The effects of veteranisation of *Quercus robur* after eight years

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The effects of veteranisation of *Quercus robur* after eight years
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Summary

During the summer of 2020, 18 of the 20 sites included in the international veteranisation trial were visited with the purpose of monitoring the impact of veteranisation on the trees. A variety of parameters were recorded for all trees, including control trees. The 16 Swedish sites were also visited in May of 2020 to monitor the use of the woodpecker holes and nestboxes by breeding birds. The frequencies and differences of various responses of trees to the treatments were statistically analysed and are presented in this report.

12 of the 225 oak trees had confirmed sightings of birds using either the woodpecker holes or the nest boxes for breeding. Blue tits were the most common species, but nuthatch, starling and great tit were also recorded. 67% of the nestboxes and 31% of the woodpecker holes had remains of bird nesting material and the nestbox had significantly more than the woodpecker hole. The nestboxes often had several layers of nesting material suggesting they have been used for several years. Live bats were seen in six nestboxes and one woodpecker hole and remains from bats were identified from 14 nestboxes and 13 woodpecker holes. Further monitoring specifically targeting bats is recommended. Almost 40% of the woodpecker holes had some form of damage on the callus, some of which appeared to be quite old. It was not clear what species had damaged the callus and this would be interesting to follow up. Live wood mice were found in two of the veteranised cavities. Aspect had no impact on the presence of decay, bats or bird nesting materials.

Only 12 of the 874 trees had died since 2012, which is equivalent to a mortality rate of 0.17% per annum and is lower than expected when compared with other studies, even without veteranisation. The fact that the oaks had good vitality, and were more than 25 cm in diameter, at the start of the study may be the reason for this as trees with good vitality cope better with damage.

The nestbox and topping treatments had the greatest impact on growth rates and had grown significantly less than any of the other treatments. This is expected given that this treatment involved the greatest impact on the tree. Regarding the amount of live growth in the crown, horse damage had the least compared with all other treatments apart from woodpecker hole. Horse damage and nestbox trees had decay more frequently than either the control or the woodpecker hole. Horse damage and nestbox treatments also seem to encourage different fungal species' assemblages and are thus promising techniques for the encouragement of decay. Veteranisation did not have an impact on the frequency of naturally occurring hollows over 5 cm and the nestbox and woodpecker holes represented four times the number of hollows than occurred naturally. Veteranisation did not speed up the development of dead branches over 10 cm in diameter, which means that it may, in future, be worth focusing on larger branches (i.e. over 25 cm in diameter) or ringbarking the main stem at height.

21% of the woodpecker holes had completely occluded and it is proposed that in the future it may be worth removing the bark from around the hole to slow down the process of occlusion. The 'lids' associated with the nestbox had fallen out from 20 out of 127 trees. It is worth ensuring that the lids are properly secured in place and are a good fit when creating the nestboxes and they also seem to slow the process of occlusion.

Sap runs were more frequently associated with nestboxes and woodpecker holes than all other treatments and controls. This may be due to the greater amount of damage associated

with the climbing spikes when creating nestboxes and woodpecker holes. Social wasps, ants and bees were more frequently associated with the nestbox and woodpecker holes. It was interesting to note that tree ants were found making nests in association with these veteranisation features and suggests the treatments are at least in part successfully mimicking natural cavities. The presence of tree ants can also indicate suitability for other species.

In summary the horse damage, nestbox and woodpecker hole treatments after eight years have created microhabitats more quickly than would have occurred naturally. The presence of decay, birds, bats, tree ants and other social bees and wasps are positive indications that the veteranisation features are mimicking naturally formed features.

Sammanfattning

Under sommaren 2020 besöktes 18 av 20 undersökningsområden som ingår i den internationella uppföljningen av veteraniserade träd. Syftet med uppföljningen var att undersöka vilken effekt veteraniseringsåtgärder har haft på träden. Information från ett antal parametrar samlades in på alla träd, inklusive kontrollträd. De 16 undersökningsområden som är belägna i Sverige besöktes dessutom i maj 2020 för att undersöka i vilken utsträckning häckfåglar nyttjar träd som undergått veteraniseringsbehandlingarna hackspetthål och holk med toppkapning. Inventeringsresultaten och skillnader i hur träden svarar på de olika behandlingarna har analyserats statistiskt och presenteras i denna rapport.

På 12 av 225 ekar noterades fåglar häcka i antingen hackspetthål eller holk. Blåmes var den vanligaste arten, men även nötväcka, stare och talgoxe noterades. 67% av holkarna och 31% av hackspetthålen innehöll äldre bomaterial. Antalet holkar med bomaterial var signifikant fler än antalet hackspetthål med bomaterial. I holkarna noterades ofta flera lager av bomaterial vilket tyder på att de nyttjats under flera år. Levande fladdermöss noterades i sex holkar och ett hackspetthål. Spillning från fladdermöss påträffades i 14 holkar och 13 hackspetthål och ytterligare uppföljning av i vilken utsträckning fladdermöss nyttjar holkar och hackspetthål rekommenderas. Närmare 40 % av hackspetthålen hade någon typ av skada på invallningen, varav flera förefaller vara relativt gamla. Det är oklart vilken art som orsakat dessa skador och det vore intressant att studera detta vidare. Levande skogsmöss noterades i två veteraniserade håligheter. I vilket väderstreck som behandlingen utfördes påverkar inte förekomsten av röta, fladdermöss eller fågelbomaterial.

Endast 12 av 874 träd hade dött sedan 2012, vilket motsvarar ett dödstal på 0,17%/år och är lägre än förväntat jämfört med andra studier, även jämfört med dödstal bland träd som inte veteraniserats. Att ekarna vid studiens början hade god vitalitet och var mer än 25 cm i diameter kan vara ett skäl till det låga dödstalet, eftersom träd med god vitalitet generellt är bättre på att hantera skador.

Behandlingen holk med toppkapning hade störst inverkan på trädens tillväxt och dessa träd hade signifikant mindre tillväxt än träd med andra behandlingar. Detta resultat var väntat då holk med toppkapning är den behandling som mest påverkar trädet. Gällande andel levande krona var hästgnag den behandling som resulterat i minst andel levande krona jämfört med alla andra behandlingar förutom hackspetthålen.

Träd med hästgnag och holkar hade röta i fler fall än både kontrollträd och träd med hackspetthål. Hästgnag och holkar förefaller dessutom skapa förutsättningar för olika artsammansättningar bland svampar och är därmed lovande tekniker för att stimulera röta. Veteranisering påverkade inte frekvensen av naturligt förekommande hålrum (större än 5 cm). Hålrum som utgörs av holkar och hackspetthål är hela fyra gånger fler till antalet än naturliga hålrum. Veteranisering påskyndade inte utvecklingen av döda grenar över 10 cm, vilket innebär att det i framtiden kan vara värt att fokusera på grövre grenar (över 25 cm i diameter) eller ringbarkning av huvudstammen på hög höjd.

21% av hackspetthålen hade slutit sig helt och det föreslås att det i framtiden kan vara bra att skala bort bark kring hålet för att sakta ned invallningsprocessen. Holkarnas ”lock” hade fallit bort på 20 av 127 träd. Det är värt att försäkra sig om locken är ordentligt fixerade och passar väl i hålrummet när holkarna skapas. Locken verkar dessutom sakta ned invallningsprocessen.

Savflöden förekom i större utsträckning i anslutning till holkar och hackspetthål än på träd med andra behandlingar och kontrollträd. Detta kan bero på att dessa träd i högre grad utsatts för skador från spikskor när behandlingarna utförts. Även sociala steklar, myror och bin förekom mer frekvent i anslutning till holkar och hackspetthål. Det var intressant att även trämyror noterades bygga bo i eller invid dessa veteraniseringsstrukturer. Förekomsten av trämyror skulle kunna indikera goda förutsättningar även för andra arter.

Sammanfattningsvis har mikrohabitat efter åtta år bildats snabbare på träd som behandlats med hästgnag, holk eller hackspetthål, än vad som hade uppstått på naturlig väg. Förekomsten av röta, fåglar, fladdermöss, trämyror och andra sociala bin och getingar är positiva indikationer på att veteraniseringsstrukturer på många sätt liknar naturligt uppkomna strukturer.

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Introduction and background

Veteranisation is a method where young trees are actively damaged to create habitats for organisms normally associated with older trees. This is nothing new as we have been veteranising trees for thousands of years through pollarding, for example. We know that pollarding results in the trees hollowing more quickly than unmanaged trees (Sebek et al., 2013). The idea behind veteranisation is thus to try and mimic nature, using tools. The techniques used should not kill the trees, but instead encourage the decay process to develop at a younger age, in living trees. The aim thus being to shorten the delivery time for habitats found otherwise only in old trees. These techniques should never be carried out on ancient or other veteran trees that already contain valuable habitat. Veteranised trees cannot be a replacement for ancient trees that have gone through the natural aging process, but they may provide a bridge over an age gap and help to reduce the risk for random extinction of species because many sites with old trees are small and fragmented.

Figure 1 – Strömsholm, one of the sites included in the international trial. Here you can see an old hollow oak in the centre of the photo surrounded by younger oaks, some of which have been veteranised.

Veteranisation is generally most suitable on sites where there are plenty of younger trees, which would otherwise be removed (see Figure 1). Removal may be desirable to reduce competition and increase the level of light to favour other younger individuals or existing ancient trees. Veteranisation means that you make use of the existing tree resource instead of removal.

Trees of all species can be veteranised, however the focus has primarily been on long-lived broadleaved trees such as beech (Niklasson, 2017) and oak (Bengtsson et al., 2015; Hedin et al., 2018). The reason for this focus is that beech and oak take a long time before they develop habitats for associated species and there is often a large age gap on sites with ancient oak and beech trees. Oak is the deciduous tree species with the most species associated and is an important host for almost 900 species, of which

350 are specialized on oak in Sweden. The reason for the high number of species associated, is that oak is exceptionally long lived and thus can provide a wide range of niches that are stable over time (Jansson, 2009; Sundberg et al., 2019).

In 2010 there were relatively few studies where the efficacy of veteranisation had been evaluated (Carey and Reed Sanderson, 1981; Forbes and Clarke, 2000; Cavalli and Mason, 2003). In 2011/2012 an international trial (16 sites in Sweden, 1 in Norway and 3 in England – see Appendix 1 and Table 3) was thus set up to try and evaluate five different veteranisation techniques on oak (with controls, see Table 4). The main aim was to try and understand whether veteranisation of oak may help conserve threatened species associated with old oaks (see Appendix 1, Bengtsson et al., 2013 and Hedin et al., 2018 for more details of the trial). More recently other work has also been published, primarily from Australia on the results from chainsaw-carved cavities (Rueegger, 2017; Griffiths et al, 2018; Griffiths et al, 2020) and on beech in Sweden (Niklasson, 2017).

In 2020, Pro Natura was contracted to undertake monitoring work in the 16 Swedish sites. Colleagues in England helped (due to Covid-19) with the tree monitoring on two of the three sites in England. In this report, we present the results from this monitoring and identify lessons learned for future veteranisation projects.

Method

Tree monitoring

Between 16th June and 9th September all oak trees included in the trial at each of the 16 sites in Sweden were visited, (see Figure 2). On 25th September (Ashtead Common) and 12th October (Ickworth) two of the sites in England were visited. At all 18 sites, a range of parameters were recorded for each tree including controls (see Table 1 for an overview of the numbers of trees in each category and Appendix 1). All trees were photographed, the tag and nail were checked. If the tag had disappeared, a new tag was placed on the tree and the database updated. For all trees, where the tag was still present, the nail was pulled out to avoid the tag becoming calloused over. On some trees, the tag had already become calloused over. In these cases, where possible the tag was pulled out and repositioned on the tree. If it was not possible to pull the tag and nail out, this was noted, and a new tag was placed on the tree. For the woodpecker hole and nestbox with topping treatments, a ladder was used to come up to the height of the treatment and an endoscope was used to see inside, if the lid was locked in position. Aspect, which is potentially something which may impact on the development of decay and the associated species was not recorded in combination with the visit in 2020. For the analysis, the aspect as recorded in 2012, when the veteranisation work was done was used.

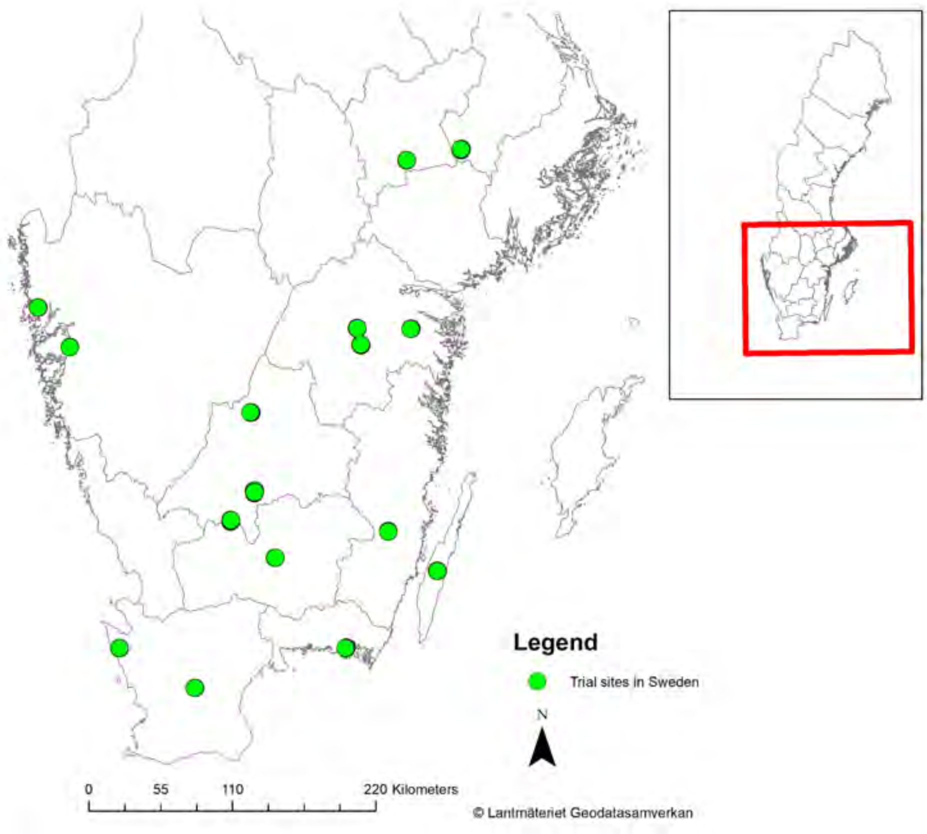

Figure 2 – map of southern Sweden showing the location of the 16 sites with oak trees included in the veteranisation trial.

For all trees, the following parameters were noted:

1. Date of survey
2. Girth at breast height in cm
3. Name of surveyor
4. New tag number if relevant
5. Tree alive or dead? (1 – alive, 0 – dead)
6. Tree status/condition (1-standing, 2-fallen, 3- felled, 4- stem broken, 5-spoiled, 6 - not found)
7. Proportion of the existing crown which is alive (1>75%, 2- 50-75%, 3-25-50%, 4 <25%)
8. Sap runs up to 8m (yes – 1, no – 0)
9. Natural hollows in trunk over 5 cm (yes – 1, no – 0)
10. Dead branch over 10 cm and under 8 m (yes – 1, no – 0)
11. Obvious decay (yes – 1, no – 0) – N.B. for many of the ringbarked and broken branches this was often not possible to determine with certainty.
12. Fungal fruiting bodies present and species if identifiable in the field.
13. Photo number
14. Comments

In addition to the above information, several parameters were recorded for the individual treatments, with the exception of broken branch (BB), as follows:

Ringbarked branch (RBB)

1. Ringbarked branch dead or alive (yes – 1, no – 0)
2. Ringbarked branch broken off (yes – 1, no – 0)

Horse damage (HD)

1. Decay in connection with treatment (yes – 1, no – 0)
2. Lifting bark in connection with treatment (yes – 1, no – 0)
3. Social bees/wasps directly on or in treatment (yes – 1, no – 0)
4. Width of exposed wood in cm (measured between the inner edges of the callous, at about half the height from the ground)

Nestbox and topping (NBT)

1. Decay in connection with nestbox (yes – 1, no – 0)
2. Lifting bark in connection with nestbox (yes – 1, no – 0)
3. Social bees/wasps directly on or in nestbox (yes – 1, no – 0)
4. Side cut open (yes – 1, no – 0)
5. Social bees/wasps directly on or in treatment (yes – 1, no – 0)
6. Width of opening in cm (measured along the top of the lid)
7. Length of opening in cm (measured from the upper edge of the callous to the top of the lid)
8. Bird nesting material (yes – 1, no – 0)
9. Bat droppings/evidence (yes – 1, no – 0)
10. Live bats (yes – 1, no – 0)
11. Endoscope photo number (if available)
12. Lid and position (0 - gone, 1- in original position, 2- remaining but not in original position)

Woodpecker hole (WPH)

1. Decay in connection with treatment (yes – 1, no – 0)
2. Lifting bark in connection with treatment (yes – 1, no – 0)
3. Social bees/wasps directly on or in treatment (yes – 1, no – 0)
4. Width of opening (measured in the middle between the inner edges)
5. Length of opening (measured in the middle between the inner top and bottom)

6. Bird nesting material (yes – 1, no – 0)
7. Bat droppings/evidence (yes – 1, no – 0)
8. Live bats (yes – 1, no – 0)
9. Endoscope photo number (if available)

Bird monitoring

Between 14th and 27th May 2020, all oak trees that were veteranised with the woodpecker hole and nestbox and topping treatments were visited at the 16 sites in Sweden (see Figure 2). The trees were located using a digital tablet where all trees were marked with the tree number and treatment. At each tree, the field observer stood watching the artificial hole for seven minutes. Any birds that flew in or out of the hole during that time were recorded. Bird droppings associated with the hole were noted if present. A photograph was taken of the hole, and one of the birds if possible.

Data analysis

The frequencies of various responses of trees to the treatments (including type and orientation of treatment) were analysed using Chi-squared tests, using a continuity correction where appropriate.

Mann-Whitney *U* tests and Kruskal-Wallis analysis of variance using ranks were used to explore differences in measured (scored) variables between treatments, using corrections for tied values where appropriate. Dunn’s multiple comparison tests were used to elicit differences between pairs of treatments where significant differences were revealed using Kruskal-Wallis analysis of variance using ranks.

Spearman’s rank correlation coefficients (controlling for ties) were used to examine relationships between growth of the tree and the degree of response to specific treatments.

Results

Tree monitoring

Of the 883 oak trees that were subject to a range of treatments in 2012 at 18 of the 20 sites included in the trial, 881 were visited in 2020. The two oaks that were not visited could not be located in the field during the monitoring visits in 2020 and have likely been felled. In addition, seven trees, that were visited, had either been felled or spoiled in another way (e.g. ringbarked branch removed). Therefore, 874 oaks were included in the analysis.

Table 1 – overview of the numbers of trees per treatment for 18 sites.

	Total number of original trees per treatment (18 sites)	Spoiled/ felled/not found	Numbers for analysis	Alive 2020	Dead 2020
Controls	252	1	251	251	0
Broken branch	127	2	125	124	1
Horse damage	126	1	125	123	2
Nestbox and topping	128	1	127	121	6
Ringbark branch	125	4	121	120	1
Woodpecker hole	125	0	125	123	2
Totals	**883**	**9**	**874**	**862**	**12**

Mortality

Of the 12 trees that have died since the trial began in 2012 (all of which were veteranised trees), 11 have died since 2014. This gives a mortality rate of 0.17% per annum for the whole population of trees. For the control trees, the mortality rate was zero and for the treated trees 0.24% per year. Three trees have broken at 4 m or above on the main stem (1 nest box, 1 woodpecker hole, 1 control). Using a Mann Whitney U test, there was no indication that the trees that died were smaller either in 2012 (Z = -0.761, P = 0.4464), or in 2020 (Z = -1.146, P = 0.2519). There was also no significant association between condition (standing or fallen) and treatment (X^2 = 17.550, DF = 20, P = 0.6170), however here there may have been too few trees to be able to identify any pattern.

Girth and live growth

Most sites did not differ significantly in terms of girth in 2012, girth in 2020 or growth rates between 2012 and 2020. There were some minor differences between a few sites, but these differences were too small to be able to identify where the significance was using Dunn's MCT.

Differences in growth between 2012 and 2020 were compared between the treatments (where the difference between girths in 2012 and 2020 was used as a proxy for growth). The nestbox and topping treatments had grown significantly less than any of the other treatments (H = 45.121, DF = 5, P <0.0001).

Good growth rate (higher change in girth) correlated with higher amount of live growth for all trees (r_s = 0.283, n = 833, P < 0.0001). Horse damage treatment however, had the least amount of live crown growth compared with all other treatments except woodpecker hole (H = 34.491, DF = 5, P < 0.0001).

Decay and hollows

Examination of the frequency of the presence of decay was not possible with certainty and consistency in relation to the broken branch or the ringbarked branch treatments. The horse damage and nestbox and topping treatments had more decay (see Figure 3) than expected, whereas woodpecker hole and controls had less (X^2 = 148.05, DF = 3, P < 0.0001). It was also interesting to note that there were lower frequencies of decay in the horse damage treatment with less exposed stem area (Z = -2.450, P = 0.143) and woodpecker holes with more occlusion (Z value = -4.189, P <0.0001), although this pattern was not seen with the nestbox and topping (Z value = -1.463, P = 0.1434). Our data showed that the impact of veteranisation did not significantly increase the frequency of naturally developed hollows over 5 cm in diameter (X^2 = 1.838, DF = 5, P = 0.8711) after eight years. Just under 7% of the trees studied contained naturally developed hollows over 5 cm in diameter. This compares with 28% which had hollows created by veteranisation.

Figure 3 – early signs of decay in a horse damage tree

Occlusion and 'lids'

21% of the woodpecker holes had completely closed over due to the development of callus growth (see Figure 4). The woodpecker holes were created as a standard size independent of girth in 2012. The size of the remaining hole in 2020 was correlated with the growth rate in that high growth rates resulted in smaller openings (r_s = -0.344, n =124, P = 0.0001), where the openness was calculated as the area of an oval. There was however no correlation between occlusion and the amount of live growth (r_s = 0.027, n =124, P = 0.7675).

Figure 4 – a woodpecker hole which has completely occluded. Marks on the callus can be clearly seen here.

The 'lids' from 20 of the 127 nest boxes had fallen out and an additional 18 were no longer in the original position, see an example in Figure 11. Where the lids remained, the width and depth of the opening was measured. The original size of the nestbox cavity was correlated with the diameter of the tree in 2012 (r_s = 0.416, n =100, P < 0.0001) and in 2020 (r_s = 0.339, n =100, P = 0.0007). Despite larger holes being created in larger trees, the high growth rate also resulted in more occlusion, in other words the trees with good growth in terms of girth change had smaller holes by 2020 (r_s = -0.324, n =101, P = 0.0012).

Higher growth rates (r_s = -0.342, n =124, P = 0.0001) and more live crown years (r_s = -0.237, n =124, P = 0.0083) were both negatively correlated with the amount of remaining exposed wood on the horse damage. In other words, there was less exposed wood on horse damage trees with higher growth rates and more live crown. This is despite the fact that the size of the exposed wood created in 2012 was directly related to the girth of the tree at that time.

Sap runs and dead branches

211 (24%) of the oak trees had sap runs (see Figure 5) of varying sorts (sticky, runny). More sap runs were associated with nestbox and topping and woodpecker holes than the other treatments and controls (X^2= 173.07, DF = 5, P < 0.0001).

Figure 5 – the ground beetle *Carabus violaceus* feeding from a sap run associated with climbing spike damage

63% of the trees contained naturally dead branches over 10 cm in diameter, and these were not significantly more associated with veteranisation i.e. there was no significant difference in the presence of dead branches between the treatments (X^2 = 4.161, DF = 5, P = 0.5264). All, apart from one of the 121 ringbarked branches had died.

Lifting bark, creating a small void (see Figure 6), was a feature that has been created because of the veteranisation treatments and was recorded from 66% of the horse damage, woodpecker holes and nest boxes.

Figure 6 – the lifting bark that forms with a void underneath between the dysfunctional wood and the callus, here associated with a woodpecker hole.

Associated species

A comparison between the treatments that created holes showed that there were more social wasps, ants and bees associated with the nestbox than woodpecker hole (X^2 = 4.69, DF = 1, P = 0.0303).

Figure 7 – a woodpecker hole with bird nesting material in the base and a roosting bat (*Pipistrellus pygmaeus*)

67% of the nest boxes, and 31% of the woodpecker holes, had remains of bird nesting material in them (see Figure 7). The nestbox and topping treatments had significantly more nesting material than expected and woodpecker holes had less than expected (X^2 = 31.623, DF = 1, P < 0.0001).

Live bats were seen in 6 nest boxes and 1 woodpecker hole (see Figure 7) and evidence of bats was recorded from 14 nest boxes and 13 woodpecker holes, however evidence of bats is easy to miss even when using an endoscope. There were no significant associations found between the presence of bats (X^2 = 2.259, DF = 1, P = 0.1329) or bat droppings (X^2 = 0.107, DF = 1, P = 0.7435) with woodpecker hole or nestbox and topping, but this may be due to there being too few records to be able to identify any patterns.

Figure 8 – a woodpecker hole where the callus has been damaged. It is unclear what species caused this.

Almost 40 % of the woodpecker holes had some form of damage on the wound wood, some of which appeared to be quite old (see Figure 8). It was not clear what species had created this damage. Live wood mice (*Apodemus sp.*) (see Figure 9) were found in two of the veteranised cavities (one woodpecker hole and one nest box) and hazel nuts that had been eaten by wood mice were found in another woodpecker hole and a nestbox. In addition, fresh leaves (see Figure 10) were found in three woodpecker holes and the nestbox that contained live wood mice.

Figure 9 - wood mice (*Apodemus sp.*) in a woodpecker hole.

Figure 10 – fresh oak leaves filling a woodpecker hole.

Aspect

The aspect of the treatments was evenly distributed in the implementation of the trial (X^2 = 31.279, DF = 28, P = 0.3048). Southern-ness did not have any impact on the presence of decay on the horse damage, nestbox, woodpecker hole and controls (X^2 = 4.694, DF = 4, P = 0.3202). There were very few numbers of woodpecker holes and nestbox and topping treatments with either live bats or bat droppings, and the orientation of the treatment did not show any association with bats (live bats: X^2 = 3.691, DF = 4, P = 0.4495; presence of bat droppings: X^2 = 1.014, DF = 4, P = 0.9077). Similarly, for bird nesting material there was no significant association with these treatments and orientation (X^2 = 7.691, DF = 4, P = 0.1036).

Bird monitoring

225 trees were visited between 14th and 27th May 2020. Only 12 of these trees had confirmed sightings of birds using either the woodpecker holes or the nestboxes for breeding (see Table 2). A pied flycatcher (*Ficedula albicollis*) and a great tit (*Parus major*) behaved as though they were nesting but were not seen either leaving or entering the woodpecker hole and nestbox respectively (and are thus not recorded in Table 2), in the time period allowed.

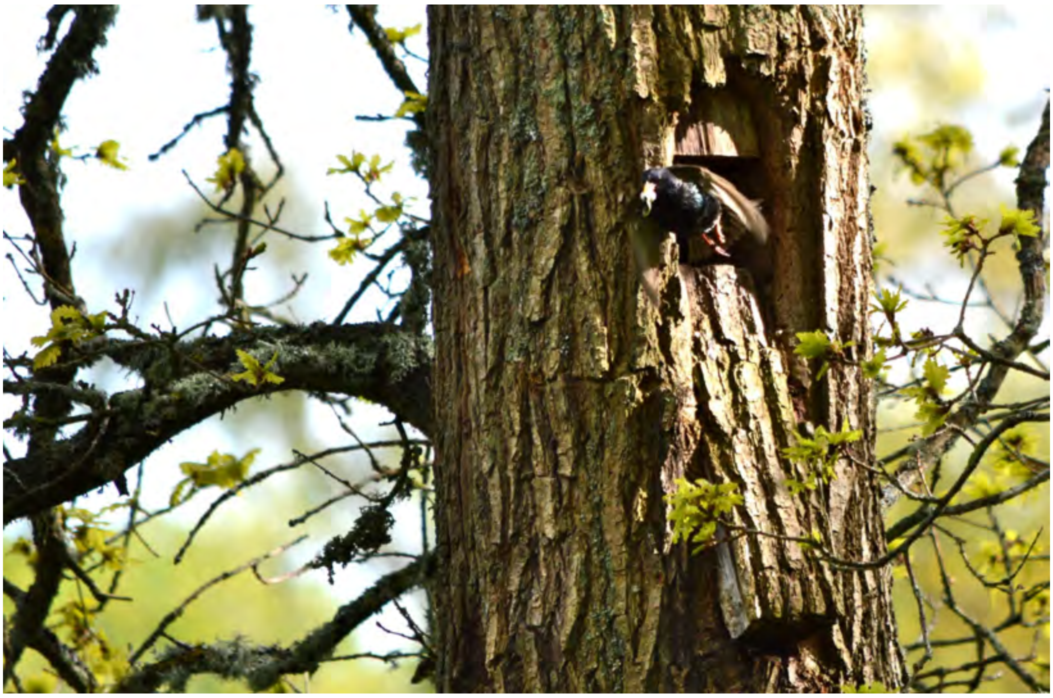

Figure 11 – a starling (*Sturnus vulgaris*), using a nest box, despite the fact that the 'lid' is no longer in the original position.

Table 2 – Overview of the treatment and bird species where nesting birds were recorded in 2020.

Treatment	Number	Bird species
Nestbox and Topping	5	Blue tit (*Cyanistes caeruleus)*
Woodpecker hole	4	Blue tit (*Cyanistes caeruleus)*
Woodpecker hole	1	Great tit (*Parus major*)
Woodpecker hole	1	Nuthatch (*Sitta europaea*)
Nestbox and Topping	1	Starling (*Sturnus vulgaris*)

Discussion

Mortality rates are lower than expected given that a study by Drobyshev et al., 2008 found that annual mortality rates of oak varied between 0 and 13% with an average 1.68%. In our population of trees, the annual mortality rate was, amongst the treated trees, around 0.24%, with only 12 trees having died since the start of the study. According to Drobyshev et al, 2008, and Monrad Jensen and Löf, 2017, it could be expected that in the region of 10-14 oak trees would die per year. We cannot draw any conclusions about the size of trees veteranised in combination with the treatment, as the mortality rates were so low. It is very positive however that so few trees have died, given that the objective with veteranisation is to damage the trees and not to kill them. It is perhaps also a reflection of the fact that all trees included in the trial were considered to have good to high vitality at the point of veteranisation. Trees cope much better with damage when they have good vitality (Lonsdale, 2013).

In terms of growth rates, the treatment nestbox and topping had grown significantly less than any of the other treatments. This is expected given that nestbox and topping treatment involved two major types of damage with the removal of a large chunk of the main stem and up to one half of the live crown. This compared with ringbarked branch, broken branch and control which would not be expected to cause much, if any, impact on the tree. Horse damage appears to have had a significant impact on the proportion of the crown which was alive in 2020 compared with most of the other treatments. This is likely to be a consequence of root death, which may be expected when a third of the sapwood on the lower trunk is removed. It would be interesting in the future to monitor the development of decaying wood in the crown associated with this treatment and even the impact on roots. The impact on the root system has not been followed up and this may prove interesting in any future work.

It proved challenging to measure or identify any parameters, such as decay, consistently for the broken branch and the ringbarked branch treatments, also for the topped part of the nestbox tree. These treatments could occur high up from the ground and with the trees being in full leaf it was often difficult to even find the treated branches, particularly the broken branches. It is expensive and time consuming to have to undertake monitoring which involves an arborist; alternatively, these treatments would have to be studied when there are no leaves on the trees.

Previous studies of cavity formation in oak (Ranius et al, 2009) have shown that they are commonly associated with dead branches that subsequently break off. This was why two branch treatments were included in this study. The results show however, that dead branches over 10 cm in diameter are a feature that were present on all trees regardless of veteranisation treatment. This would indicate that veteranisation treatments on specific branches do not necessarily speed up the production of cavity formation in the way it was intended. In this regard in future, it may be more fruitful to ringbark the main trunk or branches over 25-30 cm in diameter.

Encouraging the development of decay, by creating dysfunctional wood, is one of the key objectives with veteranisation, given that a wide range of threatened species are dependent upon decay or the fungi which cause decay (Sundberg et al, 2019). Horse damage (Figure 3) and nestbox creation (Figure 12) had more decay than either the controls or woodpecker holes. This means that in terms of creating decay, the nest box along with the horse damage are useful treatments, particularly given that they seem likely to encourage different fungal assemblages following treatment (Menkis et al, 2020). It seems likely to be important to leave a large amount of exposed wood in the horse damage treatments to increase the chance of decay development. This is because there significantly less decay where the amount of exposed wood was less. It is still early days in terms of decay development in trees, but it is promising that decay did develop more quickly than would have occurred naturally as a consequence, of at least two of the treatments (nestbox and topping and horse damage) (see Figure 3 and Figure 12).

Figure 12 – a nestbox with decay. This nextbox has also been used by bats. Exit holes from saproxylic beetles can also be seen on the exposed wood below the nest box.

The fact that there was less decay than expected in the woodpecker hole could perhaps be explained by the fact that the size of the damage was much smaller than either of the other two treatments (horse damage and nestbox). 21% of the woodpecker holes had also completely occluded (see Figure 4), meaning that decay

could not be seen, even if present. In addition, the amount of decay was less where there was more occlusion and higher growth rates.
After eight years, veteranisation did not increase the frequency of naturally occurring hollows over 5 cm in diameter, which means that the visible impact of veteranisation was still confined to where the treatment was carried out. This means that the cavities created by veteranisation make up a greater resource than would have been expected in a population of oak trees without veteranisation. Some of the observations such as the use of the cavities by birds, bats and mammals highlight the huge significance of cavities, for many species other than those directly targeted by this work.

The 'lids' 20 of the 127 nestbox and topping treatments had fallen out. It is not possible to say what impact this may have on the value of the damage for associated species. It could be speculated that without the 'lid' the cavities created will not provide shelter for bats or birds and the microclimate will presumably be different due to the increased exposure of the heartwood and sapwood. The 'lids' also appear to have some form of function in inhibiting the cavity from completely occluding. It is however interesting that birds had still nested in several of the cavities despite not having any protection in the form of the lid (see Figure 13)

Figure 13 – nesting material in a nestbox, despite the 'lid' having fallen out some time ago.

Sap runs are a microhabitat feature that are used for feeding by a range of insects and birds (Sundberg et al, 2019). In the author's previous veteranisation efforts, it has been an unpredictable feature to create. Some 24% of the trees had sap runs in 2020. There were more sap runs associated with the nestbox and woodpecker hole than the other treatments and controls. Sap runs were associated both with the climbing spike damage as well as around the cavities that had been created. However, given the fact that sap runs were more commonly associated with nestbox and woodpecker hole treatments than for example ringbarked branch and broken branch, (where climbing spikes were also used), suggests that more damage may be required to stimulate sap runs. In general, the damage by climbing spikes was greater in association with both the nestbox and topping and the woodpecker hole because the arborist had to move around into several positions when undertaking these treatments. This has however, not been possible to quantify in this study.

The lifting bark (Figure 6), which created a small void on 66% of the horse damage, nestboxes and woodpecker holes has been identified as a feature used by several bat species (Andrews, 2018) as low as 1 m from the ground. This was a microhabitat that was created as a consequence of the callus formation and the development of dysfunctional wood. It would be worth investigating the use and sustainability of this feature in future studies.

Bats in trees are very easy to miss when surveying trees as they can squeeze into the tiniest of spaces. They are also very transient and thus may not be present at the time of the survey (Andrews, 2018). Finding evidence of their presence, such as from droppings is challenging and was likely under-recorded in our monitoring work, particularly as an endoscope often had to be used to look inside the cavities (see Figure 14). It is however very interesting that live bats were found in both the nest boxes and the woodpecker holes and this is a promising result. Creating artificial roosts for bats, particularly for tree-roosting bats has not been undertaken to any large extent and bat boxes do not always provide roosts for the targeted species of bats (Grüebler et al, 2014; Griffiths et al, 2017). Several studies have also shown that cavities in trees compared with boxes have a greater buffering capacity (Fabianek et al, 2015; Rueegger, 2017; Griffiths et al, 2018). Of particular interest was the nest box that contained a group of brown long-eared bats (*Plecotus auritus*), which are a species often associated with trees. Further work, specifically searching for bats would be very useful, perhaps even using remote camera traps, to better understand the features and species that use the cavities created by veteranisation (Griffiths et al, 2020).

Figure 14 – a group of brown long-eared bats (*Plecotus auritus*) captured on film in a nestbox.

The damage seen quite frequently on the callus (see Figure 8) is an interesting phenomenon and requires further investigation. They may have been feeding marks from woodpeckers, but on one of the trees the marks were clearly teeth marks rather than woodpecker feeding marks (see Figure 15). Studies in North America, where cavities were created reported that squirrels gnawed on the callus wood (Carey and

Reed Sanderson, 1981) and they suggest the importance of small mammals in keeping cavities open. Very little literature could be found to help explain what species could be causing the damage from Europe. It could be speculated that the wood mice or perhaps squirrels have been gnawing on the callus to slow down the process of occlusion. Once again it would be very interesting to do further work specifically looking at what species might be causing the damage to the wood wound. Another observation which was difficult to explain was the presence of lots of fresh oak leaves in three woodpecker holes and one nestbox, but after the bird nesting season (one of which also contained live wood mice). The mice perhaps took in the leaves to create a nest or to ensure they were not conspicuous for predators?

Figure 15 – marks on the edge of a woodpecker hole which resemble teeth marks. This hole also contained hazelnuts that had been eaten by a wood mouse.

It was interesting to note that the treatments were being used by various social bees, wasps and in particular tree ants and wasps. The tree ants (e.g. *Lasius brunneus*) were seen at several sites and are known as a species associated with cavities in trees. Their nests are in turn often home for several beetle species (Ehnström & Waldén 1986). The fact that these species were found associated with the horse damage, woodpecker hole and nestbox treatments could indicate that the veteranisation treatments are mimicking naturally formed features attractive to the tree ants.

In our study, we wanted to identify if the aspect of the treatment had any impact on the species associated or the development of decay. After eight years, the aspect of the veteranisation treatment did not have any significant impact on the presence of decay, bats or use by birds. It might be expected that the aspect may have a greater impact on the presence of saproxylic insects given the fact that many of these species require warmth and sunlight to develop (Stokland et al, 2012; Sundberg et al, 2019). There were too few records of bats and bat remains, to see any patterns at this stage, although this is something that would be interesting to follow up as bats show some degree of roost selection according to aspect at different times of the year (Griffiths et al, 2017; Andrews, 2018).

Conclusions and lessons learned

The mortality rate of the trees included in this trial was low, which suggests that tree selection was in the right order for veteranisation, given the objective was for the trees to survive. The cavity forming methods alongside horse damage have created microhabitats more quickly, than would have occurred naturally, including decay, sap runs and of course the cavities themselves. That decay is now developing and species such as birds, bats, tree ants and other social bees and wasps that are making use of the features are also positive indications that the chainsaw-carved features are mimicking naturally formed features.

It is challenging to undertake monitoring of veteranisation features that cannot be seen/reached from the ground such as the ringbarked and broken branches and the 'topped' part of the nestbox treatment (see Figure 16). It would require arborists to undertake monitoring of these features in the future, which is something to bear in mind when planning future work. This also means that there are few conclusions that can be drawn about the value of these features from this monitoring study.

Figure 16 – a lesser spotted woodpecker drumming on a 'topped' fracture cut in association with the nestbox treatment. These were often difficult, if impossible to see when the trees were in full leaf.

The fact that dead branches over ten centimetres in diameter were found equally as frequently on control trees as treated trees suggests that this treatment is of limited benefit in speeding up the production of these features. In the future, selecting much larger branches e.g., over 25 cm, or ringbarking the stem at midway point in the live crown (as has been undertaken in other more recent projects) may be more fruitful.

The fact that many of the cavities created have been used and are being used by several different bird species and by mammals (bats and mice) is very promising and means that these techniques do improve habitat quality on sites with few tree hollows.

In future it may be worth considering removing the bark and cambium around the woodpecker hole as this may help slow down the process of occlusion. It is possible that the dysfunctional wood created as a consequence of the woodpecker hole may decay anyway and thus provide habitat in the future, even if completely occluded.

It appears that the size of the trees included in this trial is in the right order. Some observations from individual trees and sites where nestboxes had been created in smaller trees (25 cm in diameter) suggest that larger trees would be recommended in the future (30 cm diameter and above). This is because several of these smaller trees had grown so much that the 'lid' of the box had been pushed into the cavity such that there was no remaining cavity behind the lid. The treatment may still have the desired effect with regard to the encouragement of decay, but these trees no longer had functioning 'cavities'. The 'lids' also appear to slow the process of occlusion.

Figure 17 – a nestbox where the 'lid' is no longer in the original position and is being 'pushed' out of the tree!

At the start of the study, there was concern that the trees with nestboxes may be vulnerable to failing at the point of the nestbox and this treatment was thus combined with 'topping' to reduce the height, and thus risk, of torsional failure. Only one tree had broken off at the point of the nestbox, which is a reassuring result and suggests that the combination of topping with the nestbox is worthwhile continuing with.

After eight years, a large proportion of the lids were secured in place by the callus growth, which was also the intention. It is however important to ensure that the lid is a good fit when undertaking the treatment (by being accurate when cutting), and adopting a method to secure the lid in place is also worthwhile. An example of this involves drilling a hole through the lid and into the wood, into which a dowel stick is pushed in to secure the lid in place. It is also worth noting that despite the nestbox looking rather like a 'letterbox' when created, the growth of the callus means that the cavities look much more natural after eight years than when first created (see Appendix 2).

In summary, after eight years, the veteranised oaks included in this study show positive results in terms of improving the quantity of microhabitats in young trees. It is recommended that the focus in the future is primarily on the creation of cavities and stem damage, rather than branch damage.

Future monitoring

In 2018 there was limited amounts of decay in the nestbox, woodpecker hole and horse damage treatments. In 2020 however, decay had become more frequent. It would thus be very interesting to repeat the fungi survey to see if and how the species assemblages have changed in the treated trees compared with the controls (Menkis et al, 2020).

The insect monitoring carried out in 2014 would be useful to undertake again in the coming year or two so that the results from 2014 can be compared after 8 – 10 years. It would be useful to use the same method as used in 2014 (window traps) but perhaps combine with emergence traps to see how the results differ. Information regarding the value of the veteranised treatments for saproxylic insects is important to establish.

It is challenging to monitor features, which are higher than four to five metres above the ground, without the help of an arborist. The cost of doing any monitoring of these features on all trees and sites may be prohibitive, but it would be interesting to look at the ringbarked branches, broken branches and the topped fracture cuts at a selection of sites by working with an arborist. Another challenging, but interesting area to investigate further is the impact of the veteranisation treatments on the roots of the trees. This may be possible by carefully excavating an area of the root system on a selection of treated trees and controls. It would be expected that the live crown may be a proxy for the impact on the root system, but this does not provide any insight in the microhabitats created as a consequence of root damage such as pockets of decay or cavities.

More detailed monitoring of the cavities would be very interesting given the difficulties of being certain of the presence of bats and other animals potentially using the cavities. To find out the reason and the creature behind the damage to the callus would be particularly interesting. Perhaps this could be undertaken using trail cameras set up at a selection of trees/sites. This has been very fruitful when trialled on a small-scale by the author. A more detailed survey targeting bats would be very useful, given the fact that bats are less likely to use bat-boxes. Measuring the temperature of the cavities such as Griffiths et al, 2018 and Rueegger, 2017 have done may also be very interesting when compared with bird/bat boxes and natural cavities.

Better results in terms of the variety of bird species using the cavities created might be expected if the holes created were more targeted in size i.e. 5 cm for starlings and higher up in the tree, to reduce the likelihood of predation. The height of four metres was chosen to make it possible to undertake monitoring with a ladder. Smaller holes would however more quickly callus over. Work by Zapponi et al, 2014 showed that targeted hollows for bird species do work but require maintenance after only a few years.

Much of the dysfunctional wood created in the nest box and the lid and the horse damage had lots of insect exit holes. This would be something worth following up to see if it were possible to identify the species that had emerged, or at least the assemblages of species.

Finally, the veteranisation techniques do create more dysfunctional and decaying wood, but this is not something that was measured in a quantifiable way. It may be useful to develop a method for measuring the amount and type created by specific veteranisation techniques.

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Appendix 1 – description of the international trial

Tree and site selection

This international trial was initiated by the County Board Administrative Board of Kronoberg in relation to their work with threatened species and in cooperation with Nordens Ark and funded by The Swedish Environmental Protection Agency, with Pro Natura engaged as a part of the project management team for implementation. The aim was to make it possible to evaluate the benefits of veteranisation on a large scale by the establishment of a network of sites over a large geographic area (Southern Sweden (16 sites), Norway (1 site), England (3 sites) and by keeping the number of treatments tested at a relatively low level. The treatments still covered a broad enough spectrum so that there was good variation in the type of substrate created and more importantly how it is created (ringbarking, hole creation, bark damage: each stimulate a different type of decay process). The intention was also to ensure that the mortality rate of the treated trees would not be too high.

A total of 49 oaks, between 25 and 60 cm in diameter, and a maximum age of 120 years were selected. The oaks did not have any visible natural hollows or holes in the trunk. It was acceptable however, that the oaks had small dead branches under 10cms in diameter. All oaks were visibly healthy at the time of selection and treatment. Of the 49 oaks required for each site, 21 oaks needed to have at least one large live branch (at least 10cms in diameter below 8m in height) for broken branch, ringbarked branch and associated control. The other 28 trees for the other treatments, nestbox and topping, woodpecker hole, horse damage and associated control, could be either with or without large branches.

Each oak was marked with a metal tag, attached to the tree with a single 6 cm nail so that so that the tag rested on the tree and the nail stuck out at least 2cm, allowing for growth of the trunk. The tag was placed on the northern side of the tree at a height of 2 m. Coordinates and girth were recorded for all trees and a photograph was taken when the treatment was carried out. Oaks with for example twin-stems were not included.

35 of the 49 oaks, were treated with one of the five different selected veteranisation techniques and 14 trees were controls. A stratified random selection process decided which tree had which treatment and those which were controls. This avoided bias and ensured that the treatments will be spread across the diameter ranges. The cardinal point of the tree where the treatments was applied was evenly distributed among treated trees.

The five veteranisation treatments were tested practically and calibrated in 2011, with the four different teams of arborists who undertook the work. The methods were described in detail following calibration to iron out any potential difficulties in carrying out the treatments. The actual veteranisation work took place in September and October 2012, apart from at Haga Ekbackar which was done in the autumn of 2011. In total 700 trees were veteranised of the 980 trees included in the trial.

Table 3 – the list of sites included in the original trial.

Site name	County	Country	Owner/Manager	Protection status
Berg fengsel	Vestfold	Norway	NINA Norge	
Ashridge Estate	Buckinghamshire	England	National Trust	NR
Ickworth Park	Suffolk	England	National Trust	
Ashtead common	Surrey	England	City of London	NR
Tromtö	Blekinge	Sweden	Länsstyrelsen Blekinge	NR, N2000
Bondberget	Jönköping	Sweden	Jönköpings kommun	NR
Brunnstorp NR	Jönköping	Sweden	Länsstyrelsen Jönköping	NR
Ekenäs	Kalmar	Sweden	Länsstyrelsen Kalmar	NR
Vannserums bäck	Kalmar	Sweden	Länsstyrelsen Kalmar	NR
Huseby	Kronoberg	Sweden	Statens Fastighetsverk	
Toftaholm	Kronoberg	Sweden	Länsstyrelsen Kronoberg	NR
Harsbo-Sverkersholm	Östergötland	Sweden	Länsstyrelsen Östergötland	NR
Tinnerö eklandskap	Östergötland	Sweden	Linköpings kommun	NR, N2000
Västerby	Östergötland	Sweden	Länsstyrelsen Östergötland	NR
Fulltofta	Skåne	Sweden	Region Skåne	NR
Hjälmhults kungsgård	Skåne	Sweden	SFV	
Haga ekbackar	Uppsala	Sweden	Länsstyrelsen Uppsala	NR, N2000
Strömsholm	Västmanland	Sweden	SFV/Länsstyrelsen Västmanland	NR, N2000
Gatumarken	Västra Götaland	Sweden	Nordens Ark	
Korsviken	Västra Götaland	Sweden	Nordens ark	

Veteranisation techniques used (treatments)

All of the treatments were carried out using climbing spikes to get up into the trees, to ensure a safe working position. The climbing spikes also formed a part of the veteranisation treatments. The only exception was the ringbarking at ground level (horse damage). All cut material was left, as far as possible, in situ. At least one of each of the treatments was carried out in each of the four main cardinal points.

Nestbox and Topping

This involved cutting a long rectangular hole into the centre of the trunk and putting this back as a 'lid', but with a cavity behind. The lower part of the rectangular hole was placed at 4m above the ground. The width of the hole was a maximum of 1/3 of the stem diameter or at least 10cm and the length 50 cm. The piece of wood was then removed by placing a cut in at the side of the trunk at 90^{o}. After the piece of wood was removed, the top 8 cm was cut off (and saved providing the opportnuity to calcuate the age of the tree at a later date) and approximately 7-10 cm of the inside of the piece of wood was cut away. This 'lid' was then returned to the hole and secured using two nails. The tree was also 'topped', ensuring that at least half of the living crown was retained and at a point at least 2 m above the top of the nestbox. The cut surface was given a 'fracture cut'. Climbing spikes were used.

Woodpecker hole

An oval-shaped hole, 8 cm wide and 12 cm long was sawn into the tree using a chainsaw with a carving bar. The lowest point of the hole was placed at 4m above the ground. Climbing spikes were used.

Horse damage

The bark was be removed from ground level up to 1m in height and from 1/3 of the girth of the trunk and all living tissue was removed. Bark from any surface roots were removed as well.

Broken branch

The lowest, living branch over 10 cm in diameter under a height of 8 m, was sawn off at approximately 20cm from the trunk with a cut from above which went half way through the branch. The branch was then be pushed/pulled so that it ripped off as much as possible. The remaining part of the branch was cut so that it looked like a natural fracture. Climbing spikes were used.

Ringbarked branch

The lowest, living branch over 10 cm in diameter and under a height of 8 m had the bark and living tissue removed all the way around the branch from about 20cm from the main trunk and for a width of 20cm. Climbing spikes were used.

Control trees

Two types of controls were created, where the only difference was that one group of controls had a live branch over 10 cm in diameter under a height of 8 m. The other control group could both have or not have a live branch over 10 cm under a height of 8 m.

Table 4 – Numbers of trees per treatment type at each site.

Treatment	Total number of original trees per treatment and site
Controls	14
Broken branch	7
Horse damage	7
Nestbox and topping	7
Ringbark branch	7
Woodpecker hole	7

Appendix 2 – photos of treatments in 2012 and 2020


The same nestbox in 2012 (left) and 2020 (right)


The same woodpecker hole in 2012 (left) and 2020 (right)


The same broken branch in 2012 (left) and 2020 (right)


The same horse damage in 2012 (left) and 2020 (right)


The same ringbarked branch in 2012 (left) and 2020 (right)

Länsstyrelsen skapar samhällsnytta genom rådgivning, samordning, tillstånd, tillsyn, prövning, stöd och bidrag. Vi skyddar miljön, ser till att viktiga natur- och kulturvärden bevaras och skapar förutsättningar för att utveckla landsbygden och näringslivet i länet. Vi har även samhällsviktiga uppdrag inom bland annat krisberedskap, sociala frågor, djurskydd och samhällsplanering.
På så sätt bidrar vi till Länsstyrelsens vision om ett livskraftigt Östergötland

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