InCal13 calibration curve (Reimer *et al.* 2013) and are to two sigma calibration (95.4 % probability). $\delta^{13}\text{C}$ values are relative to VPDB. Detailed descriptions of the methods employed by the SUERC Radiocarbon Laboratory can be found in Dunbar *et al.* (2016)

Monolith one

0-2 cm: Light-red brown silt, Sh 1, Ga 2 (Nig 1; Strf 0).

2-6 cm: Dark brown, well humified peat: Sh 3, Ga 1 (Nig 3, Strf 0).

6-9 cm: Lighter brown silty peat band, Sh 3, Ga 2 (Nig 2; Strf 0).

9-13 cm: Dark brown, well humified peat: Sh 3, Ga 1 (Nig 3, Strf 1).

13-14 cm: Light brown, humified silty peat, Sh 3, Ga 2 (Nig 2; Strf 0).

Monolith two

0-42 cm (Unit 2): Organic-rich dark brown clay, Sh 2, As 2 (Nig 3; Strf 0; Sicc 2; Elas 2), with two very large stones between 0-10 cm and 12-19 cm. This unit also contained random scatters of small stones, charcoal flecks and wood pieces.

50-42 cm (Unit 1): Brown-orange/brown organic-rich clay, Sh 3, As 2 (Nig 3; Strf 0; Sicc 2; Elas 2)

Core 1

0-71 cm: Homogeneous fibrous herbaceous peat with some mineral matter and occasional gravel. Th 3

, Ga+, Ag+ (Nig 2; Strf 0; Sicc 2; Elas 2).

71-105 cm. Herbaceous peat with mineral matter Th 3, Ag 1, Ga+ (Nig 3; Strf 0; Sicc 2; Elas 2

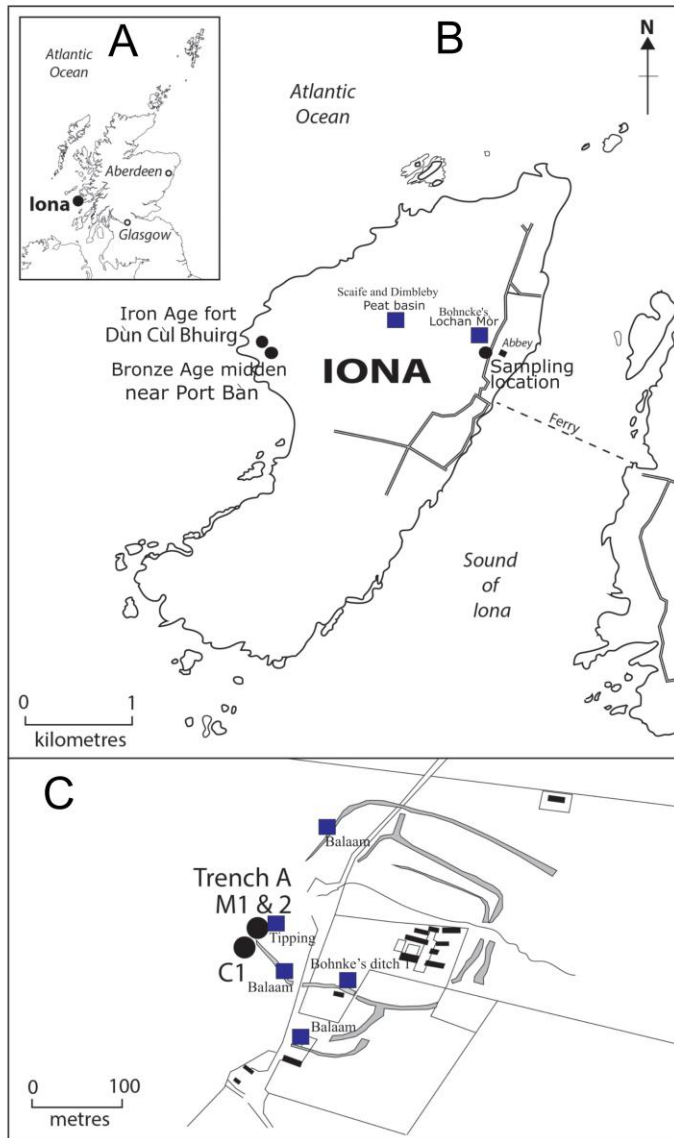
Table 2: Stratigraphy for monolith one, monolith two and core 1

Species	Food and habitat preferences
<i>Elasmotethus interstinctus</i>	Principal food is birch (<i>Betula</i>); found in mixed woodlands such as birch-oak-hazel or birch-pine; also sometimes found on alder (<i>Alnus</i>)
<i>Drymus brunneus</i>	Damp, shaded woody habitats in ground litter and mosses
<i>Scolopostethus decoratus</i>	On heathland
<i>Aphrophora</i> sp.	Associated with trees and shrubs
<i>Oncopsis tristis</i> group	Associated with birch
<i>Conomelus anceps</i>	On rushes (<i>Juncus</i>)
<i>Strophingia ericae</i>	On heathers (<i>Calluna vulgaris</i> and <i>Erica</i>)
<i>Serica brunnea</i>	Associated with grassland; the larvae feed at the roots of turf and woody vegetation
<i>Dascillus cervinus</i>	Rough grassland, usually on flowers, sometimes in bushes. The larvae mainly feed at the roots of grasses
<i>Dalopius marginatus</i>	In wooded places or scrub
<i>Denticollis linearis</i>	Typically found in woodland or scrub
<i>Orchestes</i> spp.	On trees and shrubs
<i>Ceutorhynchus</i> sp.	On various wild and cultivated Brassicaceae
<i>Micrelus ericae</i>	On heathers (<i>Calluna</i> and <i>Erica</i>)
<i>Strophosoma melanogrammum</i>	Typically found in woodland, wooded pasture and hedgerows; polyphagous on a variety of shrubs and trees but there may be a general preference for hazel (<i>Corylus</i>) and oak (<i>Quercus</i>)

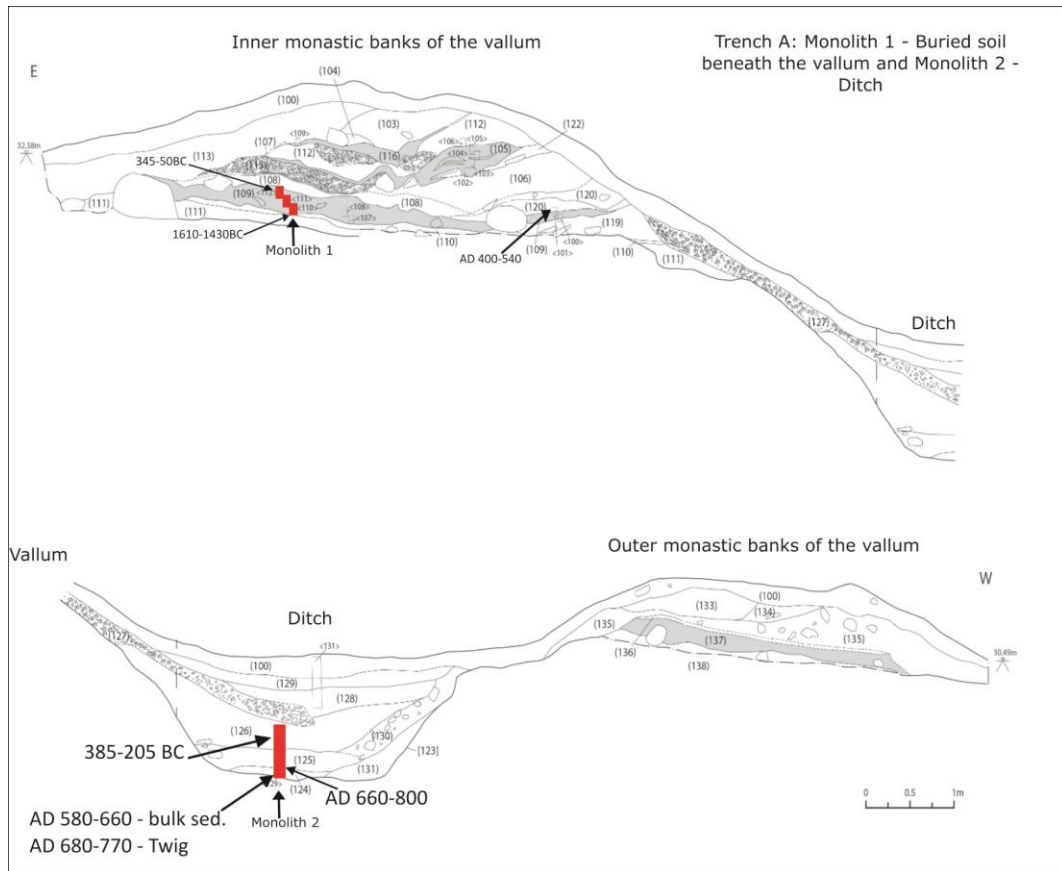
Table 3. Habitat and food preferences of strongly plant-associated beetles and bugs

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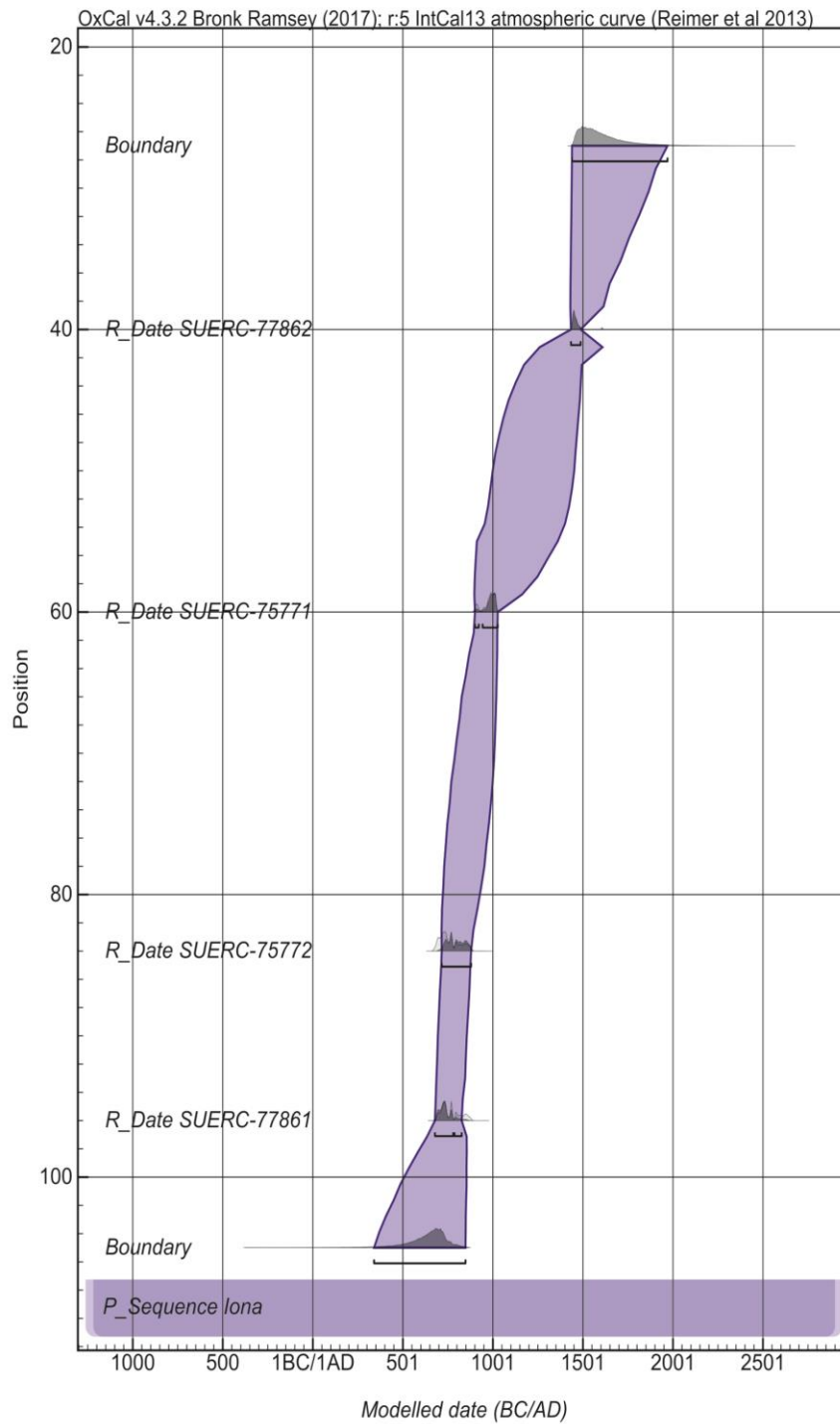
1. Location of Iona (A), the monastic site (B) and the sampling locations (C). Black dots on the lower panel represent the sample locations in this investigation (C1, and M1 & 2). Squares represent the sample locations for previous palynological investigations



2. Cross-sections of the vallum bank and ditch of Trench A showing the locations where both monoliths were extracted.



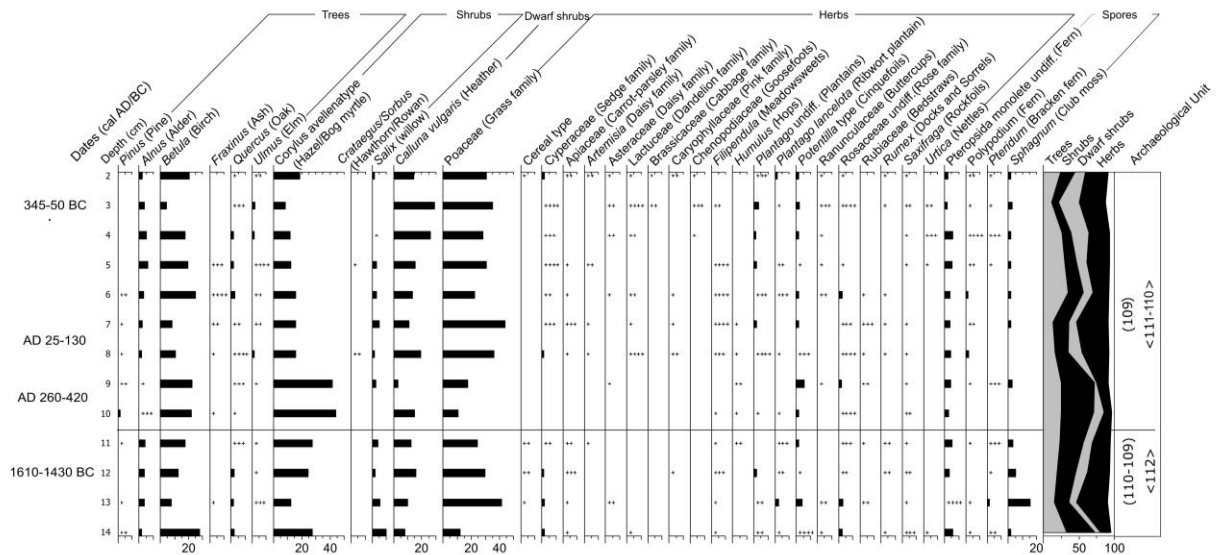
3. Bayesian age-depth model for core 1 constructed using OxCal v4.3. The blue envelope represents the 95.4% confidence limits on the model.



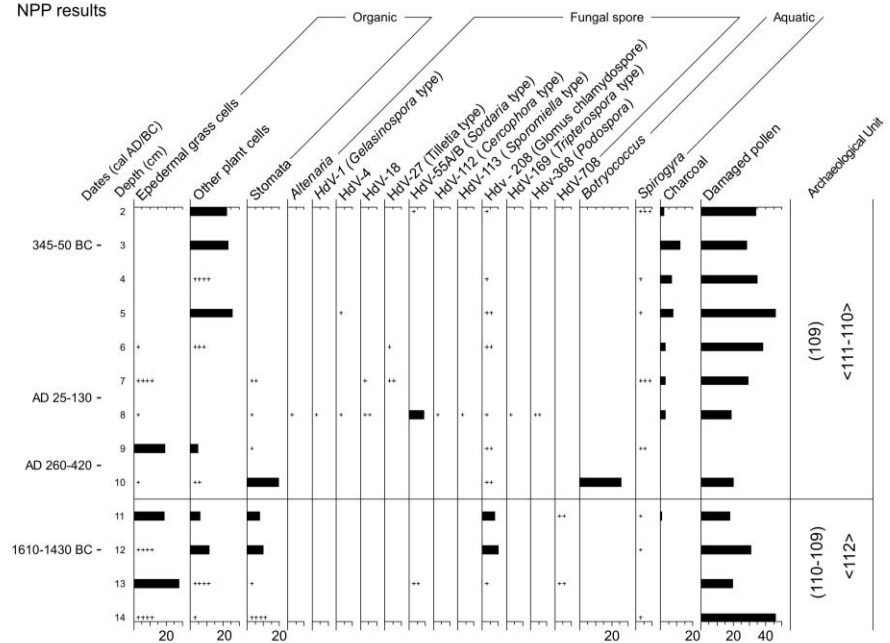
4. Percentage pollen and NPP data for Monolith one. Rare types are indicated by a cross (+), where one cross is equal to one pollen grain or NPP.

Monolith 1

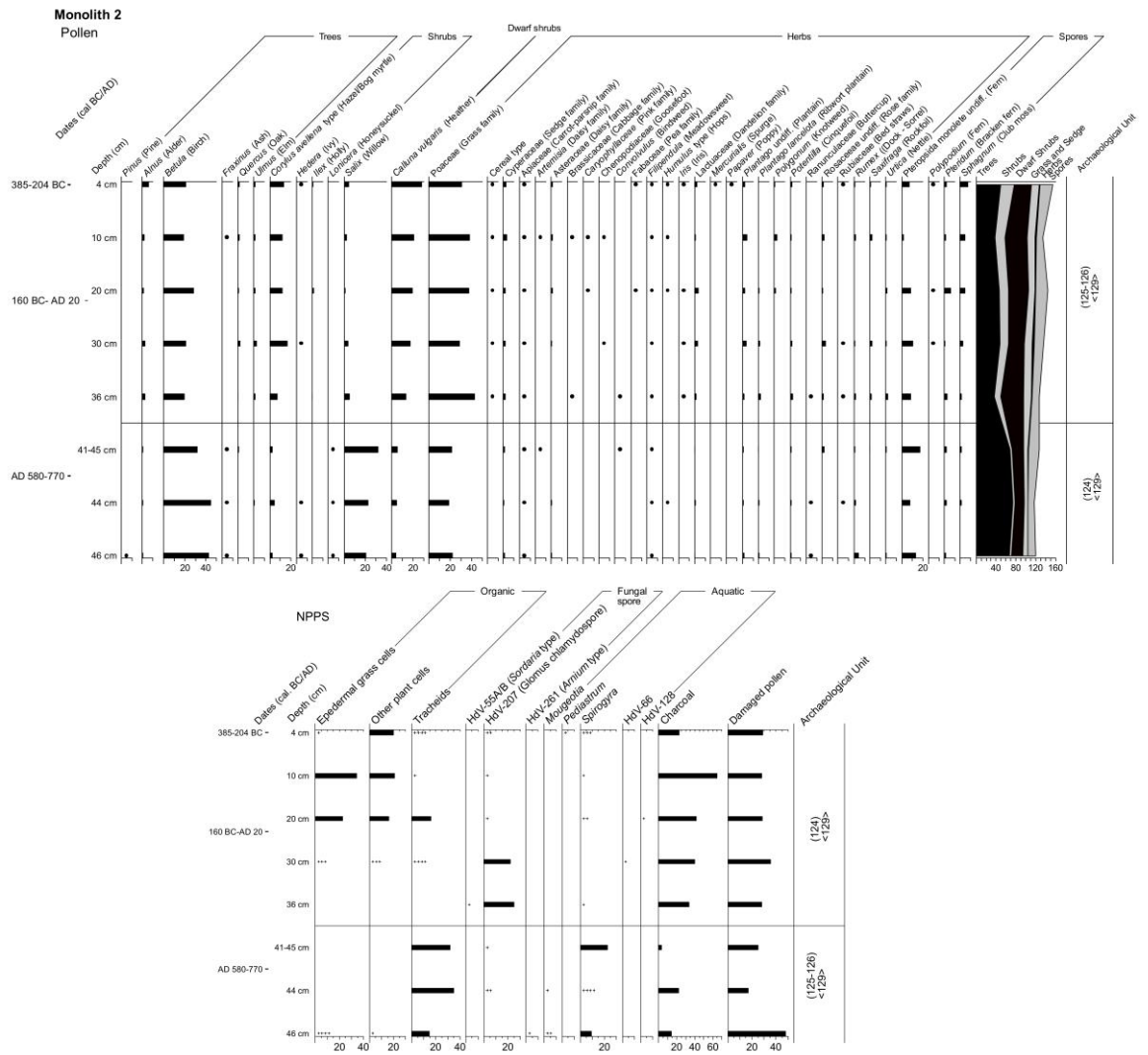
Pollen results



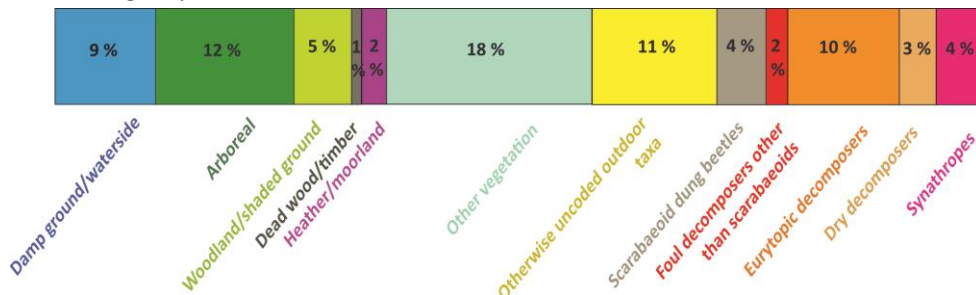
NPP results



5. Percentage pollen and NPP data from Monolith two. Rare types are indicated by a cross (+), where one cross is equal to one pollen grain or NPP.



6. Proportions of terrestrial beetles and bugs representing selected ecological groups expressed as a percentage of the terrestrial fauna. Note that some taxa are assigned to more than one group. Uncoded taxa are not included.



7. Insects and other invertebrates recorded from ditch sample <123>. The ecological codes shown in square brackets are: d - damp ground/waterside, l - wood/timber, m - moor/heathland, oa-outdoor taxa not usually found within buildings or in accumulations of

decomposing matter, ob - probable outdoor taxa, p- plant-associated, sf - facultative synanthropes, ss - strong synanthropes, st- typical synanthropes, t - tree, u - uncoded, w - aquatic. The abundance of insects other than adult beetles and bugs has been estimated as + 1-3, ++ 4-10, +++ 11-50. Abundances of other invertebrates have been recorded as present (P), common (C) and abundant (A).

Context	124				
Sample	<123				
Sample volume	3L				
CRUSTACEA		INSECTA			
<i>Daphnia</i> sp. ephippia	C	<i>Pterostichus minor</i>	2	<i>Aphodius contaminatus</i>	2
Cladocera spp. ephippia	P	<i>Oxypselaphus obscurus</i>	2	<i>Aphodius</i> spp. [ob-rf]	2
Ostracoda spp. carapaces	P	<i>Agonum</i> sp. [oa]	1	<i>Serica brunnea</i> (Linnaeus)	1
INSECTA		<i>Paradromius linearis</i> (Olivier)	1	Clambidae (fringe-winged)	
DERMAPTERA (earwigs)		Carabidae sp. and sp.	4	<i>Clambus</i> sp. [rt-sf]	1
Dermaptera sp. [u]	+	Helophoridae (grooved water		Scirtidae (marsh beetles)	
HEMIPTERA: HETEROPTERA		<i>Helophorus aequalis</i> or	2	<i>Cyphon</i> spp. [oa-d]	16
Acanthosomatidae (shield bugs)		<i>Helophorus</i> spp. [oa-w]	5	Dascillidae (orchid beetles)	
<i>Elasmostethus interstinctus</i>	1	Hydrophilidae		<i>Dascillus cervinus</i>	1
Pentatomidae (shield bugs)		<i>Anacaena globulus</i> (Paykull)	6	Elateridae (click beetles)	
<i>Picromerus bidens</i> Linnaeus	1	<i>Anacaena</i> sp. [oa-w]	2	<i>Denticollis linearis</i>	1
Anthocoridae (minute pirate bugs)		<i>Hydrobius fuscipes</i>	2	<i>Dalopius marginatus</i>	5
<i>Anthocoris</i> sp. [oa-p]	2	<i>Cercyon haemorrhoidalis</i>	2	Elateridae spp. and sp.	6
? <i>Anthocoris</i> sp. [oa-p]	1	<i>Megasternum concinnum</i>	1	Cantharidae (soldier beetles)	
Lygaeidae (ground bugs)		<i>Cryptopleurum minutum</i>	1	Cantharidae spp. [ob]	3
<i>Drymus brunneus</i> (Sahlberg)	3	Hydraenidae		Ptinidae (spider and	
<i>Scolopostethus decoratus</i>	1	<i>Hydraena</i> spp. [oa-w]	6	<i>Ptinuscf fur</i> (Linnaeus) [rd-	1
Lygaeidae sp. [oa-p]	1	<i>Limnebius ?truncatellus</i>	3	<i>Grynobius planus</i>	1
Corixidae (water boatmen)		<i>Limnebius</i> sp. [oa-w]	10	Cryptophagidae (silken	
Corixidae spp. [oa-w]	7	<i>Ochthebius c.f. minimus</i> [oa-	5	<i>Atomaria</i> sp. [rd-sf]	4
Corixidae sp(p). nymphs [oa-w]	+	Ptiliidae (featherwing beetles)		Endomychidae (handsome	
HEMIPTERA: HOMOPTERA		<i>Acrotichis</i> sp. [rt]	3	<i>Mycetaea subterranea</i>	1
Aphrophoridae (spittle bugs)		Leiodidae		Latridiidae (minute brown	
<i>Aphrophora</i> sp. [oa-p-t]	1	Cholevinae spp. [u]	2	<i>Latridius minutus</i> group	1
Cicadellidae (planthoppers)		Silphidae (sexton beetles)		Anthicidae (ant-like flower	
<i>Oncopsis tristis</i> group [oa-p-t]	19	Silphidae sp. [u]	1	<i>Omonadus floralis</i> or	1
Macropsinae sp. [oa-p]	2	Staphylinidae (rove beetles)		Chrysomelidae (seed and leaf	
<i>Anosopus</i> sp(p). [oa-p]	2	<i>Anthobium atrocephalum</i>	3	Alticini sp. [oa-p]	1
Cixidae (lacehoppers)		<i>Lesteva sicula</i> ssp. <i>heeri</i>	3	Apionidae	
<i>Cixius</i> sp. [oa-p]	1	<i>Olophrum piceum</i> or <i>fuscum</i>	7	Apionidae sp. [oa-p]	1
Delphacidae (leafhoppers)		<i>Omalius</i> sp. [rt]	1	Curculionidae (weevils)	
<i>Comomelus anceps</i> Germar [oa-	1	Omaliinae spp. [u]	2	<i>Orchestes</i> sp(p). [oa-p-t]	4
Delphacidae spp. [oa-p]	11	<i>Megarthus</i> sp. [rt]	3	<i>Ceutorhynchus</i> sp. [oa-p]	1
Auchenorrhyncha spp. [oa-p]	9	<i>Metopsia clypeata</i> (Müller)	5	<i>Micrelus ericae</i>	2
Psylloidea (jumping plant lice)		<i>Proteinus</i> sp. [rt]	2	<i>Strophosoma</i>	3
<i>Strophingia ericae</i> (Curtis) [oa-	2	<i>Micropeplus staphylinoides</i>	1	<i>Phyllobius</i> sp. [oa-p]	2
Psylloidea sp. indet. [oa-p]	1	Pselaphinae spp. [u]	2	Curculionidae sp. [oa-p]	3
Coccoidea (scale insects)		<i>Sepedophilus</i> sp. [u]	1	Coleoptera spp. and sp. indet.	2
Diaspididae sp.	++	<i>Tachinus laticollis</i> or	8	DIPTERA (flies)	
COLEOPTERA (beetles)		<i>Tachinus</i> sp. [u]	1	Bibionidae sp. leg spine	+
Gyrinidae (whirligig beetles)		<i>Tachyporus</i> spp. [u]	2	Chironomidae spp. larval	++
<i>Gyrinus</i> sp. [oa-w]	2	<i>Aleochara</i> sp. [u]	2	Diptera spp. puparia	+
Halipidae (crawling water beetles)		Aleochariinae spp. [u]	12	Insecta spp. indet. larval	++
<i>Haliplus</i> sp. [oa-w]	1	<i>Anotylus rugosus</i> (Fabricius)	1	HYMENOPTERA (bees,	
Dytiscidae (diving beetles)		<i>Anotylus tetracarlinatus</i>	1	Formicidae spp.	++
<i>Agabus bipustulatus</i>	5	Scydmaeninae spp. [u]	1	Apoidea sp. (bee)	+
<i>Agabus</i> or <i>Ilybius</i> spp. [oa-w]	5	<i>Stenus</i> spp. [u]	8	Hymenoptera Aculeata sp.	+
<i>Hydroporus incognitus</i> Sharp	9	<i>Lathrobium</i> spp. [u]	1	Hymenoptera Parasitica	++
Hydroporinae spp. and sp.	13	<i>Othius</i> spp. [rt]	2	SIPHONAPTERA (fleas)	
Dytiscidae spp. [oa-w]	1	<i>Gyrophypnus fracticornis</i> or	1	Siphonaptera sp., partial	+
Carabidae (ground beetles)		<i>Xantholinus linearis</i> (Olivier)	1	TRICHOPTERA (caddis flies)	
<i>Leistus terminatus</i> (Hellwig in	1	Staphylininae spp. [u]	7	Trichoptera sp. larval	++
<i>Nebria brevicollis</i> (Fabricius)	1	Geotrupidae (dor beetles)		ARACHNIDA	
<i>Notiophilus</i> sp. [oa]	1	Geotrupinae sp. [oa-rf]	2	Acarina spp. (mites)	C
<i>Trechus obtusus</i> or	2	Scarabaeidae (dung beetles and		Araneae sp. (spiders)	P
<i>Ocys harpaloides</i> (Audinet-	2	<i>Aphodius ater</i> (De Geer) [oa-	1	TOTAL INDIVIDUALS	##
<i>Bembidion</i> spp. [oa]	2	<i>Aphodius prodromus</i> or	3	Concentration beetles and	108

8. Percentage pollen and NPP taxa from core 1. Top: Core 1 pollen results (%). Centre left: pollen summary (%). Centre: preservation data. Centre right: charcoal (counts) and LOI (%) comparison. Bottom: NPPs (%). Rare types are indicated by a cross (+), where one cross is equal to one pollen grain or NPP. Note – Both actual and modelled ages are included in the

pollen summary; actual calibrated ages are displayed as age ranges and modelled ages as single mid-values.

