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Firewood, food and human niche construction: the potential role of Mesolithic hunter–gatherers in actively structuring Scotland's woodlands

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ABSTRACT

Over the past few decades the potential role of Mesolithic hunter–gatherers in actively constructing their own niches, through the management of wild plants, has frequently been discussed. It is probable that Mesolithic hunter–gatherers systematically exploited specific woodland resources for food and fuel and influenced the 'natural' abundance or distribution of particular species within Mesolithic environments. Though there has been considerable discussion of the pollen evidence for potential small-scale human-woodland manipulation in Mesolithic Scotland, the archaeobotanical evidence for anthropogenic firewood and food selection has not been discussed in this context. This paper assesses the evidence for the active role of Mesolithic hunter–gatherer communities in systematically exploiting and managing woodlands for food and fuel in Scotland. While taphonomic factors may have impacted on the frequency of specific species in archaeobotanical assemblages, it is suggested that hunter–gatherers in Mesolithic Scotland were systematically using woodland plants, and in particular hazel and oak, for food and fuel. It is argued that the pollen evidence for woodland management is equivocal, but hints at the role of hunter–gatherers in shaping the structure of their environments, through the maintenance or creation of woodland clearings for settlement or as part of vegetation management strategies. It is proposed that Mesolithic hunter–gatherers may have actively contributed to niche construction and that the systematic use of hazel and oak as a fuel may reflect the deliberate pruning of hazel trees to increase nut-yields and the inadvertent – or perhaps deliberate – coppicing of hazel and oak during greenwood collection.

1. Introduction

The nature of human–environment interaction in Mesolithic Europe is a contentious area of debate. Hunter-gathering and farming have traditionally been perceived as diametrically opposed economic and social systems with the transition between these two ways of life occurring during a period of abrupt change during the Neolithic (Childe, 1936:74, 1965:55; Pluciennik, 2002:115). Consequently, whereas Mesolithic peoples have been seen as mobile hunters that had little control over or impact on their environment, Neolithic people have been viewed as sedentary agriculturalists that actively modified their environment through large-scale woodland clearances (Austin, 2000:72–73; Warren, 2005:69). Since the late 1960s this dichotomy has been increasingly questioned (e.g. Simmons, 1969; Smith, 1970:82; Woodburn, 1980:100–101; Simmons et al., 1981:103; Harris, 1989:12–13; Layton et al., 1991:260; Anderson, 2006:252), and it has been recognised that Mesolithic hunter–gatherers may have actively managed wild resources in a similar manner to domestic crops (Simmons and Innes, 1987; Harris, 1989; Zvelebil, 1994). At the same time, the widespread existence of highly developed and intensive systems of wild plant exploitation in modern hunter–gatherer societies in Africa, North America and Australia (e.g. Mellars, 1976; Lewis, 1982; Vincent, 1985; Anderson, 2006; Gammage, 2011; Rowley-Conwy and Layton, 2011; Smith, 2011; Hallam, 2014) indicates that similarly sophisticated systems of wild plant exploitation of non-domesticated native species may have existed in Mesolithic Europe (Zvelebil, 1994:36), without this

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necessarily leading to the agricultural production of these resources (Rowley-Conwy, 2001:58–59; Rowley-Conwy and Layton, 2011:854).

Within this context, it has been argued that Mesolithic hunter–gatherers may have played an active role in shaping woodland ecodynamics through the deliberate manipulation of the structure of plant communities to increase the production of economically important plants and to attract desirable animals for hunting (Smith, 1970:82; Mellars, 1976; Simmons et al., 1981:103; Simmons and Innes, 1987; Zvelebil, 1994; Simmons, 1996). It has also been

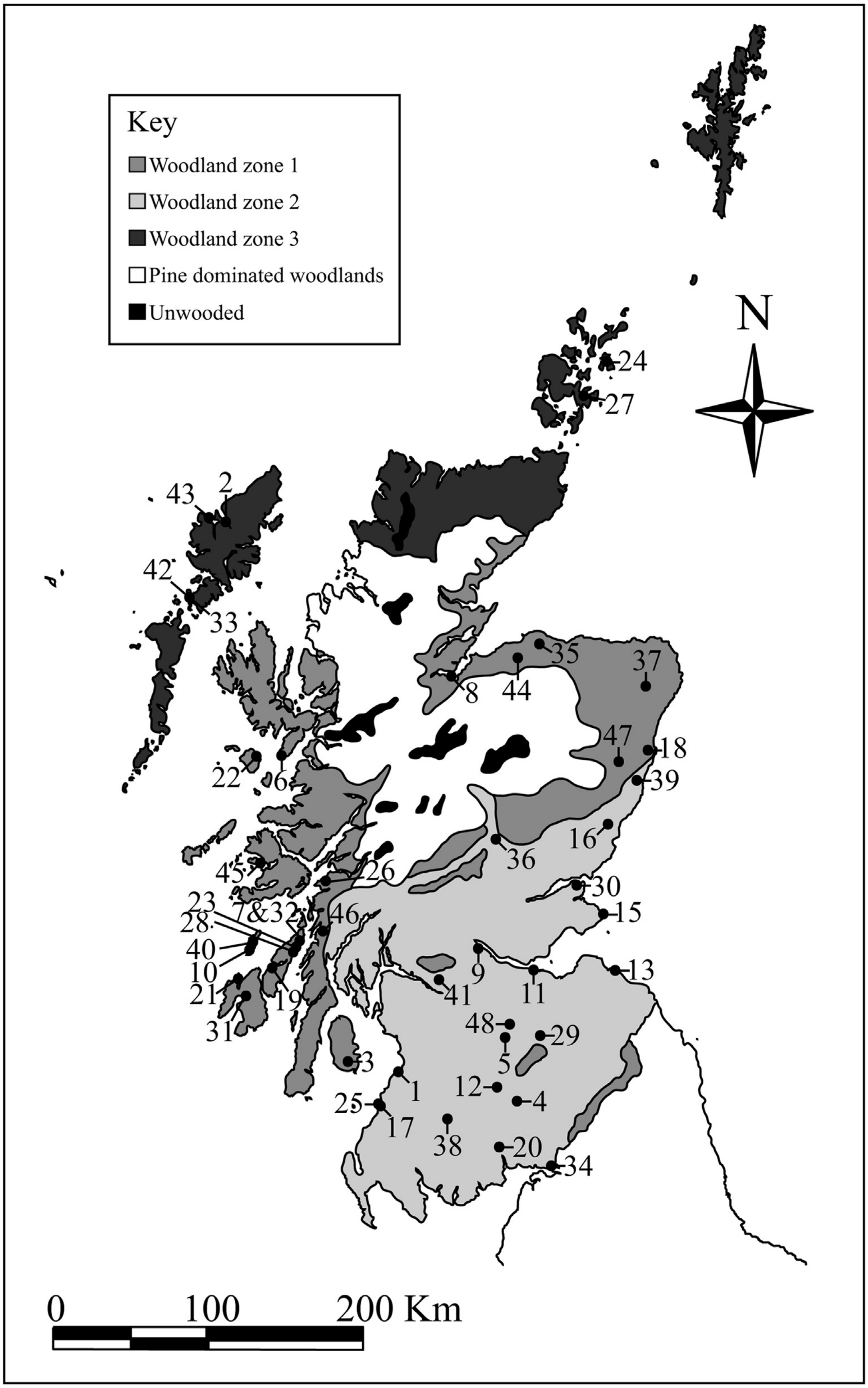

Fig. 1. Map of Scotland showing Mesolithic site locations. Numbers correspond to the sites listed in Table 1 and woodland zones are taken from Tipping (1994, 2004).

Table 1
Description of each site in the review. For a description of the woodland zone classifications see Section 3.1. LMI: later Mesolithic I; LMII: later Mesolithic II; M: Mesolithic. The locations of the sites are shown in Fig. 1.

Site	Site number	Woodland zone	Site period	Period block	Site description	Sampling information	References
Ailsa view	1	2	Mid 8th–Early 7th millennium cal BC	LMI	Possible hearth pits, pits and a lithic scatter	Judgement sampling, bulk samples, flotation	Cook and Engl (2002); Gooder (2002, 2004); Gooder and Engl (2002); Miller (2002)
Aird Calanais	2	3	Early 6th–Mid 5th millennium cal BC	LMII	Old ground surface	Total sampling, bulk samples, flotation	Flitcroft and Heald (1997); O'Brien et al. (2009)
Auchareoch	3	1	Late 8th–Late 7th millennium cal BC	LMI	Lithic scatter, fire spots and a pit	No information available	Affleck et al. (1988)
Beattock	4	2	Late 7th–Early 6th millennium cal BC	LMII	A pit	Total sampling, bulk samples, sieving	Dunbar (2008)
Biggar Common	5	2	Mid 6th–Early 5th millennium cal BC	LMII	Stakeholes, postholes, charcoal spread and shallow hollow (stake-built structure)	Judgement sampling, bulk samples, no further information available	Crone (1997); Johnston (1997)
Camas Daraich	6	1	Late 8th–Late 7th millennium cal BC	LMI	Occupation layers, scoops and a possible hearth	Bulk samples, no further information available	Cressey (2004); Wickham-Jones et al. (2004)
Carn Southern	7	1	Associated with Mesolithic artefacts	M	Flint scatters, occupation layer, but no hearths or structures	Wet sieving of most deposits, no further information available	Searight (1990)
Castle Street	8	1	Late 8th–Early 6th millennium cal BC	M	Occupation layers containing artefacts and ecofacts and incorporating a possible hearth	Soil wet sieved to 5 mm, no further information available	Dickson (1985); Wordsworth et al. (1985)
Chapelfield Pit 5	9	2	Late 7th–Mid 6th millennium cal BC	M	3 pits (only pit 5 securely dated and included in this analysis)	Hand collection, bulk samples, flotation, no further information available	Alldritt (2002); Atkinson (2002)
Cnoc Coig	10	1	Early 5th–Early 4th millennium cal BC	LMII	Shell midden, occupation surfaces, possible stake-built structures and hearths	3-stage cluster sampling; bulk samples and flotation to 1 mm; all soil wet-sieved to 3 mm	Boyd and Kenworthy (1991–1992): 18; Mellars (1978, 1979, 1987); Peacock (1978)
Cramond	11	2	Early–Late 9th millennium cal BC	LMI	Lithic scatter, old ground surfaces, pits, a scoop and stakeholes (phase 1 & 2 only in this analysis)	100% sampling, bulk samples, flotation	Hastie (2003b); Lawson (2001); Reed (1995); Saville (2008)
Daer Valley Site 84	12	2	Late 5th millennium cal BC	LMII	Old ground surface, a pit and a lithic scatter	Total sampling, bulk samples, flotation to 1 mm	Ward (2005a, 2005b, 2005c)
East Barns	13	2	Late 9th–Early 8th millennium cal BC	LMI	Sunken floor with postholes and burnt walling around it and a possible hearth, stakeholes and slot features within floor (oval structure with internal furniture), and pits and an occupation horizon around structure	Bulk samples, flotation, no further information available	Gooder (2007); Hall (2002)
Fife Ness	15	2	Early 8th–Late 8th millennium cal BC	LMI	Occupation layer, pits, shallow scoops, linear cut, possible hearth, curving line of pits (possible windbreak structure)	Total sampling, bulk samples, flotation	Holden (1996); Wickham-Jones and Dalland (1998a, 1998b)
Fordhouse Barrow	16	2	Early: Mid 8th–Early 7th millennium cal BC; Late: Mid –Late 5th millennium cal BC	Early:LMI; Late:LMII	Pits and old ground surfaces beneath barrow	No information available	Peterson and Proudfoot (1996, 1997); Proudfoot (1999, 2001)
Gallow Hill	17	2	Late–Mid 5th millennium cal BC	LMI	Pits and a lithic scatter	No information available	Donnelly and Macgregor (2005); Miller (2005)
Garthdee	18	1	Early–Mid 5th millennium cal BC	LMII	A pit	100% sampling, bulk samples, flotation	Murray and Murray (forthcoming); Timpany (2008)
Glenbatrick Waterhole	19	1	Associated with Mesolithic artefacts	M	Occupation layer and lithic scatter	No information available	Mercer (1972–1974)
Irish Street	20	2	Associated with Mesolithic artefacts	M	Lithic scatter in a layer and cut feature containing postholes and stakeholes (possible wind break or drying rack)	Dry sieving to 5 mm; no further information available	Mackenzie et al. (2002)

(*continued on next page*)

Table 1 (*continued*)

Site	Site number	Woodland zone	Site period	Period block	Site description	Sampling information	References
Kilellan Farm	21	1	Associated with Mesolithic artefacts	M	Areas of laid pebbles and flat stones, a pit and lithic scatter in sand layer	Bulk samples, no further information available	Boardman (2005); Ritchie (2005)
Kinloch	22	1	Late 9th–Late 7th millennium cal BC	LMI	Pits, postholes, hollows, stakeholes, slots and lithic scatter	No sampling, soil sieved to 3 mm	Wickham-Jones et al. (1990)
Lealt Bay	23	1	Associated with Mesolithic artefacts	M	Lithics and ecofacts in gravel/sand layers	No sampling, main occupation horizon partially wet sieved to 3 mm	Mercer (1967–1968)
Links House	24	3	Late 8th–Early 7th millennium cal BC	LMI	Lithic scatter, stakeholes, postholes, pits, hollows, natural features and thin occupation layers (stake and post structures, external structures)	100% sampling of features, bulk samples, flotation, top soil 100% wet sieved to 4 mm	Alldritt (2011); Lee and Woodward (2008, 2009a, 2009b); Woodward (2008)
Littlehill Bridge	25	2	Late 7th millennium cal BC	LMI	Scooped features, occupation deposit and lithic scatter	Bulk samples, flotation, no further information available	Macgregor et al. (2001); Miller and Ramsay (2001)
Lon Mor	26	1	Late 7th–Early 4th millennium cal BC	M	Organic rich horizon containing artefacts and ecofacts	No information available	Bonsall et al. (1993); Bonsall (1996)
Long Howe	27	3	Late 8th–Early 7th millennium cal BC	LMI	Old ground surface beneath a barrow	Total sampling, bulk samples, flotation	Robertson and Woodward (2007); Wickham-Jones and Downes (2007)
Lussa Wood	28	1	Late 9th–Mid 7th millennium cal BC	LMI	3 conjoined stone rings in a scoop, area of flat stones and occupation layers	No sampling, soil wet sieved to 3 mm	Mercer (1978–1980); Moore (1978–1980)
Manor Bridge	29	2	Mid 9th–Early 8th millennium cal BC	LMI	Lithic scatter, cobble area and possible pit	Bulk samples, flotation, no further information available	Hastie (2002); Warren (1998, 2003); Graeme Warren pers. comm.
Morton	30	2	Morton A: Mid 8th–Early 5th millennium cal BC; Morton B: Early 6th–Early 5th millennium cal BC	Morton A: M; Morton B: LMII	Morton A: lithic scatters, occupation floors, hearths and stakeholes (possible shelters/ windbreaks); Morton B: shell midden incorporating hearths, stakeholes, postholes and stone walling	Site A = hand collection; Site B = judgement sampling, bulk samples, flotation	Coles (1971)
Newton	31	1	Late 8th–Late 7th millennium cal BC	LMI	Gullies, pits and depression containing artefacts and ecofacts (possible structure)	Bulk samples, flotation to 0.35 mm, no further information available	McCullagh (1989a, 1989b)
North Carn	32	1	Mid–Late 7th millennium cal BC	LMI	Lithic scatter, scoops and an L-shaped stone setting in an old land surface	Some soil sieved, no further information available	Mercer (1971–1972)
Northton 2001/2010	33	3	Late 8th–Late 7th millennium cal BC	LMI	Old ground surface containing artefacts and ecofacts	Total sampling, bulk samples, flotation	Bishop et al. (2010, 2011); Gregory et al. (2005); Simpson et al. (2006)
Redkirk Point	34	2	Late 8th–Mid 7th millennium cal BC	LMI	Hearth within shallow hollow	Bulk samples, sieving, no further information available	Masters (1981)
Silvercrest	35	1	Post-circle 1: Late 7th–Early 6th millennium cal BC; post-circle 2: Mid –Late 8th millennium cal BC	Silvercrest 1 & 2: LMI	2 post–circle structures and a possible post alignment	Bulk samples, flotation, no further information available	Cressey and Lyons (forthcoming); Cressey and Suddaby (2002); Suddaby (2007)
Sketewan	36	2	Mid–Late 7th millennium cal BC	LMI	70 possible pits/tree holes in old land surface	Bulk samples, no further information available	Dickson (1997); Mercer and Midgley (1997)
Skilmafilly	37	1	Mid 5th–Early 4th millennium cal BC	LMII	A large pit	Total sampling, bulk samples, flotation	Cressey (2003, 2012); Hastie (2003a, 2012); Johnson and Cameron (2012)
Smittons	38	2	Mid 6th–Late 5th millennium cal BC	LMII	Lithics scatter, fire spots and arc of stakeholes	No information available	Affleck (1983); Edwards (1996b)
Spurryhillock	39	2	Early–Late 5th millennium cal BC	LMII	A pit	Hand collection, judgement sampling, bulk samples, flotation	Alexander et al. (1997); Clarke (1997)

Staosnaig	40	1	F24:Late 8th–Early 6th millennium cal BC; F41 & F49:Late 8th–Late 7th millennium cal BC; F30:Late 5th millennium cal BC	F24:M; F41 & F49:LMI; F30:LMII	Pits, a hearth and a large pit containing a posthole (probable hut reused for disposing of knapping debitage and plant processing debris)	Feature F24:25–50% random sampling of 0.5 m grid squares, bulk samples and flotation; other features: wet sieved to 3 mm	Carruthers (2000); Hather (2000); Mithen (2000); Mithen et al. (2001)
Summerston	41	2	Late 5th millennium cal BC	LMII	A post-pit	No information available	Baker (1998)
Temple Bay	42	3	Early–Mid 6th millennium cal BC	LMII	Old ground surfaces containing artefacts and ecofacts	100% sampling, bulk samples, flotation	Blake et al. (2012b); Church et al. (2012a)
Tràigh na Beirigh 1	43	3	Late 5th millennium cal BC	LMII	Shell midden	100% sampling, bulk samples, flotation	Blake et al. (2012a); Church et al. (2012b)
Tulloch Wood	44	1	Pit 1:Early–Mid 6th millennium cal BC; pit 2: Early -late 6th millennium cal BC; pit 3: Early –Late 5th millennium cal BC	Pits 1–3: LMII	Pits	Judgement sampling, bulk samples, flotation	Carter (1993)
Ulva Cave	45	1	Early 7th–Late 5th millennium cal BC	M	Shell midden	Column samples, dry sieving to 2 mm, no further information available	Bonsall et al. (1991, 1992, 1994); Russell et al. (1995)
Upper Largie	46	1	Mid–Late 5th millennium cal BC	LMII	Pits and postholes	Bulk samples, flotation, no further information available	Gale (2007); Cook et al. (2010); Vandorpe (2007)
Warren Field	47	1	Pit 5: Late 8th–Mid 6th millennium cal BC; other pits: Late 9th–Mid 8th millennium cal BC	Pit 5:M; other pits:LMI	Pit alignment	Bulk samples, flotation, no further information available	Hastie (2004); Lancaster (2009); Murray et al. (2009); Timpany (2006)
Weston Farm	48	2	Early: Late 6th–Early 5th millennium cal BC; Late: Late 8th–Early 7th millennium cal BC	Early:LMII; Late:LMII	Lithic scatter, pits, old ground surface containing artefacts and ecofacts	Bulk samples, flotation, every feature sampled	Ward (2005d, 2006)

suggested that some Mesolithic hunter–gatherers may have systematically exploited specific woodland resources for food and fuel (Zvelebil, 1994; Asouti and Austin, 2005:9; Bishop et al., 2013) and thereby influenced the 'natural' abundance or distribution of particular species within Mesolithic environments (Smith, 2011; Warren et al., 2014). These practices can be viewed as a form of 'human niche construction': the alteration of natural selective pressures through the deliberate modification of environments, which may result in genetic and behavioural changes in humans and other animals and plants (Kendal et al., 2011; Rowley-Conwy and Layton, 2011; Smith, 2011). Not only is the recognition of these practices important for understanding the degree of continuity and change during the Mesolithic–Neolithic transition, but also for understanding the environmental pressures that may influence cultural and societal change in small-scale societies (Kendal et al., 2011; Rowley-Conwy and Layton, 2011) and the environmental consequences of different human economic adaptations. The existence of these practices in early-mid Holocene hunter–gatherer communities would have effected the extent of openness in post-glacial European forests, bringing into question the idea that a 'natural primeval wildwood' that developed without human interference ever existed in Europe (cf. Peterken, 1996; Vera, 2000; Mitchell, 2005; Rackham, 2006:90–101). This possibility has significant implications for understanding the environmental trajectory from the 'natural wildwood' to late Holocene forests and consequently for the nature of modern forest conservation and management strategies (Vera, 2000).

In Scotland, there has been considerable discussion of the pollen evidence for potential small-scale, human-woodland manipulation in the Mesolithic (e.g. Edwards and Ralston, 1984; Bohncke, 1988; Hirons and Edwards, 1990; Tipping, 1995a, 1995b; Edwards, 1996a, 2000a, 2004, 2009; Edwards and Sugden, 2003) and some debate about the potential importance of plants within Scottish Mesolithic economies (see Bishop et al., 2013). However, the archaeobotanical evidence for anthropogenic firewood and food selection in Early-Mid post-glacial woodlands has not been discussed in this context. This review will assess the role of Mesolithic hunter–gatherer communities in actively constructing niches in Scotland by systematically exploiting and managing woodland resources, using the archaeobotanical evidence from 47 Scottish Mesolithic archaeological sites, together with contemporary palynological evidence. The paper is split into three main sections that address key research questions relating to this theme:

- What evidence is there that trees were systematically and selectively exploited for food and fuel in Mesolithic Scotland?
- How reliable is the evidence for woodland management in Mesolithic Scotland?
- Did humans actively structure Scottish Mesolithic woodlands?

2. Regional setting

Radiocarbon chronologies for Scotland date the main period of the Mesolithic to c. 8600–4000 cal BC (Ashmore, 2004a, 2004b). These dates place the main phase of the Scottish Mesolithic within the Later Mesolithic of Britain, which is currently accepted to have begun at about 8400 cal BC (Saville, 2008; Passmore and Waddington, 2012: 121). Though several Scottish archaeological sites have produced artefactual assemblages typologically similar to material from radiocarbon dated Early Mesolithic English sites, these assemblages are not associated with Early Mesolithic radiocarbon dates and there are currently no Mesolithic archaeological sites with secure radiocarbon dates from before *c.* 8600 cal BC (Ashmore, 2004a, 2004b; Saville, 2004: 205).

Table 2
Summary of the charred remains from deciduous and coniferous trees and shrubs at Scottish Mesolithic sites; where possible each site is split into chronological blocks (see Section 3.1). The dominant charcoal taxon is highlighted in bold for each site. P: wood charcoal present; A: wood charcoal abundant; +ns: nutshell present; +fs: fruit stone present; +s/f: seed/fruit fragment present. Definitions of each woodland zone category are given in Section 3.1 and site numbers correspond to site locations in Fig. 1.

Site	Site number	Woodland zone	Alder (*Alnus* sp.)	Alder/Hazel (*Alnus*/*Corylus* sp.)	Ash (*Fraxinus* sp.)	Birch (*Betula* sp.)	Cherry/Blackthorn (*Prunus* sp.)	Crab apple (*Malus* sp.)	Crab apple/pear/whitebeam/Rowan/Hawthorn/Wild service (Rosaceae: Pomoideae/Maloideae/*Sorbus* sp.)
Earlier Mesolithic									
Ailsa View	1	2	3			5			**9**
Auchareoch	3	1							
Camas Daraich	6	1				**19**			
Cramond Phases 1–2	11	2							
East Barns	13	2							
Fife Ness	15	2				3			
Fordhouse Barrow (E)	16	2							
Gallow Hill	17	2	P					P	
Kinloch	22	1							
Links House G3-5	24	3		1					1
Littlehill Bridge	25	2	P			P			
Long Howe	27	3							
Lussa Wood	28	1							
Manor Bridge	29	2				1/7 samples			2/7 samples
Newton	31	1					P		P
North Carn	32	1							
Northton 2001	33	3							
Redkirk Point	34	2							
Silvercrest circle 1	35	1							
Silvercrest circle 2	35	1				P			
Sketewan	36	2				P			
Staosnaig F41 &49	40	1							
Warren Field (Other pits)	47	1		2/7 samples					
Weston Farm (early)	48	2				6			
Later Mesolithic									
Aird Calanais	2	3				8			
Beattock	4	2							**A**
Biggar Common	5	2							
Cnoc Coig	10	1	P						
Daer Valley Site 84	12	2							
Fordhouse Barrow (L)	16	2							
Garthdee	18	1							
Morton B	30	2							
Skilmafilly	37	1				15			
Smittons	38	2							
Spurryhillock	39	2							
Staosnaig F30	40	1							
Summerston	41	2							
Temple Bay	42	3							
Tràigh na Beirigh	43	3							
Tulloch Wood1	44	1							
Tulloch Wood2	44	1							
Tulloch Wood3	44	1					1		
Upper Largie	46	1							
Weston Farm (Late)	48	2							
Mesolithic									
Carn Southern	7	1							
Castle Street	8	1				P			P
Chapelfield Pit 5	9	2							
Glenbatrick Waterhole	19	1							
Irish Street	20	2							
Kilellan Farm	21	1	**A**			P			P
Lealt Bay	23	1							
Lon Mor	26	1			P?				
Morton A	30	2							
Staosnaig F24	40	1						+s/f	5/17 samples
Ulva Cave	45	1							
Warren Field (Pit 5)	47	1	1/6 samples			**2/6 samples**			

Elm (*Ulmus* sp.)	Hawthorn (*Crataegus* sp.)	Hazel (*Corylus* sp.)	Field maple (*Acer campestre* L.)	Oak (*Quercus* sp.)	Pear (*Pyrus* sp.)	Willow (*Salix* sp.)	Willow/ poplar (Salicaceae)	Pine (*Pinus* sp.)	Indeterminate conifer	Unidentified	Unidentifiable
3	+fs	6 + ns		1							
										P	
		6 + ns									
		+ns								P	
		+ns								P	
		16 + ns		2		1					
		+ns									
		+ns		P		P					
		+ns								P	
		4 + ns									5
		P + ns		P							
		1 + ns									
	3	+ns	1?								
		5/7 samples + ns		1/7 samples		1/7 samples					
		P + ns		P		P					P
		+ns								P	
		23 + ns				**25**		2			3
P				P							
				P				P			
								P			
				A							
		2/2 samples + ns									
		3/7 samples + ns					1/7 samples				
		156 + ns		7		48					
		+ns					**21**				
				P							
				A							
P		+ns		P						P	
		50									
		+ns									
		32		7							1
		P								P	
		4		**95**							
		+ns								P	
				88.9 g							
		+ns									
		+ns									
		+ns								P	
		+ns								P	
				4				**9**			
				A							
		2 + ns						**7**			
		1		**12**							1
		19 + ns		1		2					
		+ns			+s?					P	
P		P + ns						P			
	+fs	0.25 g		0.65 g				**4.3 g**			0.6 g
		+ns								P	
		+ns									P
		P		P		P					
		+ns								P	
		+ns							P	P	
		+ns								P	
		17/17 samples + ns									
		+ns									
		1/6 samples		1/6 samples			1/6 samples				

Table 3
Summary of the main woody taxa present in each woodland zone.

Woodland zone	1a (Inner Hebrides, west coast mainland and North-East Scotland) = birch/hazel dominated woods	1b (Inner Hebrides, west coast mainland and North-East Scotland) = birch/hazel dominated woods (with oak also dominant in some areas)	2a (Southern and central Scotland) = birch/hazel dominated woods (with oak also dominant in some areas and alder locally dominant during the later part of this period)	2b (Southern and central Scotland) = mixed deciduous woodlands dominated by oak/hazel/elm, (with alder/birch also locally dominant in some areas)	3a (Northern and western Isles) = open birch/hazel dominated woods	3b (Northern and western Isles) = open birch/hazel dominated woods
Taxon	Later Mesolithic I	Later Mesolithic II	Later Mesolithic I	Later Mesolithic II	Later Mesolithic I	Later Mesolithic II
Birch (*Betula* sp.)	D	D	D	P/D	D	D
Hazel (*Corylus* sp.)	D	D	D	D	D	D
Oak (*Quercus* sp.)	P	P/D	P/D	D	P	P
Alder (*Alnus* sp.)	*/†	P/D	*	P/D	*	P
Elm (*Ulmus* sp.)	P	P	P	D	*/†	*/†
Willow (*Salix* sp.)	P	P	P	P	P	P
Pine (*Pinus* sp.)	P/†	P/†	P/†	P/†	P/†	P/†
Ash (*Fraxinus* sp.)	*	*	*	P	*/†	*/†
Juniper (*Juniperus* sp.)	*	*	*		*	
Poplar/Aspen (*Populus* sp.)	*	*	*	*	*	*
Rose Family: includes Crab apple/pear/Whitebeam/Rowan/Hawthorn/Wild Service/Wild Cherry/Wild Plum/Blackthorn (Rosaceae)	*	*	*	*	*	*

D: dominant at most sites, P: present at most sites, *: present at some sites, †: pollen may be derived from long distance transport. P/D is used to indicate species which are dominant in some areas/periods of the zone, but not all areas/periods of the zone, and P/† and */† are used to indicate species which are present in some areas of the zone, but in other areas the pollen may derive from long distance transport or to indicate a difference of opinion on the native status of particular species by different authors. Woodland zone 1. local pollen diagrams: Warren Field, North-East Scotland (Murray et al., 2009:16–20), Loch Cholla, Oronsay (Andrews et al., 1987), Loch a' Bhogaidh, Islay (Edwards and Berridge, 1994), and Newton, Islay (McCullagh, 1989a); regional pollen diagrams: Braeroddach Loch, North-East Scotland (Edwards, 1979) and Loch of Park, North-East Scotland (Vasari and Vasari, 1968; Gunson, 1975), Loch Cill an Aonghais, Argyll (Birks, 1993), Loch Meodal, Loch Cleat, and Loch Ashik, Skye (Birks and Williams, 1983). Woodland zone 2. regional pollen diagrams: Black Loch, Fife (Whittington et al., 1991), Round Loch of Glenhead, Galloway (Jones et al., 1989), Loch Dungeon (Birks, 1972) Galloway, and Dubh Lochan (Stewart et al., 1984) and Loch Lomond (Dickson et al., 1978), Stirling/West Dunbartonshire. Woodland zone 3. regional pollen diagrams: Loch Lang (Bennett et al., 1990a), Loch Buailaval Beag and Loch a' Phuinnd (Fossitt, 1996), Western Isles, and Quoyloo Meadow, Crudale Meadow (Bunting, 1994) and Scapa Bay (de la Vega-Leinert et al., 2007), Orkney.

Palynological evidence suggests that whilst birch (*Betula* sp.) and hazel (*Corylus avellana* L.) were already well-established in most areas of Scotland prior to c. 8600 cal BC, elm (*Ulmus* sp.), oak (*Quercus* sp.), and pine (*Pinus sylvestris* L.) only colonised Scotland from c. 7600 cal BC and alder (*Alnus glutinosa* (L.) Gaertn.) from c. 6500–6000 cal BC (Birks, 1989; Tipping, 1994; Edwards and Whittington, 2003). The precise timing of the arrival and expansion of each species into each area was locally divergent and woodlands varied considerably both spatially and temporally on both local and regional scales (Edwards and Whittington, 2003:64; Tipping, 2004:46–48). Overall, outwith the Highland pine-forests, birch-hazel woodlands dominated most of Scotland throughout the Mesolithic, with oak and elm also important after c. 7600 cal BC in Southern and Central Scotland. Scottish Mesolithic woodlands also contained a variable range of other less important species, such as juniper (*Juniperus communis* L.), willow (*Salix* sp.), poplar/aspen (*Populus* sp.), ash (*Fraxinus excelsior* L.), rowan (*Sorbus aucuparia* L.), hawthorn (*Crataegus monogyna* Jacq.), crab apple (*Malus sylvestris* (L.) Mill.) and wild cherry (*Prunus avium* (L.) L.; Tipping 1994:11). The importance of these minor woodland species is difficult to establish, because of the poor pollen production rates of many of these species (Fossitt, 1996:192; Tipping, 1997a:18; Bunting et al., 2005).

Archaeological evidence suggests that the inhabitants of these environments lived in both inland and coastal locations, exploiting a range of wild marine and terrestrial animals and plants (McCormick and Buckland, 2003; Kitchener et al., 2004; Bishop et al., 2013). Typical settlement features include pits, postholes, scoops, stakeholes, hearths/fire spots, gullies and old ground surfaces/occupation horizons, and are suggestive of temporary and/or semi-permanent settlement (Wickham-Jones, 2004). Well-preserved wetland archaeological sites of Mesolithic date are absent from Scotland and organic plant materials are only preserved by carbonisation.

3. Materials and methods

3.1. Archaeobotanical data collection

Following the methodology of Bishop et al. (2009, 2013), a database of Mesolithic archaeological sites with identified charred remains from deciduous and coniferous trees and shrubs was compiled (Fig. 1; Table 1) by systematically searching through regional and national journals, major monograph series and excavation reports produced after 1960. Wood charcoal and seed, fruit and nut remains from trees/shrubs were recorded for all archaeological sites where environmental samples had been taken so that semi-quantitative methods could be utilised. In addition, hand-collected archaeobotanical remains from archaeological sites with edible plant remains were also added to the database (Bishop et al., 2013).

Table 4
Summary of the burning properties of dry wood (Boulton and Jay, 1946:112; Edlin, 1973; Wicks, 1975; Taylor, 1981:45–55; Kreuz, 1992; The Scout Association, 1999; Milliken and Bridgewater, 2004; Barnes and Barnes, 2008; Eco Tree Care & Conservation Ltd, 2012) and the density/moisture content of the main tree species present in Scottish Mesolithic woodlands. The most useful fuel woods are listed towards the top of the table and the least useful towards the bottom of the table. Green/air dry densities and moisture content data is from Lavers (2002), with asterisked (*) values from Boulton and Jay (1946) and oven dry densities from Francescato et al. (2008).

Species	Firewood usefulness rating	Burning speed	Burning properties	Green density (kg/m^3) – at 50% moisture content	Green moisture content (%)	Air dry density (kg/m^3) – at 12% moisture content	Oven dry density (kg/m^3)
Ash	Excellent	Steady	Wood burns very well and produces a good and long-lasting flame and heat. It has a low moisture content and can be burnt when green.	801	48%	689	670
Hawthorn	Excellent	Steady	The wood is an excellent fuel, which burns very well even when green, with a good heat and little smoke.	–	–	–	–
Crab apple	Excellent	Steady	Wood burns very well, with little flame but good heat and gives off a pleasant smell; when used to smoke fish and meat, it gives the fish/meat a sweet, distinctive flavour.	–	–	–	–
Oak	Excellent	Steady	It is an excellent fuel, producing a good heat, but not much flame and little ash. It has been a favoured wood for smoking meat and fish because it produces a thick preservative smoke. An excellent wood for keeping fires lit overnight.	833	89%	689	670
Elm	Good	Steady	Wood burns well if dry (but poorly if fresh due to its high moisture content) and is an excellent wood for keeping fires lit overnight.	753	75%	609	640
Hazel	Good	Steady	Wood provides a good fuel.	–	–	–	560
Birch	Good when mixed with other woods	Fast	Wood burns well, produces good heat, bright flame and smells pleasant. However, the wood burns quickly due to its high tar content, so it is best used for firewood when mixed with other species or as kindling.	801	76%	673	640
Cherry	Good when mixed with other woods	Slow	Wood difficult to ignite but once alight burns well (provided it is dry). Burns slowly, with good heat and a pleasant scent.	753*	77%*	625*	–
Rowan/ Whitebeam	Good when mixed with other woods	Slow	Wood produces a hot fire but it burns slowly.	929* (Whitebeam)	73%* (Whitebeam)	–	–
Alder	Poor	Fast	Wood burns quickly with a low heat and bright flame.	625	94%	513	490
Willow/poplar	Poor	Slow	It is a poor fuel that burns slowly (even when well dried) and produces little flame, heat or smoke and has a tendency to spark.	529/529–577	113%/154%	433/433–481	520/410
Scots pine	Poor	Fast	It burns hotly, rapidly and with considerable flame due to its high resin content and has a tendency to spark. It is useful for torches and fire-lighting.	625	89%	513	510

The abundance of wood charcoal for each taxon at each site was recorded numerically where possible and on a scale of 'present' ('P'), absent (blank), or 'abundant' ('**A**') or as a proportion of the number of samples when plant components were not numerated in the archaeobotanical reports. Seed, fruit and nut remains were listed in Table 2 on a presence-absence basis only, with full details available in Bishop et al. (2013). Quantification was based on numerical charcoal fragment counts where possible, as this was the most consistently used recording method for Mesolithic charcoal assemblages in Scotland, but the masses were also noted where this was the only information available. Species classed as 'cf.' were added to the definite genus identifications, for example cf. hawthorn (cf. *Crataegus* sp.) was placed in the hawthorn (*Crataegus* sp.) charcoal fragment category in Table 2. The sampling methodologies employed and background information about each archaeological site was also recorded and are detailed in Table 1. For the purpose of consistency and ease of comparison, the sites were numbered (Table 1) using the same site numbers as in Bishop et al. (2013), though one of these sites (site 14: Elginhaugh) lacked tree/shrub remains and is not included in this paper either individually or with respect to the number of sites.

Before data analysis was undertaken, each stratigraphic archaeological context at each site included in the review was classified according to accepted radiocarbon chronologies for the Mesolithic of Scotland (c. 8600–4000 cal BC; see Section 2; Ashmore, 2004a, 2004b). Uncalibrated radiocarbon dates from each site were calibrated using IntCal13 (Reimer et al., 2013) within OxCal v 4.2 (Bronk Ramsey, 2009). In order to assess whether there were any chronological trends in the dataset, each site was classified as Later Mesolithic I (c. 8600–6000 cal BC) or Later Mesolithic II (c. 6000–4000 cal BC). The arbitrary date of 6000 cal BC was used as the divider between these periods because the Later Mesolithic of Scotland cannot be subdivided on the basis of artefact typologies (Mithen, 2000:601; Saville, 2004:205). Sites or contexts that could not be placed into these period blocks due to an absence of radiocarbon dates or an insufficiently tight radiocarbon chronology were classed as Mesolithic (c. 8600–4000 cal BC).

Site features that were clearly spatially or chronologically distinct were separated into different site blocks. In order to assess the possibility of fuel wood selection in the Mesolithic, the sites were also divided into three woodland zones, based on Tipping's (1994, 2004) woodland classification scheme for the period c. 4000 cal BC: woodland zone 1: Inner Hebrides, West Coast Mainland and North-East Scotland, woodland zone 2: Southern and Central Scotland, and woodland zone 3: Northern and Western Isles of Scotland (Fig. 1). Tipping's (1994, 2004) 'pine & pine/birch woods' zone was excluded from the analysis because no Mesolithic sites with archaeobotanical remains were present in this area. Whilst it is recognised that the vegetation changed considerably between 8600 and 4000 cal BC, these zones represent useful geographical regions for comparison, reflecting the major woodland zones.

3.2. Palynological data collection

Woodland compositions were summarised for each zone, using regional and national vegetation reconstructions (Gunson, 1975; Birks, 1987, 1989; Tipping, 1994, 1997a, 1997b, 2007; Bennett et al., 1997; Ramsay and Dickson, 1997; Edwards, 2000b, 2004; Edwards and Whittington, 2003; Church, 2006) and data from representative local and regional pollen sites from each zone (Table 3). Where local pollen diagrams were available from close to the Mesolithic archaeological sites in Table 1, these were used in conjunction with regional sequences (Table 3). Dominant woodland species differed considerably both spatially and temporally during the Mesolithic on a local, as well as on a regional scale (see Section 2) and Table 3 provides a generalised and simplified picture of the vegetation in each zone.

3.3. Firewood properties data collection

In order to explore the potential relationship between wood burning properties and firewood selection, a table of the burning and wood moisture/density properties was compiled for the main species present in Mesolithic Scotland (Table 4). The assessment of the usefulness of the woods as fuels was based primarily on the burning speeds, rather than the calorific content of the different woods, because the burning speed would probably have been more important for varying fire properties to hunter–gatherers using small-scale hearths than absolute fuel values (see Section 5 for further discussion). Though influenced by other factors, such as the resin and tar content, hardwoods tend to burn more slowly than softwoods dried to the same moisture content and the lighter hardwoods burn more quickly than the heavier hardwoods (Forestry Commission, 2010a, 2010b:2; Graves, 1919:31) and so the order of the woods in Table 4 is approximately equivalent to the densities of the woods. The use of calorific values to assess the importance of different woods in the past (e.g. Marston, 2009) is based on the assumption that high heat production is of prime importance for domestic fires (Asouti and Austin, 2005:9; Théry-Parisot et al., 2010:144). In fact, all wood species are capable of producing temperatures of 250 °C, which would be suitable for most purposes (Théry-Parisot, 2002:244). It should be noted though, that the ranking of the different woods in Table 4 broadly corresponds to the fuel values of North American wood taxa determined by experiment (cf. Marston, 2009:2195).

3.4. Data analysis methods

Percentage presence analysis was undertaken to standardise the charcoal dataset and to take into account the discrepancies in the sampling methods used between different sites (Table 1). This methodology has the advantage that the percentage presences for individual taxa are unaffected by changes in the percentage presences for other taxa (Popper, 1988:61). For each category, the percentage of sites with each identified wood charcoal taxon was calculated from the number of site blocks containing each taxon and the number of site blocks in each regional or chronological category (Hubbard, 1975:198, 1980:53; Popper, 1988:60–61; Pearsall, 2000:212). Following Hubbard (1980:52) and Popper (1988:61), sites with only one identified species were excluded from the percentage presence analyses. To increase the reliability of the analyses, only sites where bulk sampling had been undertaken were included and sites with only unidentified or indeterminate charcoal were excluded from the analyses. The data were not analysed using charcoal fragment counts or masses because only 14 site reports detailed the total number of fragments for each taxa and only nine site reports detailed taxa masses. Also, the degree of charcoal fragmentation can vary considerably between different sites and between species, so fragment counts may give an inaccurate picture of the relative frequency of different species between different assemblages (Popper, 1988:60; Smart and Hoffman, 1988:190; Hubbard and Clapham, 1992:119; Pearsall, 2000:213; Chrzazvez et al., 2014). Percentage presence analysis was undertaken on a site block rather than a total sample basis, because the total sample number was not available for all sites (Popper, 1988:63).

It should be noted that though the results of this analysis provide an indication of the relative frequency that each taxon was

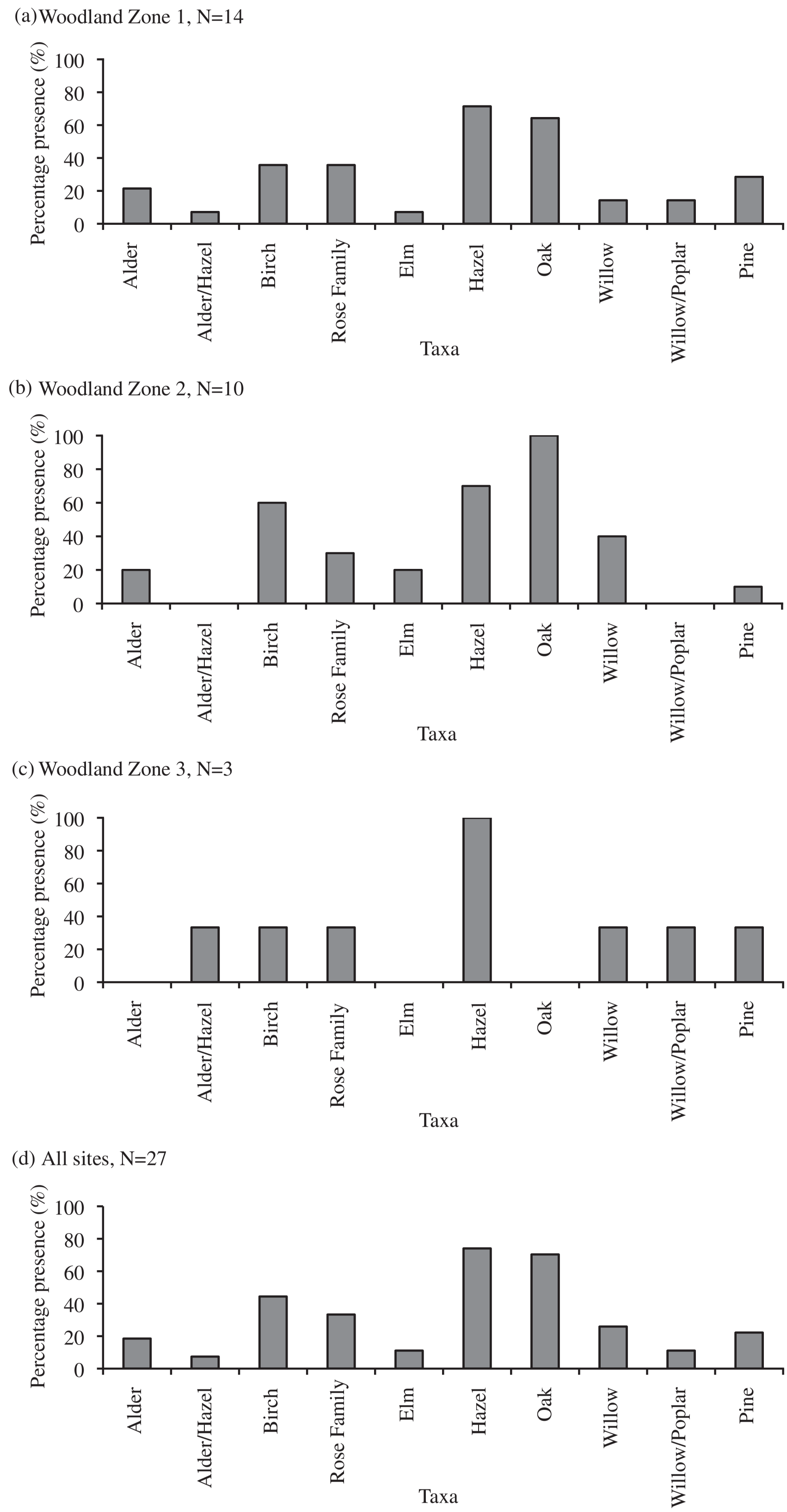

Fig. 2. Percentage presence of wood charcoal species in each woodland zone category, calculated as a percentage of the total number of site blocks in each category.

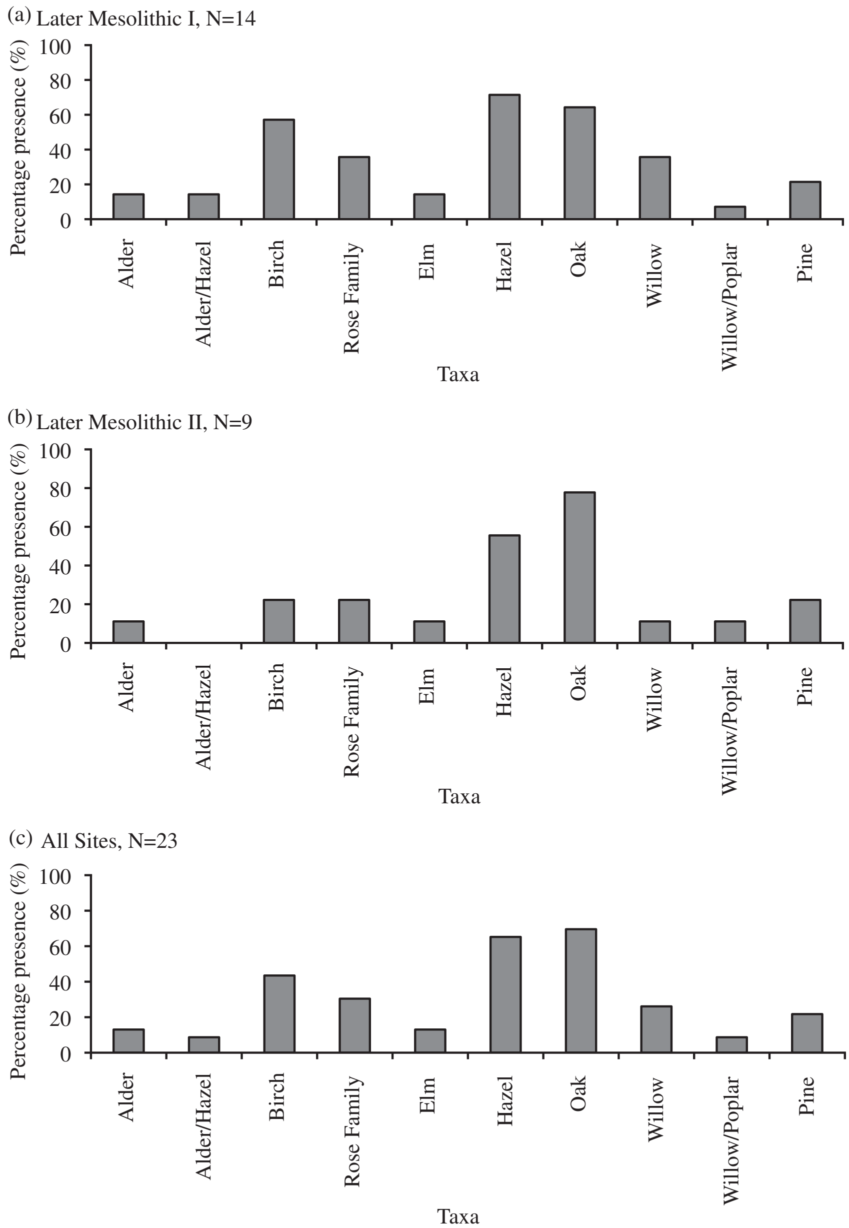

Fig. 3. Percentage presence of wood charcoal species in each chronological category, calculated as a percentage of the total number of site blocks in each category.

used across space and time, they do not indicate the absolute importance of individual taxa (i.e. how much wood was burned) within or between any of the chronological or geographical categories (Hubbard, 1975:198; Popper, 1988:61; Smart and Hoffman, 1988:190; Pearsall, 2000:213–214). Using this method, equal weight is given to small and large charcoal concentrations (Hubbard, 1975:198; Popper, 1988:61) and as there were different numbers of sites in each woodland zone/chronological category, the minimum percentage presence of a taxon differed slightly between each category (7% in woodland zone 1, 10% in woodland zone 2, 33% for woodland zone 3, 7% for the Later Mesolithic I and 11% in the Later Mesolithic II). Consequently, small differences in percentage presence between different chronological and geographical categories of less than c. 5% should be interpreted with extreme caution.

4. Results

This section presents the results of the review of 47 Scottish Mesolithic archaeological sites with carbonised tree/shrub remains, split into 56 site blocks (Table 2). Of these site blocks, 24 were classed as Later Mesolithic I, 20 as Later Mesolithic II and 12 as Mesolithic. There was an even spread of sites in woodland zones 1 and 2, with 21 sites located in zone 1 and 20 sites in zone 2 (Fig. 1). In contrast, there are currently only six Mesolithic sites with archaeobotanical remains in woodland zone 3. The small number of sites in this zone is a reflection of the lower level of modern development in this region compared to other areas of Scotland, thus reducing the likelihood of discovery, together with the fact that in situ Mesolithic archaeology has only been discovered in the Northern and Western Isles in the last decade.

Hazel nutshell was present on 70% of the site blocks in the review (Table 2), with large concentrations recovered from four sites (Staosnaig F24, East Barns, Weston Farm and Cramond; Bishop et al., 2013). The assemblage from Staosnaig F24 contained the fragmented remains of an estimated 30,000–40,000 whole hazelnuts (Mithen et al., 2001), providing clear evidence for the large-scale exploitation of hazel (Bishop et al., 2013). Plant macrofossils from other woody taxa were very scarce in the assemblages: crab apple fruits and seeds and a possible pear (*Pyrus* sp.) pip were restricted to single assemblages and hawthorn stones were discovered on just 2 sites.

In contrast, wood charcoal was abundant and was present at 91% of site blocks, with taxa identified at 70% of site blocks. Wood charcoal was present at 93% of the site blocks in woodland zone 1, 87% of the site blocks in woodland zone 2 and 100% of the site blocks in woodland zone 3.

A wide variety of woody taxa were present in the charcoal assemblages during the Later Mesolithic I and II: alder, ash, birch, cherry/blackthorn (*Prunus* sp.), crab apple, crab apple/pear/whitebeam/rowan/hawthorn/wild service (Rosaceae: Pomoideae/Maloideae/*Sorbus* sp.), elm, hawthorn, hazel, oak, possible field maple (*Acer campestre* L.), willow, willow/poplar and pine (Table 2). Despite this diversity, the charcoal assemblages were dominated by deciduous woodland taxa and in particular, hazel and oak. Hazel and oak charcoal were present at 43% and 41% of site blocks respectively and hazel was present at 84% of the sites as either wood charcoal and/or nutshell (Table 2). Of the 27 assemblages where inter-taxa comparison was possible (quantitative and semi-quantitative), hazel was the dominant taxon at 10 site blocks, oak was dominant at 6 site blocks, pine at 3 site blocks, rose family at 3 site blocks, willow/poplar at 2 site blocks, birch at 2 site blocks and alder at 1 site block. Coniferous species were present on just eight site blocks and pine was the only coniferous charcoal identified to species level. All the pine charcoal came from North-East Scotland, except for two fragments, which came from Northton, Harris. Hazel and oak were the main species exploited in Mainland Scotland and the Inner Hebrides and in the Northern and Western Isles, oak was absent and hazel was the dominant taxon utilised (Fig. 2). There was little change in the species exploited between the earlier and later Mesolithic, except there appears to have been a slight decline in the use of birch and willow in the later Mesolithic (Fig. 3). None of the available reports (Table 1) provided sufficient data on the age and diameter of the charcoal fragments to plot age and size distributions.

5. Research question 1: what evidence is there that trees were systematically and selectively exploited for food and fuel in Mesolithic Scotland?

5.1. Evaluation of firewood selection models

There are two main models of interpretation in the study of fuel wood selection using archaeological charcoal. In the first view, it is argued that the proportions of different charcoal species in archaeological assemblages directly reflect the cultural selection of wood species gathered and burnt as fuels by humans (e.g. Godwin and Tansley, 1941:118; Ford, 1979:305; Boyd, 1988:314; Smart and Hoffman, 1988:170; Kreuz, 1992; Shackleton and Prins, 1992; Pessin, 2002; Dufraisse, 2006:48; Marston, 2009; Out, 2010:1). In contrast, proponents of the so-called “Principle of Least Effort” (Shackleton and Prins, 1992), argue that past peoples simply collected wood in direct proportion to the abundance of the species growing in their immediate environment (e.g. Salisbury and Jane, 1940; Dimbleby, 1967:115; Minnis, 1987:129; Carrión, 2002; Fletcher, 2002:91; Heinz, 2002:96; Ntinou and Kotjabopoulou, 2002:84; Willcox, 2002:141).

A major problem with the latter approach is that it is based on the questionable theoretical assumption that humans were passive components of the biosphere, which adapted to, but did not actively control or shape their environments (Shackleton and Prins, 1992:632). This model therefore disregards the role of human agency in the deliberate selection of wood species for different purposes, which is well-documented in anthropological accounts of hunter–gatherer societies (Smart and Hoffman, 1988:168). Wood species differ in their suitability as fuels because of their differing thermal and mechanical properties due to differences in moisture content, density, resin/oil/tar content and the chemical composition (Marston, 2009:2194). The choice of wood species for firewood is not solely based on the energy content and heat production of the wood (contra Marston, 2009), but also combustion speeds, the amount and smell of the smoke produced (Graves, 1919:30) and the intended purpose of the fire (Table 4; Dimbleby, 1967:55; Smart and Hoffman, 1988:191; Théry-Parisot, 2002:244; Asouti and Austin, 2005:9). Some species would also have been actively avoided due to poor burning properties or cultural preferences (Ford, 1979:290; Shackleton and Prins, 1992:632–633).

In response to these points, recent proponents of the “Principle of Least Effort” have accepted that firewood was probably selectively collected, but have argued that the moisture content, physiological state and the size of the wood, rather than the species, was the primary criterion for wood selection in the past (Théry-Parisot, 2002; Théry-Parisot et al., 2010). However, the natural moisture context and rate of drying of greenwood varies by species, and it is this that causes the biggest difference in the calorific content between different wood species (Forestry Commission, 2010a, 2010b). Some species, such as ash, have a naturally lower moisture content and would be preferable fuels to woods with high moisture contents, such as willow/poplar (Forestry Commission, 2010b:5; Table 4). Therefore, the species is key in firewood selection, particularly when the wood has not been well-seasoned.

A further issue with both interpretative approaches is that taphonomy affects the composition of archaeological assemblages. Once in contact with fire, some species are more likely to become carbonised and preserved than others due to differences in the size, moisture content, burning properties and speeds, as well as the chemical composition of the wood (Rossen and Olson, 1985; Smart and Hoffman, 1988:172; Lingens et al., 2005; Forestry Commission, 2010a, 2010b; White and Dietenberger, 2010). Different woods of the same mass also produce different quantities of charcoal and so some species would be over-represented relative to the quantities combusted (Smart and Hoffman, 1988:173; Shackleton and Prins, 1993). Once carbonised, some species are more fragile than others due to differences in anatomical structure and the different amounts of shrinkage and mass and density-loss that occur during carbonisation between different species (Rossen and Olson, 1985; Smart and Hoffman, 1988:175; Chrzazvez et al., 2014). Consequently, depositional and post-depositional disturbances would affect different species by variable amounts.

Site formation processes and sampling strategies may also affect the composition of archaeological charcoal assemblages. Whilst some assemblages may provide evidence for single use domestic fires for specific purposes, other assemblages probably represent a palimpsest of different anthropogenic burning events or the charred remnants of structural timbers or natural fires. Also, sites without large systematic sampling methodologies may produce assemblages with a much narrower range of species than were originally preserved on site (Smart and Hoffman, 1988:191; Jones, 1991:64; Shackleton and Prins, 1992:632). Thus, differential preservation, depositional processes and sampling strategies may mask firewood selection strategies to some extent.

Fig. 4. Illustration of the main taphonomic process for creating assemblages of archaeological charcoal on Mesolithic sites in Scotland: (a) a fire-spot is prepared for burning by creating a pile of birch bark fragments; (b) a fire of small twigs and branches is created on top of the ignited birch bark fragments; (c) medium-large branches are added to create a small hearth; (d) fire ashes and large and small charcoal fragments remain after burning and are subsequently incorporated into archaeological deposits by trampling or deliberate deposition within negative features. Though species used as kindling are more likely to be completely burnt to ash (Smart and Hoffman, 1988:173), experimentation suggests that all stages of the burning process, including kindling and main fuel source should be represented in archaeological charcoal assemblages to some extent (Church et al., 2007a:763).

5.2. What evidence is there for the systematic selection of trees for food and fuel in the Scottish Mesolithic?

As just discussed, it is possible that there may have been a taphonomic filter in terms of the preservation of different wood species as charcoal in archaeological deposits. Whilst carbonisation differences between species and depositional and post-depositional processes may have had a major impact on the relative frequency (in terms of number or mass of fragments in the >4 mm fraction used for identification) of different species within different site assemblages, these factors would have had only a minor impact on the presence of particular species at each site. In this respect, it is probable that species with a low resistance to pressure (and hence a greater chance of complete destruction in the burial environment), such as oak and pine would be slightly under-represented in the charcoal assemblages relative to species with a high resistance to pressure, such as hazel and birch (Chrzazvez et al., 2014). It should be noted that nearly all of the quantified charcoal was identifiable (Table 2), which suggests that poor preservation would not have greatly impacted on species representation (cf. Asouti, 2003:1193). Therefore, the percentage presence of poorly-preserved species was probably slightly reduced, but well-preserved species will not have been overestimated as the analysis is not based on the quantification of fragment counts or masses.

It is probable that the on-site taphonomy, rather than charcoal preservation, would have had the greatest impact on the results of this analysis. The charcoal assemblages in this review are derived from a range of different types of features of differing purposes, including pits, postholes, scoops, stakeholes, hearths, gullies, old ground surfaces, shell middens and possible natural features (Table 1). The oak and pine charcoal recovered from the stakeholes at Biggar Common provides the only clear evidence for burnt structural remains, which were probably accidentally burnt (Crone, 1997; Johnston, 1997). Though the pits at Sketewan and Tulloch Wood containing radiocarbon-dated charcoal may have been treethrow holes (Carter, 1993:231; Mercer and Midgley, 1997:291), there is no evidence that the charcoal was derived from trees burnt in situ. Therefore, with the exception of Biggar Common, all the charcoal assemblages are assumed to have originated from fuels deliberately burnt on domestic hearths (Fig. 4).

In most cases, the wood charcoal assemblages probably represent palimpsests of hearth remnants from a mix of different fires, sometimes from multiple occupations, which accumulated accidentally in secondary contexts as a result of trampling, shifts in the location of specific activities (Asouti and Austin, 2005:10) or as a result of bioturbation, erosion or post-depositional processes occurring after site abandonment. Wood charcoal may also have been deliberately deposited as a result of the discard of domestic rubbish away from the primary hearth area. Many of the assemblages could also represent the remnants of short-term fires, either occurring in situ or in the immediate vicinity of pits into which the charcoal was later deposited, and may represent wood collected in a single episode. For example, the assemblages from Beattock, Garthdee, Tulloch Wood, Skilmafilly, Spurryhillock, Daer Valley Site 84, Lussa Wood, Redkirk Point and Chapelfield pit 5 (see Table 1) all contained a restricted range of charcoal species (1–3 taxa – Table 2) and were all derived from single pits or possible hearth contexts. Therefore these charcoal assemblages may not be representative of general firewood selection strategies. This problem is reduced by the large number of sites in the review and the fact that these sites will be considered together with assemblages derived from a more representative range of contexts.

Overall the charcoal assemblages were dominated by native deciduous species, and in particular oak and hazel. Almost all of the woodland species present in the pollen record (Table 3) are represented in the charcoal assemblages (Table 2). The only exceptions are juniper, which was relatively rare or absent from the Mesolithic Scottish environment, and perhaps rowan and poplar, though these may have been present under the identification categories of *Sorbus* sp. and Salicaceae respectively (Table 2). In contrast to later periods in Atlantic Scotland, pine was the only coniferous taxon identified and there was no evidence for the utilisation of non-native driftwood species such as larch and spruce (Dickson, 1992). This is probably a reflection of the abundance of woodlands within the environment (Table 3), meaning that driftwood exploitation would have been unnecessary.

The abundance of hazel in the charcoal assemblages is probably a reflection of the dominance of hazel in the environment in all three areas (Table 3), together with its good burning properties (Table 4). Hazel nutshell was also present on most sites, with large concentrations recovered in four assemblages, reflecting both the prevalence of hazel in Mesolithic environments and the significance of hazelnuts within the Mesolithic diet (Bishop et al., 2013). Interestingly, hazelnuts were recovered from most of the assemblages dominated by hazel charcoal (Table 2) and there were numerous sites where hazel was present as both nutshell and charcoal. This emphasises the importance of hazel within the Mesolithic economy and it is possible that the wood and nuts were gathered simultaneously at some sites. If gathered as greenwood, this could suggest deliberate pruning to increase nut production, as traditionally undertaken in Britain on commercial hazelnut farms (Pierpoint Johnson, 1862:259; Howes, 1948:179; Mason, 1996:2). The possibility of some accidental gathering of hazelnuts during the gathering of hazel greenwood cannot be discounted at sites where both are present, but it is unlikely that this accounts for the abundance of hazelnuts in Mesolithic archaeobotanical assemblages. Hazelnuts are present on numerous sites lacking hazel charcoal and it is improbable that all the sites where both were present were occupied during the autumn when the nuts were available for collection (Bishop et al., 2013, Table 2).

The importance of oak in the charcoal assemblages was also clearly influenced by its abundance in the natural vegetation in many areas of mainland Scotland. The absence of oak charcoal in the assemblages from the Northern and Western Isles, where oak was a less significant component of the vegetation, supports the idea that human firewood selection strategies were influenced by species availability and abundance. The choice of oak as a fuel may also reflect deliberate selection by Mesolithic hunter–gatherers for the excellent burning properties of the wood (Table 4). The high percentage presence of oak charcoal is significant, given that this species has a low resistance to mechanical pressure, and may be under-represented in archaeological charcoal assemblages (Chrzazvez et al., 2014).

Despite the abundance of oak in the environment and in Mesolithic charcoal assemblages, acorns were absent from the assemblages. Acorns have been recovered from a number of Mesolithic assemblages from elsewhere in North-West Europe (Zvelebil, 1994; Robinson, 2007; Andersen, 2009) and could potentially have been significant resources for hunter–gatherers in Scotland due to their storability, high calorific content (Mason, 2000:141; Barlow and Heck, 2002) and widespread availability in Scottish Mesolithic woodlands (Table 3). It is possible that acorns were processed and dehusked away from domestic hearths or that the much more fragile husks (relative to hazel nutshells) were destroyed rather than being carbonised in domestic hearths, as most acorn discoveries in other parts of Europe have been preserved by waterlogging rather than by carbonisation. The absence of acorns in Mesolithic assemblages could also reflect the fact that acorns require more elaborate processing than hazelnuts: acorns need to be leached to remove the harmful tannins as well as dehusked prior to consumption (Johnson, 1978:364; Wallace, 1978:166; Barlow and Heck, 2002:134–135), whereas hazelnuts do not. Therefore, given that there is not even a single identification of an acorn, it is possible that acorns were genuinely not a significant resource in Mesolithic Scotland.

In contrast to hazel and oak, birch appears to be under-represented in the charcoal assemblages relative to its importance in the environment, particularly in woodland zones 1 and 3 (Fig. 2). Considering that birch burns well and was a major woodland component (Tables 3 and 4), it is surprising that birch charcoal was not more frequently recovered in the archaeobotanical assemblages. This rarity could be in part due to the nature of its combustion properties. Birch burns relatively quickly and when utilised, it would probably have been used as kindling or burnt together with other steady or slow burning woods, and would also have a lower chance of carbonisation compared to steady burning woods. However, it is unlikely that this accounts for the complete absence of birch from most sites, and the relative rarity of birch does appear to reflect the fact that other woods were preferred as fuels.

Alder also appears to have been avoided for burning. Although it was locally dominant in many areas of mainland Scotland in the Later Mesolithic II (Table 3), it has only been identified on 6 of the site blocks in the review (Table 2). It is possible that none of the Mesolithic sites in the review was specifically located in an area of alder woodland dominance, and if this is the case then the rarity of alder charcoal could reflect its relative scarcity in native woodlands (Table 3). Yet, given that alder has extremely poor burning properties (Table 4), human choices rather than availability may be responsible for its low frequency in the archaeological assemblages.

Likewise elm is virtually absent in archaeological assemblages, despite being a good fuel when dry and a major woodland taxon in Southern and Central Scotland in the Later Mesolithic II (Tables 3 and 4). The fact that it is only present on 4 of the site blocks in the review suggests that elm was avoided for burning. This could be a consequence of the fact that elm burns poorly when wet (Table 4).

Again, pine was rarely selected as a fuel in Mesolithic Scotland. This can probably be explained by its rarity in Scottish Mesolithic woodlands (outwith the Highland pine woods), together with its thermal properties (Tables 3 and 4). Pine burns very rapidly and at a high temperature and would probably not have been routinely used as a main fuel source, though it may have been chosen for kindling or mixed with other species that burn more slowly (Table 4). Poor preservation may also account for the rarity of pine: as a fast burning wood, it would be less likely to form charcoal and once carbonised it would be more easily fragmented due to its low resistance to mechanical pressure (Chrzazvez et al., 2014).

Another species that is notably rare in the charcoal assemblages is ash, which was present at just one site, despite its excellent burning qualities (Tables 2 and 4). Although ash was present in many areas of mainland Scotland and the Inner Hebrides (Table 3), it was not a major woodland component. This suggests that the presence of ash in the charcoal assemblages was influenced by availability rather than selection. Similarly, the consistent, but low-medium frequency of willow/poplar and rose family charcoal/fruit remains in all areas is most probably a direct reflection of their more restricted availability in the environment, although the relatively poor burning qualities of willow/poplar and several species in the rose family (rowan/whitebeam/wild cherry) probably also influenced the scarcity of these species in the charcoal assemblages (Tables 3 and 4). The rarity of the edible crab apple and hawthorn berry remains in the samples may also be due to the

Table 5
Summary of the main benefits of vegetation burning for hunter–gatherers (Mellars, 1976; Lewis, 1982:49–52; Kuhnlein and Turner, 1991:18, 140; McCarthy, 1993; Zvelebil, 1994:61; Moore, 1996:67; Mason, 2000:142; Anderson, 2006:238; Rowley-Conwy and Layton, 2011; Smith, 2011).

Plant exploitation	Hunting
- Stimulates the growth of new seedlings of fire tolerant tree species - Increases growth of edible understory plants, such as herbaceous berry producers and edible wild grasses	- Attracts animals for hunting - Increases growing season, quantity and nutritional quality of food supplies to herbivores which increases herbivore carrying capacity, growth rates and reproductive rates
- Creates ready-dried firewood in fire-killed trees (greenwood requires months of drying prior to use) - Causes a reduction in undergrowth which would facilitate the collection of wild edible plants, such as hazelnuts and acorns	- Improves visibility and mobility in woodlands, which increases hunting success by destroying cover and increasing visibility - Enables humans to control distribution of food resources, resulting in a reduction in time and energy involved in finding food and in the uncertainty of hunting success
- Increases soil fertility and the rate of nutrient recycling within the soil - Helps to prevent destructive high-intensity fires - Reduces competition from unwanted species - Destroys parasites which attack plants	

more restricted taphonomic pathways into archaeological deposits for fruits/berries compared to other edible plants, such as hazelnuts (Bishop et al., 2013).

Several sites had charcoal identifications from species that did not grow within the local vegetation. For instance, oak charcoal was recovered from the site of Silvercrest, in North-East Scotland, and the radiocarbon dates from the site pre-date the expansion of oak into the area (Birks, 1989). Considering that the post-circle has been dated using pine charcoal and that the oak charcoal has not been directly dated, it is possible that the oak charcoal was intrusive from later deposits. Another unexpected species in the Mesolithic assemblages was the maple charcoal recovered from the stone settings at Lussa Wood, Jura and dated to 7963 ± 200 uncal BP. The native English species, the field maple (*Acer campestre* L.) is not native to Scotland (Stace, 2010:372), and its presence in a Scottish assemblage requires an explanation. Given that the radiocarbon sample was derived from a mix of hawthorn and maple charcoal, of which hawthorn was dominant, the Mesolithic date for the charcoal may not have been reliable. It is also possible that the charcoal was misidentified. Re-identification and AMS dating would be necessary to resolve this issue.

Overall, the present data suggest that birch, elm and alder were avoided for burning as fuels to some extent. Considering the good burning qualities of hazel, oak and ash, the prevalence of hazel and oak and the rarity of ash charcoal can be attributed to the relative abundance of hazel and oak and the scarcity of ash in the environment. Thus, current evidence suggests that species availability had a strong influence on the choice of fuels exploited by Mesolithic people, but that species with poor combustion qualities were deliberately avoided in favour of species with good burning properties.

6. Research question 2: How reliable is the evidence for woodland management in Mesolithic Scotland?

6.1. Ethnographic evidence for woodland management

Landscape burning is probably the most widespread method of deliberate plant management employed by hunter–gatherer societies past and present (Mellars, 1976:16; Lewis, 1982; Moore, 2000:131; Rackham, 2006:83; Gammage, 2011; 8). Periodic burning of the landscape disrupts the natural succession of plants and increases the diversity of the vegetation by creating zones of vegetation in different successional stages (Moore, 1996:67; Anderson, 2006:239; Smith, 2011:838). This increases the numbers of plants at the beginning of the successional cycle, which are economically significant (Anderson, 2006:238; Smith, 2011:838), such as blackberries (*Rubus* sect. 2 Glandulosus Wimm. & Grab.), raspberries (*Rubus idaeus* L.), hawthorn berries, elderberries (*Sambucus nigra* L.), acorns and wild grass seeds (Stewart, 1956:120; Lewis, 1982:50; Bean and Lawton, 1993:40; McCarthy, 1993; Moore, 1996:67; Mason, 2000:140–142; Anderson, 2006:262). The controlled burning of vegetation may also have been undertaken for a range of other reasons (Table 5) and was usually used to increase biodiversity rather than promoting any specific plant or animal species (Lewis, 1982:51–52; Moore, 1996:67; Bird et al., 2008; Smith, 2011:838).

Woodland coppicing was also a widespread practice in hunter–gatherer societies past and present worldwide. For instance, in North America hunter–gatherers coppiced a diverse range of trees by burning or cutting, for the construction of items such as baskets, traps, fish weirs, cordage, arrows, tools and structures (Anderson, 2006:210,224). Young coppiced branches of willow and hazel of between 1 and 2 years were particularly favoured for small items, such as baskets (Wilkinson and Vedmore, 2001:31; Anderson, 2006:213, 219), whereas larger poles used in construction would be coppiced after greater intervals, such as 4–7 years (Coles et al., 1978:24). Pruning particular branches of hazel trees can also be undertaken to increase nut production, a practice which has traditionally been undertaken in Britain on commercial hazelnut farms (Pierpoint Johnson, 1862:259; Howes, 1948:179; Mason, 1996:2).

6.2. Recognising woodland management in the Mesolithic

There are two main methods for recognising woodland management in the past. The first method involves the analysis of the age and size distributions of large samples of archaeological wood and charcoal to identify the selection of particular sizes/ages of branches or periodic branch stripping/harvesting (e.g. Crone, 1987; Christensen, 1997; Church et al., 2007b) or more formal management systems (Out et al., 2013), involving the regular cutting of branches after set intervals. The second main method is to identify palynological signatures indicative of woodland 'disturbance'. Such phases (e.g. Hirons and Edwards, 1990; Tipping, 1995b; Simmons, 1996; Edwards, 2004) are typically recognised by the decline in tree taxa, together with an increase in microcharcoal, grasses (Poaceae), sedges (Cyperaceae), heather (*Calluna* sp.) and/or other open ground indicator species such as docks (*Rumex* sp.) and cow-wheat species (*Melampyrum* sp.). It has also been proposed that the sharp rise and abundance of hazel pollen in the Mesolithic may reflect hunter–gatherer woodland manipulation (Smith, 1970:83; Iversen, 1973:62; Boyd and Dickson, 1986; Huntley, 1993:214).

Though there is an extensive body of palynological evidence for small-scale, human-woodland manipulation in Mesolithic Scotland (e.g. Edwards and Ralston, 1984; Bohncke, 1988; Hirons and Edwards, 1990; Tipping, 1995a, 1995b; Edwards, 1996a, 2000b, 2004, 2009; Edwards and Sugden, 2003), evidence for Mesolithic coppicing in Scotland is currently lacking owing to a rarity of waterlogged sites and an absence of charcoal assemblages with analysed age and size distributions. As can be seen from Table 2, there are several assemblages with more than 50 charcoal fragments of the same species, which would be amenable to age/size analysis (cf. Out et al., 2013:4092), and the full analysis of these and similarly sized assemblages should be a key priority for future research into human niche construction in Scotland. Due to the current absence of archaeological wood/charcoal evidence for woodland management in Scotland, the following discussion will focus on the evaluation of the reliability of the pollen evidence for woodland management. Two questions will be addressed using palynological evidence:

1) How reliable is the suggestion that Mesolithic hunter–gatherers increased the spread or abundance of hazel?
2) How reliable is the suggestion that 'disturbance phases' in palynological sequences were created as a result of anthropogenic woodland management?

6.2.1. How reliable is the suggestion that Mesolithic hunter–gatherers increased the spread or abundance of hazel?

It has been proposed that Mesolithic people were responsible for accelerating the spread of hazel in Britain and/or for increasing its abundance (Smith, 1970:83; Iversen, 1973:62; Boyd and Dickson, 1986; Huntley, 1993:214). Post-glacial tree colonisation is now widely regarded to have occurred as a result of natural processes (Birks, 1989; Tipping, 1994:9, 2004:46) and the sharp rise and abundance of hazel in Mesolithic phases of pollen diagrams probably relates to the climatic conditions in the early Holocene, which favoured the spread and flowering of hazel in the unshaded conditions which existed before the expansion of other canopy-forming taxa (Huntley, 1993; Tallantire, 2002). Whilst it is theoretically possible that hunter–gatherers accidentally or deliberately introduced hazel onto islands with more restricted floras, such as the Hebrides (Boyd and Dickson, 1986), there is no archaeobotanical evidence to support this hypothesis: in areas where hazel was late to colonise, such as Arran and Mull (Boyd and Dickson, 1986), there are no hazelnut shells present in archaeobotanical samples prior to palynological evidence for hazel colonisation. Considering the probable key importance of hazelnuts in Mesolithic diets (Bishop et al., 2013), it is more likely that human populations followed the natural spread of hazel woods across North-West Europe than vice versa (Birks, 1989:508; Huntley, 1993).

After hazel became established, it has also been proposed that Mesolithic people managed hazel to increase its abundance or productivity (Smith, 1970). Current evidence from studies of areas of known coppiced hazel (Waller et al., 2012) show that hazel pollen production increases following coppicing and this could explain the evidence for the abundance of hazel within Mesolithic phases of pollen diagrams. However, a review of 8 pollen sequences from across Scotland provided no evidence for a chronological relationship between microcharcoal frequency and the abundance of hazel in the Mesolithic (Edwards, 1990). Also, whilst hazel may well have thrived in more open areas created by clearances (and produced more pollen and/or more trees), hazel often declines during disturbance phases (see Section 6.2.2) and not all palynologists and ecologists accept that the native British hazel is a fire-responsive species (e.g. Rackham, 2006:356). If hazel management was undertaken to further increase the production of hazelnuts then this could have been achieved by pruning or cutting particular branches rather than by woodland clearance or coppicing (Pierpoint Johnson, 1862:259; Howes, 1948:179; Mason, 1996:2). Added to this is the fact that hazel dominated the landscape in most areas before the arrival of shade-producing species (Birks, 1989:511; Rackham, 2006:80), and arguably there was no need to increase hazel frequency artificially (Simmons and Innes, 1996:191). In these conditions, it seems likely that hazel would have been much more productive than it is at present, where (outwith areas of coppice) it usually grows as an understory shrub.

6.2.2. How reliable is the suggestion that 'disturbance phases' in palynological sequences were created as a result of anthropogenic woodland management?

A major interpretative problem is that there is no clear-cut signature for recognising anthropogenic woodland management in pollen diagrams (Tipping, 2004:48). Consequently, before considering the reliability of the suggestion that 'disturbance phases' were created as a result of human woodland management, it is necessary to consider the strength of the evidence for the alternative natural processes that could have produced these signatures: natural woodland dynamics, overgrazing by large herbivores, and a climatically induced increase in natural fire frequency.

The first point to note is that though the extent of 'natural' Mesolithic woodland openness has been much debated in recent years (Vera, 2000; Svenning, 2002; Bradshaw et al., 2003; Whitehouse and Smith, 2004; Mitchell, 2005; Moore, 2005; Rackham, 2006:90–101), most ecologists and palaeoecologists believe that some open areas would always have been present within Mesolithic woodlands due to natural processes such as windthrow, senescence, disease, flooding, droughts, insect/fungal attack and natural fire (e.g. Rowley-Conwy, 1982; Edwards and Ralston, 1984:24; Tipping, 1994:16, 2004:48; Moore, 1996:63; Peterken, 1996:70; Simmons, 1996:129; Brown, 1997:141; Svenning, 2002; Edwards and Whittington, 2003:70; Whitehouse and Smith, 2004; Rackham, 2006:91) and that the natural terrestrial fauna would have impacted on woodlands either by consumption of tree leaves, branches and bark or grazing on grasses in natural clearings and preventing tree regeneration (Peterken, 1996:95; Kreuz, 2008:53). Beavers in particular may have been responsible for creating large clearings of several hectares by tree-felling to make river dams and by consumption of tree bark (Peterken, 1996:95 and 340). Therefore some clearings would have been created as a result of these processes.

It is unlikely though, that natural woodland dynamics and herbivore impact would account for all 'disturbance phases'. Firstly, fires, and in particular crown fires, are extremely rare in deciduous woods because they grow in moist habitats, their foliage has a high moisture content and they lack highly flammable resins present in coniferous species (Moore, 1996; Peterken, 1996:101; Murgatroyd, 2002:3; The Scottish Government, 2011:5). Today British woodlands are considered to have a low fire risk (Murgatroyd, 2002:1) and even in coniferous forests in North-West Europe, lightning induced-fires are relatively rare, occurring approximately once every 80 years (Peterken, 1996:103). Secondly, clearings produced as a result of natural woodland dynamics would have been spatially restricted and (with the exception of natural fire) would not result in an increase in microcharcoal. They would therefore be difficult to detect in the palynological record (Simmons, 1996:129). Added to this is the evidence for Mesolithic vegetation impact in the Outer Hebrides (e.g. Bohncke, 1988; Edwards, 1996a, 2000a; Edwards and Sugden, 2003), a region where Mesolithic archaeological excavations (Gregory et al., 2005; Simpson et al., 2006; Bishop et al., 2010, 2011, 2013; Church et al., 2011a, 2011b, 2012a, 2012b) have so far provided no clear evidence for the presence of large terrestrial mammals, such as red/roe deer (Hamilton-Dyer, 2005; Rowley-Conwy unpublished data). This suggests that terrestrial mammals were not responsible for the disturbance phases in the Outer Hebrides and considering the similarity of the palynological signatures of disturbance phases in this region to those in mainland Scotland, it seems likely that this was also the case for many disturbance phases noted in pollen diagrams from the mainland (cf. Mitchell, 2005).

Another possibility is that disturbance phases reflect an increase in climatic dryness in the Mesolithic, which could have resulted in a rise in naturally occurring fires (Tipping, 1996, 2004:50; Tipping and Milburn, 2000:189; Cayless and Tipping, 2002). Tipping (1996) calculated the percentage of pollen sites in Atlantic Scotland with high microcharcoal frequencies in 250 year time-slices, arguing that there was a large increase in fire frequency at c. 8000 uncal BP (c. 7100–6700 cal BC), which reflected increasing aridity and the development of readily combustible heathland. Elsewhere Tipping has proposed (2004) that the increase in fire-frequency in several pollen cores from Southern Scotland at c. 8200 cal BP (c.6200 cal BC) coincided “with the period of climatic restructuring that would have followed the 8200 cal BP event”, a rapid shift to a cooler and drier climate, which lasted for approximately 200–400 years.

There are a number of issues with these arguments. Firstly, the chronological precision of the palynological sequences summarised in Tipping's (1996) paper is insufficient to identify whether microcharcoal increased synchronously at c. 8000 uncal BP. The chronologies of most of these pollen sites are based on linear interpolation between small numbers of uncalibrated radiocarbon dates from bulk sediment samples, which would produce large errors associated with the interpolated dates due to the variability in sediment accumulation and the errors associated with the radiocarbon dates. Also, the summing of low, moderate and high microcharcoal frequencies in 250 year blocks (Tipping, 1996:50) obscures the chronological variability of the high microcharcoal signals between different pollen cores, which appear to be anything but synchronous (Edwards, 1996a). Similarly, the “region-wide increase in fire frequency and/or intensity” in Southern Scotland at c. 8200 cal BP (c. 6200 cal BC) referred to by Tipping (2004:50), was said to have occurred after c. 5000, 4800 and 4400 cal BC respectively in the original publication for the 3 pollen cores which provided evidence for increasing microcharcoal frequency (Tipping and Milburn, 2000:189). Furthermore, current climatic data suggest that the increase in cumulative charcoal frequencies identified by Tipping (1996), occurs before the climatic deterioration of the ‘6200 cal BC event’ and continues into a period of wetter climate between c. 5050–4350 cal BC (Tipping et al., 2012). High microcharcoal frequencies are also evident in individual diagrams during this wetter terminal Mesolithic phase (Tipping, 1996:46; Tipping and Milburn, 2000:189; Edwards, 2004:65). Therefore, the lack of clear chronological correlation between fire frequency and drier climatic phases and the presence of clearance phases in areas lacking large terrestrial mammals, suggests that most ‘disturbance phases’ are more likely to reflect human action than natural causes. Further support for this comes from the evidence for the decline in microcharcoal frequency in the Neolithic in some areas of Scotland (Edwards, 1988:262, 1998:74; Tipping, 1997b:156; Tipping and Milburn, 2000), at a time when the climate was probably relatively dry (Anderson, 1998; Bonsall et al., 2002; Whittington and Edwards, 2003:21; Tipping and Tisdall, 2004:76; Tipping et al., 2012) and natural fires should have been of equal frequency to the drier phases of the Mesolithic.

Against this is the inconsistency of the palynological signatures that have been proposed as anthropogenic disturbance phases. In some instances all tree taxa are affected, whereas in other cases only certain tree species decline. For example, a clearance phase is argued to have occurred at Kinloch on Rhum between c. 5950–5700 uncal BP, when there was a sudden decline in alder and hazel and an increase in charcoal and grasses (Hirons and Edwards, 1990) and at Loch a' Bhogaidh, Rinns of Islay where there was a reduction in hazel (but not birch) and an expansion in microcharcoal, grasses and sedges at c. 7670–7080 uncal BP (Edwards, 2004). At Burnfoothill Moss, anthropogenic woodland disturbance at c. 7800–7700 cal BP was argued to have been indicated by a microcharcoal peak and the presence of cow-wheat species, hawthorn (*Crataegus* sp.), Ribwort Plantain and bracken (*Pteridium* sp.) together with a small increase in grass pollen, but without an associated decline in major woodland taxa (Tipping, 1995b). The inconsistency of these records points against a unitary explanation for all of these ‘disturbance phases’. In fact, it can be questioned whether a decline in tree taxa is a suitable model for identifying woodland *management* in the palynological record at all: the continued presence of important taxa together with constant microcharcoal levels might be a more appropriate indicator of successful management (Moore, 1996; Mason, 2000:146). Current evidence from studies of areas of known coppiced hazel (Waller et al., 2012) for instance, show that hazel pollen production increases rather than decreases following coppicing.

Furthermore, arguably the chronological resolution of the ‘disturbance phases’ that have been identified in Mesolithic Scotland are insufficient to distinguish anthropogenic action from natural processes. Unlike the fine resolution pollen analyses that have been undertaken in North Yorkshire (e.g. Simmons and Innes, 1996; Innes and Simmons, 2000; Innes et al., 2013), which provide evidence for repeated burning of a frequency and scale inconsistent with natural fires, most ‘clearance phases’ identified in diagrams from Mesolithic Scotland are of long duration (>100 years) and they do not represent single events within a human timeframe. Therefore most ‘disturbance phases’ in Mesolithic Scotland should be viewed as general periods of increased woodland disturbance combined with regeneration and probably represent an amalgamation of multiple events occurring at different spatial scales (cf. Rowley-Conwy, 1981:86; Simmons and Innes, 1987:396; Simmons, 1996:150; Innes and Simmons, 2000:162).

It can also be questioned whether these ‘disturbance phases’ represent deliberate landscape-level niche construction practices. Ethnographic evidence shows that most hunter–gatherer impacts were spatially restricted, involving the burning of grasslands, individual trees or naturally cleared areas within woodlands rather than large areas of mature deciduous forest (Lewis, 1982:50; Moore, 2000:131). Considering this, together with the fact that deciduous trees are not readily combustible in Britain (Edlin, 1972:86; Rackham, 2006:58), it is questionable to what extent such relatively small-scale fires would be distinguishable from the microcharcoal signal produced from domestic fires (Simmons, 1996:139). It is possible that most microcharcoal was derived from the burning of wood on domestic hearths rather than from large-scale woodland burning (Bennett et al., 1990b; Edwards and Ralston, 1984:25; Edwards and Whittington, 2003:71). Despite advances in the last few decades (e.g. Patterson et al., 1987; Clark and Royall, 1995; Blackford, 2000; Innes et al., 2004; Peters and Higuera, 2007), microcharcoal taphonomy is still not well understood, and microcharcoal peaks could reflect changing patterns and intensity of domestic settlement in the source area of pollen sampling sites (Bennett et al., 1990b), with most microcharcoal peaks representing composite records of multiple events (Innes et al., 2013:92).

‘Disturbance phases’ could also simply reflect people taking advantage of naturally open areas for settlement. Rather than burning woodlands, humans may have maintained or enlarged existing woodland clearings that had been created by herbivores and/or natural woodland dynamics (Simmons and Innes, 1987:396; Simmons, 1996:154; Brown, 1997; Bell and Noble, 2012:81; Innes et al., 2013:94). Mesolithic hunter–gatherers would also have required considerable amounts of wood for fuel and construction, and they may have created clearings as a result of the exploitation of woodlands for these purposes. The creation of these open areas would have attracted herbivores, which may have subsequently maintained the clearings (Buckland and Edwards, 1984; Bell and Noble, 2012:81), as well as increasing the abundance of economically important plants within and at the edges of clearings. A range of anthropogenic processes could therefore have produced 'disturbance phases' within pollen diagrams.

Overall, the pollen evidence for woodland management is equivocal, but it hints at the role of hunter–gatherers in deliberately shaping the structure of their environments. Whilst the resolution of these impacts are not sufficiently resolved to identify specific episodes of deliberate human intervention within woodlands, the lack of clear correlation between fire frequency and periods of climatic dryness suggests an anthropogenic rather than a natural origin for many 'disturbance phases'. In light of the fact that Mesolithic anthropogenic 'disturbance phases' in pollen diagrams in Scotland come from a range of environments and differed in duration, clearances were most probably created as a result of a number of contrasting human activities, together with other non-anthropogenic factors, which occurred at different temporal and spatial scales (Bell and Noble, 2012:82–3; Tipping, 1997b:156). It is likely that human and natural environmental causes of woodland clearance were interrelated, producing reciprocal relationships between anthropogenic and natural factors (Simmons, 1996:153–4; Bell and Noble, 2012:81).

7. Research question 3: did humans actively structure Scottish Mesolithic woodlands?

As previously discussed, some 'disturbance phases' in pollen diagrams may represent deliberate landscape-level niche construction practices to encourage wild game for hunting and/or to increase berry or nut production. The composition of the archaeobotanical assemblages from Mesolithic Scotland also provides some support for the existence of deliberate interventionist strategies. The detailed analysis of this archaeobotanical evidence has shown that humans were systematically exploiting woodlands for food and fuel. The wood species people selected for combustion were not simply a direct reflection of 'natural' forest compositions and are suggestive of a deliberate strategy to harvest and use the species with optimum burning properties. Likewise, the widespread occurrence of hazelnut shell on Mesolithic sites across Scotland, and the presence of considerable nutshell deposits on some sites, suggests that hazel was intensively exploited for food. These practices could reflect a degree of intentional niche construction, with the harvesting (and subsequent burning) of hazel greenwood a reflection of a deliberate promotional strategy to increase nut-yields, perhaps evidenced by the large nutshell deposits on some Mesolithic sites (cf. Warren et al., 2014:637). As part of such a strategy, particularly productive areas of hazel and oak woodland may have been regularly settled on an annual basis for intensive nut-gathering (Bishop et al., 2013) and branch harvesting for timber and fuel. The seasonal harvesting of branches at specialised hazelnut processing camps would have allowed the creation of substantial stores of ready-seasoned firewood for the following year, a strategy which would have produced optimum burning properties.

The systematic use of hazel and oak as a fuel in Mesolithic Scotland may also reflect the inadvertent coppicing of hazel and oak during greenwood collection for construction purposes, with old timbers subsequently used for fuel. Judging by the size of the stakeholes and post-holes (measuring up to c. 0.7 m) on Scottish Mesolithic sites, both narrow branches and medium-sized timbers were evidently used for construction, suggesting harvesting of at least some medium-sized timbers (Wickham-Jones, 2004; Gooder, 2007; Suddaby, 2007). Small trees with narrow diameter branches, such as hazel, and/or young hazel and oak trees in areas of regeneration may have been particularly targeted for fuel and small timbers. Such areas would have been an easily exploitable and renewable resource (Asouti and Austin, 2005:8) for hunter–gatherers without axes or tools capable of cutting down large trees: no stone axes have been recovered from in situ Mesolithic contexts in Scotland (Saville, 2004:189) and tree felling experiments have shown that antler mattocks require re-sharpening after 5 minutes (Jensen, 2001), suggesting they were not particularly well-suited to this task. Ring barking using small lithic tools, perhaps followed by the burning of specific trees, would have provided the most likely mechanism for felling small and medium-sized trees (Simmons, 1996:136).

Coppiced trees within and at the edge of natural and anthropogenically derived woodland clearance would also have provided naturally coppiced branches (Crone, 1987:334). If particular areas of woodland were settled and cleared regularly, it is possible that such a strategy would result in "adventitious coppicing" (Crone, 1987:328) – periodic branch harvesting of re-grown branches from trees previously felled/cut that was not part of a formal management system (Warren et al., 2014). Such a practice could reduce the pollen production of selected trees and produce a palynological signature indicative of an opening in the woodland canopy (cf. Simmons, 1996:147 on the effects of small-scale branch removal for fodder). Thus, human activities would clearly have impacted on the productivity of trees, such as hazel and oak, in Mesolithic woodlands and would have contributed to the frequency and maintenance of open areas within woodlands.

It is also possible that in some instances, Mesolithic people over-exploited woodland resources and had a detrimental environmental impact. For example, palynological evidence from Loch Cholla, Colonsay, suggests that the intensive exploitation of hazel nuts and wood evident at the Mesolithic site at Staosnaig (see Section 4) resulted in a substantial decline in birch-hazel woodlands on the island at c. 7044–6534 cal BC (Mithen, 2000:437). Given the lack of herbaceous species indicative of clearances, the apparent woodland decline may simply have been a statistical consequence of the increase in grasses, heather and sedge percentages as a result of the increased local growth of these species in the basin (Andrews et al., 1987:66; Edwards, 2000a:127). Whatever the case, it should not be assumed that all Mesolithic hunter–gatherer strategies had a neutral or positive environmental impact (Austin, 2000; Warren, 2005:69). Likewise, rather than enhancing environmental productivity, in some areas repeated fire-disturbance may have prevented woodland regeneration, leading to the spread of unproductive heath and bog (Simmons and Innes, 1985:13–14). Hunter–gatherer impacts may also have contributed to coastal instability and machair formation in the Western Isles of Scotland. Windblown sands began to accumulate around the coasts of this region as early as the 7th–5th millennium cal BC (Ritchie, 1979; Gilbertson et al., 1999; Edwards et al., 2005), and this may have been partially accelerated by the removal of woodlands by humans (Edwards et al., 2005). Therefore, whether or not Mesolithic hunter–gatherers purposefully constructed productive woodland niches to exploit particular plants and animals, they would nonetheless have impacted on woodlands and shaped eco-dynamics (cf. Warren et al., 2014:9). The identification of these potential impacts and practices supports the idea that there was not a fundamental distinction between hunter–gatherer and farmer environmental interactions and suggests that the structure of native woodlands in Scotland has always been influenced by anthropogenic activities.

8. Conclusions

Current evidence suggests that hunter–gatherers in Mesolithic Scotland were systematically exploiting specific woodland plants for food and fuel, and in the process they may have contributed to niche construction. The availability and abundance of different trees within the Mesolithic environment clearly influenced the importance of different woods within archaeobotanical assemblages. However, the relative rarity of several taxa (birch, elm and alder) which were abundant in the environment, suggests a degree of avoidance of particular taxa for fuels, in favour of species with specific burning properties, such as hazel and oak. Though taphonomic factors may have impacted on the representation to some extent, the absence of acorns in Mesolithic assemblages, suggests that acorns may have been deliberately avoided for consumption. In contrast, the widespread evidence for the collection of hazel wood and nuts suggests that hazel was a deliberately targeted resource. Whether as part of a deliberate niche construction strategy, or whether it was incidental to harvesting strategies, it is likely that the systematic exploitation of hazel for food and fuel and oak for fuel influenced the productivity of hazel and oak within Mesolithic environments and may have created areas of adventitious and/or deliberate coppice. The pollen evidence for woodland management is equivocal, but it hints at the role of hunter–gatherers in shaping the structure of their environments, through the maintenance or creation of woodland clearings for settlement or as part of vegetation management strategies.

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