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Richard J. Evans^a, Lorcán O'Toole^b & D. Philip Whitfield^c

^a RSPB Scotland, 2 Lochside View, Edinburgh Park, EH12 2DH, UK

^b Golden Eagle Trust Ltd., 22 Fitzwilliam Square, Dublin 2, Republic of Ireland

^c Natural Research, Brathens Business Park, Glassel, Banchory, Aberdeenshire, AB31 4BY, UK

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The history of eagles in Britain and Ireland: an ecological review of placename and documentary evidence from the last 1500 years

RICHARD J. EVANS^{1*}, LORCÁN O'TOOLE² and D. PHILIP WHITFIELD³

¹RSPB Scotland, 2 Lochside View, Edinburgh Park, EH12 2DH, UK, ²Golden Eagle Trust Ltd., 22 Fitzwilliam Square, Dublin 2, Republic of Ireland and ³Natural Research, Brathens Business Park, Glassel, Banchory, Aberdeenshire AB31 4BY, UK

Capsule The loss of eagles from large tracts of lowland and upland habitat in Britain and Ireland over the last 1500 years is attributed to human activity.

Aim To estimate changes in past distribution and population size of Britain and Ireland's two native eagle species.

Methods Placenames suggesting the past presence of eagles were categorized according to modern knowledge of the species' ecology. Together with documented historical locations, these sites were mapped to derive approximate former ranges. Population estimates were made for each species at about 500 and 1800 CE.

Results Estimated range at about 500 CE was 110 250 km² for White-tailed Eagles *Haliaeetus albicilla* and 98 500 km² for Golden Eagles *Aquila chrysaetos*, with 44 600 km² of overlap. Population sizes were 800–1400 pairs of White-tailed Eagles and 1000–1500 pairs of Golden Eagles, declining to 150 and 300–500 pairs, respectively, by 1800.

Conclusion Our results provide evidence for the presence within the last 1500 years of one or other species of eagle throughout much of Britain and Ireland. The influence of climate change on eagle habitat has been subsumed by the effects of habitat destruction and persecution as primary causes of absence from much of their former range.

INTRODUCTION

Britain and Ireland form part of the historical range of two species of eagles: Golden Eagles *Aquila chrysaetos* and White-tailed (Sea) Eagles *Haliaeetus albicilla*. The distribution of both has been greatly affected by human activity in the past (Ritchie 1920, Bijleveld 1974, Lovegrove 2007). Golden Eagles are known to be absent from many areas with documentary evidence for their breeding, because of past persecution (Baxter & Rintoul 1953, Holloway 1996); and their range continues to be constrained by illegal killing (Whitfield *et al.* 2004). The extinction of White-tailed Eagles from the British Isles is also attributed to human persecution (Love 1983). The species' subsequent reintroduction to Scotland has been well-documented (Love

1983, Bainbridge *et al.* 2003, Evans *et al.* 2009). Both species now breed in close proximity to each other in the west of Scotland (Evans *et al.* 2010).

Further reintroduction releases of White-tailed Eagles are formally proposed or underway in England, Ireland and the east of Scotland, and have been suggested for Wales (Dennis 2003). Releases of Golden Eagles are underway in Ireland and have been suggested for England, Wales and southern Scotland (O'Toole *et al.* 2002). In order to meet strict licensing requirements, any such projects would need to meet international criteria for species translocations (IUCN 1998). These stipulate that release sites must be within the species' historical range. If not, a translocation cannot, by definition, be a reintroduction. Thus, as full an understanding as possible of past distribution is an essential requirement of a properly planned species recovery programme.

*Correspondence author. Email: richard.evans@rspb.org.uk

IUCN guidelines also recommend monitoring the effect, if any, of reintroductions on the established native flora and fauna. Golden Eagles are dominant over White-tailed Eagles in Norway (Halley & Gjer-shaug 1998). Nevertheless, the possibility that White-tailed Eagles reintroduced to Scotland might outcompete resident Golden Eagles (Watson 1997, Halley 1998) has not been entirely ruled out, in spite of substantial evidence to the contrary (Whitfield *et al.* 2002, Love 2003, Evans *et al.* 2010). Arguments for possible future competition are predicated on assumptions that the past distribution of the two species was separate and that this resulted from competitive exclusion. Reviewing the information on the historical distribution of eagles may thus inform current and future conservation management for both species in Britain and Ireland.

Several methods are available to reconstruct a species' former distribution (Aybes & Yalden 1995, Boisseau & Yalden 1998, Cox *et al.* 2002, Holloway 1996, Love 1983, 2003). We used two data sources: (1) literature-based documentary evidence and (2) placename evidence. Both have their limitations but can be complementary. There is little parish-level or finer-scale documentary information on the breeding distribution of eagles in the British Isles before the end of the 18th century, when the *Statistical Accounts* were published for Scotland (Sinclair 1791–1799; Anon. 1834–1845). By this time, both species of eagles had been almost entirely lost from England and Wales (Lovegrove 2007), so the distributions subsequently compiled from detailed documentary evidence by Harvie-Brown and co-authors (1887, 1888, 1892, 1895, 1904) of the *Scottish Vertebrate Fauna* series and their Irish contemporaries Ussher & Warren (1900) (with later refinement by Baxter & Rintoul 1953, Love 1983 and D'Arcy 1998), should be regarded as absolute minima, greatly reduced and altered from an undocumented former 'natural' state, as a consequence of habitat destruction and persecution (Bijleveld 1974, Lovegrove 2007). This is particularly true for Golden Eagles, with the earlier authors explicitly stating that detailed nesting locations known to them had been disguised or omitted from their published accounts, in order to avoid drawing the attention of collectors. In spite of this, some accounts include sufficient detail to infer the relative spatial distribution of the two species for some localities.

Some wild animal species are sufficiently charismatic or iconic for their former presence to have been recorded in placenames (Ekwall 1960, Gelling & Cole 2000). Although a place may conceivably be named after a single occurrence of a notable creature, biological

historians consider placenames a valuable resource in reconstructing past landscapes (Rackham 1986). In particular, the work of Gelling (1984) and Gelling & Cole (2000) argues persuasively that placenames, at least in parts of Britain, tended to describe the landscape in terms of persistent and familiar features. A number of studies have used the distribution of animal placename components to indicate past species distributions in Britain (Aybes & Yalden 1995, Boisseau & Yalden 1998, Yalden 1999, 2002, Moore 2002, Yalden & Albar-ella 2009) and in North America (Cox *et al.* 2002, Cowell & Moss 2003). Placename evidence has previously been cited to demonstrate the former presence of White-tailed Eagles in many parts of Britain and Ireland (Watters 1853, Love 1983, Gelling 1987, Yalden 2007). However, British and Irish placename elements denoting 'eagle' do not differentiate between species (Yalden & Albarella 2009). This is not surprising, given the relative novelty of species as a concept and the difficulty in distinguishing between similar species without optical aids. However, Golden and White-tailed Eagles use different habitats for nesting and foraging, even when breeding in close proximity, both in Norway (Halley 1998), and in modern Scotland (Madders & Marquiss 2003, Evans *et al.* 2010). If current habitat preferences reflect enduring differences between the species, then categorizing 'eagle' placenames according to habitat might give a much longer historical perspective on the fine-scale distribution of each species in Britain and Ireland than is currently possible from analyses of documentary sources alone.

In this article we: (1) attempt to map the pre-medieval (about 500 CE) distribution of the two species, based on placenames (which we categorize to species in light of modern knowledge of the species' ecology); (2) review and map the species' 19th-century distribution, based on published documentary sources; (3) assess changes in population size for each species over time, including population estimates for each species based on our maps of pre-medieval distribution; (4) review the evidence for and against strongly separated distributions and competitive exclusion between the two species; and finally (5) consider the implications of our findings for the conservation of eagles in Britain and Ireland today.

MATERIALS AND METHODS

Placename evidence

We collated placenames with components ostensibly representing 'eagle', in languages used for placenames

in all parts of Britain and Ireland (Table 1 and see also Supplementary online information Table S1). Germanic placenames in Britain date only from the period of settlement by Angles, Saxons and other Germanic-speaking peoples in the 5th century CE onwards, and tended to replace earlier Celtic names in the areas concerned (Nicolaisen 1975, Gelling 1997). Consequently, Old English, Scots and Norse names of places in Britain and Ireland generally date from the period about 500–1000 CE; and natural and landscape features in names derived from these languages are likely to reflect the perception of the landscape by those people at that time (Gelling 1984, 1997, Gelling & Cole 2000). Topographical names in the Celtic languages are more difficult to date, but as these tend to be confined to the northern and western part of Britain and Ireland, falling within Rackham's (1986) zone of 'ancient landscape', where anthropogenic impacts on natural habitats are likely to have had much less effect on eagle habitat than in the lowland south and east, we have assumed that in these areas both placenames and later documentary evidence of eagles are reasonable indicators of their earlier presence about 500–1000 CE. Therefore, we adopt an approximate date of about 500 CE as a baseline for the earlier period of our study.

Our primary sources were Ordnance Survey gazetteers and wherever possible we validated definitions using a wide range of published placename studies and online material. For Scotland, we collated placenames from gazetteers of 1:25 000 Ordnance Survey maps (Hooker 1990–1993) held as a computerized database by the National Library of Scotland's map library, cross-checked against documentary sources, and online

material hosted by the Scottish Place-name Society (<http://www.spns.org.uk/index.htm>).

For England and Wales, our primary source material was the Ordnance Survey's 1:50 000 gazetteer of Great Britain (Ordnance Survey 2010), supplemented by online sources, in particular the Ordnance Survey website (<http://www.ordnancesurvey.co.uk>) and the Institute for Name Studies' Key to English Place-names (<http://www.nottingham.ac.uk/english/ins/kepn/>).

For Ireland, our main source material comprised the Placenames Database of Ireland (<http://www.logainm.ie>), the IreAtlas Townland database (<http://www.seanruad.com>) (based on Anon. 1861) and the Ordnance Survey gazetteer of Northern Ireland (Government of Northern Ireland 1969). We then applied the following crude filters to the placename collection.

1. 'Hybrid' names (possible eagle component from one language, but other components from another) were classified as 'not eagle'. This principally affected Gaelic-origin names incorporating 'arn', 'earn', or variants. In most cases, plausible, purely Gaelic definitions that did not involve eagles could be found.
2. Except in Ireland, names incorporating the modern English component 'eagle' were classified as 'not eagle', unless we could find positive evidence that the name had clearly derived from the presence of eagles. Rejected names fell into two categories: old settlement names such as Eaglesfield, the 'eagle' part of which is generally derived from *eglwys* (W), *eccles* (OE) meaning 'church'; or modern constructions such as Mouteagle (Highland). In Ireland, because of the complicated history of placenames in both Irish and English languages (Andrews 1975), we took definitions in the Placename Database of Ireland at face value and retained all names in Ireland with a possible 'eagle' component in our long list of sites possibly associated with the past presence of eagles.
3. Names with a 'human' component – for example, indicating 'settlement' – were classified as 'not eagle', unless there was positive evidence of an association with eagles (Mawer 1919).

Having eliminated names unlikely to be associated with the past presence of eagles, we then made a biological assessment of the remaining sites as to whether eagles could have been present in the past, and if so which species was more likely to have been involved.

White-tailed Eagles and Golden Eagles now breeding in the west of Scotland select nest sites with different

Table 1. 'Eagle' placename components used in this study, by language.

	Language	'Eagle'	Source
Celtic	Gaelic (S)	lolair; Fhírr-eoin	Watson 1904, Macdonald 1900, MacBain 1922
	Gaelic (I)	lolar (-iller, -ilra, -uller, -ulra)	Joyce 1901, Scharff 1915
	Manx	Urley	Moore 1890
	Welsh	Eryr	
Germanic	Cornish	Er	Yalden 2007
	Old English	Erne (arn, earn, yarn, yearn)	Ekwall 1960, Kitson 1997, 1998
	Scots	Earn (arn, earn, ern, yearn)	Watson 1904
	Norse	Ørn (arn; orn)	MacBain 1922
	English	Eagle	

characteristics. White-tailed Eagles tend to nest more often in trees, at lower altitudes and closer to water than Golden Eagles (Evans *et al.* 2010). That study recorded a strong influence of altitude on species' use of nesting habitat: the mean altitude of White-tailed Eagle nest sites was 67 ± 12 m above sea level, compared with 231 ± 18 m for Golden Eagle; all White-tailed Eagles nested below 150 m (the mid-point between the mean altitude for each species), compared with 28 % of Golden Eagles (18 % excluding the low-lying Outer Hebrides) (Evans *et al.* 2010, R.J. Evans unpubl. data). We adopted 150 m as a cut-off altitude to categorize placenames to eagle species. One of our objectives was to assess the likelihood of White-tailed Eagles having excluded Golden Eagles from coastal areas in the past, so risking mis-classifying Golden Eagle sites as White-tailed Eagle was a conservative assumption, because if in spite of this we still found a notable degree of overlap between the two species we could be more confident that this was unlikely to have been the result of overestimating the extent of Golden Eagle distribution. Because Golden Eagles tend to hunt higher ground than their nest sites (Watson 1997), we required sites to have high ground within 3 km (McGrady *et al.* 2002) before we classified them as 'Golden Eagle'.

As there was no reason to assume that placenames potentially indicating 'eagle' would be confined to coastal areas, and bearing in mind the likely large-scale loss of potential habitat (Rackham 1986), we needed to distinguish within our list of low-altitude names between those where habitat is likely to have been suitable, or not suitable, for White-tailed Eagles. For this, we assumed that White-tailed Eagles would have required wetland habitat for foraging within a reasonable distance of a breeding place (Love 1983, Halley 1998, Evans *et al.* 2010). We adopted 10 km as a conservative potential maximum foraging radius to provision nests (Madders & Marquiss 2003), and assumed a tendency for wetlands to have been lost over time (Rackham 1986). As no suitable GIS data were available to use as a surrogate for wetland habitat about 500 CE, we assessed each site individually by examining 1:50 000 Ordnance Survey maps within a 10-km radius of the named place, and searching for existing natural wetlands, or flat low-lying areas with drainage patterns suggestive of the past presence of wetlands, including fishponds.

We classified the remaining names to eagle species according to altitude and proximity to wetland habitat (or to land appearing from maps to have a high likelihood of at one time being wetland on the basis of

topography and the presence of heavily modified water-courses or drains):

1. **Golden Eagle:** sites more than 150 m asl (above sea level), with higher ground close by, not necessarily close to water or wetlands.
2. **White-tailed Eagle:** sites less than 200 m asl, within 10 km of water or potential wetland.
3. **Unknown:** sites between 150 and 200 m asl, with higher ground close by, and within 10 km of water or wetlands.
4. **Not eagle:** sites more than 10 km from water or wetlands, and/or with no higher ground close by.

Documentary sources

Our main documentary sources were the 19th-century natural history accounts. These tend to describe White-tailed Eagles in greater detail than Golden Eagles, particularly once the former species had been lost and while the latter was felt still to be at risk from persecution and collecting (Harvie-Brown & MacPherson 1904; Baxter & Rintoul 1953). Although precise identification of nest sites from the published accounts is difficult, especially for Golden Eagles, these accounts include useful information on the presence and former presence of both species of eagles. For Scotland, the *Vertebrate Fauna* series (Harvie-Brown and co-authors, 1887–1906) indicates the presence of eagles at an island or parish scale, and includes detailed comparative descriptions of nesting habitat, albeit from unspecified locations. The principal 19th-century sources for Ireland are Thompson (1849) and Ussher & Warren (1900). We collated information on both species from these and other published accounts (Baxter & Rintoul 1953, Colquhoun 1840, 1866, Dixon 1885, Evans 1911, Graham 1880, Gray 1869, 1871, Gordon 1915, 1955, MacGillivray 1836, 1840, Mackenzie 1921, MacPherson 1892, Macpherson & Duckworth 1886, Maxwell 1832, Maxwell 1897, 1919, McWilliam 1936, Newton 1864–1907, Paterson 1909, Payne-Gallwey 1882, Ralph 1996, Rintoul & Baxter 1935, St. John 1884, Scrope 1838) in order to derive comparable qualitative estimates of the distribution of both species, using the same source material. We included data redrawn from both Love (1983) and D'Arcy (1998); and following Love (1983), we plotted 19th-century breeding localities by 10 km national grid square.

We considered including archaeological records (Yalden 2007, Yalden & Albarella 2009), but chose not to, partly because relatively few localities were

added as a consequence and also because of the likelihood that eagle remains may have been transported to their final location by humans, either incidentally or deliberately (Grosman *et al.* 2008).

In order to derive approximate ranges of both species within Britain and Ireland about 500 CE, we combined both main data sets at a 10-km resolution on the British and Irish national grids, keeping the species distinction for each 10 km square. In a GIS (MapInfo v6.0) we buffered the centroid of each 10 km square by 15 km, partly to represent a maximum distance over which individual territorial eagles might range, and partly to compensate for likely gaps in our data set coverage of the actual past distribution of both species. From these layers we derived rough estimates at about 500 CE of: (1) area and extent of distribution; and (2) area and extent of range overlap between the species. We made similar estimates for the early 19th century by applying the same methods to the documentary records only. In order to estimate population size at those times, we measured the area occupied by 15-km buffers of the centroids of 10 km grid squares occupied by Golden Eagles and White-tailed Eagles in 2003 (the year of the last national survey) and 2008, respectively. For Golden Eagles, we calculated the density of (a) territorial pairs and (b) all known territories, to give density estimates for low and high rates of occupancy; we also calculated the density of pairs south of the Great Glen only, to account for the additional effects of persecution (Whitfield *et al.*, 2004). For White-tailed Eagles, we calculated densities for (a) core areas only, omitting territories > 10 km from their nearest neighbour, and (b) all territories. We then applied these high and low densities for each species to our area estimates of past range, to give population estimates for both species at about 500 CE and the early 19th century.

Finally, we attempted to describe changes in population size over time, by combining these speculative population estimates with others made for 5000 BP (Yalden & Albarella 2009; Endnote a) and for more recent dates from the 19th century to the present day, based on the literature (Love 1983, Nicolson 1957, Everett 1971, Brown 1976, Dennis *et al.* 1984, Green 1996, Eaton *et al.* 2007, Evans *et al.* 2009).

RESULTS

Placenames

Of 717 placenames apparently including 'eagle' components, we rejected 161 as unlikely to indicate a

Table 2. Placenames apparently including 'eagle' components classified by placename language and habitat suitability for eagle species.

Species/ Language	Golden	White- tailed	Unknown	Not eagle	Total
Gaelic (S)	142	64	12	58	276
Gaelic (I)	12	44	3	4	63
Manx				2	2
Welsh	12	4	2		18
Norse	5	39		11	55
Scots	35	20		11	66
Old English	26	77	2	47	152
English	27	32		26	84
Total	257	280	19	161	717

former presence of eagles (Table 2, and Supplementary online information Table S1). In a third of these cases, the potential eagle component 'arn' would have required a hybrid Scots/Gaelic construction and we were able to identify more plausible, single-language Gaelic meanings that did not involve eagles. Around a quarter of rejected placenames included the component 'eagle', in circumstances suggesting either: a modern construction unrelated to past presence of eagles; or on investigation had an historical meaning unconnected with eagles.

The remaining 556 placenames were distributed over much of Britain and Ireland (Fig. 1). We categorized 257 as Golden Eagle, 280 as White-tailed Eagle and 19 as uncertain (Table 2). See supplementary online information for details of eagle placename locations. This supplementary information also, includes the Grid References to locations, original languages and placename meanings.

Documentary sources

We identified 335 10-km national grid squares in Scotland and Ireland with 19th-century evidence of eagle breeding (Fig. 2). Slightly more than half were in Scotland and Golden Eagle squares were slightly more numerous than White-tailed Eagle squares. Thirty-two squares (just under 10 %) had evidence of both species breeding; and many more squares occupied by one species were adjacent to grid squares occupied by the other.

Using 19th-century natural history accounts, we identified 14 areas of western and northern Scotland for which it was possible to derive qualitative descriptions of the presence of eagles (Table 3). Most were islands, but four mainland areas were also included. Twelve areas held both species of eagles. Only the

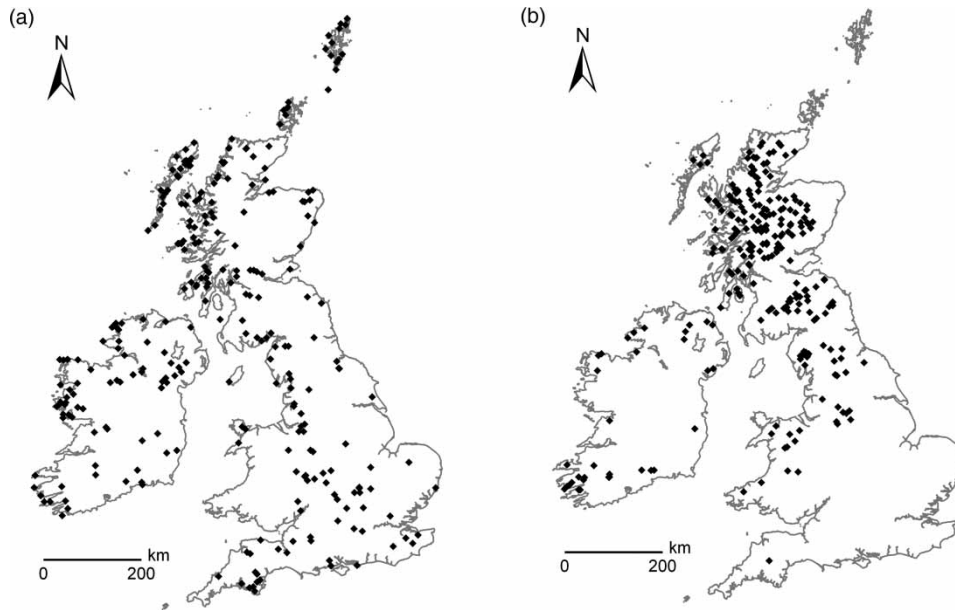


Figure 1. Geographical locations of 'Eagle' placenames interpreted as indicating the presence of (a) White-tailed Eagles and (b) Golden Eagles.

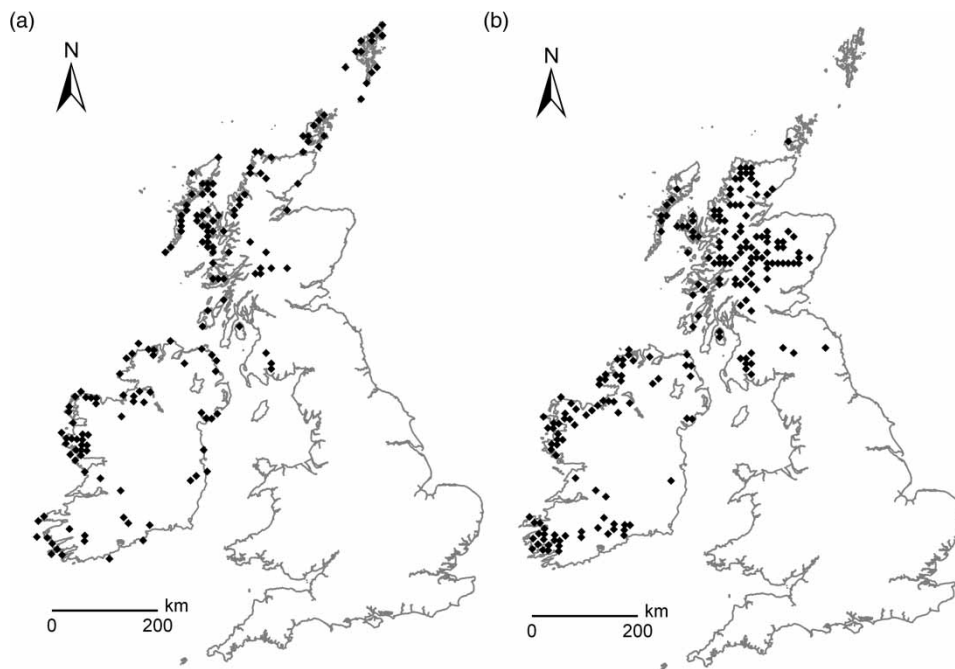


Figure 2. Geographical locations of 19th-century breeding records of (a) White-tailed and (b) Golden Eagles, by 10 km grid square.

small (< 35 km²) islands of Canna and Eigg had no record of Golden Eagles.

On Harris, Harvie-Brown & Buckley (1888) recorded White-tailed and Golden Eagles breeding within 1.6 km of each other. On Skye, Harvie-Brown & MacPherson

(1904) list at least eight Golden Eagle sites, including some within 2 km of the coast; and 17 White-tailed Eagle sites, stating that 'there were no Sea Eagles among the Cuillins [mountains] proper'. Further east, in the Moray and Tay catchments, Harvie-Brown & Buckley

Table 3. Status of White-tailed and Golden Eagles in parts of Scotland in the 19th and early 20th centuries.

Area	White-tailed Eagle	Golden Eagle	Source
Galloway	Bred until 1860s	Bred until 1870s; recolonized C20th	Maxwell (1897, 1919)
Arran	Bred regularly until 1849	Bred until 1850	Harvie-Brown & Buckley (1892)
Jura	Breeding until at least late-C18th	Bred until 1887; extinct; recolonized by mid-C20th	Harvie-Brown & Buckley (1892), Baxter & Rintoul (1953)
Islay	Bred until mid-C19th	Present C18th; nesting early C20th	Harvie-Brown & Buckley (1892), Baxter & Rintoul (1953)
Mull	Pretty numerous early C19th; scarce by 1867	Many deserted sites, south and west Mull 1860s; breeding 1914–1918; three nests 1938	Graham (1880), Harvie-Brown & Buckley (1892), Baxter & Rintoul (1953)
Rum	Bred until early C20th	Bred until 1886; Recolonized by mid-C20th	Harvie-Brown & Buckley (1892), Baxter & Rintoul 1953
Eigg	Three pairs 1833; last bred 1877		Harvie-Brown & Buckley (1892)
Canna	Bred until 1875		Harvie-Brown & Buckley (1892)
Skye	Many more killed than Golden Eagle; relatively abundant on the coast, but absent from the Cuillin hills	Many fewer killed than White-tailed Eagle; coastal and mountain nest sites known; regular nester and still present mid-C20th	Harvie-Brown & MacPherson (1904)
Lewis, Harris	Commoner than Golden Eagle early C19th. Breeding within 1.6 km of Golden	'By no means rare' early C19th. Breeding within 1.6 km of White-tailed Eagle late C19th	Harvie-Brown & Buckley 1888, Harvie-Brown (1903), Ralph (1996)

(Continued)

Table 3. Continued

Area	White-tailed Eagle	Golden Eagle	Source
	Eagle late C19th		
North Uist	Breeding late C19th	Breeding late C19th	Harvie-Brown & Buckley (1888), Harvie-Brown (1903)
Gairloch, Wester Ross	Breeding mid-C19th	Commoner than White-tailed Eagle, mid-C19th	Dixon (1885), Harvie-Brown & MacPherson (1904), MacKenzie (1921)
Rannoch Moor	Breeding (tree nest on island in loch) mid-C19th	Breeding close to but higher than White-tailed Eagle mid-C19th	Colquhoun (1840)
Caithness	Commoner than Golden Eagle mid-C19th	Less common than White-tailed Eagle mid-C19th	Harvie-Brown & Buckley (1887)
Sutherland	Coastal and inland sites used C19th	Breeding, but no detailed site information	St. John (1884), Newton (1864–1907)
Orkney	Bred in several locations until early/mid-C19th	Bred on Hoy until early/mid-C19th	Buckley & Harvie-Brown (1891)

(1895) and Harvie-Brown (1906) list many Golden Eagle localities, but few for White-tailed Eagle (Fig. 2).

Combined data

Our tentative reconstruction of the extent of range for each species in Britain and Ireland at about 500 CE was 110 000 km² for White-tailed Eagles and 98 600 km² for Golden Eagles, with an overlap of 44 900 km² (Fig. 3a). Thus, just over a quarter of all potential eagle range was shared. Based on current densities of both species in Scotland (at a similar landscape scale of 15 km), we estimated the population size of each species at about 500 CE to be 800–1400 and 1000–1500 pairs for Golden and White-tailed Eagles, respectively (Table 4). By the early 19th century, both range (Fig. 3b) and numbers of both species had declined greatly, to around 150 pairs of White-tailed Eagles (Love 1983) and 300–550 pairs of Golden Eagles

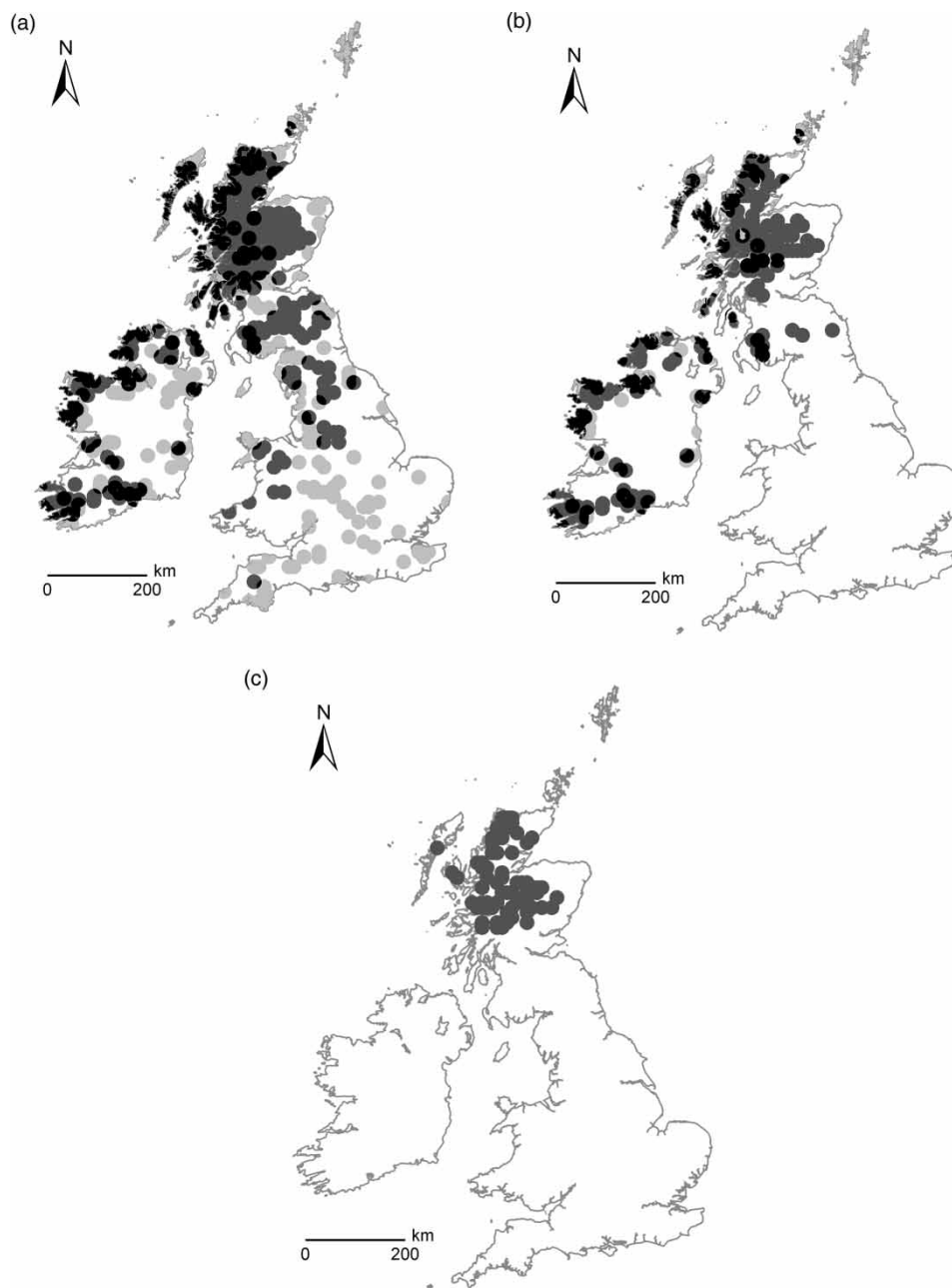


Figure 3. Reconstructed historical ranges at approximately (a) 500, (b) 1800 and (c) 1920 CE of Golden Eagles (dark grey), and White-tailed Eagles (pale grey). Potential overlap ('shared airspace') is shown in black.

(assuming that the documented 19th-century range held higher densities of birds before the persecution campaign of the early 19th century took hold: Table 4). By the middle of the 19th century there were unlikely to have been more than 50 pairs of White-tailed Eagles in Britain and Ireland (Love 1983). Based on the distribution of deer forests (Orr 1982) (which seem to have acted as a refuge for Golden Eagles; Love 1983), it

seems likely that numbers of this species may also have been halved to around 150–250 pairs by the same time. The final decline of White-tailed Eagles during the second half of the 19th century is well described by Love (1983); while precise changes in Golden Eagle numbers over the same period are impossible to calculate, because of deliberate and well-intentioned obfuscation in the published record. However, if we assume that

Table 4. Breeding population estimates (pairs) and estimated mean annual rates of population change (in brackets) since the preceding date for Golden and White-tailed Eagles in Britain and Ireland; 5000 BP to the present.

Date	Golden Eagle	White-tailed Eagle	Source
5000 BP	650	2550	Yalden & Albarella (2009)*
c. 500	1000–1500 (0.02%)	800–1400 (–0.025%)	This study
c. 1800	300–500 (–0.09%)	150 (–0.15%)	This study
c. 1850	200–250 (–1.1%)	50 (–2.15%)	Love (1983); D’Arcy (1998)
1920	100–200 (–0.6%)	0 (–7.0%)	Love (1983); this study
1950	280 (2.1%)	0	Nicolson (1957)
1971	400 (1.8%)	0	Everett (1971); Brown (1976)
1982	420 (0.5%)	0	Dennis <i>et al.</i> (1984)
2003	440 (0.25%)	31 (7.2%)	Eaton <i>et al.</i> (2003)

Note: * see Endnote a).

the steady increase in the extent of deer forest into the first decade of the 20th century (Orr, 1982) offset the effects of continued persecution in coastal areas (where Golden Eagles were probably killed out along with White-tailed Eagles), then the population in Scotland probably did not decline much below its mid-19th century level. If 50 pairs had remained in Ireland at that time (which seems optimistic), then numbers for Britain and Ireland combined may have dropped no lower than 150–200 pairs, a sufficiently large reservoir (Fig. 3c) to allow slow recovery during the 20th century (Table 4), partly in response to reduced levels of persecution during the two world wars, but more significantly to altered patterns of land-use resulting from wider social and economic change.

DISCUSSION

Attempts to reconstruct historical ranges of species inevitably involve much speculation. Although placename evidence has been used previously in this way for pre-medieval Britain and Ireland, we are not aware of previous studies that have applied modern ecological knowledge to distinguish between two species represented by a shared, generic placename component. Studies of this type have many possible sources of error, which we discuss below. Although our results are inevitably an oversimplification of a complex historical reality, at a landscape scale we feel that the general patterns make biological sense, and consequently are a sound interpretation of the available data, with implications for the conservation of eagles today.

Placename evidence

Authoritative scholarly studies on the derivation of individual placenames were available only patchily across

Britain and Ireland. The English Place Name Society’s *Survey of English Place Names* now runs to 80 volumes, but many areas still lack coverage. In Northern Ireland, the *Northern Ireland Place-Name Project* (organized by the Institute of Celtic Studies at Queen’s University Belfast) provides detailed coverage only for some areas. Similarly, in-depth and spatially detailed studies are not available for other parts of Britain and Ireland. Consequently, we cannot validate our assumption that a placename identified as representing eagles by detailed research in one area will do so elsewhere; it is possible that some names included in our study may not directly reflect the past presence of eagles. In particular, some Earn/Arn elements may represent proper names (or nicknames) of people. Placename scholars of 100 years ago frequently favoured such an explanation on the grounds that the place in question was ‘an unlikely place for eagles’ (Duignan 1902, and see also Mutschmann 1913, Sedgfield 1915, MacBain 1922, Rackham 1986). Given that by the early 20th century eagles had been exterminated from all but the wildest and most remote areas of Britain and Ireland, such an interpretation is understandable, although biologically and historically flawed. During the much earlier period when many places are likely to have been named, eagles of both species would have been more numerous and much more widespread, and thus familiar components of landscapes described by placenames not only in the Celtic languages, but also in Old English (Gelling & Cole 2000), Scots and Norse (Nicolaiesen 1975). We disagree with Rackham (1986) and earlier authors and favour Gelling’s (1987) interpretation of ‘earn + natural component’ names as indicating the former presence of eagles. Our general categorization of placenames with a human component as ‘not eagle’ follows Mawer (1919) and Yalden (2007), and in our view is likely to have correctly identified most localities named after a person, rather than for the presence of eagles.

There seems little doubt that the eagles contributing to Gaelic placenames in Scotland were real, as many of these localities remain occupied by Golden Eagles today. Because of the basic similarity in approach to naming landscape features in other Celtic languages, we extend the same assumption to 'eryr' placenames in Wales. However, in Ireland, interpretation of placenames is greatly complicated by deliberate policy of Anglicization during the 19th century and earlier (Andrews 1975), as well as subsequent reinforcement of the Irish language in the 20th century. Although this renders the derivation of names less certain, the basic pattern in Ireland is consistent with that for Britain, with 'eagle' places apparently widespread in both low and higher altitude areas.

The quality of placename data available to us varied between parts of Britain and Ireland. The availability for Scotland of a gazetteer based on 1:25 000 maps increased the number of names found compared with the 1:50 000 scale gazetteer of Great Britain; the spatial resolution for Ireland (where our search was based largely on lists of 'townlands' of unspecified size) is difficult to quantify, but is likely to be even coarser than for England and Wales. Thus, Fig. 1 shows a minimum distribution of eagle names, particularly outside Scotland, and should not be overinterpreted to derive comparative densities between different areas. This inconsistency in the placename data set is compensated for to an extent by the 15-km buffer used in our range mapping (Fig. 3). However, if variable quality of the gazetteers means that placenames have been overlooked further than this distance from the next-nearest name, these maps too will underrepresent past eagle range.

The apparent absence of eagle placenames from some areas of lowland Britain (notably the Fens and much of the catchment of the river Humber, both in eastern England) that must at one time have provided suitable habitat for White-tailed Eagles is surprising. This might be because human influence on these areas before the Anglo-Saxon era had been so great (Rackham 1986, Simmons 2001) that eagles once present were already largely absent; or possibly because the Anglo-Saxon occupiers of these particular parts of England may have been less culturally predisposed to name places after wild animals than elsewhere. Certainly, eagle placenames seem to be absent from lowland parts of Britain that also lack pre-1066 placenames indicating the presence of woodland (Simmons 2001), and other animals including beaver, an aquatic mammal of wetland habitats also suitable for White-tailed Eagles (Yalden 1999).

As in Britain, many of the coastal and mountain 'eagle' names in Ireland coincide with the documented 19th-century distribution of both species. It seems highly likely therefore that at least some lowland 'eagle' places in Ireland were associated with the earlier presence of White-tailed Eagles. At any rate, given the survival into the 19th century of White-tailed Eagles on the rugged coast of Ireland, it seems inconceivable to us that the species did not also at one time occupy many of the lowland wetlands that were formerly widespread in Ireland (Aalen *et al.* 1997).

Nineteenth-century distribution

Our maps of 19th-century evidence of eagle breeding show species' ranges broadly similar in size, with significant overlap in coastal areas with high physical relief, in both Ireland and Scotland (Fig. 2). The principal difference between the countries is a relative absence of White-tailed Eagles from more inland parts of highland Scotland, identified by Love (1983) as the deer-forest range to which Golden Eagles became confined due to the effects of persecution elsewhere. Golden Eagles seem to have been protected on at least some Scottish deer forests (Harvie-Brown & Buckley 1895; Love 1983), possibly because of a perception that their presence improved the quality of deer-stalking by keeping grouse numbers in check, making it less likely that deer would be startled by grouse accidentally flushed during the stalk (Booth 1881–7).

It would seem that closer to the coast, where persecution is thought to have been particularly motivated by a desire to remove potential predators of sheep, both species of eagle were eventually eradicated (Harvie-Brown & MacPherson 1904, Ritchie 1920). Ireland lacks inland mountain areas as remote and extensive as Scotland; red deer are also largely absent (Mitchell-Jones *et al.* 1999) and private deer forests of the 19th-century Scottish type did not develop in Ireland. Consequently, there was no remote, benignly managed, higher-altitude refuge for Golden Eagles in Ireland – and both species of eagle suffered the effects of persecution equally. This process is likely to have been mirrored on the west coast of Scotland and in its immediate hinterland, leading in all of these areas to the extinction of both species.

The consequence seems to have been a reservoir of Golden Eagles subsequently able to repopulate the coastal zone of western Scotland during the 20th century (Love 1983). However, in our view this process was one of recolonization of former range, as opposed to occupation of habitat left vacant by White-tailed

Eagles. Exceptions to such a pattern may be the relatively small islands of Eigg and Canna, where Golden Eagles have bred since the mid-20th century, but where the historical record indicates a 19th-century presence of White-tailed Eagles only. Elsewhere in coastal Scotland and Ireland in the 19th century, the pattern appears to have been one of coexistence of the two species, at least at a landscape scale, and at least in areas with low-lying wetland or coastal habitat in close proximity to open hill ground, where habitat was available for both species.

This contrasts with some interpretations of Love's (1983) maps of 19th-century eagle distribution inferring that the two species originally occupied exclusive ranges in Scotland (Watson 1997), due to competitive exclusion (Halley 1998). However, rigorous comparison of Love's (1983) distributions of the two species is not possible because: (1) the types of data being compared are dissimilar and potentially subject to different bias (Love's maps include all White-tailed Eagle records; but only clutches of Golden Eagle eggs in museum collections); and (2) many Golden Eagle clutches were not taken until White-tailed Eagles were almost extinct – a time when the cumulative effect of persecution of eagles in Scotland can reasonably be assumed to have been at its greatest and so the distribution of Golden Eagles least 'natural'. Inferences of competitive exclusion are not justified (Love 2003). Reconstructions of the range of both species are inevitably incomplete and represent known minimum distributions, with little indication of density and thus likely to underestimate the capacity for the two species to coexist in close proximity.

Both species bred in the Lake District of northwest England until the latter part of the 18th century, thus falling just outside the timeframe of this part of the study (MacPherson & Duckworth 1886, MacPherson 1892). There is some confusion as to the association of species with individual sites, but the higher altitude sites are more characteristic of Golden Eagles than White-tailed Eagles. As most Lake District breeding locations also have 'eagle' names, this is reflected in our placename maps, and tallies reasonably well with the 19th-century accounts, as opposed to some subsequent descriptions, which indicate the presence of White-tailed Eagles in some unlikely locations, considerable distances from wetland habitats (Ratcliffe 2002).

Implications for eagle conservation today

Perhaps the most striking feature of our placename maps is the sheer number of localities in the uplands of southern Scotland and northern England that according

to our altitudinal classification seem highly likely to have been occupied within the last 1500 years by Golden Eagles (and not White-tailed Eagles). The broad limits of our conjectured historical Golden Eagle range are largely consistent with the archaeological record (Yalden & Albarella 2009) and with historical accounts of Golden Eagles breeding as far south as Derbyshire (Holloway 1996). However, the density of localities is surprising, particularly because of estimates of the relatively small estimated size of the Golden Eagle population at 5000 BP (Yalden & Albarella 2009). Even allowing for additional Golden Eagles breeding at low densities in forests (Endnote a), this still implies more than a doubling of population size in the millennia up to 500 CE. This seems most likely a response to increases in the extent of open upland habitat (Tallis 1991, Tipping 1994, 2008) available to Golden Eagles during the millennia between the Atlantic climate optimum (when woodland cover and White-tailed Eagle numbers seem likely to have been at their maximum; Yalden & Albarella 2009) and the Anglo-Saxon era, before when we assume that no places were named for 'earns'. If this is the case, then it is possible that this increase represented population recovery, as recent genetic studies indicate an effective population size (albeit with wide confidence intervals) for British and Irish Golden Eagles larger than our estimate of actual population size for about 500 CE, and a likely large population decline prior to the last glaciation (Bourke *et al.* 2010). Taken together, this may suggest significant long-term fluctuations in population size prior to 500 CE, in response primarily to climate change, including recovery in spite of loss of genetic diversity.

Although climate fluctuations over the last 1500 years have affected the extent of some habitat types in the uplands of Britain and Ireland (Simmons 2001), the principal mechanism seems to have been anthropogenic in the form of agricultural intensification or abandonment, according to the nature of climate effect on the viability of productive farming on the upland margins. Therefore, the influence of climate change effects on the extent of eagle habitat over the last 1500 years has probably been small compared with that of human factors over the same period. This is in contrast to the likely influence of the widespread deterioration of climatic conditions at the end of the Atlantic period, which may well have benefited Golden Eagles in Britain and Ireland by reducing the extent of closed-canopy woodland and thus increasing the extent of Golden Eagle foraging habitat. More recent climate

fluctuations may have influenced habitat quality, along with the abundance of some prey species. However, given the wide variety of prey species exploited by the two eagle species over the whole of their respective ranges (Cramp & Simmons 1980, Love 1983, Watson 1997), climate-influenced changes in the local abundance of particular species of eagle prey seem likely to have had much less influence on eagle numbers than anthropogenic habitat change and persecution. Although we have no means of assessing the effect of natural changes in habitat quality on eagle densities over this period, the modern low- and high-density values used to derive our historical population estimates seem to us reasonably likely to encompass natural variations in eagle density (and consequently our estimates of population size) since 500 CE.

In contrast to Golden Eagles, our use of placenames may underrepresent the post-glacial maximum distribution of White-tailed Eagles, as a consequence of restricting our evidence base to the last 1500 years. Climate change impacts on woodland between 5000 BP and 500 CE will probably have had moderate effect on the carrying capacity for White-tailed Eagles of the landscape of lowland Britain, compared with the conversion to agriculture of natural wetland and woodland habitats during the same period (Rackham 1986, Simmons 2001). 'Eagle' placenames are absent from areas of lowland England that also lack pre-Conquest names indicating woodland (Simmons 2001), presumably as a consequence of wide-ranging and large-scale woodland clearance prior to the settlement there of Germanic-speaking people. Large gaps in our reconstructed range of White-tailed Eagles at about 500 CE can therefore be attributed with some confidence to the effects of anthropogenic habitat loss (Bijleveld 1974, Rackham 1986, Simmons 2001) and persecution (Ritchie 1920, Lovegrove 2007).

At a landscape scale, our results suggest significant overlap between the broad historical ranges of the two eagle species, whether assessed by placenames, documentary evidence, or both. These findings contradict suggestions that the 19th-century ranges of the two species resulted from competitive exclusion of Golden Eagles by White-tailed Eagles, based on analyses at a similar spatial resolution to ours (Watson 1997, Halley 1998), not least because we found documentary evidence to show Golden Eagle distribution in the 19th century covering a wider area than that indicated by museum egg collections alone (Love 1983). In our view, it is likely that within areas of broad range overlap at a landscape scale, the two species may nevertheless have occupied different niches, tending to exploit habitats with

different characteristics for foraging and nesting (Evans *et al.* 2010). Therefore, we conclude that the likelihood of significant adverse effects of reintroduced White-tailed Eagles on resident Golden Eagles in Scotland may be less than suggested by some earlier studies (Watson 1997, Halley 1998), as in our view the historical record does not present good evidence of past competitive exclusion.

For Golden Eagles, our placename map may represent the maximum potential distribution of the species within Britain and Ireland. The principal obstacles to reoccupation, apart from the natural limits of juvenile and natal dispersal, are likely to be persecution and loss of some open upland habitat to blanket afforestation (Whitfield *et al.* 2006), notably in areas such as Dumfries & Galloway (Marquiss *et al.* 1985).

By contrast, our White-tailed Eagle placename map represents a greater extent of more fundamentally altered habitat: the extent of woodland and wetland available to White-tailed Eagles in contemporary lowland Britain and Ireland will have been massively reduced since Anglo-Saxon and Viking times (Rackham 1986, Simmons 2001). However, White-tailed Eagles successfully occupy intensively farmed landscapes in parts of Europe including Denmark and northern Germany, provided there are some trees for nesting and enough wetland habitat to support adequate prey (Gensbøl 2003, Sulawa *et al.* 2010). Nesting and foraging habitats in these landscapes tend to be found in widely dispersed patches, and may themselves be anthropogenic in origin (woodland plantations and fishponds, respectively). Thus, in terms of the future for White-tailed Eagles, our placename map may perhaps most accurately represent not the extent of potential habitat, but rather the distribution of landscapes within which potential habitat might still be found.

In view of the extent of lost range of both species, arguably neither can be considered to be in favourable conservation status. However, the population trajectory of White-tailed Eagle following reintroduction is strongly upwards (Evans *et al.* 2009), whereas population recovery for Golden Eagle during the middle decades of the 20th century would now appear to have stalled (Eaton *et al.* 2007; Table 4), in spite of the recent extension of range in Ireland, as a result of continuing reintroduction releases (O'Toole *et al.* 2002).

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ENDNOTE

a. Yalden & Albarella's (2009) British population estimate of just over 400 pairs of Golden Eagles in the Mesolithic (about 5000 BP) assumes that the species was found only in areas with no woodland cover (Bennett 1998). However, in eastern North America Golden Eagles live in forested landscapes at low density, occupying territories up to 500 km² in size, foraging in widely spaced patches of more open habitat (Brown & Amadon 1968). Therefore, we assumed this to have been the case during the Mesolithic for those parts of our about 500 CE range indicated by Bennett (1988) as forested about 5000 BP. In Britain, we estimate that there may have been an additional 140 pairs of Golden Eagles occupying 70 000 km² of forested habitat. In Ireland, Bennett (1988) indicates roughly 1750 km² of treeless habitat at 5000 BP, which would potentially have supported around 35 pairs of Golden Eagle. We estimate that another 65 pairs could have occupied 32 500 km² of hilly land in Ireland likely to have been wooded at 5000 BP. Thus, we estimate that Britain and Ireland together may have supported around 650 pairs of Golden Eagles at the time of maximum post-glacial woodland cover (Table 4).

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