Is the population of ancient trees at Burnham Beeches sustainable?

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Summary

Burnham Beeches is designated as a nature reserve of European importance because of the ancient pollarded trees and their associated saproxylic species. Historical and recent surveys of the numbers of pollards have been used to calculate mortality rates and produce maps to indicate changes in live tree density over time. While the rate of loss has declined in recent years, likely due to intensive work on the trees, it is evident that fragmentation of the population is occurring as well as an overall decline in numbers. The consequences of this are discussed and some suggestions made for how to mitigate for the tree loss. The area of Burnham Beeches supporting the ancient pollards is relatively small. It would be beneficial to improve the management of adjacent areas in different ownership in order to buffer the nature reserve and provide suitable habitat for saproxylic species in the long term, given that saproxylic beetles in particular are, according to Cálix *et al.* (2018), the most threatened species group in Europe.

Introduction

Burnham Beeches is located in south Buckinghamshire, and is unusual for the county in being on acidic gravel soils of the Thames terraces. It is a wooded common and it is believed that it was historically used intensively by the local people who obtained firewood from it and grazed their livestock on it. In 1880 it passed to the City of London under the City of London (Open Spaces) Act principally for the recreation of the people of London, although there was also a requirement in the Act to 'maintain the natural aspect'. At this time, the area was known to be important for its botanical interest, and inventory work since the 1990s has revealed its importance for saproxylic species associated with the old pollarded trees (Alexander 2020). These interestingly-shaped trees were a key factor in the purchase of Burnham Beeches in 1880 and the main reason that it was popular with Victorian visitors with many of the trees acquiring names at this time (Read 2011).

Increasing awareness of the nature conservation value of Burnham Beeches raised its status from Site of Special Scientific Interest, SSSI (1951), to National Nature Reserve, NNR (1993) and Special Area of Conservation, SAC (2005). While the SSSI and SAC include a larger area of land in multiple ownership, the main biological value lies in the wooded common with the ancient pollarded trees set within historical wood pasture. This covers the majority of the area in City of London ownership and the area which is the subject of the present study; see Figure 1. Over the centuries, decline in past management practices such as pollarding and grazing, has resulted in ancient trees that are very top-heavy and drawn up tall to reach the light, surrounded by dense thickets of holly and secondary woodland which developed as grazing ceased.

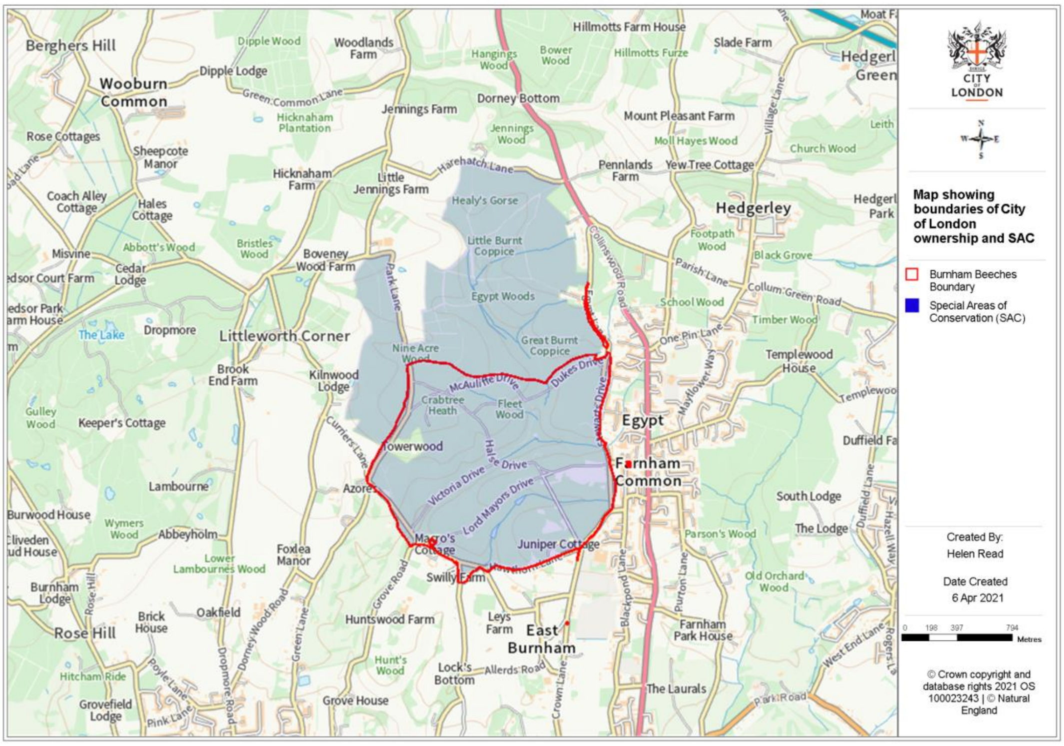

Figure 1. Map showing boundaries of City of London ownership and Special Area of Conservation (SAC)

In the last 30 years intensive management work has been undertaken to attempt to keep as many of the old trees alive for as long as possible and to restore grazing by cattle, ponies, pigs, and for a short time sheep, to around 95% of the area. Today the majority of the pollards have sufficient light, but ongoing crown reduction work delivered via a series of 10-year management plans is still being carried out to prevent them from falling apart (Read *et al*. 2010).

Across the UK there are very few areas with large numbers of beech *Fagus sylvatica* pollards; beech being a relatively unusual species to cut as a pollard. Epping Forest, also owned by the City of London, has the most and there are small numbers in the Chilterns, Kent and Norfolk. Other wood pasture areas that are important for their beech trees, although not pollards, include the New Forest and Savernake Forest. In Europe the biggest concentration of beech pollards is in the Basque mountains of southern France and Northern Spain which, although it has many similarities with those in the UK, has a slightly different suite of associated saproxylic species, including the spectacular alpine longhorn beetle *Rosalia alpina*. Several much more extensive sites in northern Spain are also designated as SACs (Read 2008).

The wooded common of Burnham Beeches sits within what Rackham (2003) has termed ‘ancient countryside’, areas of commons, small fields and woodlots, where many of the old boundaries on the tithe maps of 18th and 19th centuries are still visible. Today this forms part of the South Bucks Heaths and Parkland Biodiversity Opportunity area (https://bucksmknep.co.uk/biodiversity-opportunity-areas/). Roughly 50% of the SSSI and SAC is not historically common land, but mostly in the ownership of a private estate, managed largely for forestry and pheasant shooting. This was formerly a mix of small furze fields and coppice woodland. Pollarded beech trees only occur in the City of London part of the SAC, making them special in a local context as well as internationally and thus understanding their population dynamics is of high importance.

Methods

Historical information, gathered by a previous Superintendent of Burnham Beeches, (Le Sueur 1931) describes aspects of the pollards within Burnham Beeches, including estimates of tree numbers. In 1989/90 the pollards were all tagged with individual numbers, their locations plotted on paper maps, data sheets completed for each tree and photographs taken. The survey was repeated in 2000 when the first detailed work programme was drawn up. In 2006 an evaluation of the responses of the beech trees to cutting was carried out (see Read *et al.* 2010) and following this in 2007 the trees were surveyed in detail using the Specialist Survey Method (http://www.treeworks.co.uk/downloads/SSM_HandBook.pdf). More recently in 2015 and 2018 rapid surveys were done largely for the purposes of reviewing the work programme, the latter to fulfil the specific requirements of a Countryside Stewardship grant application.

The trees included in all the surveys carried out since 1989 are only those that can be identified as ancient pollards. In Burnham Beeches these are beech or oak, both *Querus robur* and *Quercus petraea*. Generally, it is relatively straight forward to distinguish these trees from their shape and size, however some are slightly more ambiguous. As our understanding of these trees grows some relatively small fragments, all that remains of once larger trees, have been spotted and included. In the earlier surveys many of the trees were hidden in dense holly or Rhododendron and, as the scrub has been cleared, more trees have been 'discovered'. In addition, whilst trees have died, a few previously considered to be dead have been found in later surveys to be alive, and others have stems arising from the base of the trunk and so are technically still alive. These latter few individuals have been included, even if their value for saproxylic species may be lower. Trees have also fallen over and continued to grow. Hence the total number of pollards has decreased over the years but with some flux. Thus, precise numbers for each year are not as easy to confirm as might be expected.

Restoration work on the trees has gathered pace over the past 30 years. Between 1990 and 2000 a range of experimental work was carried out. Some 199 trees were haloed, i.e. surrounding younger trees and scrub competing for light and water were removed in a series of phases to prevent shocks to the tree through a sudden change in environment. Around 166 trees were subjected to some pruning work which initially tended to remove quite large amounts of the canopy. In 2007 a review of the impacts of the pruning was carried out and, as a consequence an individual plan for each tree was drawn up. Since 2007 a more comprehensive work programme has been carried out and trees cut at relatively frequent intervals with generally smaller amounts of canopy removed each time. A small number have not been worked on, either because it would be too difficult/dangerous, or because work was not considered to be required. The time periods between surveys can be characterised as in Table 1.

Table 1. Time periods for work carried out on old pollards since 1990

1990-2000	Experimental work. Fewer than half the trees receiving any treatment, more trees worked on as the time progressed. = Minimal amount of work.
2000-2007	Formal work programme implemented. = Transition period between relatively little work and an active work programme.
2007-2018	Almost all trees have received some work. Many trees cut more than once.

Trees are now mapped on a Geographical Information System using remote satellite location equipment and their data stored on linked spreadsheets. Photographs are taken at the time of each survey and before and after any work is carried out on or around the tree. The detailed work programme includes further haloing through the clearance of shade from around the trees (with clearings gradually increasing in size as the trees are reduced in height) and crown reduction work to reduce the weight of the branches on increasingly fragile, decayed stems. More interventionist work has become increasingly frequent such as cable bracing, tethering, propping, mulching and moving paths (Lonsdale 2013).

Using the figures of trees alive at the time of each survey it is possible to calculate mortality rates using the method outlined in Lonsdale (2013). Calculations were made for different species and periods of time representing phases with different methods of tree management.

Using the distribution of the pollards across Burnham Beeches, changes in connectivity/density over time were calculated using ESRI ArcMAP 10.4.1 Spatial analyst kernel density tool. Kernel density analysis calculates the average density for "core areas" between points with known data i.e. pollards in this case. Kernel density thus provides an indication of the effect of fragmentation (greater fragmentation = lower kernel density value) and thus highlights connectivity or lack of connectivity based on a specific distance. In this case, the distance used was 250 m between each old pollard. The analyses were done using the population of trees known to be alive in 1990 (to avoid false increases due to new trees being discovered since then), 2007 and 2018.

For 2007 and 2018 two analyses were carried out, one based on actual mortality rates and the other based on the mortality rate between 1990 and 2000 assuming that no management had been carried out to provide a comparison. Figures for the population in 2028 have been extrapolated with expected dead trees removed randomly from the tree population. Again, two analyses were made, one assuming ongoing management and the other assuming no management. This allowed a comparison of the population density over time with and without management. These maps give an indication of the value of the area for associated organisms that require populations of trees to support a viable population i.e. the potential change in ecological functionality of the wooded common by showing the density of live veteran pollards per hectare, which are not more than 250 m from one another. The search parameters were 125 m search radius i.e. 250 m between trees as the maximum distance that an organism might travel between trees.

Getting accurate figures for how far saproxylic species are able to disperse is quite difficult; most relate to larger beetles that are relatively easy to study. Dispersal distances for hermit beetles *Osmoderma eremita* in Sweden were found to be between 30-190 m with only an estimated 15% of the population moving between trees at all (Ranius & Hedin 2001). In Italy the maximum distance recorded for a single beetle of the same species was 1,504 m with 39% of the population reported to disperse more than 250 m (Maurizini *et al.* 2017) but the weather conditions in the study area were very different to Sweden (and the UK). Noble chafer *Gnorimus nobilis* was reported to fly a maximum of 700 m (Whitehead 2003 cited in Bunney 2012) in Worcestershire. Stag beetles *Lucanus cervus* in Italy were found to cover distances of up to nearly 300 m in a single flight and around 1 km over the entire period they were tracked but females covered significantly shorter distances (Tini *et al*. 2017).

In the UK female stag beetles showed much poorer dispersal and generally did not fly at all but only crawled, a situation backed up by studies in Switzerland (Hawes 2008). In Germany Rink & Sinsch (2007) radio tracked the same species and found males flew frequently and the maximum total displacement distance was 2065 m. In contrast females generally made a single flight and then crawled on the ground, the total displacement distance being up to 763 m. They pointed out that colonisation of new sites depends on the total dispersal distance of the females, which amounts to less than 1 km.

G. nobilis and *L. cervus* have both been recorded in Burnham Beeches in recent years. For many studies it seems that the majority of individuals do not travel very far at all, and only the occasional individual will go a bit further. For the smaller species information is not available, but Alexander (2004) comments that species living in habitats such as decaying wood are under little or no selective pressure to cross large expanses of habitat so they could be expected to have low mobility. It is thus tricky to define the distances required for dispersal and for the purposes of this study 250 m was used as a reasonable measure that may apply for a larger number of species.

Data for a very contrasting taxonomic group is equally, or perhaps more, uncertain. The old beech trees at Burnham Beeches are host to a good population of Forster’s knot-hole moss *Zygodon foresteri* which here, rarely seems to be found on trees other than the pollards. The dispersal range of this species has not been studied but it has very small spores which have the potential to be dispersed several kilometres by wind (although it is not known how much this actually happens). The protonema of this species produces gemmae which are potentially also dispersed but over much shorter distances (Des Callaghan written communication March 2020).

These studies suggest that some organisms dependent on wood decay and old trees might be able to disperse over longer distances than 250 m if the habitat is continuous. However, since the data for the very many much smaller species is unknown, we have taken a precautionary approach. Note also that some saproxylic invertebrates are unable to fly and therefore will only be able to colonise new trees by walking.

Modelling of tree populations by Kirby (2015) was based on 1, 2 and 4 trees (more than 400 years old) per hectare which he based on information from Rose (1993) and Hedin *et al*. (2008). This equated to 100 m, 71 m and 50 m between trees, rather closer than used in the current analysis, suggesting that the distances used by the authors are not conservative.

Results

Numbers of pollards

Despite the intensive and expensive management intervention carried out on the trees, the number of live ancient pollards continues to decrease. Table 2 shows the numbers of live trees recorded in the various surveys. Numbers may not be completely accurate for the reasons outlined in the methods above but they do give an indication of the decline.

Table 2. Changes in the number of pollarded trees in Burnham Beeches over time

Date	Number of trees recorded alive	Live beech pollards	Live oak pollards
17th century	Maximum 3000 (estimate)		
1887	2095		
1931	1795 (beech only)		
1956	1300		
1990	540	462	78
2000	463	383	80*
2007	426	348	78
2018	377	299	78

*The increase is due to two pollards being ‘discovered’ between 1990 and 2000. Two different oaks subsequently died prior to 2007.

Although the beech pollards are perhaps the most important and unusual feature of the nature reserve there are ancient oaks too. Most earlier estimates do not separate the two but since 1990 that has been possible (Table 2).

The proportion of oak pollards was 15% in 1990 but by 2018 this had increased to 20% as disproportionately more beech trees had died. The remnants of dead old oak trees indicate that there were more oaks in the past than the total recorded in 1990 but it seems likely that the beech are now declining faster, therefore the proportion of oak has probably been lower in the past but will continue to rise.

Density of pollards

The distribution of the ancient pollards across the City of London area of Burnham Beeches is not even (Figures 2 and 3). To the south the numbers of trees dwindles so that there is a substantial area of former heathland and valley mire with no ancient pollarded trees and no evidence that there were ever pollards here, although there is no clear feature marking this change to be seen on the ground. Within the northern area, two 17th century wood banks enclose areas that must have been removed from the common, probably in order to cut beech or oak as coppice. It is not known if these areas contained pollards prior to their enclosure but it is possible that they did.

By taking the approximate area of the land on which these trees occur (170 ha) it is possible to calculate a density for both species, based on the 2018 figures, which results in a figure of 1.7 trees per hectare for beech and 0.46 for oak. There are many more trees than this at Burnham Beeches, but these figures are for the old pollards only. The density of trees in British wood pastures is extremely variable, ranging between that more typical of woodland and open, park-like locations where the trees are widely spaced. The overall tree density within most of Burnham Beeches is probably comparatively high.

Mortality rates

Mortality rates for the decline of trees over the last 30 years, during which active restoration work has been carried out are shown in Table 3. The figures are based on the known 1990 population to avoid the uncertainty regarding how many other trees might have been alive in 1990, were missed in the survey and have subsequently died.

Table 3. Mortality rates for beech and oak pollards over the last 30 years.

Time span	No. of beech pollards alive (of 1990 population)	Mortality rate (% per annum)	No. of oak pollards alive (of 1990 population)	Mortality rate (% per annum)
1990-2018 (whole period)	461-281		77-68	
1990-2000	461-375	2.04*	79-76	0.39*
2000-2007	375-327	1.94*	76-70	1.17*
2007-2018	327-281	1.37	70-68	0.26

*These figures are slightly different to those reported in previous internal reports. The differences relate to the different numbers of trees found at the time of each survey and hence used in the calculations.

Note that the mortality rate for beech only between 1930s (Le Sueur 1931) and 1990 is 2.24%. The population of ancient oak pollards at Burnham Beeches is rather small, which makes the mortality rates more variable. Hence with a small population of trees it is more difficult to draw conclusions from the data.

Kernel density analysis

The maps in figures 2 to 4 show the changes in the density of beech pollards over time together with actual numbers of live trees. Figure 5 shows the density of live trees assuming no management had been carried out prior to that time i.e. based on a mortality rate of more than 2% per annum. This last map was produced assuming that an additional 20 trees would have died, thus 20 trees were randomly removed from the 2018 dataset).

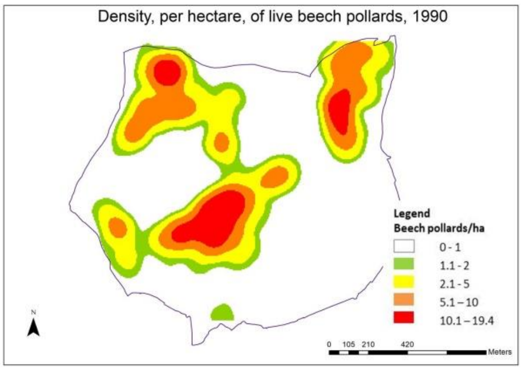

Figure 2. Beech trees alive in 1990

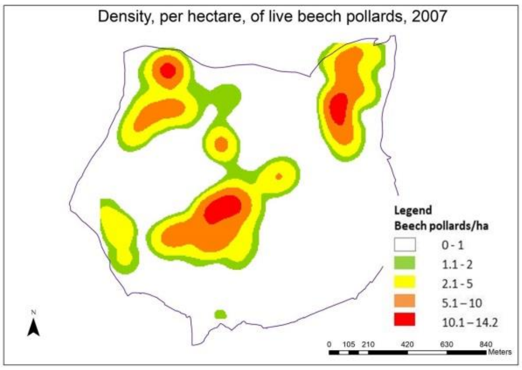

Figure 3. Beech trees alive in 2007

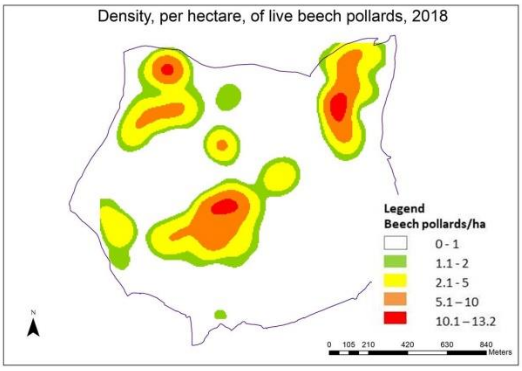

Figure 4. Beech trees alive in 2018

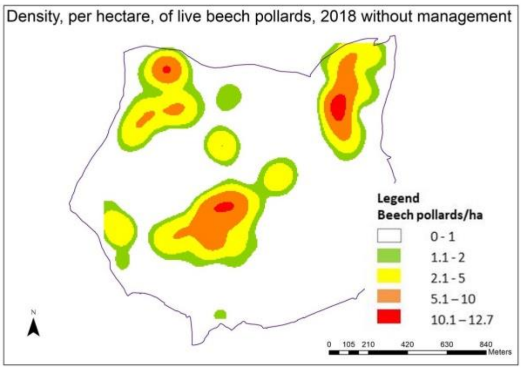

Figure 5. Beech trees predicted to have been alive in 2018 if no management had taken place

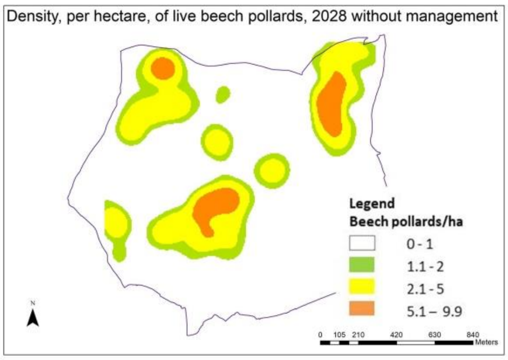

Figure 6. Kernel analysis showing the projected distribution of old pollards in 2028 assuming no management of the trees

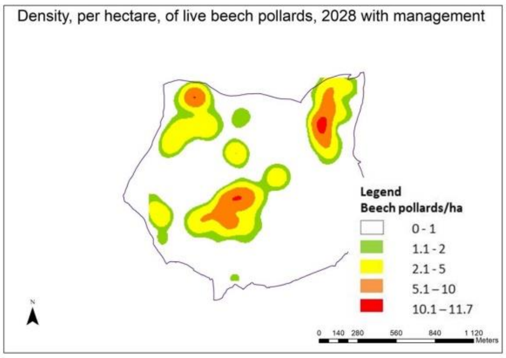

Figure 7. Kernel analysis showing the projected distribution of old pollards in 2028 assuming that management of the trees continues

Figures 6 and 7 show projections for 10 years into the future and contrast the situation assuming no further management of the trees with that of continued management. Over time the core areas with the highest tree density become gradually smaller and more widely spaced apart so that they are more fragmented. While trees are lost and the population becomes more fragmented in both scenarios, the situation is worse without further management. These maps could provide indications of where new pollards should be created to help “join up” the patches (see discussion below).

Discussion

Mortality rates and impact of active management

The mortality rate of beech trees in the absence of any management work on the trees seems to be around 2.24%, based on that between 1930s and 1990. It appears that the active management being carried out since 2007 has reduced the mortality rate for the beech trees by approximately 28% to around 1.4%. This apparently small reduction in mortality rate has quite a large impact on the number of trees that survive.

For the oak trees the results are less easy to interpret and this may be a reflection of the smaller number of trees in total. The increase in mortality rate between 2000 and 2007 might be the consequence of over enthusiastic halo clearance. During the 1990s and early 2000s it was discovered in several places (including Burnham Beeches) that sudden clearance of surrounding vegetation quickly killed oak trees. Anecdotally it appeared at Burnham Beeches that the adverse effects are more pronounced on oak than beech. The results are also perhaps more difficult to interpret because a higher proportion of oak pollards have had just halo clearance with no, or minimal, reduction pruning.

In comparison, the mortality rate for trees categorised as ancient or veteran, and mostly pollards (but not beech), at Leigh Woods near Bristol between 2004 and 2016/7 with minimal management was found to be 1.21% (V. Stanfield written communication July 2018) and for oak at Ashtead Common the mortality was approximately 1.3% (Bengtsson *et al.* 2018). Few figures are available for beech trees, but in Denny Wood (New Forest) the mortality rate between 1964 and 1999 was 3.3% (Mountford 2001) and at Moccas Park it was calculated as 5.9% (Harding & Wall 2000). However, neither of these places have ancient beech pollards so the calculations are presumably for maiden trees without active management.

Tree population size and density in relation to associated species

Although some saproxylic species can survive on both oak and beech trees we can assume that at least some species are obligate to specific tree species. Therefore it is important to ensure that there is sufficient suitable habitat for those specialists that require decay features specific to a single tree species. It has been noted that even on a site where there are 100 apparently suitable hollow oaks, beetle species such as *Osmoderma eremita* may only be found in 20 of them (Bergman 2003; Bergman 2006). Clearly there are specific micro-habitat features that species require which we are currently unable to predict.

Larsson & Svensson (2011) studied *Elater ferrugineus*, a beetle predator of *O. eremita*, and found that the population density of this species over a 7-year period was much more variable than that of its prey. They concluded that this may make it more vulnerable to local extinctions and therefore a large assemblage of suitable hollow trees is essential for ensuring the long-term persistence of this species. This work gives an indication of the variability between different saproxylic species, even within the same taxonomic group.

Ranius (2002) noted that the larger the stand of hollow trees with suitable habitat for these rare species the greater the number of species able to persist and for a longer time. Bergman (2006) calculated that a minimum of 160 hollow oaks in an area of at least 56 ha, is required to sustain populations of sensitive saproxylic invertebrates (in this case O. *eremita*). Whilst this work was for Sweden it seems highly likely that the situation would be similar in the UK. Currently in Burnham Beeches we have just 78 old oak pollards.

Bergman (2006) also looked at the density of hollow oaks required to allow for a suitable age structure (tree recruitment) as well as associated habitats like sunny glades. His estimate was 2.8 hollow trees per hectare. The density of pollard oak trees in Burnham Beeches is 0.46 and thus much lower than advocated by Bergman. The categories of trees however, do differ between the two studies. In Sweden the survey included oaks with hollows of over 10cm in diameter. In Burnham Beeches we have not surveyed all trees looking specifically for hollows, only the old pollards.

Further work by Bergman (2012) concluded that 250 hollow oaks were needed in an area of 1600 ha to ensure a rich saproxylic oak fauna. This is far in excess of what we currently have at Burnham Beeches for oak trees.

For beech trees there are no equivalent studies, either regarding total population or density. The figures obtained for the Burnham Beeches were a total population of 299 and density of 1.7 per ha. Assuming that the desirable figures might be similar to oak trees, this suggests that the absolute number may still support a good population of saproxylic species but that the density is a bit low.

The figures used by Kirby (2015) based on information that he was able to gather about dispersal rates for various species were 1, 2 and 4 trees per hectare which also suggests that the figures for Burnham Beeches are a little low.

Kernel density analysis

The kernel density analysis shows in a very visual way how the connectivity (and potentially the ecological functionality) between the various areas with pollards declines as trees are gradually lost. This will have an impact on the organisms associated with the trees as they have progressively fewer opportunities to disperse. The population gradually fragments, and the resulting sub populations become more isolated. Ranius (2002) described more sophisticated computer simulations which showed that for *O. eremita*, the decline in the population could be very slow, thus taking centuries from the fragmentation to result in eventual extinction. The kernel analysis maps show this process in action in terms of habitat for Burnham Beeches. Although we have no detailed information about how specific species associated with the old trees have changed over time it is likely that the tree distribution can act as a crude surrogate.

These maps can also potentially be used to focus attention on where new pollards might be cut from maiden, naturally regenerated trees (in Burnham Beeches there is no lack of beech regeneration) to help provide saproxylic habitat for the future. They can also highlight where it is important to ensure that trees that are not pollards, but which might have suitable characteristics, should be retained and valued.

There are other trees (both oak and beech) within Burnham Beeches that have not been included in the figures here which have hollows, water pools etc. although there is a generation gap between the pollards and the next oldest trees (probably in the region of 150-200 years of age). In the wider area these additional trees tend to occur in the following places:

- Oak and beech coppice and smaller maiden trees – within the SAC, both adjacent to the old pollards and nearby including parts of the nature reserve outside City of London ownership.
- Outside the SAC. Boundary bank trees (those probably previously managed as hedges) and coppice occur in the local area although there are very few (if any) pollards. Further afield there are trees in hedges and remnants of old hedges around pasture or arable but they are more likely to be oak than beech.

The Ancient Tree Inventory (accessed 6 April 2021) shows relatively few hedgerow ancient or veteran trees in the surrounding area. There are a good number of veteran trees recorded in the National Trust Cliveden Estate some 3 km to the west but in between is mostly arable, improved pasture and golf course.

Impact of restoration work on the old pollards

Evaluation of the responses of the trees to management through a comparison of the mortality rates prior to and after the implementation of restoration pruning indicates that the work carried out on them is justified and appears to be having an effect, although the time periods (in the life of these long-lived organisms) is very short. The kernel density analysis also shows the impact that the loss of just 20 trees (i.e. those that could be predicted to have died if no restoration work had been carried out) has on the distribution and hence indicates the consequences for associated species. Clearly it is not possible to know exactly which trees would have died and therefore Figure 5 is only indicative of the situation.

Thinking to the future, the need for management is clearly present, it can be projected that this may save in the order of 40 trees by 2028. The importance of this is evident as the future projections show the areas of veteran trees becoming smaller and more fragmented, threatening populations of saproxylic species which may increasingly become unviable. By undertaking management more time is bought in terms of 'new' or replacement habitat. High intervention comes at a cost in both staff time and money and it is increasingly necessary to find grants and other means to support this work. Forty trees does not sound many but in a population that is so vulnerable even this small number is worthwhile saving, when we have no idea which trees are crucial for species' populations survival.

Looking to the future

Active conservation work may be slowing the loss of the old beech trees but it will not be possible to save all of them and the overall population size will continue to decline. There will be a critical point when the number of old trees has declined below that which can provide sufficient good quality habitat for some of the important saproxylic species. Thus we are likely to be in an extinction debt situation (Hanski 2000) where the populations of some of the rare species continue to linger, sometimes for decades, because there is some habitat left for them but this is not sufficient to provide a viable population for the long term (Johansson *et al.* 2013). This critical point has probably already been reached regarding the old oak pollards within Burnham Beeches. There is also an age gap in the recruitment of the oak trees (Bengtsson & Muir 2013) on the reserve, such that there is not only concern over the numbers of old oak trees but also the next generation that will replace them.

Providing saproxylic habitat into the future is essential if the role of Burnham Beeches in providing habitat for some of Europe's rarest invertebrate communities (Cálix *et al.* 2018), can continue. Within the City of London landownership this is largely being addressed through the creation of new, young pollards. This is possible because natural regeneration has been generally very good and there is no lack of young beech trees, unlike the situation for oak (Bengtsson & Muir 2013). Over 1,200 new pollards have now been created with a variety of tree species represented. Some new pollards started approximately 30 years ago are now starting to show substantial decay and hollowing but it will be many years before there are sufficient of these to provide suitable habitat and in the right locations to help the rarer saproxylic species. In the meantime, other measures will be needed, such as veteranisation i.e. the creation of decaying wood habitats through the active damaging of younger trees that would otherwise be removed (Bengtsson *et al.* 2015). The installation of saproxylic boxes could also be considered (Carlsson *et al.* 2016). The clearance of secondary woodland on the former heathland area, leaving some oaks (in particular) to grow on as open grown trees, should help. One further advantage from the creation of a new population of pollards is that it is generating a landscape with pollard trees showing how Burnham Beeches may have looked in the past.

Conclusions

In the 1930s there were nearly 2000 beech pollards within Burnham Beeches and distribution of these was such that new habitat would have been relatively easy to locate by poorly dispersing saproxylic species. In addition, the surrounding countryside would have contained further trees with suitable habitat, albeit potentially more widely dispersed.

Today the situation is very different. The population of the most valuable trees for the saproxylic species is declining rapidly, despite best efforts to keep individual trees alive as long as possible. Stopping tree loss altogether is not possible. The situation is potentially already critical for oak trees. For beech the numbers are still probably at a level that can support good populations of associated species but in the next 20 to 50 years this will change. Suitable trees will become increasingly further apart and the wood decay habitat increasingly fragmented. Mitigating work is already being carried out with the creation of many young pollards, however the associated habitats cannot be created with such relative ease and speed; changes in bark morphology only come with increasing tree age for example and these young pollards are just not large enough to develop extensive quantities of decaying wood. In addition, there are many other changes locally, such as the increasing urbanisation to the south and east of the nature reserve, which limit the potential for finding good quality habitat in adjacent areas.

The problems of providing sufficient quality and quantity of saproxylic habitat cannot be solved solely within the boundary of the SAC that is in City of London ownership and appropriate management of the northern part of the SAC could be a partial solution. There are no pollards but there are some mature trees, although some have been felled for timber in recent years. Farmland to the west could also potentially play an important role through increased protection and management of existing trees, for example through agri-environment schemes to encourage open grown and/or pollard trees on land close to the existing populations of saproxylic species. This will require a co-ordinated, landscape scale approach working with a variety of land-owners and needs to be explored soon in order to effectively mitigate the impact of loss of pollards. In the medium term, interventionist approaches to temporarily provide wood decay habitat such as the installation of saproxylic boxes or veteranisation as described above, may be needed (Bengtsson *et al*. 2015; Carlsson *et al*. 2016) and these could be used together with a more landscape scale approach to gradually increase the availability of suitable habitat beyond the existing boundary of the SAC to provide both more habitat for saproxylic species and a more effective buffer for the nature reserve.

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