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The impact of ash dieback on veteran trees in southwestern Sweden

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Abstract

Ash dieback (*Hymenoscyphus fraxineus*) is a fungal disease which affects ash throughout Sweden. Monitoring to study of the impact of ash dieback on veteran trees was undertaken in southwest Sweden in 2009, 2011, 2013, 2015, and 2020. The study found that 94.5% of the ash trees observed were affected by ash dieback disease in 2020 compared with 62% in 2009. 70 of the studied ash trees have died (21%) since the monitoring began. In 2009 there was no relationship between girth and ash dieback, but in 2020 the correlation between girth and the impact of ash dieback was statistically significant. In 2020, also for the first time during monitoring, the ash trees in the shade were significantly more affected by ash dieback, compared with trees standing in the open. This difference was not detected in 2013 or 2015. The effect of ash dieback on pollarded trees has varied between the years studied, but in 2020 there is no longer any significant difference between the pollarded and the non-pollarded ash trees. There was however a significant difference in the mortality rates between the groups of trees, with ash trees pollarded in more recent times having the highest mortality. Therefore, the recommendation in relation to veteran trees with ash dieback is that all pruning on veteran ash trees should be avoided. Pollarding should only be done on ash pollards that are in a regular cutting cycle and are not showing any symptoms of ash dieback. If possible, clear around old ash trees if they are in shaded conditions. Given that there are relatively few studies on the impact of ash dieback on veteran ash trees, the results of this study should also be relevant outside of Sweden and for the management of ash trees in non-woodland situations.

Keywords: Ash dieback, pollards, veteran trees, *Hymenoscyphus fraxineus,* ash

Introduction

Ash dieback is a wind-borne fungal disease caused by *Hymenoscyphus fraxineus* which affects ash (*Fraxinus excelsior*) throughout Sweden and was first recorded in 2001 (Barklund 2005). More detailed background information on the impact of *H. fraxineus* in Sweden can be found in Cleary et al. (2017). According to a national study of random plots in Götaland, which was carried out by SLU in 2009 and 2010, some 25% of all ash trees larger than 10 cm in diameter were heavily affected or dead (Wulff and Hansson 2011). In Sweden, a great deal of money is invested in pollarding ash trees (Rural Development Programme) and in restoring old, lapsed pollards because of their biological and cultural importance in the landscape. Pollarding is a technique whereby branches are pruned on a regular basis at a specific point for a product, usually fodder or firewood. When pollards become lapsed (not pollarded for more than 30–40 years), they can become top heavy and break apart, thus efforts are being made to avoid such losses through careful pruning (Lonsdale 2013). Historically in Sweden, ash was an important tree in grazed landscapes (agro-forestry) such as wooded meadows and wood pastures in southern Sweden. Ash was a favoured tree to pollard on a three to five-year rotation for winter fodder (Slotte 1999). Some studies have suggested that the restoration of old pollarded ash trees is riskier when ash dieback is present, because epicormic shoots may be more easily infected (Eklund 2009) and others have seen positive results following pruning affected branches (Stenlid 2013, Marciulyniene et al. 2017). There are, however, relatively few studies regarding the impact of ash dieback in relation to pollarding and veteran ash trees.

In addition, veteran ash trees are important cultural history elements in the Swedish landscape and bearers of a wide range of biodiversity. Ash was put on the Swedish Red List in 2010 ranked as VU (Gärdenfors 2010) and then raised to EN in 2015, where it remained in 2020 (Artdatabanken 2015, Artdatabanken 2020). It is recognised that 483 species use ash in Sweden; 11% of which are obligate to ash and another 23% are strongly associated with ash (Sundberg et al. 2019, Hultberg et al. 2020). These include the Red Listed species *Agrilus convexicollis* (saproxylic beetle), *Pyrenula nitidella* (lichen), *Perenniporia fraxinea* (wood decay fungus) and *Euphydryas maturna* (butterfly). Hultberg et al. (2020) show that 115 species are at high risk of extinction in Sweden because of ash dieback, where lichen species represent 40% of this group. Prognoses from research from Roberge et al. (2011) have shown that the moss *Neckera pennata* is likely to reduce significantly because of ash dieback. There is also a risk that the tree species that will replace ash, when they die, will not have the same bark characteristics as ash. This will lead to a further reduction in the habitat for species associated with trees with a high bark pH (Jönsson and Thor 2012). Even if some ash trees appear to have a greater level of resistance to ash dieback, the disease remains a great threat to the ash population in Sweden. This is not only because it can kill trees itself, but also because landowners have expressed that they fell ash trees due to a lack of information, perceived safety risk or because they believe that they then reduce the risk of spread of the disease as was the advice in relation to, e.g., Dutch Elm Disease (personal communication between a number of landowners and the research team).

There is still relatively little scientific evidence relating to ash dieback and pollarding, or indeed the impact of ash dieback on veteran ash trees in general. Due to the lack of data, relating to pollards and veteran ash trees, a monitoring programme was established in 2009 by the County Administrative Board of Västra Götaland (Bengtsson and Stenström 2009). Västra Götaland contains a fifth of the ash trees in Sweden (Skogsdata 2012) and therefore it is a useful study area. The aims of the monitoring were to obtain an overview of how ash dieback was affecting the veteran ash trees in the County of Västra Götaland and to be able to follow the development of the disease over the coming years. The degree of openness has been shown by Drenkhen et al. (2017) and Grosdidier et al. (2020) to have an impact on the severity of the disease. Given that many of the veteran ash trees in Sweden have grown up in open, grazed landscapes, it seemed relevant to collect information relating to these factors and analyse their potential impact. This paper describes the results from 2020 and compares with the results of previous years (Bengtsson and Stenström 2017).

Methods

In 2009, around half of the County of Västra Götaland had been surveyed to record veteran trees and the national database contained information on more than 25,000 trees, of which 17% were ash. A random sample of 330 of these trees (just over 7.5% of the total ash trees), both pollards and maidens (trees that have never been pollarded), was examined in the summer of 2009 and re-visited during the summer seasons of 2011, 2013, 2015 and 2020, which was when funding was available (Figure 1), (Bengtsson and Stenström 2009, Bengtsson et al. 2012, Bengtsson et al. 2013, Bengtsson 2014, Bengtsson and Stenström 2014, Bengtsson 2016, Bengtsson and Stenström 2017).

Among the group of trees that were recorded as pollards (226 of the 330), there was an even spread between those which had been recently pollarded (within the last ten years in 2009) and lapsed pollards (more than thirty years since they were last pollarded in 2009). The recently pollarded groups of trees were cut on a relatively regular basis, although the exact dates of cutting were not available. The lapsed pollards have not been cut throughout the period of the study. The ash trees were located with the help of a GPS and map. The trees were assessed from the ground with the help of binoculars, using field symptoms of ash dieback such

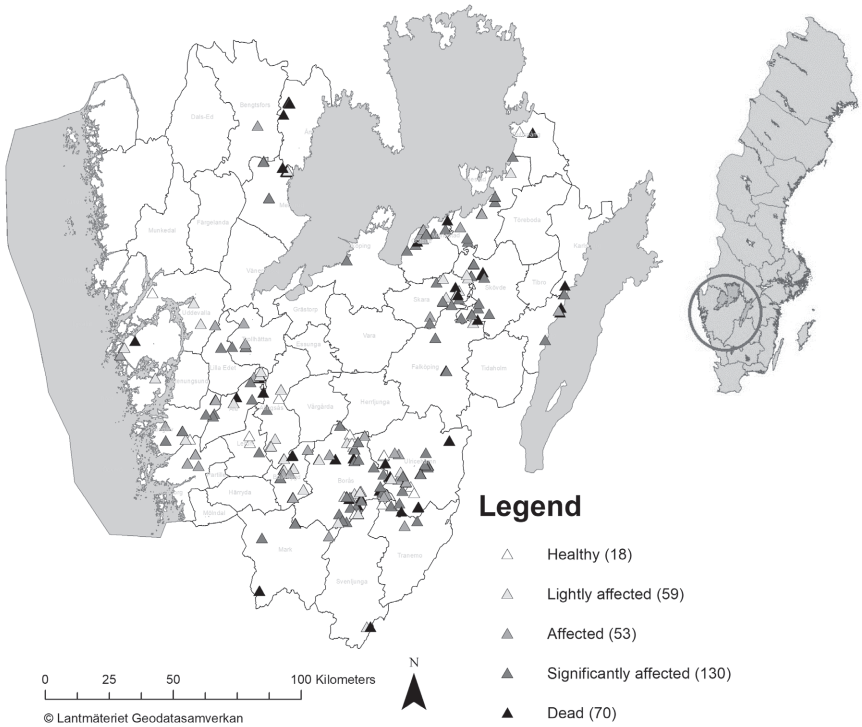

Figure 1. Map showing the location of the ash trees that have been monitored and the location of the County of Västra Götaland in Sweden (inset). The number in brackets refers to the number of trees within the respective category

as red/brown shoots and necroses as indicators. No laboratory analyses were carried out. Health assessed in the field, i.e., level of damage in the crown, has been shown by McKinney et al. (2011) to strongly correlate with the abundance of necroses and has thus been judged as a reliable method to assess the impact of *H. fraxineus* on ash trees. In this method the crowns of the trees were scored according to a five-point scale:

0 – completely healthy;
1 – lightly affected (c. < 10% of the crown affected);
2 – affected (c. 10–30% of the crown affected);
3 – significantly affected (c. > 30% of the crown affected);
4 – dead.

The degree of openness in which the trees were growing was also recorded (open – no other trees shading, semi-open – part of the tree shaded by other trees, shaded – tree shaded on all sides) and whether the site was grazed or not.

The differences in condition between the years were analysed using chi-squared tests. Relationships between girth and ash dieback score were assessed using Spearman's correlation tests. The impact of pollarding was analysed using ANOVA.

Mortality between the years was analysed using Friedman's matched group test for ranked data (matching data for each date by type of pollarding, i.e. comparing mortality by date). Mortality between the different groups of trees was analysed using Friedman's matched group test for ranked data (matching by year, i.e. comparing different pollarding types). The statistical analyses were carried out using SPSS Statistics 26™ (IBM 2019) and StatView V.5.0.1 (SAS 1998) software packages.

Results

More veteran ash trees have been infected in 2020 compared with all previous years (comparing infection score across the years: $X^2_{0.05;16} = 244.9$, $P < 0.001$). There were more significantly affected (130) and dead trees (70) in 2020 than would be expected according to a random distribution. The number of dead trees were more than double the expected number (calculated as part of the chi-squared test).

The mean ash dieback score has increased from 1.22 in 2009 to 2.53 in 2020, where 0 are completely without symptoms and 4 are dead. This is a significant increase between the years (ANOVA $F_{4,325} = 69.22$, $P = 0.001$) (Figure 2). In 2020, 94.5 % of the veteran ash trees had some symptoms of ash dieback, compared with 62% in 2009 when the monitoring began (Figure 3).

In 2020, the analysis of the whole population found there was a significant correlation (Spearman's $r_s = –0.114$, $n = 289$, $P = 0.04$) in that larger trees were less affected. No ash tree under 136 cm in girth (equivalent to 45 cm diameter) was healthy in 2020. This trend explains only a small amount of the variation in the disease and only 10% of the population had a girth of less than 136 cm. This was similar to the results reported for 2013 and 2015 (Bengtsson and Stenström 2017). To examine whether pollarding was a possible explanatory factor, the analysis was carried out on each type of tree (unpollarded, pollarded under 10 years ago, pollarded over 30 years ago). There were no significant correlations between girth and infection score for either trees pollarded over 30 years ago (Spearman's $r_s = –0.038$, $n = 117$, $P = 0.664$) or for unpollarded trees (Spearman's $r_s = –0.082$, $n = 102$, $P = 0.408$). There was

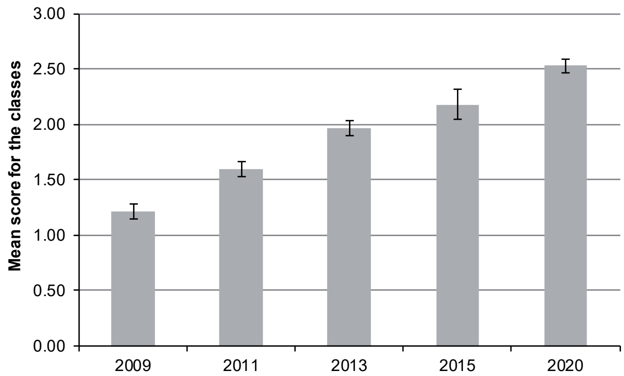

Figure 2. Mean scores for ash dieback class have increased between the years where 0 is healthy, 1 is lightly affected, 2 is affected, 3 is significantly affected and 4 is dead

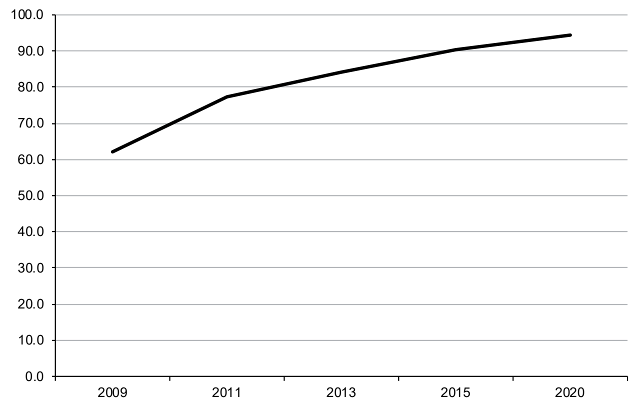

Figure 3. 94.5% of the veteran ash trees had symptoms of ash dieback in 2020 compared with 63%, 77%, 84% and 90% in 2009, 2011, 2013 and 2015, respectively

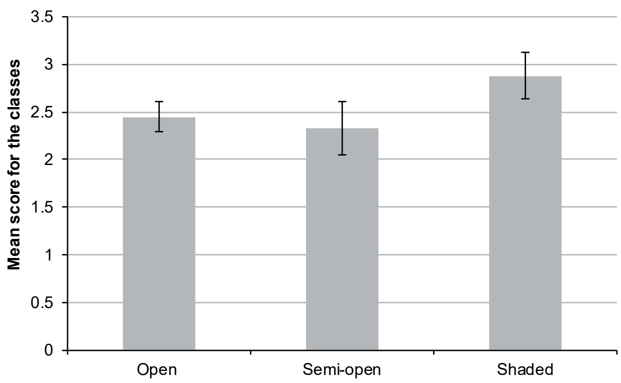

Figure 4. Mean scores for ash dieback class regarding the degree of openness, where 0 is healthy, 1 is lightly affected, 2 is affected, 3 is significantly affected and 4 is dead

however a significant correlation between girth and infection score for trees pollarded under 10 years ago (Spearman's $r_s = -0.217$, $n = 70$, $P = 0.039$).

In 2020 data were also collected regarding the degree of openness and whether the ash trees were in a grazed area. In 2013 and 2015 no statistical significance was found for either openness or grazing (Bengtsson and Stenström 2017). In 2020 however, there was a significant difference in the degree of openness; trees that were shaded were more affected by ash dieback than those standing in the open or semi-open (ANOVA $F_{2,327} = 4.08$, $P = 0.018$), see Figure 4. There was however still no significant result regarding grazing ($F_{1,328} = 0.03$, $P = 0.86$).

Pollarding and ash dieback

In 2020, there was no significant difference in severity of ash dieback symptoms in the crown between the three groups of trees ($F_{2,327} = 1.72$, $P = 0.18$), see Figure 5. This is a change from the results in 2015, where trees that had not been pollarded were more affected by ash dieback than old pollards (see Bengtsson and Stenström 2017).

There is an interesting pattern which emerges when looking at the spread of each type of tree in each ash dieback class (Figure 6), which appears to show more recently pollarded trees in class 4 and less in class 3 compared with the other two groups. Indeed, analysis of the frequencies of each class across the period shows significant differences ($X^2 = 23.452$, df = 8, $P = 0.0028$). There were fewer of the trees pollarded under 10 years ago in class 3 (significantly affected), and more in both classes 0 and 4 than would be expected by chance. The trees that had been pollarded over 30 years ago, have fewer in class 4, whilst the trees that have never been pollarded, have more in class 3.

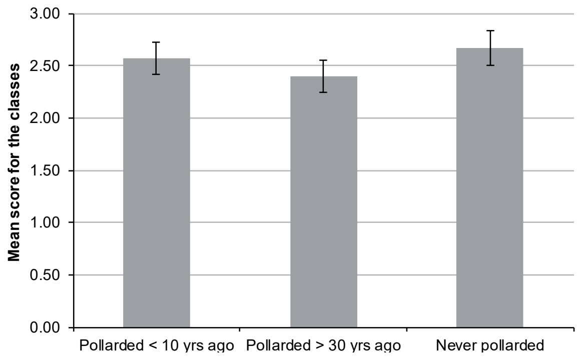

Figure 5. The impact of ash dieback between the different groups of trees studied, where 0 = healthy, 1 = lightly affected, 2 = affected, 3 = significantly affected, and 4 = dead. The results from 2020 showed that there was no significant difference between the different groups of trees studied (ANOVA $F_{2,327} = 1.72$, $P = 0.18$)

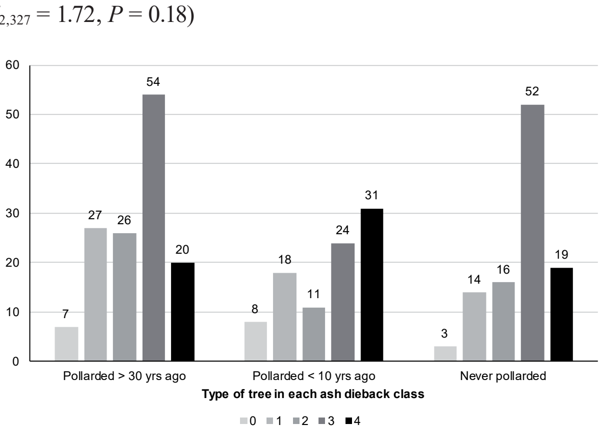

Figure 6. Numbers of trees per type of tree and ash dieback class in 2020

Pollarding and mortality

In total 70 ash trees have died since the monitoring began in 2009 (see Table 1). A comparison of the mortality rate between years and between the three groups of trees was carried out to see if pollarding could result in a higher mortality rate (see Table 2).

Examining the mortality during the early six years (three time periods of two years each), using Friedman's matched group test for ranked data (matching data for each date by type of pollarding, i.e. simply comparing mortality by date) there was a significant difference (the test statistic $X^2 = 6.0$, df = 2, $P = 0.0498$). Although there were too few data to use a multiple comparison test to investigate further into where the differences lay, the rank means for the years indicated that most (annual) mortality seemed to occur between 2013 and 2015. Figure 7 shows that the mortality is very similar across all time periods in the controls (never pollarded) and, to a slightly lesser extent, in the trees pollarded over 30 years ago. However, mortality is elevated in the trees pollarded less than 10 years ago (especially after 2011).

In comparisons between the different pollarding types, using Friedman's matched group test for ranked data (matching by year, i.e., comparing between the different types of trees), there was a significant difference found ($X^2 = 6.0$, df = 2, $P = 0.0498$). Again, multiple comparison tests were not feasible because of the low sample sizes but

Table 1. Number of living trees per year and type of ash tree

	Pollarded > 30 yrs ago	Pollarded < 10 yrs ago	Never pollarded
2009	133	89	102
2011	131	85	99
2013	127	79	96
2015	122	73	93
2020	114	61	85

Table 2. Mortality rate per year and period (%)

	Period			
	2009–2011	2011–2013	2013–2015	2015–2020
Pollarded > 30 yrs ago	0.008	0.015	0.020	0.013
Pollarded < 10 yrs ago	0.023	0.036	0.039	0.035
Never pollarded	0.015	0.015	0.016	0.018

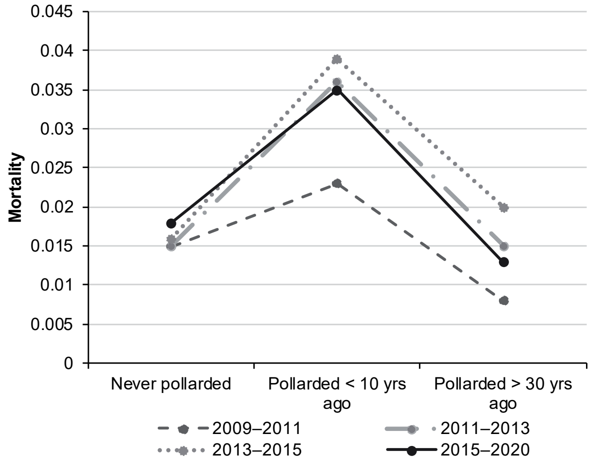

Figure 7. Comparison of mortality rates (% annual mortality) with time across the different types of tree (plotted from Table 2 data using treatment (tree type) and separated by time period (time periods are highlighted by different shades/patterned lines)

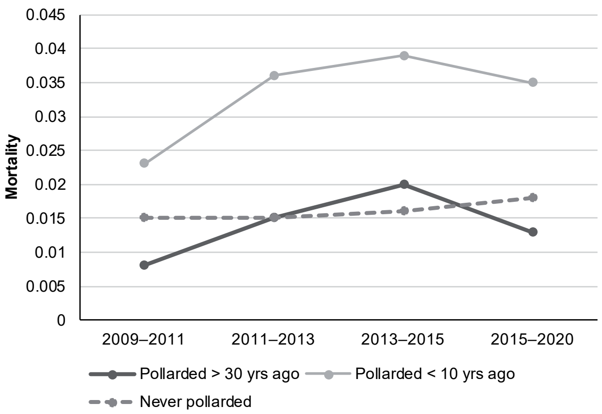

Figure 8. Comparison of mortality rates (% annual mortality) by treatments (type of tree) across the time periods (plotted from Table 2 data using time period as the x axis, mortality rate as the y axis and separated by type of tree which are marked with different shades/patterns)

ranked means for the different pollard types indicated that the mortality was higher in the trees that were pollarded under 10 years ago than in either of the other two groups of trees. Figure 8 shows that although the annual percentage mortality changes over time for all treatments, this is relatively minor in the trees that have never been pollarded and the lapsed pollards (pollarded over 30 years ago).

Discussion

Our study showed that trees with a larger girth were showing fewer symptoms of ash dieback, which concurs with other studies. Marcais et al. (2017) showed that from sites in France and Belgium, mortality rates of small trees (under 5 cm dbh) were 35% per year compared with trees larger than 25 cm in diameter at breast height, where mortality was 3.2% per year. Similar results, where larger trees cope better than smaller trees, have been published by Enderle et al. (2018) from Germany and Timmermann et al. (2017) in Norway. The reasons why ash trees with a larger girth seem to have fewer symptoms is still unclear. It may be as simple as it takes longer for the fungus to spread in larger trees and that older trees may have more complex branch architecture (Lonsdale 2013). It could also be that larger and older trees may be growing in more optimal conditions (Coker et al. 2019) and they thus have a greater tolerance. This effect may be particularly relevant to regularly pollarded trees, where the girth may be smaller because pollarding can slow the growth rates, additional stress has been imposed and the potentially smaller girth is perhaps less resilient. Further work on tree size and pollarding could be useful here, where a trial could be set up with specific sizes of ash trees and regular frequency of pollarding, to help understand these factors.

Given that many studies (McKinney et al. 2014, Enderle et al. 2019) suggest that only a low proportion of the ash population is resistant, it was expected that more veteran ash trees would become more affected over the years. In 2020, only 5.5% of the population were free of ash dieback symptoms. It was hoped that the proportion of the population that showed symptoms would begin to level out, given that ash dieback has been in Sweden since at least 2001 (Barklund 2005), but there appears to be little sign of this. 5.5% with no symptoms is however a greater proportion than many researchers have predicted, given that the disease has been in Sweden for at least 20 years (Barklund 2005) and that only 1–2% of ash trees have adequate genetic resistance to be useful for a breeding programme (McKinney et al. 2014, Cleary et al. 2017). Enderle et al. (2019) report from various studies across Europe that typically only 1% of trees show no or only insignificant symptoms. Studies from Denmark (Madsen et al. 2021) highlight the fact that older ash trees seem to be less affected by ash dieback and the trees in their study were less than a hundred years old, likely much younger than those in our study.

The ash trees in our study showed less symptoms of ash dieback if they were situated in more open conditions and this differs from the results in 2015 when there was no statistical difference in the degree of openness (Bengtsson and Stenström 2017). The result from 2020, showing there has been a change over time, is in line with a study from France, where Grosdidier et al. (2020) showed that the environment, in which the ash grew, had little impact in the early phases of disease establishment, but had a strong impact on the development of the disease over time. They showed that impact of ash dieback was less severe when ash trees were growing in the open. Drenkhan et al. (2017) from work in Estonia found a similar pattern; trees that were growing in more open conditions were healthier. Veteran ash trees in Sweden are more common in the rural landscape and thus are often found in more open condi-

Figure 9. A few old pollards which were last cut in 2012 and which show different levels of ash dieback. The tree in the middle was alive in 2013 but had died by 2015. The tree furthest to the right has no symptoms of ash dieback

tions, which could potentially limit the total impact of ash dieback over time. This may also be a reason why only 21% of our study trees have died and may also support work to clear around veteran ash trees that may be becoming overgrown by secondary woodland. Grosdidier et al. (2020) suggested that this pattern may be because the trees in the open are subjected to microclimates which are less favourable for pathogen development, particularly during hot summers. They also suggest that fewer trees and thus leaves may result in lower quantities of spores at a local level. Grazing animals, if present, may also damage and push the leaf rachises into the soil.

Our results show there was no statistical difference in the degree of ash dieback symptoms in the crown, between the different types of trees we have studied in 2020. This result has varied over the years we have studied these trees (Bengtsson and Stenström 2017). The groups of trees that have been pollarded more recently (under 10 years ago in 2009) are generally a more variable group than either the lapsed pollards or maiden trees (which have not been cut during our study period). For example, some of the group of trees pollarded more recently, are still in a regular cutting cycle, and have been cut every fifth year, whilst others have been cut more sporadically, but all of this group have been pollarded in recent times. Thus, the exact date of pollarding for each tree and the time at which the disease arrived at the tree's location are however unknown, and this may explain why the results have varied between years. Marciulyniene et al. (2017) showed that the presence of *H. fraxineus* declined with increasing distance from visible lesions, and at 30 cm, the ash dieback fungus was missing completely from the samples, confirming that pruning may remove the fungus, at least temporarily.

Even if the statistical power of our calculations makes it difficult to identify where the differences lie, it does seem that trees that have been pollarded more recently have had a higher mortality rate throughout the study period. This group of trees has however also had the greatest proportion of trees with fewer symptoms. This may appear to be a contradiction, but it is possible that pollarding removes the affected shoots and thus the fungus, providing temporary respite from the disease as per the study by Marciulyniene et al. (2017). Pollarding, however, stimulates the production of epicormic shoots, often directly from the main stem, which may result in a shorter route for the fungus to reach the main stem and thus a quicker death (Bengtsson et al. 2014, Cleary et al. 2017). This means that it is a tricky balance to know how to deal with pollards; on the one hand it may be possible to lengthen their lives by removing ash dieback infected branches, but on the other hand, it may also shorten their lives because the live growth will be made up of young shoots with a shorter infection route into the main stem. More research is required in this area, and it would be interesting to undertake a study pollarding young trees under controlled conditions. It would also be interesting to undertake more studies on veteran trees, which might help to gain a greater understanding of the potential tolerance they may have to ash dieback. Old trees, and especially old pollards, very often have a more complex trunk and crown structure compared with younger trees. Old trees exhibit more often the feature of having separate functional units, which are relatively independent of one another. This is a survival strategy where different parts of the same tree can behave to some extent like separate individuals. Each of these functional units can cater for their own energy requirements and take up water and nutrients from the closest part of the root system. Even if there may be a connection between these units, they can respond, for example, differently to the same type and amount of pruning (Lonsdale 2013a). This may be an advantage in terms of ash dieback because the fungus has difficulties in moving through a more complex branch structure (Gross et al. 2014) and it can thus not as easily girdle the entire stem. The lapsed pollards (those pollarded over 30 years ago) may also have a more complex crown structure because of the historic pollarding and this may also explain why fewer of this group have died than would be expected. The trees that have never been pollarded have more in class 3 than would be expected, which suggests that the disease is developing but has not yet resulted in death. This may just be a factor of time, in that it may take longer for the pathogen to kill some trees (Coker et al. 2019). It should also be noted however, that class 3 in our study covers a large range from 30–99% defoliation. This includes trees which may be expected to survive (less than 50% defoliation) and trees which are less likely to survive (more than 60% defoliation). In future studies it would be useful to divide up this class when assessing the impact of the disease on the crown.

On a positive note, only 21% (70 trees) of the veteran ash trees studied have died since 2009, and this is much lower than that reported in other studies. Coker et al. (2019), who have analysed many studies across Europe, have seen that there are few ash trees completely free of symptoms, even if many of these studies are from forest situations, with much younger trees than in our study and where the impact of honey fungus may be greater (Madsen et al. 2021). There are however few sites where all the ash trees have died. They have also seen that the mortality rates of ash trees growing in more natural conditions (rather than plantations) are lower. Coker et al. (2019) discuss that this may be due to a wide range of factors such as the trees possibly being better adapted to the place where they are growing and that there may be more microorganisms that can compete with the ash dieback fungus. They also suggest that there may be greater variation in the tree species resulting in lower infection rates or that the age and size of the trees may mean it takes longer for these trees to die. Which of these factors are the most significant is as yet unknown.

Conclusions

Despite the lack of statistical power in our data, it seems sensible, as a precautionary measure, to avoid pollarding veteran ash trees that have symptoms of ash dieback. These old trees often host a great deal of biodiversity, and it is far from desirable to speed up their decline, even if they still have biodiversity value after death (Hultberg et al. 2020). Another management action, which may benefit old ash trees, would be to clear around them if they have become overgrown, since openness seems to limit the severity and development of the disease.

Cutting old ash trees can have significant consequences even if they are not affected by ash dieback (Lonsdale 2013b). Other studies have shown that old ash pollards that have been cut hard to restore them back into a pollarding cycle after a long period of lapse are weakened and thus may be more at risk from ash dieback (Eklund 2009, Skovsgaard et al. 2010, Bakys et al. 2011, Skogsstyrelsen 2013, Cleary et al. 2017, Skovsgaard et al. 2017). Therefore, we recommend avoiding all types of cutting on old lapsed and maiden ash trees if there is no acute risk of the crown failing. It is also possible that after cutting, the new shoots (where infection primarily occurs) develop closer to the main stem, thus shortening the distance and potentially speeding up the rate at which the fungus may enter the main stem of the tree (Stenlid 2013, Marciulyniene et al. 2017). However, if management needs to be carried out, then avoid cutting all the trees in the same year and spread the cutting out (and thus any risks) over a longer period (Lonsdale 2013b, Bengtsson and Stenström 2017).

There is currently no treatment for ash dieback. As the fungus is spread by the wind it can spread a long way and there is little benefit in felling individual trees that are affected to reduce the risk of the disease spreading. Indeed, there may even be a risk in removing trees as a preventative measure because those trees could hold the key to the future conservation of ash and the associated species. The most important current focus should be to collect as much information as possible regarding ash trees which appear to have an increased tolerance to the disease and retaining veteran ash trees for as long as possible.

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