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Timber in Scottish buildings, 1450–1800: a dendrochronological perspective

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ABSTRACT

This paper examines the dendrochronological data from Scottish buildings in terms of the proxy evidence it provides for the timber trade and the condition of the woodland resource in the centuries under review. The bulk of the timber used in the construction of high status buildings during this period was either oak or pine, imported mainly from Scandinavia and the countries bordering the eastern Baltic. The documentary record for timber imports in Scotland is examined and compared with the physical evidence from the timbers themselves. The poor state of the native deciduous woodlands during this period is reflected in the dendrochronological data and explains the predominance of imported timber. While native Scottish pine has a long history of domestic use, exploitation escalated from the 17th century; there is much more pine in Scottish buildings of post-medieval date, both imported and native, and the difficulties and successes in identifying native pine in buildings is discussed.

For the architectural historian and archaeologist, the relationship between the felling date of the timber and the construction date of the building is critical to the interpretation of dendrochronological data. The issues which bear upon that relationship, seasoning, transportation times, stockpiling and recycling, are considered in a Scottish context.

INTRODUCTION

Over the last two decades, dendrochronological analysis of timbers from standing buildings and archaeological sites has become routine in Scotland. Archaeological sites that produce timbers are few and far between, and the number of buildings in Scotland with their timber infrastructure still in situ is small in comparison with England. Nonetheless, a significant body of data has now accumulated which has enabled us to explore more thematic issues, over and above the calendar dates which are the key product of any dendrochronological analysis.

In 2002, we presented an overview of the state of dendrochronological research in Scotland as part of the 'Scottish' Antiquity volume (Crone & Mills 2002). In the years since that paper, the focus of our work has been almost exclusively on late medieval and post-medieval buildings and consequently our understanding of timber use and trade in these periods has broadened and refined. The stimulus for writing this updated overview has been the completion of a five-year programme of research, the Native Oak and Pine Project (NOAP), the aim of which has been the expansion of native, that is, Scottish-grown, oak and pine chronologies in Scotland. This paper is thus mainly concerned with the dendrochronological study of oak and pine in post-1450 buildings.

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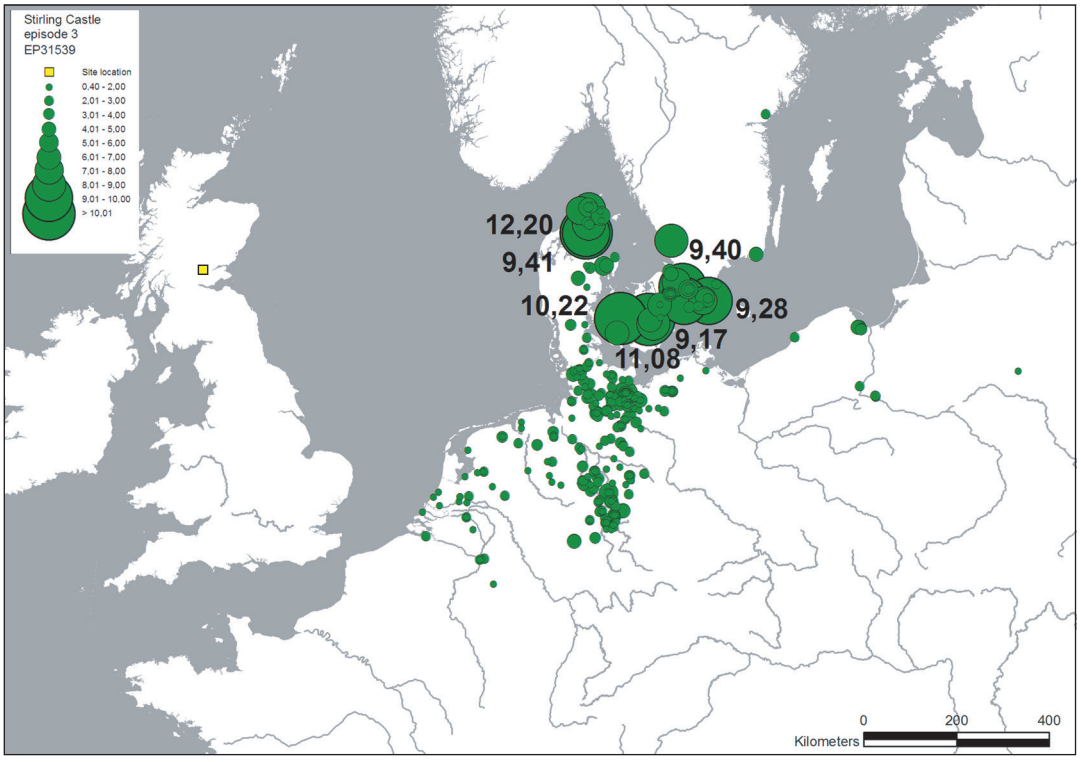
In addition to felling dates for the timbers, most dendrochronological studies will yield information on the source and the quality of the timber, and by extension, the nature of the woodland resource. The accumulated evidence from post-1450 Scottish buildings is presented below under those headings. The relationship between felling dates and construction dates, and the factors that can bear upon our interpretation of a dendrochronological date, such as seasoning, stockpiling and recycling, are also examined in a Scottish context. Thus we hope that this overview will provide the reader with information on the use and limitations of dendrochronological dates, as well as the rich source of proxy evidence that they can provide.

TIMBER SOURCE

DENDROPROVENANCING

The development across Europe of an extensive network of regional tree-ring chronologies, based on locally grown trees and timber, means that it is now possible to determine the origin, or provenance, of imported structural timber and wooden artefacts (Bonde et al 1997; Haneca et al 2005). Dendroprovenancing, as this technique is known, is based on the strength of the statistical correlations between the regional chronologies and the site-, or object-chronology being dated (illus 1). In northern Europe, where timber was being transported in bulk throughout the medieval period from



ILLUS 1 How dendroprovenancing works. This map shows the distribution of statistical correlation values between one of the oak master chronologies from Stirling Palace and site chronologies from northern Europe; the very high correlations clustering around Denmark and southern Sweden identify southern Scandinavia as the source of the timber. It is important to note that site chronologies from Denmark in particular probably include timber from both Norway and Sweden so it is difficult to identify the individual country of origin or pinpoint geographical sources more closely (see text)

neighbouring countries with similar climatic and environmental characteristics, very high-value correlations (t-values over 9.0) are needed to identify provenance meaningfully (Daly 2007: 236). Deductions from the dendrochronological work carried out so far in Scotland indicate that growing conditions in Scotland were sufficiently distinct from those in the principal source areas elsewhere in northern Europe to allow the identification of imported timber, even when the correlation values are not quite so high, and particularly when this is combined with an absence of any correlation with native Scottish chronologies. Dendroprovenancing depends on the existence of strong regional chronologies based on large numbers of tree-ring samples; for a variety of reasons, some areas have weaker tree-ring coverage and consequently it is less easy to identify timber from these areas with any confidence. As we shall see, this has had a bearing on our ability to date some of the imported timber in Scotland.

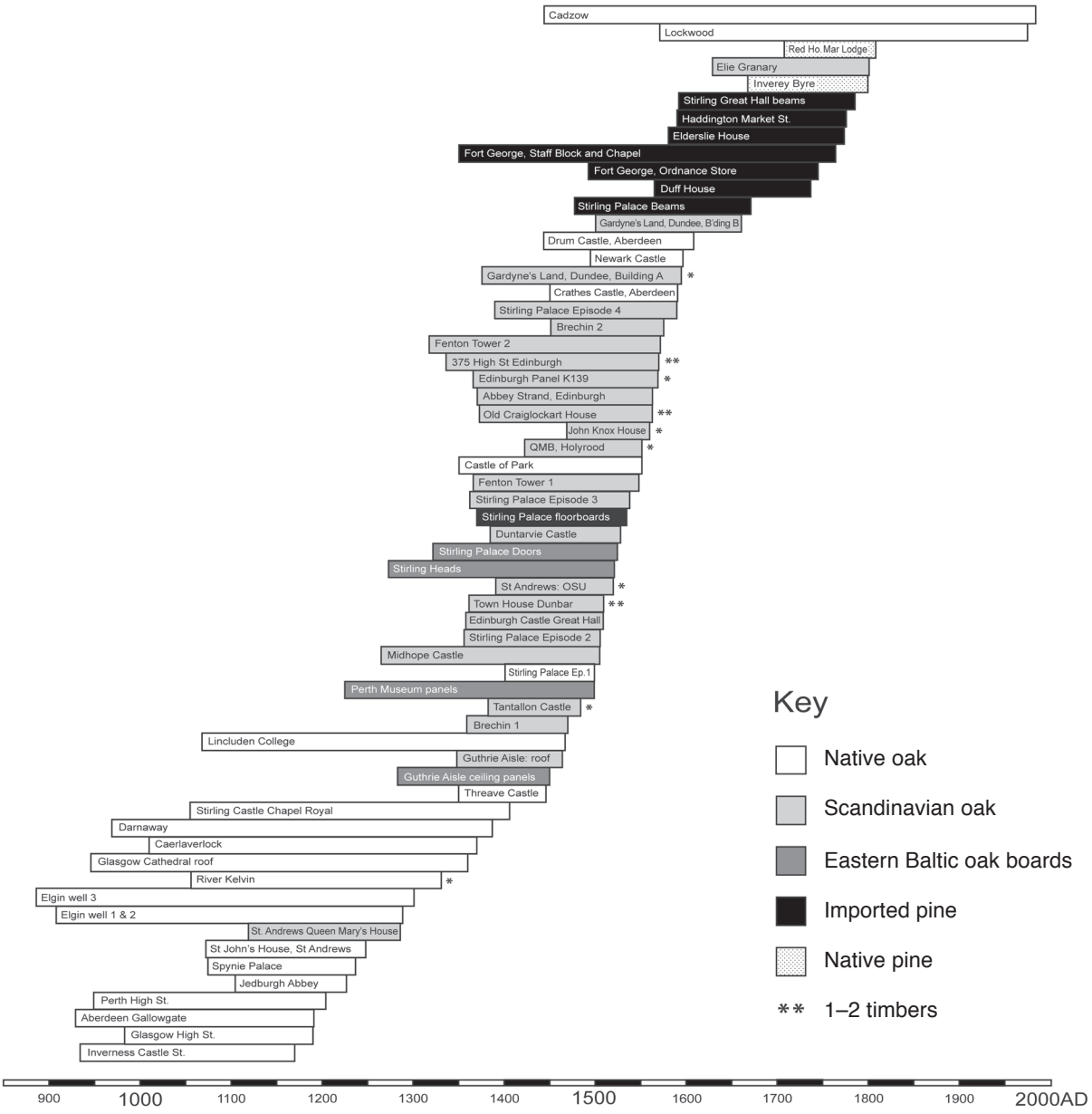
While external correlations can identify provenance, the strength of internal correlations, that is, within an assemblage, can indicate whether the timber came from a single source or from multiple sources, either different regions altogether, or from different woodlands within the same region. In an era of widespread transport of wood from across Europe, this information can contribute towards an understanding of the mechanics of the timber trade.

DOCUMENTARY EVIDENCE FOR IMPORTED TIMBER

Illustration 2 summarises the dendrochronological evidence from standing buildings and archaeological sites in Scotland from the 12th century through to the early 19th century. Apart from native Scottish timber, two distinct principal source areas have been identified – Scandinavia and the eastern Baltic. That timber was imported extensively into Scotland throughout the later Middle Ages and into the Early Modern period is well documented and this evidence is summarised briefly in this section.

Sources such as the *Accounts of the Lord High Treasurer of Scotland* (*TA*), and more particularly, the *Accounts of the Masters of Works* (*MA*), who were responsible for the repair and construction of the Royal buildings, are peppered with references to imported timber. These documents, which cover the greater part of the 16th century and first half of the 17th century, mention Sweden, Denmark and Norway as sources of timber. Although Norway is frequently cited as Scotland's main source of imported timber (ie Lythe 1960: 146; Smout 1963: 153–8), this seems to be more the case from the latter half of the 16th century. In the early years of the century, skippers were occasionally sent to Norway to choose timber for masts and to 'bring hame gret tymmer', possibly to support the shipbuilding ambitions of James IV (TA 4: 289). The references to Denmark consist mainly of payments to Danes for 'aiken tymmer' (oak timber – 1531–2; MA 1: 179) and 'sawin dalis' (sawn deals – 1537–8; MA 1: 219) but ships were also sent to Denmark in 1538 and 1539 (TA 6: 389; TA 7:159).

Voyages to Sweden are not mentioned at all in these sources but there are numerous references to 'Sweden boards' (variously 'Suethin burdis', 'Swydin burds', 'Suadin burd' and 'Swadin burd'). It is possible that this was a trade name for a type of product rather than a reference to its source; unfortunately, the species of wood is never mentioned but it is used for both sarking and for doors and windows at Holyrood Palace in 1531–2 (MA 1: 95–7), suggesting that it could be of variable quality. 'Sweden boards' may have been sawn boards; Sweden was the earliest of the Scandinavian countries to use the sawmill (it was introduced there in the 1460s; Lillehammer 1986: 99) so it is possible that any sawn board produced in Scandinavia was identified as a 'Sweden board'. 'Aiken tymmer of Lowdis in Swadin' (oak timber from Lodose, near the modern city of Goteburg) is



ILLUS 2 Summary bar diagram of all dated tree-ring chronologies from Scottish buildings and archaeological sites in 2010. Each bar represents the span of the master chronology for that particular site or building. Some key living tree native oak chronologies used in dating are also included

bought for Falkland Palace in 1537 (MA 1: 219) as is 'Lowdis tymmer' and 'Swadin tymmer' (ibid: 220); these latter are referred to as such in the same entry, suggesting that there was a distinction between the two types.

Other trade names occur throughout the records: 'Estland burdis', or Eastland boards being the most frequent. This was the common name for timber imports from the eastern Baltic, and it is clear that it was invariably imported already prepared as boards. By the early 14th century in England, 'Eastland boards', or 'Estriche board', had become differentiated into 'wainscots', which were usually German oak, and 'righolts', oak from around the port of Riga (Salzman 1952: 246). This differentiation does not occur in the Scottish records, although 'wainscots' are mentioned occasionally. Between 1535 and 1541, there are several references to 'Reys' or 'Reis' boards, probably Russian boards, so this may be the same type of timber as the 'righolts'. 'Eistland, Swadyn and Reys burdis' are bought for works at Holyrood in 1535–6 and are mentioned together in a single entry (MA 1: 181), again implying a distinction between the types of boards.

The species of wood used was clearly implied in the trade name; rarely are the type of timber product and the species of wood mentioned together. As noted above, there are frequent references to 'Sweden boards' but not what the species is. There are only two references to oak timber specifically from Sweden and Denmark in Royal sources from the 16th century, yet the earliest surviving customs book from the Swedish port of Lodose, from 1546, records that oak and spruce were the main timber exports to Scotland, the spruce being shipped as boards and the oak being shipped as both boards and 'rough lengths', presumably undressed logs (Dow 1969: 70). In that year, Scottish ships bought virtually all the oak boards exported through Lodose.

However, caution is needed in interpreting the names for wood species used in the documentary sources. As described above, spruce is recorded in foreign sources as a major export to Scotland but it is rarely mentioned in the Scottish records. It may be relevant that in the late 18th century, 'spruce deals' were not necessarily spruce (*Picea abies*); usually they were Scots pine (*Pinus sylvestris*) deals greater than 20ft (6.1m) in length (Thomson 1991: 29). Fir timber is also frequently mentioned but this is not silver fir (*Abies alba*). 'Fir' was the Scots word for pine (Smout 1997: 116) and it is possible that it was used as a generic term for all softwoods. For instance, one entry lists the timber products to be floated from Dundee to Lindores in 1538 (MA 1: 262); these include 'sawin dalis', 'firrin mastis', 'aiken treis', 'aiken sparis', 'firren sparrs' and 'rewin dalis' (sawn deals, fir masts, oak trees, oak spars, fir spars and ?riven deals). 'Deal' is generally understood as the trade name for sawn softwood boards but as the entry above makes clear, riven, or cleft deals were also available.

The other source of information about imported timber is the 'particular' customs accounts of the ports. Ditchburn (1990: 80) has examined the patchy records that survive for the first half of the 16th century and found very few references to Scandinavian commodities, ships or merchants. However, these customs accounts could never provide anything like a complete picture of Scottish overseas trade because they did not have to record those goods on which customs dues were not levied. From 1550, all foreign ships entering the port of Dundee were recorded in the burgh and court books and a very different picture begins to emerge; between 1550 and 1555, ten ships with Danish skippers arrived laden with timber, as well as eight ships with Norwegian skippers also laden with timber. Swedish timber is also mentioned. Oak and fir is being imported as boards and beams, the latter of varying lengths.

From the 17th century, primary sources of information relating to Scotland's timber trade multiply (Thomson 1991: 7); these include the increasingly detailed port books for both Scotland and the ports with which she traded,

merchants' papers and correspondence and, from the mid-18th century, the annual Accounts of the newly established Inspector-General of Exports and Imports (ibid: 98). Analysis of these varied sources has revealed the major shifts in the source, form and level of timber imports which occurred over the course of the 17th and 18th centuries (ibid: 262) – these are briefly summarised below.

By the latter half of the 16th century and throughout the 17th century, Norway was undoubtedly the main supplier of Scotland's timber requirements, and, in some regions of Norway, Scotland was her most important customer, to the extent that the 17th century was known as 'the Scottish period' (Lillehammer 1990: 100; Newland 2011: 72–4). Scottish merchants and skippers traded directly with farmers along the fjords of western Norway, carrying away sawn boards and roughly dressed beams, as well as other smaller wood products. Beams of a certain length were known as *skottebjelker* – Scottish beams – indicating their importance to the Scottish merchants; as an example, in 1641–2, almost 91% of the total export of beams from Ryfylke, the region just east of Stavanger, left in Scottish vessels (Lillehammer 1990: 104).

Not surprisingly, the level of felling activity needed to fulfil the demands of the Scottish, and other markets, led to the over-exploitation of the forests along Norway's west coast and what was left was inaccessible and could no longer produce large-dimensional timber (Lillehammer 1999: 18–21). Attention moved to the forests of southern and eastern Norway until, by the mid-18th century, they too were exhausted, and the poor quality and size of Norwegian timber was frequently observed (Thomson 1991: 8–15: 23–6). By this time, Sweden, via the port of Gothenburg, had become the major supplier of Scotland's deal requirements, largely due to improvements in the sawmilling technology of that country (ibid: 70–4).

However, Sweden's role in the Scottish timber trade was short-lived; in the second half of the 18th century '… the balance of the Scottish import trade in timber switched from Norway, briefly to Sweden, and then decisively to the Baltic' (Smout 1999: 54). Governmental policies in both Sweden and Russia initially influenced this change (Thomson 1991: 266) but the quality and size of the timber that Russia's hitherto unexploited forests could provide was clearly a decisive factor (ibid: 197). The major type of timber import also changed at about this time, from deals to 'fir timber' – large squared logs of pine (at least 300 mm^2) which were needed for every aspect of Scotland's burgeoning economy, and which could also be sawn down to size in the sawmills which were being established in many Scottish ports (Shaw 1984). Initially, the ports of St Petersburg and Riga supplied the Scottish demand for 'fir timber', most of the timber from St Petersburg coming from around Loch Onega or from as far north as Archangel (Thomson 1991: 204), while most of the wood from Riga came from the area of modern-day Belarus and Lithuania (Zunde 1998b: 72; 1999). However, after 1764 the Prussian port of Memel (modern-day Klaipeda) quickly became Scotland's major source of 'fir timber', to the extent that, by 1768, Memel supplied over 72% of Scotland's pine timber imports (Thomson 1991: 267), most of it, nonetheless, still coming from Russian forests (ibid: 213).

The commercial exploitation of the native pinewoods of Scotland began in earnest in the early 17th century (Smout et al 2007: 193) but, despite the best efforts of the landowners, investors and merchants, little of the timber moved beyond local markets, imported timber being generally preferred (ibid: 129–30). The reasons for the failure of the Scottish timber trade to compete with foreign markets have been researched by Lindsay (1974) and succinctly summarised by Thomson (1991: 150) as relative scarcity, poor quality and technological backwardness, but above all, difficulties of extraction leading to high transportation costs. Nonetheless, native-grown pine did

supply local markets and would probably have provided for the building needs of many inland rural communities (Smout et al 2007: 134). The Royal Navy always considered Scottish-grown pine to be inferior for use as masts and other ship timber (Albion 1926: 30) but in times of war, most notably during the Dutch wars of the mid-17th century and later the Napoleonic wars, when trade was disrupted and prices escalated, the output of the native pinewoods became more attractive and thus more competitive, and much was shipped south for ship-building (Albion 1926: 207–8, 217; Smout et al 2007: 218–20).

In summary, the documentary evidence indicates that in 16th and 17th century buildings we might expect to find mainly oak and pine imported from the eastern Baltic, Norway, Denmark and Sweden. In the early 18th century, we should expect to find mainly pine imported from Norway and Sweden and, in the latter half of that century, pine imported almost exclusively from the eastern Baltic, accompanied by an increasing visibility of home-grown pine. The dendrochronological evidence for timber use in Scotland is presented below, species by species.

OAK; THE DENDROCHRONOLOGICAL EVIDENCE

Native oak

With one exception, all the timber used in pre-1450 buildings has been identified as native oak, much of it from mature, long-lived trees such as those used in Darnaway Castle (418 years – felled 1387; Stell & Baillie 1993), the Chapel Royal at Stirling Castle (342 years – felled *terminus post quem* 1416; Crone & Fawcett 1998), Glasgow Cathedral (359 years – felled *c* 1385; Baillie 1982: 158) and the bridge at Caerlaverock Castle (320 years – felled 1371; Baillie 1982: 160–3). This is also reflected in the structural timbers found on archaeological sites of medieval date, such as the linings of the wells found in Elgin (Murray et al 2009 – and see illus 2). The only imported structural timbers found so far which pre-date 1450 are from Queen Mary's House, South Street, St Andrews; these timbers were probably felled sometime in the 14th century and they came from the eastern Baltic (Baillie 1995: 132; Mills 2000: 204). Trade between the Hanseatic ports of the eastern Baltic and the east coast Scottish ports began to develop in earnest in the late 14th century, with the opening of the Sound between Denmark and Sweden (Ditchburn 1988: 165) and the timber in Queen Mary's House may have arrived via this newly established route.

As illustration 2 so forcefully demonstrates, after the mid- to late 15th century, native oak is rarely used in construction in Scotland. Of 33 post-1450 buildings which have been dendro-dated, only five include any native oak. Only 10% of all the surviving oak timbers in Stirling Castle were native-grown and these all came from the earliest episodes of building activity (Crone 2008: 13). The other buildings known to have used native oak lie either in south and west Scotland (Newark Castle roof timbers (Crone unpubl a) and a choir stall in Lincluden College (Baillie 1982: 149)), or Aberdeenshire (roof timbers from Drum mansion house and Crathes Castle (Crone & Mills unpubl a)). On the whole, buildings in central and east coast Scotland came to rely heavily on imported oak for their construction. The reasons for this growing reliance on imported timbers will be explored more fully in the next section.

Scandinavian oak

The oak timbers identified as Scandinavian in illus 2 are invariably baulks, or beams, hewn to a square or rectangular cross-section and used as joists or rafters. They were probably hewn at source; squared timbers would certainly allow a greater packing density for shipment and where stockpiling has been observed, as at Edinburgh Castle, the smooth toolmarks on the dressed surfaces of the timbers indicates that the initial shaping of the timbers must have been done soon after felling, while the timber was green (Crone & Gallagher 2008: 254).

TABLE 1
Scandinavian connections; statistical correlations between Scottish imported oak chronologies and regional Scandinavian oak chronologies. The statistic used is a t-value and values over 3.5 are generally considered significant. The shading indicates those Scottish chronologies that we can confidently ascribe to either Norway or Denmark/Sweden, while those chronologies without any shading can only be ascribed a generic Scandinavian provenance. Those buildings whose names are in italics are already included in the regional master, N-all01, hence the very high correlations

	Norway		Denmark		Sweden	
	SNORWAY1	*N-all01*	*2X900001*	Jutland	*SM00005*	*SM000012*
Scottish 'import' chronologies						
EP2_1505 (1355–1505) Stirling Palace (Crone 2008)	4.64	7.82	10.44	8.29	9.24	9.21
EP3_1538/9 (1366–1538) Stirling Palace (Crone 2008)	5.94	6.83	11.34	9.06	9.95	9.75
EP3_1539 (1361–1539) Stirling Palace (Crone 2008)	5.14	6.54	13.26	11.21	12.00	9.69
EP4_1592 (1390–1592) Stirling Palace (Crone 2008)	5.58	7.71	10.22	11.81	7.54	11.44
FTMAS1 (1366–1547) Fenton Tower, East Lothian (Crone unpubl a)	6.47	7.33	12.91	10.85	9.36	11.45
GAROOF2 (1350–1458) Guthrie Aisle, Angus (Crone & Fawcett forthcoming)	5.83	5.55	12.40	8.29	8.64	9.39
BRECHIN1 (1359–1470) 68–74 High Street, Brechin (Crone et al 2004)	5.78	8.52	8.98	6.08	6.21	5.77
MIDHOPEx2 (1265–1505) Midhope Castle, West Lothian (Baillie unpubl data)	5.43	4.36	9.21	5.78	5.43	9.03

	Norway		Denmark		Sweden	
	SNORWAY1	*N-all01*	*2X900001*	Jutland	*SM00005*	*SM000012*
FTMAS2 (1318–1572) *Fenton Tower, East Lothian* (Crone unpubl a)	11.04	19.46	6.32	7.18	5.13	6.08
EDINCAS2 (1358–1509) Edinburgh Castle (Crone & Gallagher 2008)	8.80	15.50	7.26	7.19	7.41	3.52
375HSMNx2 (1338–1570) *375 High Street, Edinburgh* (Crone unpubl k)	7.34	12.06	4.65	5.00	–	4.41
QMBH01mn (1423–1550) Queen Mary's Bathhouse, Holyrood (Crone unpubl l)	7.28	8.37	–	–	–	–
DUNTARVIE (1385–1529) *Duntarvie Castle, West Lothian* (Crone unpubl m)	8.97	10.72	5.72	5.41	5.19	–
OCHMN (1373–1563) Old Craiglockart House, Edinburgh (Crone unpubl data)	7.88	9.40	5.44	6.00	–	4.04
DTHMNx2 (1360–1509) Old Townhouse, Dunbar, East Lothian (Crone unpubl n)	7.38	9.01	5.65	4.43	3.85	–
ASOMNx6 (1370–1563) Abbey Strand, Holyrood (Crone unpubl d)	9.80	11.22	4.71	3.90	–	4.02
JKNOXHx1 (1466–1560) *John Knox House, Edinburgh* (Crone unpubl)	6.97	7.87	–	5.34	–	–

	Norway		Denmark		Sweden	
	SNORWAY1	*N-all01*	*2X900001*	Jutland	*SM00005*	*SM000012*
GLMEANx3 (1475–1660) Gardyne's Land, Dundee (Crone unpubl b)	8.27	9.85	6.66	7.62	6.05	6.44
BRECHIN2 (1451–1575) 68–74 High Street, Brechin (Crone et al 2004)	–	4.29	–	–	–	–
GAROOF1 (1348–1464) Guthrie Aisle, Angus (Crone & Fawcett forthcoming)	3.88	5.05	4.22	4.00	–	4.06
OSU1NEWx2 (1391–1520) Old Students Union, St Andrews (Mills 2000)	–	4.41	5.92	5.20	4.79	4.71
TC1x1 (1383–1484) Tantallon Castle, East Lothian (Crone unpubl j)	–	–	6.15	4.99	4.97	7.86
PANLKL39 (1366–1569) NMS, Edinburgh (Baillie unpubl data)	5.57	7.02	5.04	4.26	–	3.83

There are many regional tree-ring chronologies from Denmark and southern Sweden and consequently it has been relatively easy to identify timber with a southern Scandinavian provenance. However, it is much more difficult to identify a specific country of origin. This is because, from the 13th century until the mid-17th century, the southern Swedish provinces of Skaane, Blekinge and Halland were ruled by Denmark, while Norway and Denmark formed a political union from 1536 until 1814 and, as a consequence of these closely entwined political relationships, timber was probably traded freely across modern national borders. Consequently, both the regional reference chronologies in the source countries and some of the Scottish 'import' chronologies probably contain a mixture of material from Denmark, Sweden and Norway. Denmark became increasingly concerned about its own timber resources in the mid-16th century and periodically banned the export of wood from all its dominions, except Norway (Fritzboger 2004: 125); thus any timber of this date identified as Danish, either in documentary sources or through dendro-provenancing, is more likely to have come from Norway or western Sweden.

Some 90% of the dated oak beams used in Stirling Castle are from southern Scandinavia and it is notable that the Royal builders continue to use the same source, or supplier, throughout the 16th century (Crone 2008: 14). Four building episodes in the 16th century have been identified, 1500/1, 1505, 1538/9 and 1591–3; except for Episode 1, when native oak was mainly used, the timber employed in each phase has displayed very strong correlations only with Danish and Swedish chronologies (Table 1).

Other buildings have displayed a greater mixture of sources, even within the same phase. For instance, both the roof of the Guthrie Aisle, in Angus (Crone & Fawcett forthcoming) (illus 3), and the floors in Fenton Tower, East Lothian (Crone 2013) were built with oak beams from several sources (illus 4 & 12). Each building yielded two mutually exclusive building chronologies, that is, there was no correlation between the components of one chronology with the components of the other, nor was there any match between the two chronologies, despite being contemporaneous – strongly suggesting different origins for the timbers in each chronology. It is clear from the strong statistical correlations that both *Fenton Tower 1* and *Guthrie Aisle 2* came from Denmark/Sweden (Table 1), but whilst *Fenton Tower 2* and *Guthrie Aisle 1* also produced significant correlations with the same regional chronologies, they were not sufficiently high to ascribe anything more than a generic Scandinavian provenance.

We had always suspected that those generic Scandinavian chronologies might be Norwegian but, until recently, it has been difficult to demonstrate this because Norway is one of those countries with poor tree-ring coverage for oak. Oak only grows naturally in the coastal districts of south-western Norway and, during the later medieval period, the bulk of the oak was exported to countries such as Denmark, Germany and the British Isles (Thun 2002: 25–6). Oak was only rarely used in building in Norway, presumably because it had greater value as an export commodity. Consequently, there has been little native material available to build a regional chronology and dendrochronologists there have tended to concentrate on the more abundant pine and spruce (ibid: 1–3). Until recently, there was only a single oak chronology for the medieval period, spanning the years 1480–1678 (Christensen & Havemann 1998); when this chronology became available we were able to demonstrate that *Fenton Tower 2* was almost certainly Norwegian and by a series of step-wise correlations we were also able to provenance most of the roof timbers from Edinburgh Castle and Duntarvie Castle, West Lothian, to Norway (Crone & Gallagher 2008: 253). In fact, for most of the dated 16th-century buildings from Edinburgh and the Lothians listed

ILLUS 3 The Guthrie Aisle, Angus. The roof was built with small oak beams from Scandinavia, felled in and around 1464. Oak boards from the eastern Baltic had been used for the painted ceiling which was once lined the roof (© Scottish Church Heritage Ltd)

in Table 1, the strongest correlations are with the Norwegian regional chronology, suggesting that much of the oak timber used throughout the Lothians in the latter half of the 16th century was Norwegian, as the documentary sources suggest.

The work of colleagues in neighbouring Denmark, where a lot of Norwegian oak has been identified, has now resulted in the development of a 'proxy' regional chronology for Norway, *N-all01*, which contains import chronologies from other countries, including several from Scotland (Neils Bonde pers comm). The development of this chronology has now enabled us to date some material which has remained undated for nearly a decade. The analysis of the roof timbers from the building at 68–74 High Street, Brechin, had also resulted in the construction of two mutually exclusive building chronologies; *Brechin 1* was initially dated against southern Scandinavian chronologies (Table 1) and demonstrated that old timber, felled in 1470 had been re-used in the roof, but *Brechin 2* could not be dated (Crone et al 2004: 160). Low but consistent correlations with the new Norwegian regional chronology

indicates that the timber in *Brechin 2* was felled in 1575; as none of the timber in this chronology displayed any evidence of re-use we must assume that this timber was bought for the construction of the High Street building and that it is therefore 16th century in date and not 17th century as originally surmised (ibid: 164). Analysis of 11 surviving oak timbers in Gardyne's Land, Dundee, had resulted in the dating of a single timber against southern Scandinavian chronologies, indicating that Building A had been constructed in 1595 (Crone unpubl b). Several more timbers have now been dated, indicating the re-use of oak timbers as lintels in Building B, but more importantly providing a *terminus post quem* date of 1660 for the raising of the roof (*contra* Newland 2011: 77, who had suggested a date in the 1630s on the basis of timber length). The export of oak from Norway was prohibited after 1602 because the remaining supplies were vital for the construction of the Danish–Norwegian fleet (Lillehammer 1986: 104) so it is interesting to find 17th-century Norwegian oak in a Scottish building; perhaps it was the result of small-scale smuggling (ibid).

Eastern Baltic oak

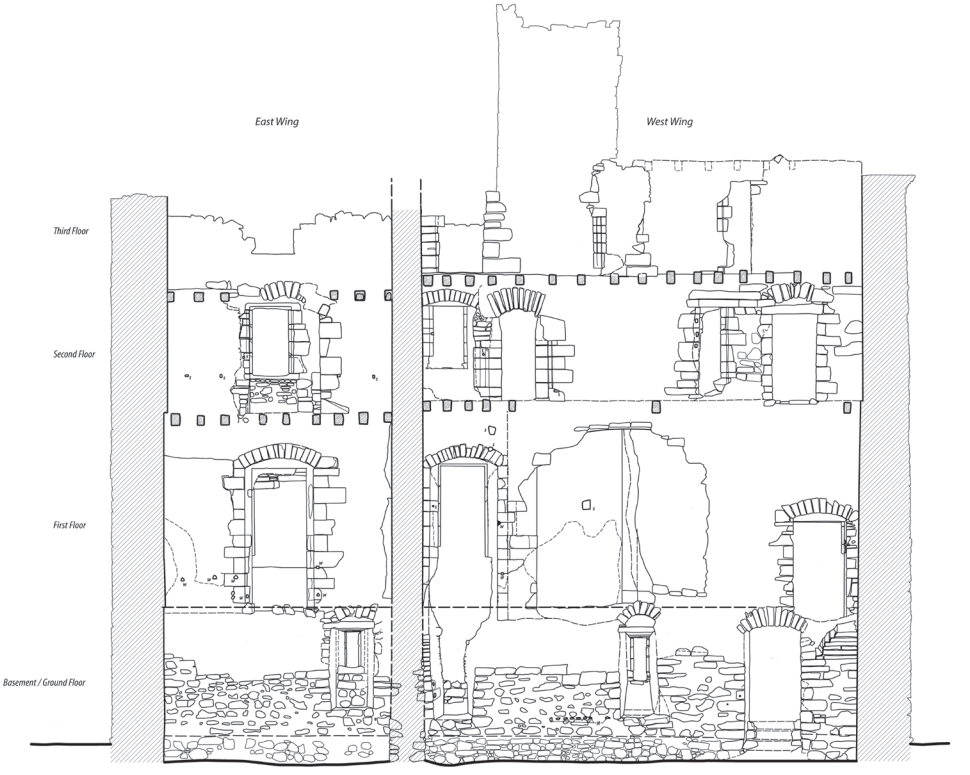
Oak from the eastern Baltic has been identified in Scotland and throughout the 16th century it is invariably in the form of radially cleft boards, very different to the beams being imported from Scandinavia. It has only been identified in four contexts so far, the painted ceiling boards from the Guthrie Aisle (*terminus post quem* 1459; Crone & Fawcett forthcoming), a group of carved panels now in Perth Museum and Art Gallery (*terminus post quem* 1508; Crone et al 2000) (illus 5), the carved roundels from Stirling Palace known as the Stirling Heads (*terminus post quem* 1530; Crone 2008: 10–11) and in three of the doors of the Palace itself (*terminus post quems* 1518, 1520 & 1533; ibid: 9) (illus 6).

All the boards have been radially cleft from slow-grown, straight-grained oak trees but they vary considerably in thickness, from the fine boards used for the carved panels from Perth which are 7–11mm thick, to the stouter boards used in the Palace doors which are 70–80mm thick. These variations may relate to the different terms used to describe timber imports from the eastern Baltic (see above). Shipments of Estland board were brought to Stirling during the period in which the Palace was being built and fitted out, in 1537–8 (MA 1: 228) and in 1541 (TA 7: 456). The Estland board bought in 1537–8 was intended for the 'chapell dur' but some of the same shipment may also have been used for the Palace doors.

All the board chronologies were dated in the first instance against either *BALTIC1* or *BALTIC2,* master chronologies based on tree-ring sequences from the oak panels of medieval and Tudor paintings from collections throughout England (Hillam & Tyers 1995). These are so named because, despite the fact that the paintings were executed in England, tree-ring analysis demonstrated that the oak panels had been imported from the eastern Baltic region; they matched best with chronologies from the region around Gdansk, on the Baltic coast of Poland (Baillie et al 1985). However, during the 14th and 15th centuries, Gdansk, that is, the Hanseatic port of Danzig, was the pre-eminent port for the export of timber: prepared boards being floated down the Vistula river from a huge hinterland throughout southern and eastern Poland and probably farther east, from present-day Belarus and the Ukraine (Wazny 1992; Haneca et al 2005: 262). During the 16th century, the centre of this trade shifted east to ports such as Riga and Konigsberg, the timber being floated down the River Daugava from sources even farther east in Russia (Zunde 1999). Thus, the *BALTIC1* and *BALTIC2* chronologies, which have quite distinctive tree-ring characteristics and represent different sources, could have come from anywhere in this vast area.

Work is underway to identify more specifically the sources of the art-historical

ILLUS 4 Fenton Tower, East Lothian; external and internal elevations of the southern walls, the latter showing the joist sockets on the 2nd and 3rd floors. Scandinavian oak, felled in and around 1572, was used for the floor joists throughout this towerhouse (© CFA Archaeology Ltd)



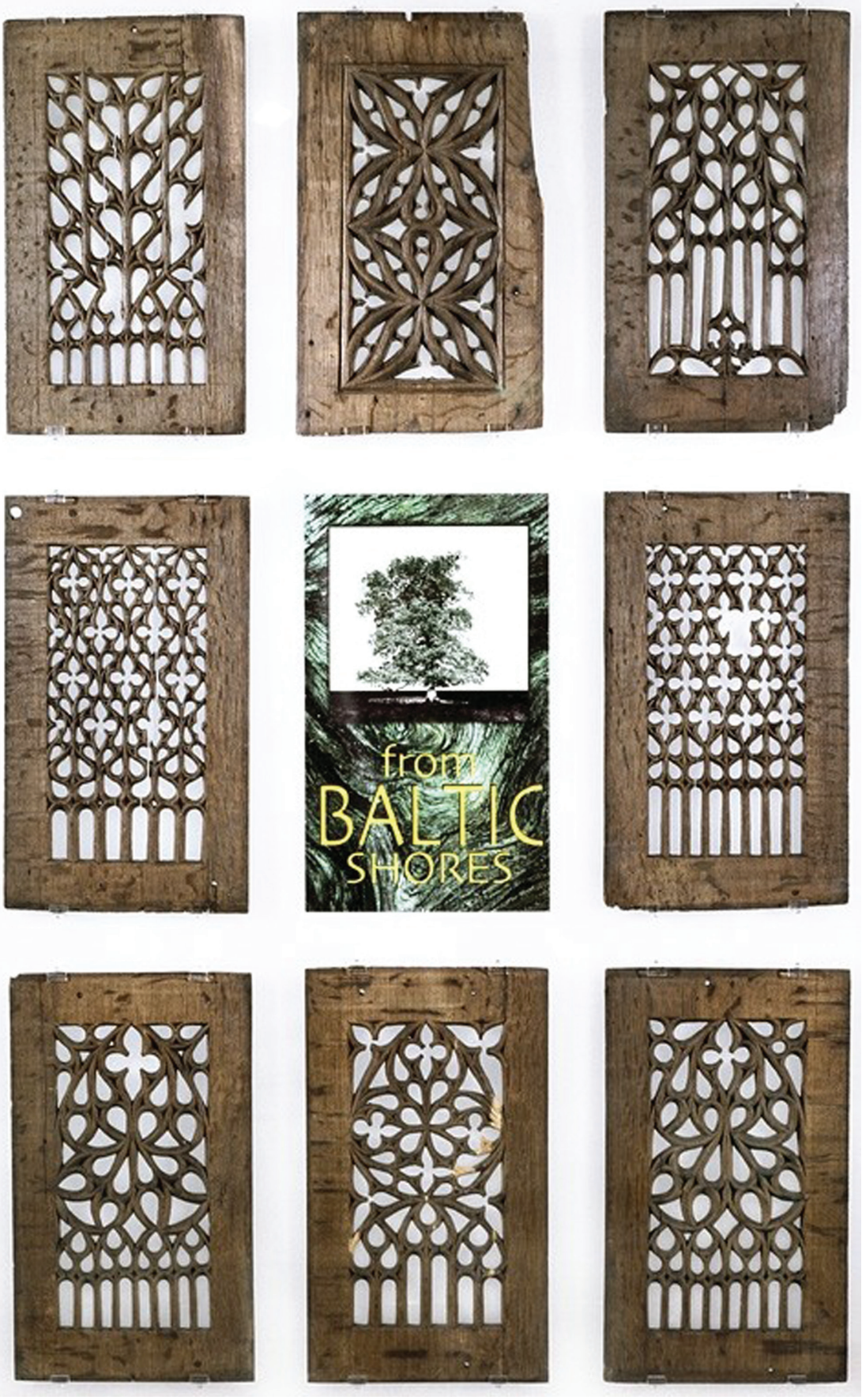
chronologies, using ultra-local site and regional chronologies (Haneca et al 2005). This is not proving straightforward, possibly because the site and regional chronologies are based on more workaday timber, not the slow-grown, straight-grained oak which was particularly prized for boards for export, but also because there are currently very few oak chronologies for the countries to the east of Poland (Wazny 2002: 318). However, Wazny (ibid: 316) has suggested that the likely source of the *BALTIC1* oak is south and east Poland; this is supported by the comparisons between the Guthrie Aisle chronology, which was dated against *BALTIC1*, and regional Polish chronologies which yielded highly significant correlations indicating that the source was probably the region around the Bialoweiza forest in eastern Poland.

Given the mixture of timber that we might expect in great rafts being floated downriver from such a vast area, it is not surprising to find that there was often a mixture of sources present in each construction, indicated by poor internal correlation within each assemblage. For instance, of the 19 boards from the Stirling Heads, 11 correlated very well together and a site chronology was constructed which matched *BALTIC1*, suggesting the same woodland within that region (Crone 2008: 10). Another five boards displayed only poor correlations with the site chronology but could be dated directly against *BALTIC1*, suggesting other sources within that region, while a group of three boards could only be dated against *BALTIC2*. Strong correlations amongst the boards used in the Palace doors was scarce, so a site chronology was not constructed and the boards were individually dated against *BALTIC1* (ibid: 9). Internal correlation within the assemblage of boards from the Guthrie Aisle ceiling was also very poor, with only a few pairs matching well (Crone & Fawcett forthcoming). Nonetheless, the pair masters and the individual sequences correlated strongly with *BALTIC1* and other regional chronologies, enabling them to be confidently dated. In contrast, the internal correlation within the assemblage of carved panels from Perth was so high as to indicate that all the panels had been cleft from the same tree (Crone et al 2000: 195). Miles (1995) has suggested that the reason why boards from the same tree were found adjacent to each other in the Winchester College painted ceiling was because the boards must have been prepared, seasoned and jointed, and then batched together before shipping.

Other sources of imported oak

While the Baltic region and Scandinavia are the principal sources of imports through much of the period under discussion, occasionally other sources are evident. When originally analysed, 16th-century timber from the Castle of Park, Glenluce, Dumfries and Galloway, was assumed to be native and was included in the 'Scotland' oak reference chronology (Baillie 1982: 148–9). Recently we have reviewed the evidence for Park with colleagues at Queen's University, Belfast, who built the chronology, because it now appears so anomalous as a lone native oak chronology amongst the sea of imported material in the 15th to 16th centuries (illus 2). Park matches most closely with Irish regional chronologies, especially those around Dublin (Brown pers comm) and shows much lower correlation with the few Scottish site chronologies which exist in this period. Provenance cannot be securely ascertained until there is a stronger Scottish native oak dataset for this period but, given the location of Castle of Park, so close to the Irish Sea, its timbers could as easily have been imported from Ireland (see Smout 1963: 178–82).

A single 16th-century timber from Fenton Tower, East Lothian, compared best against north German chronologies, suggesting that this region may also have supplied timber (Crone 2013; and see illus 12). Although just outside the study period discussed in this paper, north German oak has also been identified in an early 19th-century-harbourside warehouse, Elie Granary, in Fife (Mills 2002).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PINE; THE DENDROCHRONOLOGICAL EVIDENCE

Since the Antiquity paper (Crone & Mills 2002), the greatest advances have been in the development of pine dendrochronology. In 2002, only one building in Scotland with pine timbers had been dated – 18th-century imported pine had been identified in 42–44 Market Street, Haddington (Crone unpubl c). There were many assemblages that we were unable to date and we speculated that at least some of these might be native, the absence of native pine chronologies covering the early modern period being the key drawback (Crone & Mills 2002: 792). This was the stimulus for the development of the NOAP project, in which we set out to extend the existing pine chronologies back in time through a two-pronged approach – to find very old living pines in remnants of the native Scots pine woodlands (Mills 2008; Mills et al forthcoming) and to identify in the building stock of north-east Scotland those pre-1800 buildings which are likely to have been constructed using native timber (Crone & Mills 2011). This has resulted in the dating of a number of vernacular buildings and has also provided us with yet more evidence of imported timber in some of the buildings investigated during the course of the project.

There are still only a handful of dated pine buildings in comparison to the number of dated oak buildings (illus 2). These few examples show that, as with the imported oak, Scandinavia and the eastern Baltic were also the primary sources for imported pine. The dendrochronological evidence for the use of native pine in building is currently limited to a few examples of vernacular construction in Aberdeenshire and, as their dating is intimately connected with the development of the living pine chronologies, they are discussed in the next section.

Scandinavian pine

The earliest dated pine timbers are floorboards above the Queen's Bedchamber in Stirling Palace, felled in 1535 and thus part of the Renaissance building (Crone 2008: 17–20). These are plain-sawn boards, almost certainly imported as such from Scandinavia, probably the 'sawin dalis' of the *Accounts* (see above). The pine beams that were inserted throughout Stirling Palace to strengthen the floors of the Renaissance building were felled between 1664 and 1671 and were also imported from Scandinavia. These were mainly boxed heart baulks adze-dressed to shape. As pine is not native to Denmark (it was introduced in the late 18th century – Fritzboger 2004: 324) it must have come from either Norway or Sweden, but the correlations with the regional chronologies were not sufficiently high to specifically identify either country as the source (ibid: 40, 43).

These two dated pine constructions aside, there are still numerous assemblages of 16th- and 17th-century pine timbers which have been analysed but remain undated; for example, painted ceiling boards from Abbey Strand, Edinburgh (built by 1570; Crone forthcoming a), floor joists from the 17th-century Queensberry House, Edinburgh (Crone unpubl d), roof timbers from the 17th-century development of Gardyne's Land, Dundee (Crone unpubl b), to name but a few. Indeed, it is clear from our visual observations that by the 17th century, pine had replaced oak as the most common timber for major structural purposes, such as rafters and joists. Setting aside the remote possibility that they were built with native pine (Lythe 1960: 143 – and see below), let us consider the case of Duff House, Banff, which may provide some insights into why dating these buildings is proving difficult.

ILLUS 5 The tracery panels in the collections of Perth Museum and Art Gallery, carved from eastern Baltic oak boards some time after 1508 (the image is from a 2002 exhibition 'From Baltic shores' © Perth Museum and Art Gallery, Perth and Kinross Council, Scotland)

ILLUS 6 Sampling in progress on the massive oak door leading from the Inner Close into the Palace at Stirling Castle. This was made from Eastern Baltic oak boards some time after 1533

Duff House was selected as a candidate for the NOAP project because documentary evidence suggested that we would find native pine in the roof (Crone unpubl e). A dispute arose between the owner, Lord Braco, and his architect, William Adam, and the court papers reveal some information on timber sources:

> And as for the Timber, the Petitioner provided himself partly from his own Woods in Braemar, where there are very fine Trees, which he caused to be flotted down the River Dee to Aberdeen, and from thence brought about to Banff, and partly by Cargos, which he caused to be imported for his own Use from Norway, and some part of the Timber … were furnished to him by Mr William Adams of Edinburgh Architect (Court of Session papers 1743: 3).

As the date of construction of the roof was well-known (the foundation stone was laid in 1735 and the roof was put on in 1739; Gow & Clifford 1995), the objective in carrying out the dendrochronological analysis of the roof timbers was not to date the building but to identify native-grown pine, which would contribute to the development of a native pine chronology for Scotland. Of the 49 timbers sampled, 34 correlated well together and were combined to form a site chronology which yielded low but consistent correlations with chronologies from Norway and Sweden and indicated that the timber had been felled in 1736 and 1737, thus fitting very neatly with the known building history. However, none of the statistical correlations were sufficiently high to indicate more than a

ILLUS 7 42–44 Market Street, Haddington. Eastern Baltic pine felled in 1765 and 1776 was used for the lintels, rafters and bressumer beams sampled during the renovation of this small townhouse

general Scandinavian provenance. Lord Braco stated very clearly that he imported the timber from Norway, yet the dendrochronological results could not identify that specific country as the source. One possible explanation is that the imported timber used in Duff House came from a geographically isolated area within Norway, at the head of a small fjord, for instance. Until the early 18th century, Scottish skippers had been able to trade directly with the farmers who owned the woods on the shores of the numerous little fjords in the Stavanger area, and when this trade was forbidden in this area by royal resolution in 1717 (Lillehammer 1986: 109) this means of trading simply transferred to the fjords of Sunnhordland, south of Bergen (Thomson 1991: 5). The tree-ring signal from these small, varied environmental niches along Norway's western littoral may be too distinctively local to be picked up in the regional chronologies and thus generate little or no correlation (Thomas Bartholin pers comm). Furthermore, dendrochronological coverage for areas such as western Norway is relatively poor in the 18th century (Thun 2002: 104), meaning that during this period the regional chronologies may not be reflecting a truly regional signal.

Thus, one possible reason for the lack of success in dating some of the 16th- and 17th-century pine assemblages may be the extent and quality of chronological coverage in the source region. Certainly, there is abundant documentary evidence to suggest that from the mid-16th to mid-17th century, the bulk of Scotland's timber imports all came from Norway (see above).

Eastern Baltic pine

There are now four 18th-century constructions where dendrochronological analysis has shown that pine imported from the eastern Baltic was used (illus 2). This reflects what is known of changes in the timber trade during the 18th century (see above).

The dating of the joists from the Great Hall, Stirling Castle and the timbers from 42–44 Market Street, Haddington (illus 7), illustrate the iterative nature of the dendrochronological process and the need for pan-European co-operation. The joists from the Great Hall had been analysed in 1995 but could not be dated at that time (Crone & Fawcett 1998: 80). The timbers from the Haddington house were analysed in 1998 and were initially dated against Scandinavian regional chronologies, providing felling dates of 1765 and 1776 (Crone unpubl c; Mills & Crone 1998). The Great Hall joist chronology was subsequently compared against the Haddington chronology and produced felling dates of 1783 and 1786; however, as it did not produce correlations with any of the regional chronologies, the dates had to be considered provisional until further replication could be established. In the past decade, the establishment of dendrochronological laboratories in the countries of the eastern Baltic – Latvia, Estonia and Lithuania – has resulted in the development of many regional pine chronologies and consequently, it became possible to both confirm the Great Hall date and to determine that the source of the timber in the Haddington chronology was actually eastern Baltic and not Scandinavian (Table 2). Subsequently, both the Haddington and the Great Hall chronologies were used to date the timber piling found beneath the foundations of Elderslie House, Glasgow (illus 8; Table 2), some of which had been felled in 1768 and in 1774 (Crone unpubl f).

Like Duff House, the military complex at Fort George, Inverness, was selected as a candidate for the NOAP project because of the references in the Army ledgers to the use of native pine in its construction (Doreen Grove pers comm). As the construction history of the complex is well known (MacIvor 1976), the main objective in carrying out the dendrochronological analysis of the roof timbers was not therefore to date the buildings (although exact felling dates would provide valuable information on supply patterns to the fort) but to identify the native pine. Separate

ILLUS 8 Elderslie House, Glasgow. Eastern Baltic pine felled in 1768 and 1774 was re-used as piling under one corner of this late 18th-century mansion

building chronologies were constructed for the Ordnance Store South, the Staff Block and the Chapel; the latter two chronologies correlated very strongly with each other but there was no correlation with the Ordnance Store chronology – suggesting two very distinct sources for the timber (Crone & Mills unpubl b). The Staff Block/Chapel chronology was subsequently dated against regional and site chronologies from Finland and Russia while the Ordnance Store chronology was dated against regional and site chronologies from the Baltic states and eastern Sweden (Table 2). There were felling dates of 1762 and 1763 amongst the Staff Block timbers, but the bulk of the timber for the Staff Block and the Chapel had been felled in 1764; as the Staff Block was built between 1761 and 1766, and the Chapel between 1763 and 1767 (MacIvor 1976), this suggests that a large shipment of timber was probably ordered early to ensure that it was there for the erection of the roofs (see below). Felling dates could only be estimated for the Ordnance Store timbers as the surfaces of the timbers were worm-eaten, but they also indicate a supply date well in advance of the completion of the roof in 1761.

The Ordnance Store timbers came from the same general region as those in the Great Hall at Stirling Castle, Market Street, Haddington, and Elderslie House. This region is hard to

TABLE 2
Eastern Baltic pine; statistical correlations between Scottish imported pine chronologies, English imported pine chronologies and regional pine chronologies from the Baltic States (t-values for the Latvian chronologies have been calculated using TSAP)

Chronology	*MSHADx5*	*GHPINEx5*	*EHMNx9*	*OSMNx12*
Scottish import				
MSHADx5 (1590–1776) 42–44 Market Street, Haddington		6.01	11.60	/
GHPINEx5 (1593–1786) Great Hall, Stirling Castle			6.30	/
EHMNx9 (1580–1774) Elderslie House, Glasgow				/
OSMNx12 (1492–1744) Ordnance Store, Fort George, Inverness				
English import				
Bsta-T5a (1673–1799) Bishopthorpe Palace, Yorks (Cathy Groves pers comm)	6.52	5.10	6.67	/
DANSON1 (1489–1758) Danson House, Bexley, Kent (Cathy Groves pers comm)	4.36	4.61	6.44	4.65
DANSON2 (1545–1767) Danson House, Bexley, Kent (Cathy Groves pers comm)	5.29	5.12	5.44	/
HSEMILL (1608–1801) House Mill, Bromley by Bow, London (Cathy Groves pers comm)	3.93	3.68	4.56	/
GAYLEMILL (1581–1783) Gayle Mill, nr Hawes, Yorks (Cathy Groves pers comm)	5.79	4.09	5.85	/
Lithuanian				
ADOMAS-PINE (1487–2002) Central Lithuania (Adomas Vitas pers comm)	7.10	6.84	9.57	4.40
BZGUDZC1 (1486–1798) Historic churches, Lithuania (Rutile Pukiene pers comm)	7.62	5.68	8.42	3.95
ZP06PSC4 (1672–1903) Vilnius, Lithuania *(Rutile Pukiene pers comm)*	3.90	7.07	5.60	/

Chronology	*MSHADx5*	*GHPINEx5*	*EHMNx9*	*OSMNx12*
Latvian				
AHR_1800 (1337–1800) mean chronology for Latvia *(Maris Zunde pers comm)*	7.20	7.60	7.40	4.50
BSKD1751 (1583–1751) Holy Spirit Church, Bauska *(Maris Zunde pers comm)*	6.20	6.00	6.70	3.80
DSN1694 (1445–1694) Dannenstern House, Riga *(Zunde 1998a)*	4.80	4.90	5.20	6.10
Estonian				
3ep292av (1528–1998) mean chronology for Estonia *(Läänelaid & Eckstein 2003)*	7.53	5.52	6.86	5.19

define. The pine exported out of the Baltic ports such as Riga and Memel (and also probably used in the buildings of those ports and their hinterlands) could have come from anywhere within a huge hinterland which extended as far east as the Volga (Astrom 1988: 99; Zunde 1998b: 73). Timber from the Russian interior was rafted downriver to the ports of the eastern Baltic and the distances were so great that it could sometimes take up to two or three years for the timber to arrive, timber of varying age and source being mixed up in the river systems in the process (Albion 1926: 145; Maris Zunde pers comm). Thus, it may be necessary to add two or three years to the felling dates of any timber provenanced to this region (see below).

The timber used in the Staff Block and the Chapel at Fort George came from much farther north, from Karelia, a region which straddles the present Finnish–Russian border. Although sawn timber was the major type of timber export from this region (Astrom 1988: 34), some 'fir baulks', the type of timber used in the Fort George roofs, began to be shipped from southern Finnish ports in the early 18th century (ibid), but this type of timber seems always to have been a small proportion of forest produce from Karelia. The major ports in the Gulf of Finland, at this time, were Viborg and Fredrikshamm (now Hamina) in the north-east and St Petersburg in the south-east. Until the construction of a canal system in the mid-19th century timber was transported to the ports, either by rafting down the Ladoga channel or the River Neva to St Petersburg, or hauled overland by sleigh in wintertime to Viborg and Fredrikshamm (Astrom 1988: 81). Given the distances involved, there may have been a lag of up to a year between felling and arrival at the port. Thus, the timbers felled in 1764 may not have arrived in the port until early 1765, possibly arriving in Fort George late in that year, just in time for incorporation into the Staff Block roof, which we know was completed in 1766.

THE NATIVE WOODLAND RESOURCE

So far, this paper has concentrated largely on the tree-ring evidence for imported timber, but our dendrochronological work has also produced

insights into the historic native woodland resource which, in turn, help to explain the increasing reliance on imported timber (Mills & Crone 2012). The age and growth-pattern of building timber can provide us with information about the quality of the woodland from whence it came. During dendrochronological sampling, details such as the morphology of the timbers, the method of conversion from the tree, the scantling (ie, cross-sectional dimensions), straightness of grain, presence of branch scars, etc would be recorded as these all have some bearing on the quality of the timber available. In this section, this information is used to assess the quality of the native woodland resource at particular times, oak during the 15th and 16th centuries and pine during the 17th and 18th centuries. As the dendrochronological data represents a source of evidence which is independent of the historical record, it can be used to verify and complement documented sources of Scottish woodland history, the subject of much recent research (eg, Smout 1997; 2003; Smout et al 2007).

OAK

As the 15th century progressed, the Scottish parliament became increasingly concerned about the condition and extent of the woodlands of the realm and issued a number of Acts, in 1424/5, 1457/8 and 1503/4, all of which sought to prevent damage to the remaining woodland and encourage the planting of new trees (Smout et al 2007: 38). That there was cause for concern is reflected in the dendrochronological evidence which shows that in the early decades of the 15th century, there were still sources of large, slow-grown oak available in Scotland (see above), but that by the end of the century, builders were increasingly relying on imported oak (illus 2). Scottish timber was still available; in the early decades of the 16th century it was brought from woods at Falkland, Dalhousie, Callander, Clackmannan and Kincardine (ie, TA2: 279, 470; MA 1: 104, 124; TA 3: 134), and farther afield from Darnaway, Cawdor and Caithness, for use in the Royal building projects (ie, TA 3: 190; TA 4: 44, 330). Occasionally the quality and the species of Scottish wood is described, as in 'great oak joists' or 'great oak trees' (MA 1: 35, 126) but on the whole, the documentary sources are quiet on the quality of the native timber. However, the uses to which it was put, that is, birch for scaffolding and trestles, oak for laths and sarking (MA 1: 124, 182, 189), suggests that there was little of the quality needed for rafters and joists.

This is borne out by the small amount of dendrochronological evidence available. Native oak felled in 1500/1, and subsequently re-used in the construction of the King's Bedchamber at Stirling Palace, was relatively young and fast-grown, 80–100 years at most (Crone 2008: 13). Most of the timber used in this room was even younger, to the extent that some of timbers had too few rings to be analysed and could not be dated; we have surmised that this too is probably native wood. There is, of course, a danger of circular argument here; if the oak is young and fast-grown then we are assuming that it is native, but we cannot conclusively demonstrate its provenance precisely because it is young and fast-grown and not susceptible to dendrochronological analysis. However, the contrast with the imported timber used in the same building episode at Stirling Palace, which is older and slower-grown, between 120 and 140 years of age (ibid: 33, Table 2) tends to support the assumption that young, fast-grown oak of late 15th-/early 16th-century date is probably native. For these reasons, we believe that the young oak used for the rafters in the late 15th-century towerhouse at Alloa, Stirlingshire, was also native; it was small, fast-grown timber, all less than 60 years old, and so could not be dated (see below).

Alloa and Stirling lie in central Scotland, where woodlands may have been exhausted earlier than in other parts of the country.

Certainly, the very long-lived oaks from which the panels used to make the choir stalls in Lincluden College, Kirkcudbrightshire, were cleft (one of which was 367 years old; Baillie 1982: 149) suggests that small pockets of mature oak woodland survived in south-west Scotland into the late 15th century.

Native oak does not appear again in the dendrochronological record until the late 16th century and early 17th century (illus 1). Oak timbers were felled for Newark Castle, Port Glasgow, in 1598 (Crone unpubl a), for Crathes Castle, Aberdeenshire, in 1589 and 1591, and for the mansion house at neighbouring Drum in 1608 and 1609 (Crone & Mills unpubl a). For the very reasons outlined above, there are few other native oak chronologies against which to compare and date these chronologies. As discussed above, the late 16th-century timbers from Castle of Park could well have been imported from Ireland rather than sourced locally, and the only other native oak chronology which spans the 16th century is that from the living oaks at Cadzow, Hamilton (illus 2), and the first 50 years of that chronology consists of only a single tree (Baillie 1982: 104). Consequently, the Newark, Drum and Crathes site chronologies have been dated against regional and site chronologies from Ireland and England, and although the correlations are low, the possibility remains that the timber could have been imported from these countries.

Nonetheless, it is unlikely that English or Irish timber was used at Drum and Crathes. In 1606, Alexander Davidson, 'timber man in Saint Andrews', was licensed to build a ship within the burgh of Aberdeen, using timber from the 'wood of Drum', which was ready to be floated down the Dee to the burgh (see www.aberdeenships.com). If there were enough suitable trees at Drum to supply the timber to build this ship, reputedly called the *Bonaccord*, then there was probably enough local wood to build the mansion house. Furthermore, the difference in felling dates, combined with the internal chronological relationships between the Drum and Crathes timbers, makes it more likely that a local source was being used.

If we accept that the chronologies from Newark, Drum and Crathes are indeed native oak then it would seem that the exhortations of the Scottish Parliament to plant and grow trees may have had some impact. The trees felled to build these castles began life in the latter half of the 15th century and in the early 16th century, while half of the trees included in the Cadzow chronology had begun life around 1500 (Baillie 1982, 104). The homogeneity of the age structure amongst the late 15th-century Alloa Tower rafters (with the great majority of timbers between 40 and 50 years of age) is also suggestive of growth in managed woodland. Thus, it would appear that on certain estates at least, the landowners were either actively planting or putting conservation measures in place which allowed regeneration of woodland. The ban on the export of Norwegian oak imposed in 1602 (Lillehammer 1986: 104 – and see above) signalled the drying-up of regular sources of imported oak and so the landowners may have been forced, of necessity, to use their own woodlands.

The admittedly limited data set for native oak in the late medieval period also suggests that Scottish woodlands were not producing particularly good quality timber in this period. At Newark, the growth-rate of the timber felled in the late 16th century was very variable, with bands of both fast and extremely slow growth. The grain of the wood was often irregular, with many of the rafters and collars displaying pronounced curvature along their lengths. One might anticipate this type of growth in an environmentally stressed situation or under poor management. At both Drum and Crathes much of the timber also displayed irregular growth and was often quite knotty, with large patches of bark edge left on the edges of timbers (illus 9), presumably to get the maximum scantling out of the trees. Much of the timber from Drum was also characterised by bands of compressed

ILLUS 9 Sampling of the early 17th-century roof of the mansion house, Drum Castle. The knottiness and wavy grain of the locally grown oak is visible on the rafters above and behind the dendrochronologist

growth, which was particularly pronounced in the latter 20–30 years of each tree's life. The woodland may have been poorly managed at this time, the trees becoming crowded and competing with each other, hence the severely reduced growth.

PINE

Most of the buildings reported in this section are located in north-east Scotland because this was the area selected as the focus for the NOAP project. The reasons for this selection were two-fold. North-east Scotland has a large number of indigenous woodlands dominated by natural-origin Scots pine (*Pinus sylvestris* L); these woodlands survived large-scale exploitation until the 18th century, primarily because they were remote and inaccessible, and the lack of a developed transport infrastructure made the extraction and movement of timber in any great quantity extremely difficult (Lythe 1960: 143; Smout 1960: 12). As a consequence, remnants of the pinewoods have survived into the present day and contain occasional stands of long-lived pine suitable for building reference chronologies (Steven & Carlisle 1959; Edwards 1998; Jones 1999; Mills 2008; Mills et al forthcoming). Furthermore, timber for building is likely to have been sourced locally; not only because there were plentiful supplies but also because the very inaccessibility which prevented export will also have prevented the import of foreign timber. Thus, in this area we anticipated finding native pine in pre-1800 buildings more readily than in lowland and coastal Scotland.

Over the course of the NOAP project we examined the timber component of 48 buildings of predominantly 18th-century date and at least some of the original timberwork had survived in 36, or 75% of the sample (Crone & Mills

2011, 23). In those buildings where the original timbers have survived, the wood used is almost invariably pine (the only buildings where oak was found was in the castles of Drum and Crathes described above) and is usually young and fast-grown, the average, estimated age of the timber being 30–50 years (illus 10). This quality of timber was used across the spectrum of building types, from the agricultural steading at Dallas Lodge, Moray, to the laird's residence at Leith Hall, Huntly (ibid: 24). More long-lived pine was only observed in Duff House, Banff, and in the complex of buildings at Fort George, Inverness, but this material proved to be imported (see above). Duff House also contained a lot of young timber, some as young as 15 years, and consequently, this type of timber was not sampled. There was a mixture of sawn and axe-dressed timber within the roof and we observed that many of the sawn timbers in particular were very fast-grown. The carpenters had been instructed '… to saw out the longest of the logs that came from Braemar…' (Court of Sessions papers 1743: 28), which lends support to the contention that the young, fast-grown timber was indeed native. The Barracks at Fort George were not sampled for the same reasons, that is, the timber was too young and fast-grown. Is this the native pine mentioned in the Army ledgers? The Barracks were the first buildings to be erected in the Fort (MacIvor 1976: 33) so this may have been the only type of timber that the Army could obtain rapidly. It was clearly not up to scratch because in 1752, builders for the army garrison at Fort William wanted imported wood rather than local supplies as it would be better quality (Smout et al 2007: 130 – and see below).

The short ring-patterns of much of the timber examined during the NOAP project made it unsuitable for dendrochronological analysis (see EH 1998 for discussion of sequence length) but a handful of buildings promised longer ring-patterns and these were subsequently sampled and analysed; in particular, we targeted buildings near some of the recently developed living tree chronologies in Upper Deeside to test whether the proximity of local reference chronologies would aid in the dating of relatively short ring-sequences (Mills 2008; Mills et al forthcoming). This has resulted in the successful dating of two vernacular buildings, the first time in the UK that dendrochronological dates have been obtained for native pine timbers in buildings. The uprights of a cruck frame within the Red House, at Mar Lodge Estate (illus 11), were felled in 1799 and 1808 (Mills 2008). The presence of two felling dates suggests either re-use or remodelling, or possibly stockpiling of timber for use on the estate, which had quite a sophisticated forestry infrastructure by this time, including its own sawmills (Urquhart et al unpubl; Watson & Stewart 2004). The timbers for the main construction phase of a cruck-frame byre at nearby Inverey were felled in 1799/1800 and the building was subsequently remodelled in 1815 (Mills 2008). These dates suggest that these were new buildings constructed as part of the wider re-organisation of the Mar Estate settlement pattern, after the clearances of many of the townships in the name of 'improvement' under the 2nd Earl of Fife, in the latter part of the 18th century (Dixon & Green 1995).

Both of these dated buildings yielded longer sequences than anticipated; the Red House crucks were between 80–110 years old while the Inverey byre contained sequences up to 141 years of age. However, proximity to local reference chronologies representative of the original source area may be the most critical factor in the dating of native pine timber. Several buildings along the Spey valley were analysed but none could be dated, despite the presence in some buildings of many sequences over 80 years in length (Crone unpubl g). Poor internal correlation prohibited the construction of robust site chronologies for Castle Grant, Grantown-on-Spey, MacRobert House, Kingussie, and the building from 96 High Street, Grantown-on-Spey; only occasional pairs and trios of sequences correlated well together and this is usually indicative of a variety of woodland

ILLUS 10 The Old Laundry, Drum Castle (*c* 1800). The roof has been built with small, fast-grown, hewn pine

sources (see above). The wide variety in growth rate was particularly pronounced amongst the timbers from MacRobert House, which included fast-grown timbers less than 40 years of age and slow-grown timbers up to 124 years of age. Grantown-on-Spey and Kingussie were planned towns, the former established in 1765 and the latter in 1799 (Partridge 1982). By the late 18th century, the timber used to build these towns would have been bought either from merchants at a local burgh market, from sales held in the woodlands themselves, or directly from the landowner's factor or forester (Smout et al 2007: 147). The adverts to attract residents to Grantown-on-Spey drew attention to the abundant local timber in the woods of Abernethy and Glenchernich; the timber used in building the town is likely to have been floated down the Spey from the Grant Estates throughout Strathspey (Dickson 1976). Thus, the timbers could have originated in woodlands growing in varying conditions, from the moraines and eskers along the valley floor, to the higher altitudes of the Cairngorms (Dunlop 1994: 17), and increasingly, by the early 19th century, from the plantations around the town itself (Dickson 1976: 56).

Poor internal correlation is not necessarily an obstacle to successful dating, as we have seen with the eastern Baltic oak boards. However, the absence of local reference chronologies appears to be more of a drawback. In contrast to the situation around Upper Deeside where, as a result of the NOAP project, there is now a group of independent chronologies which extend back to the 15th century (Mills 2008; Mills et al forthcoming), there was, at the time of the NOAP project work, only one local reference

chronology for Strathspey and it only extended back to 1788 (Rob Wilson pers comm). Work is underway on the development of chronologies from other Strathspey woodlands but existing sections, at the time of the NOAP analysis, did not extend back beyond the mid-19th century (Wilson 2008). If, as other historical information suggests, the Kingussie and Grantown-on-Spey buildings were built in the early decades of the 19th century then none of the available chronologies from Strathspey could provide sufficient overlap. The dating of the Strathspey buildings will be revisited as the local native pine chronologies are expanded.

The work of the NOAP project has produced a body of data about the quality (ie, size and age) of timber used in building in north-east Scotland in the 17th and 18th centuries (Crone & Mills 2011). How does this translate into reconstruction of the pine woodlands during these centuries? While there are some earlier examples of native pine use within Scotland, the commercial exploitation of the native pinewoods is thought to have accelerated from the early 17th century and early reports described a plenitude of trees of great height and girth (Smout et al 2007: 195–6). The two 16th-century assemblages of native pine that we have examined tend to corroborate these descriptions; the pine timbers used in the mid-16th-century roof of Castle Grant were large scantling, up to 260–300mm across, and some were as much as 146+ years old (Crone unpubl h), while the undressed pines used in the construction of the late 16th-century crannog at Eadarloch, Loch Treig, were as much as 260mm in diameter and in excess of 200 years old (Crone 2011). These contrast strongly with the pine timbers found in the 17th and 18th century buildings which were, on the whole, slender poles of relatively small scantling, rarely more than 150mm across, and usually quite young and fast-grown. Presumably, once commercial exploitation started, the larger trees, which were more easily converted into beams and deals at the sawmills, were reserved for external markets, leaving the smaller timber for local domestic use. This accords with contemporary

Illus 11 The Red House, on the Mar Lodge Estate. Pine felled locally in 1799 and 1808 was used to build a cruck-framed cottage, later converted into a keeper's lodge

accounts; that although Norwegian timber was being imported for more prestigious buildings, 'there is enough at home for country purposes' (Smout et al 2007: 127) and '… for the houses of the common people' (ibid: 131).

FELLING DATES AND CONSTRUCTION DATES

Dendrochronological analysis can, given the ideal sample (ie, one on which the tree-ring sequence is complete to bark edge), produce a precise calendar date for the felling of the timber. However, the year in which the timber was felled and the year in which it was incorporated into the building are not necessarily one and the same date. There are many reasons why a lag between felling and use might occur; seasoning, transportation times, stockpiling, delays in the building schedule, etc (Miles 2006). Timber, as a scarce and valuable resource, was also extensively recycled. In this section we reflect upon these issues, primarily in a Scottish context and how they bear upon the interpretation of a dendrochronological date.

SEASONING

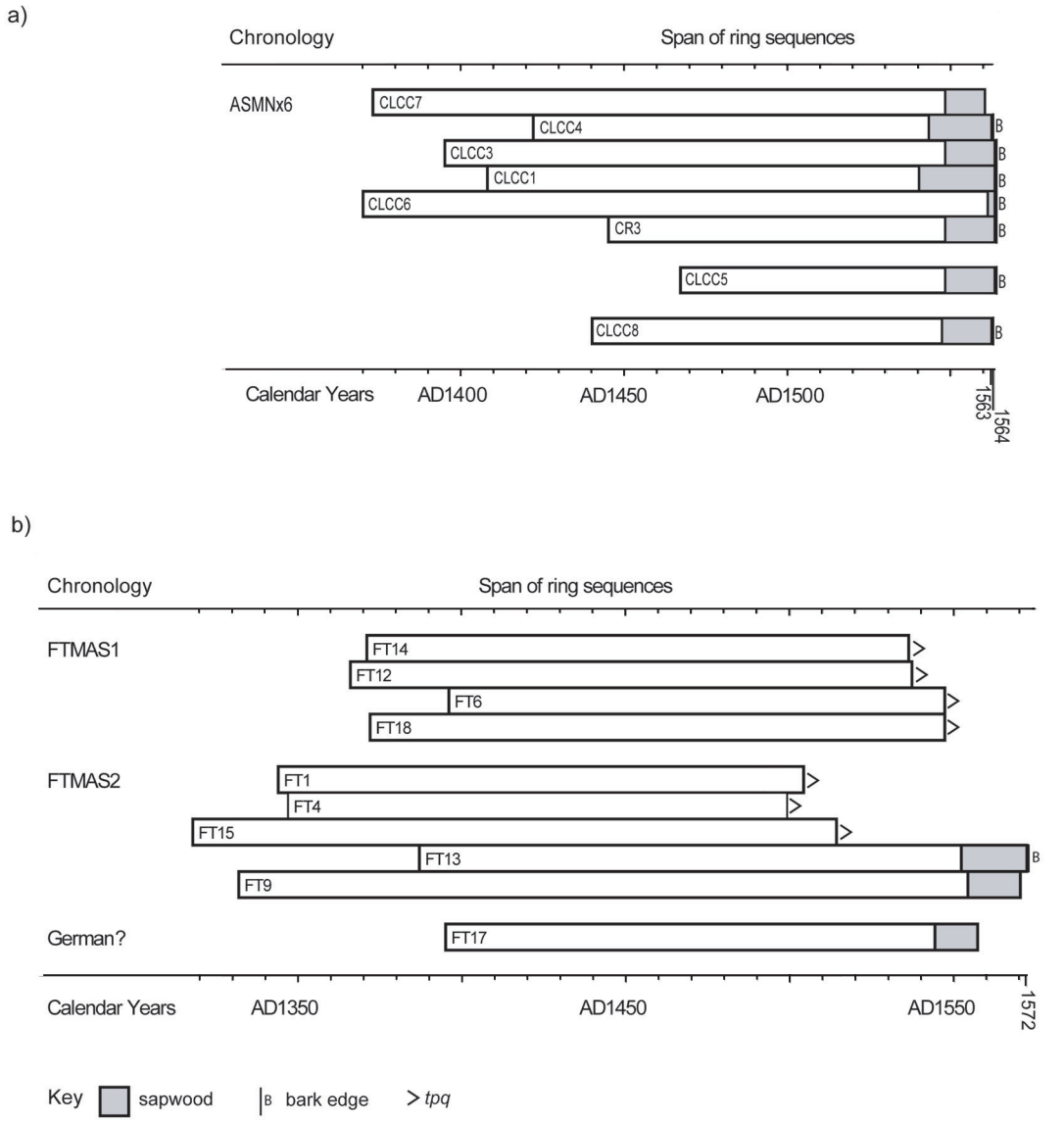
The medieval carpenter preferred to use oak when it was green, that is, immediately after felling; it was certainly easier to work in that condition and the in situ seasoning process helped the joints of the timber to lock in place following construction (Munby 1991: 382). For this very reason, the great majority of vernacular buildings were probably built in the same year in which the timber was felled. Nevertheless, we know from a number of late medieval English contracts that seasoned timber was occasionally preferred (Salzman 1952: 239), and there is a growing body of tree-ring evidence that suggests that the use of seasoned timber was perhaps more commonplace than is documented. In a survey of the dendrochronological results for medieval buildings dated by one English laboratory, Miles (1997: 52) concluded that, where documentary and other evidence such as inscribed date stones were available, there was frequently a lag of one or two years between the latest felling date and completion of building. Oak timber can take from six months to at least two years to season, depending on the cross-sectional dimensions (Fidler 1893), so the time lags observed by Miles could have been due as much to the vagaries of timber supply as to seasoning – but it would at least have ensured that all wood used in the building was fully seasoned.

Where we can identify the time lag with any confidence in Scottish buildings, it appears to be of the same order of time. The latest felling date from the oak roof of the Great Hall at Edinburgh Castle is 1509/10 (Crone & Gallagher 2008: 249), but the building was probably not completed until 1512, when the final payment for the slating of the roof is recorded (ibid: 254). The smooth toolmarks and the shakes, or cracks along the dressed faces of the baulks indicate that the timbers had been dressed square while green (Darrah 1982; Miles 1997: 54), probably at source (see above).

STOCKPILING

The Great Hall at Edinburgh Castle is not the only Scottish building for which we have both dendrochronological dates and other sources of evidence for construction date but in the other buildings, interpretation is complicated by the issue of stockpiling. In an economy heavily reliant on imported timber, stockpiles will have accumulated in merchants' or builders' yards in advance of a building project. From a dendrochronological perspective, this will mean mixed sources (see above) and a mixture of dates: timber being acquired as and when it became available. Unfortunately, stockpiling is difficult to detect dendrochronologically unless we have a large assemblage in which the bark

edge has survived on many of the timbers, thus allowing the full range of felling dates to be observed. In the Great Hall, the bark edge was present on 79% of the analysed timbers, thus allowing us to detect felling in 1505 (one timber), 1506 (two timbers), 1507 (one timber), 1508 (five timbers) and 1509/10 (six timbers). As timbers of various felling dates were scattered throughout the roof, for instance, some frames containing timbers felled in 1506, 1507



Illus 12 Stockpiling and the construction date of a building. (a) the chronological relationships between the dated oak timbers from Abbey Strand, Holyrood, Edinburgh; as five of the eight dated timbers were felled in 1564 it is likely that building began in that year or shortly after. (b) the chronological relationships between dated floor joists from Fenton Tower, East Lothian; with only one felling date, it is more difficult to determine how this relates to the construction date of the building

and 1509, it follows that the construction of the roof was a single event, the carpenters drawing from a stockpile of mixed-age timber which had been accumulating since 1505 (Crone & Gallagher 2008: 253).

Interpretation of the painted oak beams from Abbey Strand, Holyrood, Edinburgh, was also relatively straightforward, with all but one of the dated oak timbers felled in either early 1563 (two timbers) or 1564 (five timbers) (Crone forthcoming a) (illus 12). With that number of exact felling dates falling in one year, we can be more confident in asserting that construction probably began within a year or two of the latest felling date, if we allow for the one- or two-year time lag described above. This accords well with the documentary evidence; the building was described as 'new biggit' in 1570 (Gallagher 1998: 1095).

In the majority of buildings, however, the trimming-off of sapwood and/or woodworm damage to the outermost rings often means that an exact felling date can only be obtained for one or two timbers – and in these instances, the relationship between the felling date and the construction date is more difficult to determine. The bark edge survived on only one oak timber from Fenton Tower, East Lothian, indicating felling in the spring/summer of 1572 (illus 12b). Was this timber obtained just prior to construction or is it just one of many timbers from a mixed-age stockpile, the 1572 date bearing no clear relation to the date of construction other than providing a *terminus post quem*? The tower reputedly once bore a plaque inscribed with the date '1577' (Cressey et al 2013: 35); if this was indeed the date of completion of the building (but see below), then the latter interpretation is correct. Only one timber from the oak roof of the Guthrie Aisle, Angus, yielded a felling date, in 1464, so again we cannot determine whether this was the latest felling date or one within a spread of dates. Documentary sources suggest that building cannot have begun before 1466, when Sir David Guthrie's re-acquisition of his paternal estates was formally registered under the Great Seal (Crone & Fawcett forthcoming), so he may have begun buying timber in readiness for the start of his planned building project.

One might perhaps anticipate evidence for stockpiling in buildings where imported timber has been used, as is the case for all of the buildings discussed above. Yet, even in England where local supplies of native timber were more readily available for vernacular construction, the dendrochronological evidence for stockpiling is also widespread (Miles 1997: 53). While short-term stockpiling, that is, felling dates spread over one to three years was most common, approximately 30% of those buildings with evidence of stockpiling had multiple felling dates spread over four years or more (ibid). Long periods of stockpiling are also in evidence in the few examples from Scotland. At Crathes Castle, Aberdeenshire, there are felling episodes in 1589 and 1591, but the castle was not completed until 1596, according to the date on the coat-of-arms over the main entrance, so it is possible that there were other undetected felling phases amongst the oak timbers (Crone & Mills unpubl a). At nearby Drum, the lag between felling and completion was even greater; the mansion house was completed *c* 1619 (MacGibbon & Ross 1887– 92 vol 2: 436), but at least some of the oak timber was felled nearly a decade earlier in 1608 and 1609 (Crone & Mills unpubl a). It may be no coincidence that these felling episodes are roughly contemporary with the construction of the *Bonaccord* ship in Aberdeen (see above). We have speculated that there may have been a major felling episode in the Old Wood at this time, the better quality timber being selected out for the shipbuilding and the remainder (more twisted of grain and unsuitable for shipbuilding) being retained for the planned construction of the mansion house.

Almost every 17th and 18th century building in this survey that was constructed with imported timber has displayed evidence for stockpiling. There are felling dates of

1664, 1665, 1667, 1670 and 1671 amongst the Scandinavian pine beams used to strengthen the floors of the Palace in Stirling Castle (Crone 2008, Figure 5). Instructions for these repairs were issued in 1671 (Gallagher & Harrison 2008: 297) and throughout that year and the following year, numerous cargoes of timber were brought up the Forth from Leith to Stirling (ibid: 76–7). All the dated timbers came from one range of the Palace, suggesting that they had all come from the same source and had probably arrived at Stirling as a single batch or load; this in turn implies that they had been stockpiled by merchants in the source region rather than at Leith, where one might expect a greater mixing of sources.

There is also some evidence that, under certain circumstances, stockpiled timber was employed in the construction of more humble buildings; for example, two cruck elements from the Red House at Mar Lodge Estate were built from local pine, but their felling dates were 1799 and 1808, and their tree-ring patterns suggest they may have come from two different local woodlands. One of the possible explanations is that the estate stockpiled certain sorts of timber, perhaps those with least commercial value, for their own use, so that timber of different felling dates ended up in the same estate building (Mills unpublished). Local stockpiling is perhaps most likely after the commercial exploitation of the native pinewoods gathered pace in the 18th century, when the estates would often control the timber supply centrally, rather than under the older traditional servitude arrangements, where tenants often had rights to take certain types of timber directly from the woodland for their own use (Urquhart et al unpublished). The lack of correlation displayed by the pine assemblages from other Scottish vernacular buildings, which has hindered our ability to date them (see above), is also probably indicative of stockpiling of timber by both local merchants and estates, although, in the absence of felling dates, we cannot determine over what period the stockpiling took place.

TRANSPORTATION TIMES

The time that it took to transport timber from forest to port, usually by rafting downriver, and then its subsequent sea journey to Scotland, will also introduce a lag between felling and subsequent use. Thus, in an imported assemblage, the presence of multiple felling dates may be as much due to a lag caused by transportation as that caused by stockpiling.

The length of the lag might also vary from source to source. For instance, at Fort George, the Staff Block, Regimental Museum and Chapel were built with pine from Karelia, where there might be lag of one year at most (see above), while the Ordnance Store was built with pine from Russia, for which we could anticipate a lag of up to three years between felling and arrival in Memel. Albion (1926: 145) has also pointed out that in Russia, harsh winters, which brought hard frozen ground, were vital for the transportation of timber to the riverbank, while a mild winter, bringing with it soft marshy conditions, could mean that the felled timber lay in the forest for several seasons until the ground became suitable for transportation again. Such circumstances would add a further lag to that already created by distance from the Baltic ports.

Other factors might also delay transportation and thus create a lag between felling and use. In Scandinavia, timber processing was carried out in the autumn and spring when floodwater and meltwater respectively made sawmilling easy (Lillehammer 1999: 13), yet all the timber ships from the region arrived between May and September (Smout 1963: 155); this can only mean that timber felled and processed in the autumn of one year will not have been imported into Scotland until the following summer, thus introducing a lag of at least one year. Duff House, Banff, is a case in point. Norwegian pine used in the construction of the roof was felled in 1736 and 1737; these differences in date could simply reflect timber felled in the autumn of 1736 and some felled the following spring, all

of it being shipped together during the summer months of 1737.

RECYCLING

Good building timber will always have been a valuable commodity in Scotland, particularly as native supplies of oak dwindled in the late medieval period and the country was forced to import at some expense, so it was recycled wherever possible. Physical evidence of re-used timber, such as redundant joints and pegholes, and duplicate carpenters marks, are always recorded during the dendrochronological assessment of a building, as re-use will clearly affect our interpretation of the dendrochronological results. However, the physical evidence will sometimes have been removed, particularly where old timber was cut into shorter lengths, for example, for use as lintels, or as ashlar posts and sole plates in roof frames, and so it is the dendrochronological evidence that can highlight re-used timber.

The Royal builders were certainly not averse to recycling timber. Scattered throughout the Palace at Stirling Castle were oak timbers felled in 1501 and 1505 and re-used in the construction of the Palace in 1539. Some of the recycled timber may have come from a chapel which had to be knocked down to make room for the planned palace (Gallagher & Ewart 2008). The ceiling of the King's Bedchamber was built entirely of recycled timbers, whilst a few were used in the Queen's Bedchamber and also in other parts of the Palace. Perhaps the King's Bedchamber was completed first, using up all but a few timbers from the recycling pile, which were then used alongside new timber as building progressed? Apart from the secondary joists in the King's Bedchamber none of the other recycled timbers displayed physical evidence of re-use (Crone & Fawcett 1998: 79; Crone 2008: 11).

In the house at 68–74 High Street, Brechin, elements of an earlier roof, constructed in 1470, had been re-used within the extant roof (Crone et al 2004) which we now know was erected in 1575 (see above). There was plenty of physical evidence for re-use throughout the roof (ibid: illus 4) and all those re-used timbers which could be dated were ascribed to the 1470 roof (ibid: 160). However, three short collars bearing no physical evidence of re-use were also dated to 1470, so there are probably more undetected timbers of this phase within the roof. Similarly, at Gardyne's Land, Dundee, short oak lintels, with no visible evidence of re-use, had been inserted into the 17th century Building B but these have now been dendro-dated to the 16th century; it is likely that they were recycled from the earliest building on the site, Building A, which is late 16th century in date (Crone unpubl b).

The components of an earlier roof, much of it identifiable because of redundant nailholes used to fix the sarking boards, had also been re-used throughout the extant roof of Newark Castle; the latter has been dated to 1598, but it was not possible to date the earlier roof because the timber was so young and fast-grown (Crone unpubl a).

Timbers felled in the latter half of the 13th century were found in St John's House, on South Street, St Andrews, a building thought to have been built *c* 1450 and reconstructed *c* 1600 (Mills 2000). These timbers displayed evidence of re-use and may have come from an earlier building on the same plot (ibid: 204).

In each of these cases, dendrochronological analysis has helped to distinguish a 'ghost' building which has enriched our knowledge of the history of the extant building and, in the cases of the Brechin and St Andrews buildings, have contributed to the history of the burgh.

CONSTRUCTION DATES

The section above has been largely concerned with those issues that can complicate the interpretation of dendro-dates, to such an

extent, perhaps, that the reader might wonder whether there is actually any value in obtaining dendrochronological dates! To balance this, in this section we look at those examples where dendrochronological analysis has changed our understanding of the building.

On the whole, most 'clients' have a general theory as to the date of a building, either on stylistic grounds or from other sources of evidence, and on the whole, the dendrochronological result tends to confirm the theory. For instance, the analysis of the timbers from Fenton Tower confirmed the late 16th-century date attributed to the building on the basis of architectural style and authenticates the now-missing date stone (Cressey et al 2013; and see above).

There are, however, numerous examples where an earlier or later date than expected has been produced. The sheer size and plainness of the massive oak door (illus 6), which leads from the Inner Close into the Palace at Stirling Castle, was in such contrast with the decorative surfaces of the Renaissance building that it was thought to be much earlier in date (Doreen Grove pers comm). Its dendro-date demonstrated that it was, in fact, part of the mid-16th-century development, its size and scale perhaps deliberately designed to emphasise the role of the castle as a stronghold as well as a palatial residence (Gallagher & Ewart 2008: 51). The pine floorboards above the Queen's Bedchamber in the Palace were thought to be part of the 17th-century modifications to the building, but a felling date of 1535 demonstrated that they, too, were part of the Renaissance fabric (Crone 2008: 17).

Dendrochronological analysis resolved the dating of the Great Hall at Edinburgh Castle, which had long been a matter of dispute amongst architectural historians, some suggesting that the roof had been constructed by James IV in 1503, and others suggesting that it had been subsequently dismantled by James V and re-erected on raised walls with Renaissance style corbels (Crone & Gallagher 2008: 232). The felling date of 1509/10 confirms that it was indeed James IV who commissioned its construction and allows the event to be placed in its correct political context (ibid: 233).

There was little about the style and construction of the house at 68–74 High Street, Brechin, on which to assign a date, other than a lintel incised with the date '1717' over an extension to the rear, which provided a *terminus ante quem* for the High Street frontage (Crone et al 2004). Late 15th-century roof timbers had been re-used within the roof, but this did not help to date the extant building and a general 17th-century date was assigned (ibid: 164). Since the publication of the results, the development of a new regional chronology has enabled us to date the construction to 1575 (see above) and raises the tantalising possibility that, behind many an unprepossessing exterior in a Scottish town, lies a venerable, and chronologically complex timber structure.

Finally, some may dispute the value in dendro-dating a building for which the construction date is supposedly known, either through documentary references or a date stone. Fenton & Walker (1981: 211) have long advised caution in using date stones to establish the date of vernacular buildings, citing re-use of such stones and the possibility that they recorded an event or change subsequent to the original building. The results from Newark Castle, Port Glasgow, support the need for caution. The date 1597 is inscribed over the door to the castle (Tabraham 2004) yet the timbers were felled a year later in 1598 (Crone unpubl a). The builders must have been overly optimistic; clearly, they had yet to fell the roof timbers even as the walls were being built.

SUMMARY

The general pattern of timber exploitation in Scotland, in the centuries under review, is summarised below from a dendrochronological perspective.

Prior to 1450, the dendrochronological evidence shows that native-grown oak was the principal source of structural timber in Scotland. After 1450, the majority of oak timber is imported, and it is clear that timber from particular regions were preferred for specific purposes. Workaday beams from Scandinavia were used for general framing, while eastern-Baltic oak was sought out for its fine, straight grain, which made it particularly suitable for boards which were going to be carved or painted. Occasionally, other sources have been identified, such as the probable Irish oak at Castle of Park and the German oak from both Fenton Tower and Elie Granary.

It is now relatively straightforward to date imported oak because there are extensive regional oak chronologies available for Europe and because of the number of robust Scottish 'import' chronologies that now exist (Table 1). Thus, while larger assemblages of samples have the best chance of successful dating, on occasion, even single imported timbers, such as those from Queen Mary's Bathhouse at Holyrood, John Knox House and Tantallon Castle, can be dated (Crone forthcoming b; unpubl i; unpubl j; and see illus 2). In contrast, dating and provenancing the rarer native Scottish material remains challenging, precisely because it is rare and there are consequently fewer master chronologies available; it becomes a vicious circle. In the NOAP project we set out to locate native oak assemblages, yet we could find only two (Drum mansion house and Crathes Castle) amongst the 48 mainly 17th- and 18th-century buildings we examined.

In the post-medieval period, the number of buildings built with oak timber declines because, not only are native supplies few and far between, but traditional sources of imported oak, such as Norway, have also all but dried up, and pine begins to dominate the market. Most of the pine is imported, but a more systematic exploitation of the native pinewoods begins during the 17th century. So far, home-grown pine has only been dendrochronologically identified in two vernacular buildings built around 1800, but we should anticipate finding it in buildings of earlier date.

It is clear from the documentary record that pine timber was being imported during the 16th century but it is not very visible in the physical record, the dendro-dated floorboards from Stirling Palace being a rare survival. This is possibly because the sawn pine deals, which formed the bulk of the imported timber cargoes from Scandinavia, were used for those very elements in buildings which could be relatively easily replaced, that is, the flooring, sarking, panelling, etc. By the 17th century, however, building timber was almost exclusively pine, and it was used in roof structures and for floor joists, many of which have survived.

Nonetheless, the number of dendro-dated buildings with pine timber in Scotland is still quite small (illus 2). One factor is the increasing complexity of the Scottish timber trade throughout the 17th and 18th centuries, as it becomes affected by changes in quality and availability in foreign supplies, and by governmental policies and actions, both in Britain and abroad (Thomson 1991). As a consequence, in any one building we might expect to find timber from multiple sources, which has been rafted downriver over great distances, and then mixed and stockpiled in the ports, and so this hinders the development of an internally robust building chronology and our ability to date it. This issue is almost certainly related to the source of the timbers; heterogenous assemblages of timbers coming from sources with robust regional chronologies can be dated with confidence, as we have seen with the oak boards from Poland used in the Stirling Palace doors and in the Stirling Heads. We must await the further development of chronologies in some of the source areas before we can date, and more precisely provenance, some of our assemblages. This applies equally to Scotland, where the development of regional pine chronologies is essential if we are to date much of the vernacular building stock.

The general pattern that emerges from the – admittedly small – dataset of dendro-dated pine is the use, in grand buildings, of Scandinavian pine from the 16th century until the early 18th century, of eastern Baltic pine in the latter half of the 18th century, and of native pine in the smaller vernacular buildings at the turn of that century.

CONCLUSIONS

In summarising the work of two decades of dendrochronological research in Scotland, this paper has sought to demonstrate both the benefits and the limitations of the technique in the context of buildings archaeology. Felling dates and their interpretation, in terms of recycling, seasoning, stockpiling, etc, have enriched the biographies of the buildings, while more general themes relating to woodland history and the historic timber trade are highlighted.

Tree-ring data are proving vital in increasing our knowledge of the foreign timber trade, particularly for the 15th and 16th centuries. Smout (1999: 40) prophesied that dendrochronology would eventually provide the answer as to when '… the Scots began to look abroad for wood …'; we hope this paper has gone a long way to providing the answer. Two decades ago, Ditchburn wrote that 'Much research remains to be done on the subject of trade between Scotland and Scandinavia in the later Middle Ages.' (1990: 85), and certainly, the historical sources summarised earlier warrant closer scrutiny and analysis. However, dendrochronology is well-suited to address some of the specific questions that Ditchburn posed, such as when in the early 16th century the timber trade with Scandinavia became important (ibid: 81).

For the 17th and 18th centuries, the patterns emerging in the dendrochronological dataset are proving useful in clarifying those seen from a historical perspective. However, while there is a clear convergence of evidence, the dendrochronological dataset acts as a material counterpoint to the historical sources by providing specifics on date, source, and timber type and quality for particular buildings in particular places. Dendrochronology has brought the textual references to life; 'Estland boards' are the beautifully carved panels from Perth Museum & Art Gallery, 'Swadin tymmer' the squared oak joists employed throughout Stirling Palace. It has demonstrated that timbers from relatively plain and apparently 'unimportant' buildings, such as the townhouse in Brechin, or the byre at Inverey, can reveal so much about the history of their localities and contribute to the wider national story of woodland use and timber trade.

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