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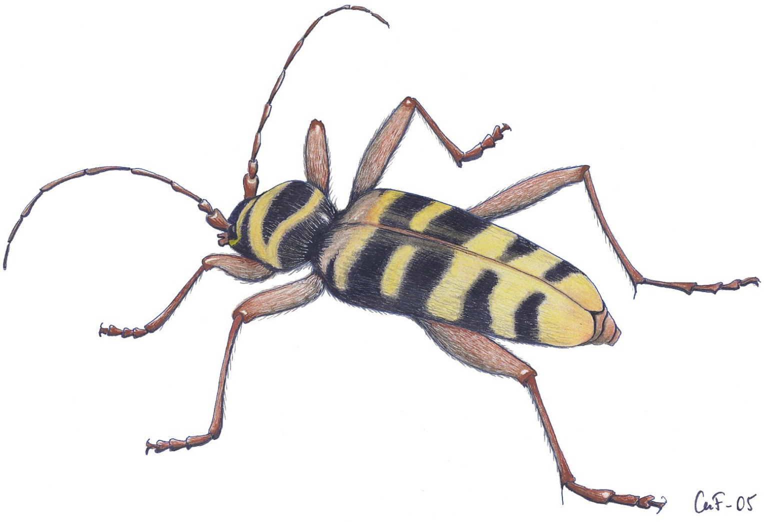

Illustration: Christina Fagergren

Habitat preferences and reproductive success for the threatened longhorn beetle *Plagionotus detritus*

Lina Sundkvist

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SUPERVISOR : *MATS JONSELL*, DEPT OF *ECOLOGY*

COSUPERVISOR: *ERIK SAHLIN*, DEPT OF *ECOLOGY*

EXAMINER: *CHRISTER BJÖRKMAN*, DEPT OF *ECOLOGY*

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SLU, Institutionen för ekologi
Box 7044, 750 07 Uppsala

Swedish University of Agricultural Sciences
Department of Ecology

Author: Lina Sundkvist
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Abstract

Plagionotus detritus is a threatend longhorn beetle that only exists at one site in Sweden. It is saproxylic and depending on recently dead coarse oak wood for its larval development. Trees at Djurgården, Stockholm that have been colonized by *Plagionotus detritus* has been studied to find out the habitat preferences of the species and to see what affects the density of beetles in a tree. The bark of some trees and wood from the breeding project at Nordens Ark has also been studied to find out what affects the species reproductive success. The reproductive success was measured in two ways, the larval mortality and the size of the hatching holes.

My hypothesis was that sun exposed, coarse trees with thick bark would produce more beetles. I found that the south side of the trunks had more hatching holes per m^2 compared to trunks that faced the north side. No relationship was found between the production of beetles and bark thickness and tree diameter. My hypothesis was to find a decreased size of the hatching holes and increased mortality when the density of larvae increases and the bark gets thinner. I also expected an increased reproductive success when the larvae consumed more bark. When the mortality was studied did all my result supported these hypotheses and mortality seems to be a good way to measure fitness. The size of the hatching holes did not show any relationship with the factors and was probably not a good way to measure fitness.

The results can be used in the future conservation work with *Plagionotus detritus*. Sun exposure is showed to be an important factor that will increase the production of beetles in a tree. It is important to cut around the potential host trees to make them as sun exposed as possible. Enough breeding material should be supplied to avoid a to high density of larvae and allow the larvae to consume as much bark as possible. An estimation from my data is that one female that deposits 50-80 eggs needs 2,5-400 m^2 of bark to make all the eggs hatch. The breeding material should preferably have thick bark and be place in an sun exposed area to minimize the risk for mortality and there by increase the fitness.

Key words: Cerambycidae, habitat preference, insect, longhorn beetle, oak, reproductive success, threatened

Populärvetenskaplig sammanfattning

Plagionotus detritus val av livsmiljö och förökningsframgång

Bredbandad ekbarkbock (*Plagionotus detritus*) är en av de mest sällsynta skalbaggarna i Sverige. Idag finns den i Sverige bara i Nationalstadsparken i Stockholm och har därför hamnar på den svenska rödlistan för hotade arter. Bredbandad ekbarkbock lever på nyligen döda, stora ekar som gärna ska vara solbelysta. Större områden med riktigt grova ekar är idag sällsynt i Sverige och anses vara ett av de största hoten mot arten. Andra hot är konkurrens från andra skalbaggar som lever i samma miljö och att larverna är föda för hackspettar.

Skalbaggen är 10-19 millimeter lång och liknar en geting med sina svarta och gula ränder. Honan lägger äggen på ekens stam eller gren, helst på grov solbelyst bark. Efter två veckor kläcks larven som börjar äta insidan av barken. Bredbandad ekbarkbock tillbringar 1-2 år som larv och lossar man barken försiktigt från trädet kan man se så kallade larvgångar där larven gnagt sig fram. Någon gång under försommaren förvandlas larven till en puppa som den sedan tillbringar cirka 2 veckor som innan en vuxen skalbagge kryper fram. Skalbaggen gnager sig ut från barken och lämnar ett kläckhål efter sig. Den vuxna skalbaggen lever bara i några veckor och ska då hitta en partner för att para sig och lägga ägg innan den dör.

Ett åtgärdsprogram har upprättats där arten beskrivs och det föreslås vad som behöver göras för att man ska lyckas bevara den. En viktig del i åtgärdsprogrammet är att göra en utsättning av skalbaggar i områden där den tidigare har funnits. Naturreservatet Båtfors i norra Uppland är ett påtänkt område och på Nordens Ark, ett zoo på västkusten, har man försökt att föda upp skalbaggar som ska användas till utsättningen. Man vet inte så mycket om hur bredbandad ekbarkbock lever och beter sig och att ta reda på det är ytterligare ett mål med åtgärdsprogrammet. För att kunna bevara bredbandad ekbarkbock i Sverige och Europa måste man veta mer om artens livsmiljö, var den trivs och vad den behöver för att klara sig bra. Hur bra en art klarar sig brukar ofta mätas i hur framgångsrik förökningen är.

Från den solbelysta sidan av trädstammen hade mycket fler skalbaggar kläckts fram än från den skuggiga norrsidan. I min studie verkade inte trädets diameter och barktjocklek ha någon betydelse för hur många skalbaggar som kläcktes fram. Jag studerade även hur artens förökningsframgång påverkades av antalet larver som finns under barken, barktjockleken och hur mycket bark en larv kan äta. Förökningsframgången mättes i dödligheten, hur många larver som dog innan de blev vuxna skalbaggar. Ju högre dödligheten är desto lägre förökningsframgång har arten och ju större skalbaggarna är, desto högre förökningsframgång har de. Fler larver hade dött om träden hade tunn bark, det var mycket larver under barken och om larverna kunnat äta lite bark.

Att friställa ekar både på Djurgården och i Båtfors så att de blir solbelysta är viktigt för att gynna bredbandad ekbarkbock. Tjock bark ger inte fler skalbaggar men minskar risken för att dö som larv eftersom den antagligen skyddar bättre mot hackspettsangrepp, det finns mer mat för larverna och mer plats att placera puppkammaren. Att välja uppfödningsved med tjock bark är därför att föredra. Om den dessutom placeras solbelyst ökar antalet skalbaggar som kläcks. En grovuppskattning från mina data visar att om en hona lägger 50-80 ägg behövs det 2,5-400 m^2 bark för att alla äggen ska kunna kläckas. Mycket information om arten saknas, bland annat är det fortfarande okänt hur långt den kan flyga och sprida sig, hur många ägg den lägger och hur könsfördelningen ser ut. Vidare studier om bredbandad ekbarkbocks biologi är viktigt om man på sikt ska kunna bevara arten och få en livskraftig population.

Introduction

Plagionotus detritus is one of the rarest longhorn beetles in Sweden and it is classified as critically endangered (CR) according to the Swedish red list (Gärdenfors 2005). In older days *P. detritus* was found in several landscapes in Sweden; Skåne, Blekinge, Gotland, Öland, Kalmar mainland, Västra Götaland and Östergötland. But now it is regarded as regionally extinct at these places (Gärdenfors 2005). Many of these observations are from the nineteenth century and some of them from the 1950´s. The species has only been found in Stockholm, Uppsala and Kalmar County during the last decades (Gärdenfors 2005). *Plagionotus detritus* colonizes coarse oak trees that preferably are sun exposed (Palm 1942). The loss of habitat is suggested to be the major threat to *Plagionotus detritus* (Ehnström 2005). Parasitism from parasitoid wasps and predation from the great spotted woodpecker are two other threats that can have caused the decrease of *Plagionotus* detritus.

In the nature conservation work with *Plagionotus detritus* it is considered so important that the Swedish Environmental Protection Agency made an action plan for the conservation of *Plagionotus detritus* (Ehnström 2005). The action plan suggest to reintroduce the species on sites where it has gone extinct to make sure that the species can survive nationally. For a successful introduction and future management is it important to know the species habitat preferences and what will affect the production of beetles. Data is needed both for the field conditions where new populations shall establish, and for lab-conditions as the introduction will require indoors breeding to get many individuals enough. The reintroduction should be done at a former site for *Plagionotus detritus* and there is one suitable site in the north of Uppland, the nature reserve Båtfors (Ehnström 2005).

The zoo Nordens Ark has been trying to breed *Plagionotus detritus* during some years and the aim is to use the beetles for a reintroduction. To make a successful breeding and a successful introduction it is important to have beetles with good reproductive capacity. Begon et al (1990) describes the fitness as: "the fittest individuals in a population are those that leaves the greatest numbers of descendants relative to the numbers of descendants left by other, less fit individuals in the population". The body size is often combined with good fitness though the offspring size and number are depending on the female size (Stearn 1992). The size of the hatching holes are at most cases the same as the cross section of the adult insect (Ehström & Axelsson 2002). The mortality is another way to measure the fitness. The mortality will affect how many beetles that can be reared out from the breeding material and more information about what will affect the mortality is therefore important.

Questions and hypotheses

From the beginning the plan was to study the dispersal capacity, mating behavior, egg laying capacity, sex distribution and wood preference with adult beetles bread at the lab. As the breeding failed this plan was rejected and instead I studied questions were I could use the wild population at Djurgården. The species habitat preferences, mortality of larvae and maximum bark utilization and density were studied.

Do stem diameter, the bark thickness and sun exposure affect the production of beetles per m²?
My hypothesis was that trees with larger diameter and thicker bark will have a higher density of beetles per m^2. I also expected to find a larger production of beetles per m^2 on the sun exposed side of the stem compared to the shaded north sides.

Is the reproductive success affected by the density of larvae, the bark thickness and the amount of bark consumed by the larvae?
My hypothesis was to find an increased mortality and/or decreased size of the hatching holes when the density of larvae increases. I expected the mortality to increase and the size of the hatching holes to decrease when the bark was thinner. I also expected the mortality to decrease and the size of the hatching holes to increase when the area of consumed bark per larva was higher.

What is the maximum production of beetles in a tree and the maximum consumed bark area of larvae? I wanted to calculate an interval for the mean production of beetles in a tree. This will be useful information for estimating population size at a site. It will also be helpful to estimate how much breeding material that is needed for each generation to make a successful reproduction.

Plagionotus detritus

In Sweden *Plagionotus detritus* is depending on recently dead, old oaks (*Quercus spp.*) for its larval development (Ehnström 2005). In Middle Europe has *Plagionotus detritus* also been found on *Betula* spp., *Carpinus betulus, Fagus sylvatica* (Ehnström 2007), *Salix* spp., *Alnus* spp. and *Castanea* spp. (Ehnström 2005).

Plagionotus detritus is often found on coarse wood (Figure 1), but it has also been found on branches with a diameter of 20 centimeters (Ehnström 2005). In 1955 Palm found the species on oaks that had been damaged by fire. *Plagionotus detritus* had avoided the burned bark and colonized the parts where the fire had not reached. In the trees damaged by fire he could only see *Plagionotus detritus* and not other saproxylic longhorn beetle species like *Plagionotus arcuatus* or *Clytus arietis* (Palm 1955).

The wood should preferably be sun exposed (Palm 1942) and it is presumed that *Plagionotus detritus* is favored by a warm microclimate (Ehnström 2005). In some cases authors have observed that larval galleries were denser in sun exposed wood than in shaded wood (Palm 1942, Isaksson 2005).

In the 1930´s the species was described as common in north Uppsala county, in the area of Båtfors (Palm 1942) and in the early 1970´s was *Plagionotus detritus* found as well (Baranowski 1975, 1980). In the early 1940´s it was also found in Strömserud, Småland (Palm 1953). Some authors have been searching for *Plagionotus detritus* in the Båtfors area during the latest decades but it has not been found since 1984 (Eriksson 2005). One individual was found in Bålsta in 2001 and in 2006 one individual was caught in a window trap in Nacka. These two observations are the only ones outside Djurgården national park in Stockholm (Isaksson 2008) but were probably from the population at Djurgården. The population at Djurgården is the only known remaining population but it is possible that the species still exists in small numbers in Båtfors and Strömserud (Eriksson 2005).

Plagionotus detritus is also found in Middle- and South Europe, Turkey and Caucasus to northern Iran (Svacha & Danilevsky 1988) and there it is also reported to be decreasing (Ehnström 2005). The latest reports of the species from Northern Europe, except Sweden, were from Denmark (Hansen 1964) and the Baltic (Pilneckis & Monsevicinus 1997). In Denmark *Plagionotus detritus* is considered to be extinct (Anonymous 2009). Those reports are more than 150 years old and some of them are not so reliable (Anonymous 2009).

Figure 1. An oak tree colonized by *Plagionotus detritus* at Djurgården.

Threats

The loss of habitat is suggested to be the major threat to *Plagionotus detritus* (Ehnström 2005). In Sweden the numbers of old large oaks have decreased drastically during the last century (Eliasson & Nilsson 2002). In 1558 all oak trees were declared to be a property to the Swedish King Gustav Vasa. This meant that they could not be damaged or felled and at this time the numbers of oaks increased and they were protected until 1830 (Eliasson & Nilsson 2002).

It has been discussed that the close relative *Plagionotus arcuatus* can out compete *Plagionotus detritus* in areas where they both exists. *Plagionotus arcuatus* is more generalistic in its diameter preferences and host use. *Plagionotus arcuatus* colonizes large oak stems and branches as small as 5 centimeters in diameter, both which preferably are sun exposed. It can also colonize *Fagus sylvatica*, *Carpinus betulus* and *Salix caprea*. In the 1970´s *Plagionotus arcuatus* was found for the first time in the Båtfors area. The number of *Plagionotus arcuatus* was higher than the number of *Plagionotus detritus*, which may be an indication of out competing (Baranowski 1975). *Plagionotus arcuatus* has not been found on Djurgården and the lack of the species may be one reason to why *Plagionotus detritus* has survived here, but this is only a hypothesis (Ehnström 2005).

Predation could be another threat and the great spotted woodpecker is probably the most obvious predator of the larva and pupa of *Plagionotus detritus* (Figure 2) (Isaksson & Sahlin 2008, Isaksson 2005). The larvae can also be attacked by parasitoid wasps (*Ichneumonidae*) (Ehnström 2005) and a certain observation was made by Isaksson (2005) of the species *Xorides filiformis* and *Spathius curvicaudis*. How large the mortality due to predation is for *Plagionotus detritus* is unknown.

Figure 2. A pupal chamber from *Plagionotus detritus* that has been predated by woodpeckers.

Systematics

Plagionotus detritus belongs to the family Cerambycidae and the genus *Plagionotus* which include ten species in the world, 6 of them are found in Europe and two in Sweden. Except *Plagionotus detritus* is also *Plagionotus arcuatus* found. *Plagionotus detritus* is 10–19 millimeters long with a cylindrical shape. It is black with yellow transverse stripes of hair on the head, pronotum and elytra (Figure 3). The larva is white, 35 millimeters long and 7 millimeters wide and has three pairs of legs. *Plagionotus* is a combination of the Greek words “plagio” which means horizontal or sideways, and “notus” which means back. *Detritus* is a Latin word which means rubbed or scrape off. What Linnaeus meant with this name is unknown. It is possible that he meant that the tree looses its bark after the larval development, although it is more likely that he meant something according to the beetle itself (Ehnström 2007).

Figure 3. *Plagionotus detritus.*

Reproduction

Plagionotus detritus deposits its eggs almost exclusively on coarser parts of oak wood with thick bark (Ehnström 2005). It is assumed that *Plagionotus detritus* prefers to place the eggs in the cracks of the bark as *Plagionotus arcuatus* does (Butovitsch 1939). It is mainly the sun exposed branches that are colonized, both the ones that are left on the tree and the ones on the ground (Palm 1942, Ehnström 2005). There is no information about the species egg laying capacity but close relatives can deposit 50-80 eggs (Butovitsch 1939).

The larvae hatch around 2 weeks after the eggs have been deposited. They start to eat their way in the inner bark next to the cambium, through the coarse bark and leave a slightly winding path (Ehnström 2005). The path is almost circular and 10 millimeters wide and it is filled with brownish-red frass (Ehnström & Axelsson 2002). The time for the larval development is 1-2 years but which of these that is more common is not known (Ehnström 2005). The temperature and if the larva is facing the sun exposed side of the wood or not will probably influence the development time. The development time for Cerambycidae larvae on the same tree, can differ 1-2 years between the north and south side (Ehnström & Axelsson 2002). If it is a warm or cold summer can also affect the development time (Ehnström 2005).

At the end of the larval development the larva goes a bit further into the wood where it makes its pupal chamber (Figure 4). The pupal chamber is cylindrical, 15-20 millimeters long and 5-8 millimeters wide (Ehnström 2005). The pupal stage is around 2 weeks. The imago stays in the pupal chamber for some days waiting for the exoskeleton to harden. Then it eats its way out through the wood and bark via a circular hatching hole that is around 6 millimeters wide (Ehnström & Axelsson 2002) (Figure 5). Larvae that live in the cambium often place the pupa in the wood or the bark where it will be protected from predation, parasitism and also gets a more even climate.

Figure 4. A hole has been ormed in the wood where the pupal chamber has been placed.

Figure 5. A hatching hole from *Plagionotus detritus*.

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Method and material

Study site

An inventory of trees colonized by *Plagionotus detritus* was carried out during April 2009 in the National park of Djurgården, Stockholm (59º 20.519'; 018º 04.922'). In a study by Isaksson (2005) 75 colonized trees were found at Djurgården. 34 of these were included in this study. The reasons for excluding 41 trees were that; 4 trees were not relocated, 1 tree was inside a locked area, 5 trees had no hatching holes and 31 trees had no or very little bark. 20 trees of the 34 trees in this study had bark all around the stem and could therefore be used to compare the numbers of hatching holes on the north and south side of the stem. These data will be referred to as “tree data from Djurgården” in the text.

On 11 of the 34 trees the bark was more carefully studied. These were trees with enough bark left to study and where the bark easily could be removed from the tree. This will be referred to as “bark data” in the text. In addition to this, 8 branches of oak wood with old larval galleries from the zoo Nordens Ark´s breeding project were studied. This will be referred to as “breeding bark data”.

Table 1. **Data collected**

Data	**Measures**
Diameter	On the trees the circumference was measured and the diameter was calculated (diameter=circumference/ π). On the branches the diameter was measured directly. For both I used a tape measure.
Bark thickness	A ruler was placed in the cracks of the bark so that it reached the hard wood. From five measurements at each tree I calculated a mean value.
Mantle area	The height of the trees was estimated. The total area of bark was calculated by using the formula of a cone.
Hatching holes north/south side	The trees was divided into north and south side. The numbers of hatching holes was counted up to 2 meters.
Area of larval galleries and pupal chambers	The area was measured by using a ruler.
Mortality	The numbers of larval galleries without hatching holes.
Density	The numbers of hatching holes were counted and divided by the bark area which gave a measure of the numbers of hatched beetles per m^2.
Hole size	The diameter of the hatching holes was measured by using a ruler.

Sampling and measured factors

The different data that were collected during the sampling are presented in table 1. For the tree data from Djurgården the diameter and bark thickness were measured and the sun exposure and height were estimated for the 34 trees. The data of the amount of woodpecker predation was taken from the study by Isaksson (2 005). The 20 trees at Djurgården with bark left around the whole stem was divided into north and south side and all hatching holes were counted up to 2 meters.

The bark data included the numbers of hatching holes and measures of the hole size, total bark area and the area of larval galleries and pupal chambers were measured. The mortality was calculated by counting the beginnings to hatching holes (unsuccessful hatching holes) and the numbers of predated pupal chambers.

The breeding bark data included the total area of bark, the area of the larval galleries and the area of the pupal chambers, the thickness of the bark and the diameter of the wood were measured. The numbers of hatching holes were counted and their diameter was measured.

Collection of wood

In February 2009 wood was picked up from Nordens Ark and transported by car to Uppsala. The wood had been used as breeding material in 2008 and had been colonized and beetles had been reared. The same wood was used as breeding material in 2009 which was colonized and supposed to contain larva of *Plagionotus detritus*. After 5 weeks waiting still no beetles had reared from the wood and it appeared to be empty. Hatching holes, larval galleries and pupal chambers could be seen from the generation from 2008. Wood from Djurgården was then collected in April (Figure 6). The wood had been colonized earlier and hatching holes and predation could be seen. This wood did not contain *Plagionotus detritus* either, only *Phymatodes testaceus* and some Hymenoptera hatched.

Figure 6. Collection of oak wood at Djurgården.

Statistics

All data was tested for normally distribution (Anderson Darling test, $p>0.05$) to decide when to use a parametric or nonparametric test. The data for density of hatching holes per m^2 versus diameter and bark thickness and the data for mortality versus consumed bark per larva were log transformed. For correlations I used the parametric regression analysis or the nonparametric Kruskal Wallis test. For comparing the median values of two samples I used the parametric two sample t-test or the nonparametric Mann-Whitney test (Fowler et al 1998). All tests were run in Minitab version 15.

Results

Sun exposed bark increase the production of beetles

There was a significantly higher density of hatching holes on the south side compared to the north side of the trunks (Mann-Whitney, W= 540.5, p=0.0004, N=20). The median value of hatching holes on the south side was 38 which are more than 6 times higher than the median value of 6 hatching holes on the north side of the trunk (Figure 7).

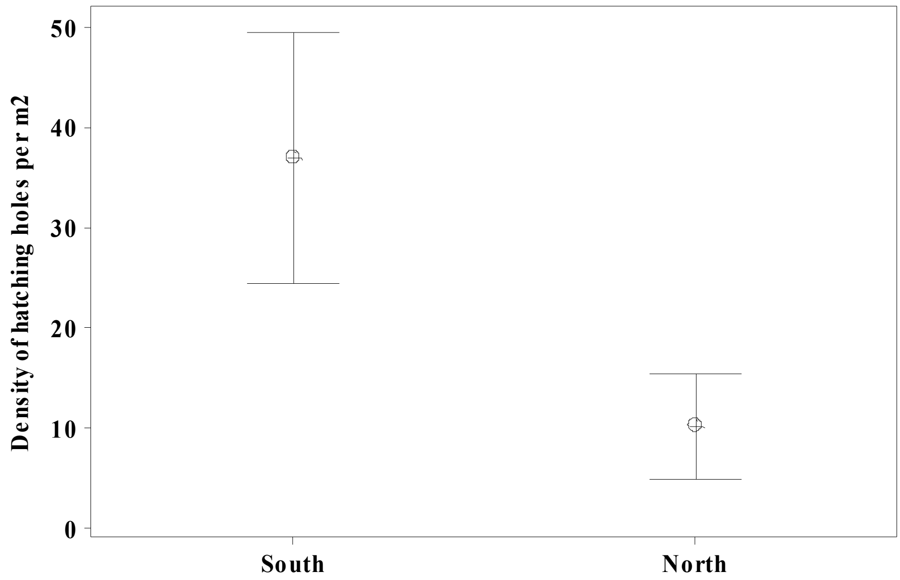

Figure 7. Median numbers of hatching holes of *Plagionotus detritus* on the south and north side of 20 oak trees. Error bars represent the standard deviation.

The bark thickness and the diameter of the tree does not affect the production of beetles

Trees with thicker bark did not have a significantly higher density of hatching holes (Regression analysis, N=34, p=0.358, Figure 8). Neither did trees with larger diameter have a significantly higher density of hatching holes (Regression analysis, N= 34, p=0.212, Figure 9).

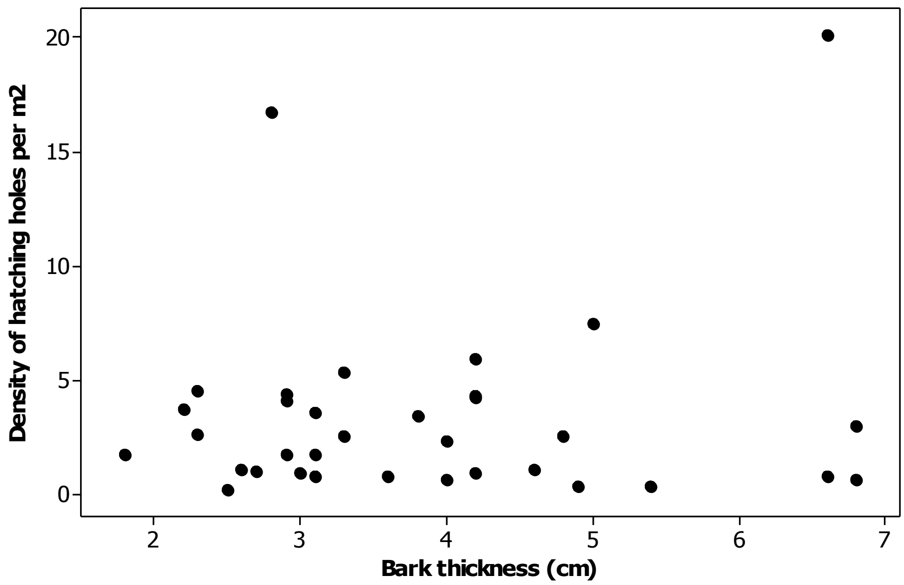

Figure 8. The numbers of hatching holes per m^2 and bark thickness did not significantly correlate (p=0.778, n=34).

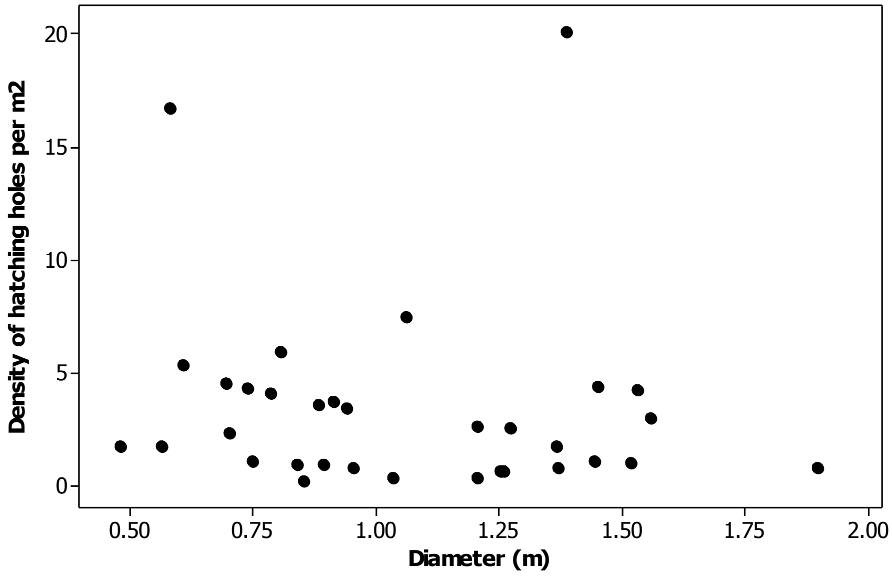

Figure 9. The tree diameter did not significantly affect the numbers of hatching holes (p=0.330, n=34).

The mortality of larvae is affected by the density, bark thickness and consumed bark area

There was a significantly higher mortality with increased larval density in the bark samples from Djurgården. In samples where no mortality could be found the median density was 25 hatching holes/m^2. In samples with a mortality of 6-9 % the median density was 53 hatching holes/m^2. The difference between categories was significant (Kruskal Wallis test, N=12, Rank 2.72, p=0.007, Figure 10). 9 % was the highest mortality found. This relationship could not be found in the breeding wood from Nordens Ark (Kruskal Wallis test, N=8, Rank 4.5, p=0.429) where the mortality was 33-71 %. To see if the mortality has a certain density threshold I also made a regression analysis (Figure 11). The test is significant (p=0.01), but since data is not normally distributed it did not really qualify for the regression analysis.

The plot in figure 11 shows that the mortality seems to start when the density is around 30-40 individuals per m^2.

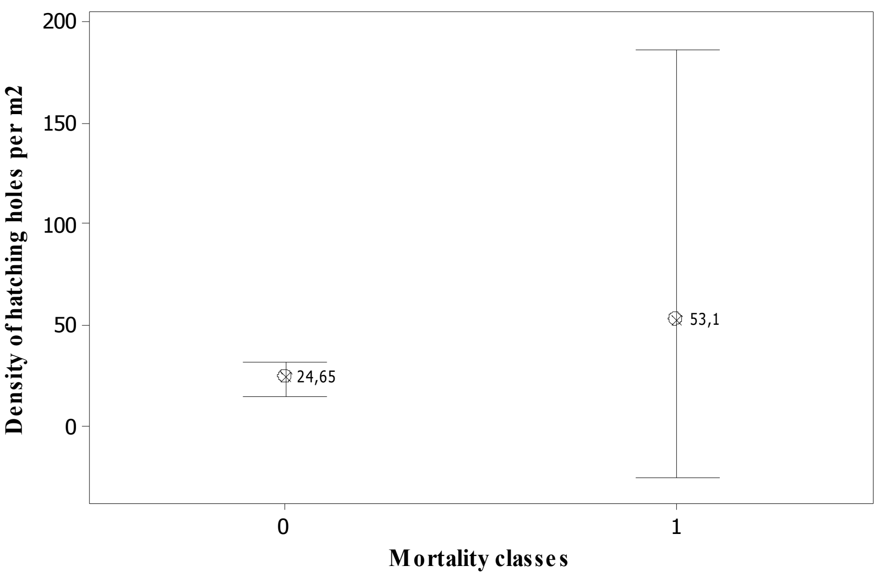

Figure 10. Median numbers of hatching holes for mortality class 0 (no mortality) and mortality class 1 (mortality). (N=12, p=0.007). Error bars represent the standard deviation.

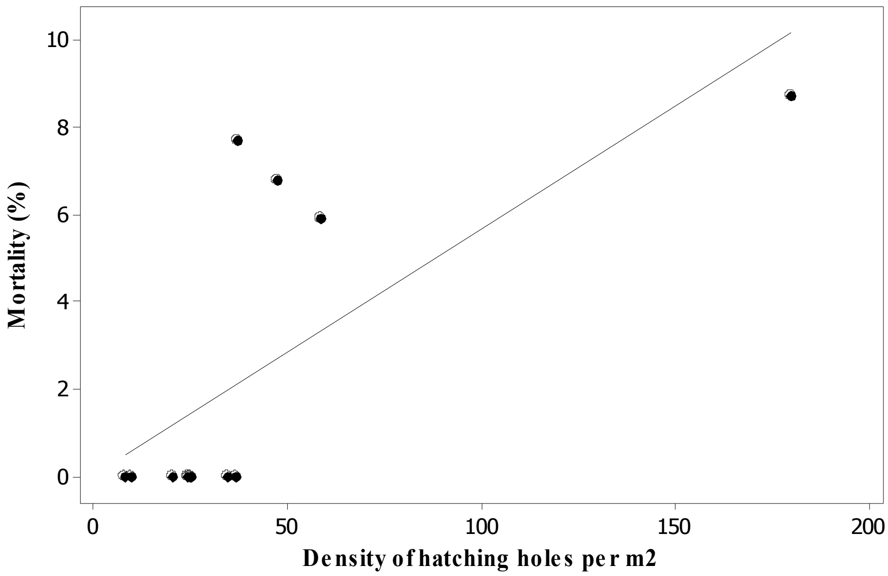

Figure 11. The density of larvae affects the numbers of dead individuals as measured on bark samples from 12 trees at Djurgården. (N=12, p=0.01).

There was a significant relationship between the mortality and the bark thickness in the breeding wood from Nordens Ark (Regression analysis, N=8, p-value 0.037) (Figure 12). The diameter for the wood from Nordens Ark was 0.1-0.95 meter. This relationship could not be found in the wood from Djurgården where the diameter ranged from 0.48 to 1.37 meters (N=12, p-value 0.0473).

There was a significant relationship between the mortality and the consumed bark area per larva in the breeding wood from Nordens Ark (Regression analysis, N=8, p= 0.037) (Figure 13).

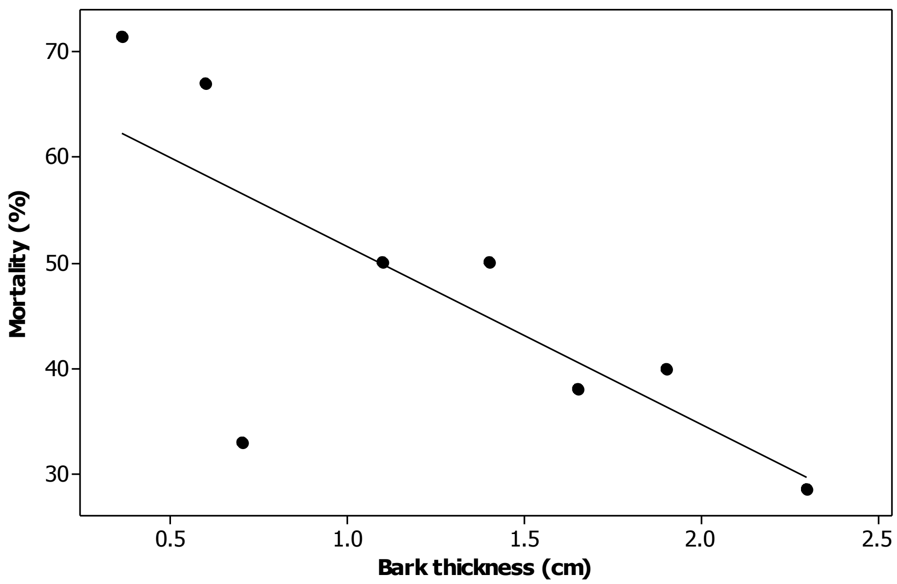

Figure 12. The relationship between the thickness of the bark and the mortality between pupa and adult stage. The mortality represents the numbers of larvae that dies before adult stage. (N=8; p= 0.037).

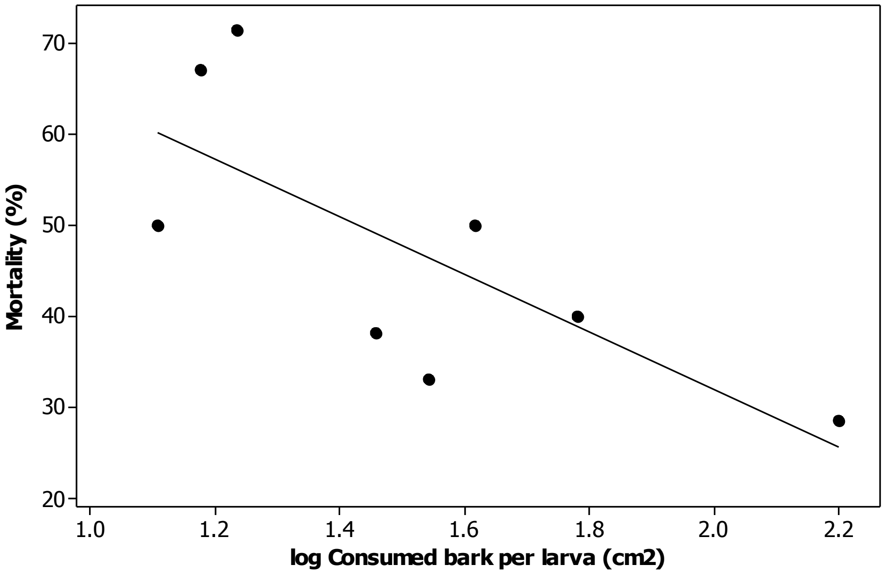

Figure 13. The mortality decreases when the larvae consume more bark. (n=8, p=0.037).

The density of hatching holes was not related with how much bark the larvae consumed (Regression analysis, N=8, p=0.709) or the mortality (p=0.204). But the mortality seems to be affected if both the density and the consumed bark area per larva are factors (p=0.05).

The maximum density and the consumed bark area

There was a significant correlation between density of hatching holes and the total area of consumed bark by the larvae (Figure 14). The highest density of larvae found was 180 hatching holes/m^2 and at this density 48 % of the bark was used. The highest proportion of consumed bark found was 58 % but then there were 34,5 hatching holes/m^2.

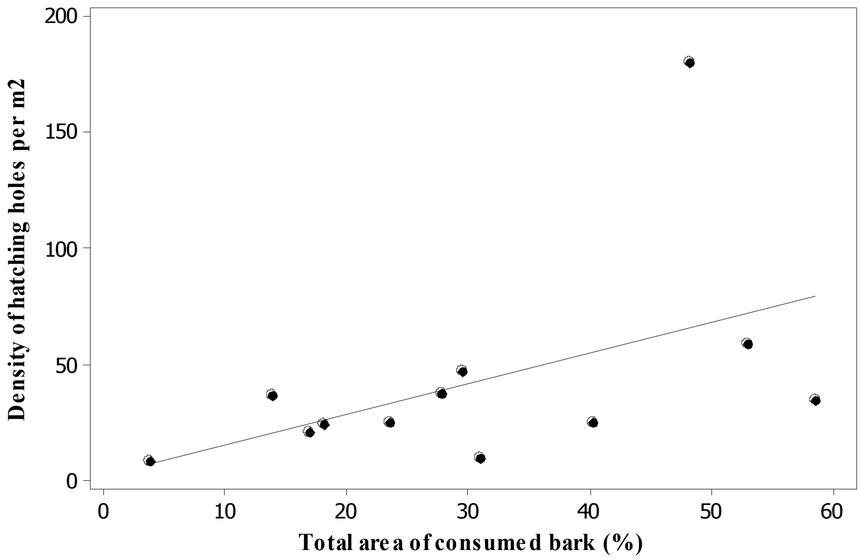

Figure 14. The relationship between the density of larvae per m^2 and the percent of consumed bark area (n=12, p=0.043).

Size distribution of the hatching holes

The size of the hatching holes was 0.4-0.9 millimetres and the mean value was 0.57 millimetres. The size of the hatching holes did not correlate with bark thickness, diameter or density (Regression analyse, N=12, p=0.938, p=0.603, p=0.853 respectively).

Production of beetles in a tree

The production of hatching holes per m^2 were counted on 34 trees at Djurgården and ranged from 0.2 to 20.1 hatching holes per m^2. If one *Plagionotus detritus* female can deposit 50-80 eggs (Butovitsch 1939) will 2,5-400 m^2 of bark be needed to make all eggs hatch. The bark area at the trees at Djurgården ranged between 5-73.8 m^2. This gives a production of beetles between 1-1500 per tree. This assumes that the hole tree dies at the same time and can be used as breeding material. The sun exposure and the mortality are not included in this calculation.

Discussion

Plagionotus detritus was strongly associated with sun-exposed parts of the wood. I found that it strongly preferred the south side of the oak trees which supports observations by Palm (1942) and Isaksson (2005). The population at Djurgården is assumed to be the furthest north in the world. The cool climate probably enhance the dependence of sun exposed trees compared to further south. A speculation is that in Southern Europe where the climate is warmer the species may also use the shaded parts of tree. The explanation can be that the south side has a warmer micro climate which is important for the insect development and activity.

In this study I could not prove that the bark thickness and the diameter of the tree had any effect to the density of hatching holes. One reason can be that 85% of the studied trees had a diameter of more than 50 centimeters and are considered as fairly coarse trees. If more and smaller trees were included in the study a correlation between diameter and density of beetles may have been found. My results could not prove the observations made by Palm that *Plagionotus detritus* prefers coarse trees (Palm 1942).

The density of larvae under bark affected the mortality in the wood from Djurgården. I could see that in a density above 30-40 hatching holes/m^2 the mortality increased from zero to 6-9 % as the density of hatching holes increased. Up to around 30-40 larvae per m^2 seems the mortality to be density independent and if there is more than 30-40 larvae per m^2 interspecific competition start. If one *Plagionotus detritus* female can deposit 50-80 eggs (Butovitsch 1939) will 2,5-400 m^2 of bark be needed to make all eggs hatch. That is important in the future work with *Plagionotus detritus* to be able to supply enough breeding material and make new habitats. The mortality in the wood from Djurgården is very low compared to the mortality in the breeding wood from Nordens Ark. No relationship could be found between the mortality and density of hatching holes in the breeding wood. The explanation can be that the breeding wood had smaller diameters and had not been held under natural conditions. The high mortality found was probably due to that the beetles did not have enough breeding material and that the breeding wood had been used so no food for the larvae was left. There was a significant relationship between the bark thickness and the mortality on the breeding wood from Nordens Ark. No relationship could be found between the mortality and bark thickness on the bark samples from Djurgården. It is probable that the mortality only shows when the bark gets really thin and a higher variation of bark thickness could have shown a relationship in the wood from Djurgården as well. Thicker bark gave more food for the larva to consume, it protected better from woodpecker predation and there was more space to place the pupal chamber in, which are three factors that may prevent mortality and explain the relationship. A good supply and low competition for food will increase the chances of survival. My results also showed that there seems to be a carrying capacity for production of beetles and consumed bark area. The highest density of beetles I found was 180 hatching holes/m^2 and at this density 48 % of the bark was consumed. When more bark than 48 % was consumed the density of hatching holes decreased.

The production of beetles per m^2 ranged from 0.2-20.1 at the 34 trees at Djurgården. This was data from earlier studies were the hatching holes had been calculated up to 2 meters on the stems. (Isaksson 2005). The largest tree (73.8 m^2) could rear around 1500 beetles if the maximum density (20.1 beetles per m^2) could be assumed and the smallest tree (5 m^2) could rear 1 beetle if the minimum density (0.2 beetles per m^2) was assumed. This assumes that no mortality is present, the whole tree dies at the same time and that the whole tree has the same potential as breeding material. It is more likely that parts of the trees dies at different times. If a tree partly dies during 10 years each tree can be used as substrate for a longer time and produce between 0.1-150 beetles per year.

The breeding wood from Nordens Ark had already been used for 1 or 2 generations of *Plagionotus detritus* and was no longer suitable as breeding material. Usually primary colonizers of wood can only breed one generation in the same wood piece (Ehnström 2005). It had been seen that the beetles laid eggs on the substrate (Christer Larsson, personal comment), but probably the larva could not survive when there was no substrate left. The beetles at Nordens Ark probably had too little substrate for egg laying and was therefore forced to deposit eggs on already used wood. One tree can be colonized by more than one generation of *Plagionotus detritus* but then different parts of the tree will be colonized (Ehnström 2005).

To get a good result at the reintroduction of the species in Båtfors is it important to place the breeding material in a place with maximal sun exposure. It is important to make cuttings around potential host trees so as much bark area as possible get sun exposed at Båtfors. The same recommendations are of course also important for the future management of the population at Djurgården. Both coarse trees and smaller branches suits as breeding material for *Plagionotus detritus*. Smaller wood that often have thinner bark will also result in an increased mortality and will only be used by one generation of *Plagionotus detritus*. Therefore it is important that new breeding material is supplied yearly. A high density of larvae will also affect the mortality so the amount of breeding material, both oak trees at Djurgården and wood pieces at Nordens Ark, must be sufficient. The amount of bark I calculated from this study was 2,5-400 m^2 bark to make 50-80 eggs hatch and this can be seen as an recommendation.

Further studies on the biology and ecology of *Plagionotus detritus* are of interest to better understand the species. A comparison between the colonized trees at Djurgården with the uncolonized trees is one suggestion. It would probably give more information about the species habitat preferences and some factors may be detected that could explain why some trees do not become colonized. Information about why the species is absent is almost as important as why the species is present. All of my premier questions about dispersal capacity, mating behavior, egg laying capacity and sex distribution, are still interesting to study to get more useful information about *Plagionotus detritus*.

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