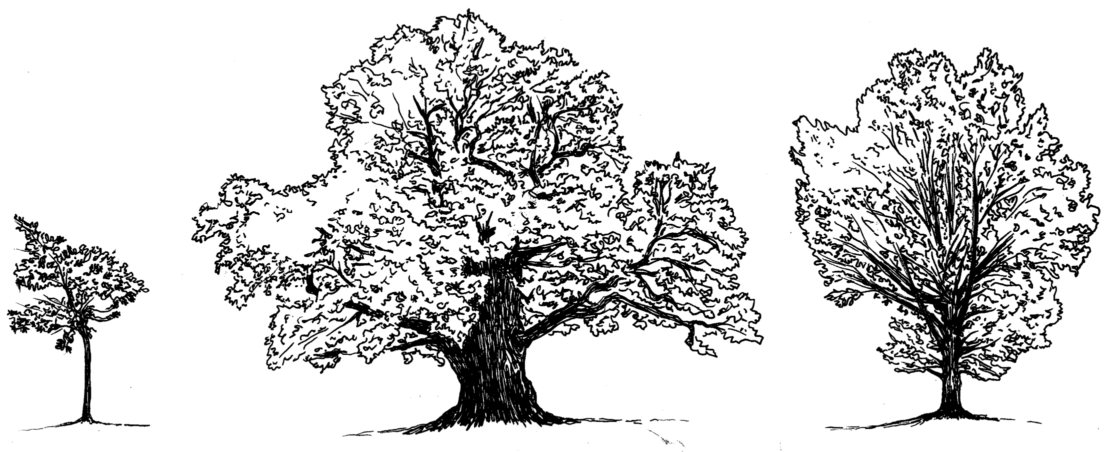
Generational gaps in ancient oak populations and how they can affect biodiversity



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Bachelor's Programme in Biology-Earth Sciences
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ABSTRACT

With the continued loss of biodiversity, conservation of valuable biotopes is increasingly important. In Sweden, one biotope of ecological significance is populations of large, old oaks. With changing microhabitats and microclimates during its long life, the oaks can harbor many different species and contributes to biodiversity. Populations dominated by old oaks are on decline and loss of biodiversity is certain if they were to perish. In this study I research where generational gaps of oak populations exist to see where these gaps could possible threaten biodiversity in the future. The studied area is the borough of Östermalm and by applying my method here, gaps in the generations is shown and where they are more critical. By calculating on generation dynamics, visualizing generational gaps and connectivity, the necessity of long-term planning and management is discussed and its importance to avoid loss of biodiversity.

SAMMANFATTNING

Med fortsatt global förlust av biodiversitet blir bevarandet av biologiskt värdefulla habitat allt viktigare. Ett habitat med signifikant ekologiskt värde i Sverige är stora populationer med gammal ek. Eken har under dess livstid varierande mikrohabitat och mikroklimat som huserar många arter och bidrar till biodiversitet. Dessa typer av ekosystem håller på att försvinna och med det bidrar det till en förlust av biologisk mångfald. I den här studien så undersöker jag generationsglapp i ek populationer för att kunna identifiera kritiska områden där biodiversiteten är lokalt hotad. Det studerade Östermalms stadsdelsområde där jag har applicerat min metod för att se vart glapp genom generationerna kan finnas, och vart de är kritiska. Genom att räkna på tillväxt och dödlighet samt visualisera generationsglapp och förbindelser i ekbestånden, så diskuterar jag vikten av långsiktig planering och varför det är nödvändigt för att motverka förlust av biologisk mångfald.

INTRODUCTION

Of the 16 environmental quality goals set by the Swedish government (prop 2009/10:155) to implement the ecological aspect of the UN Sustainable Development Goals, nine are directly related to biodiversity. The 16 goals are set for 2020 and the main goal concerning biodiversity is *Ett rikt växt- och djurliv* (*"A rich plant and animal life"*), and it is one of three goals currently developing in a negative trend (Naturvårdsverket 2019). In light of the continued global depletion of biodiversity (Ceballos et al. 2015) and studies that show that loss of biodiversity is most likely to reduce ecosystem functions and the stability of these (Cardinale et al. 2012), this is an issue that need attention to avoid severe consequences.

The common oak and its ecological role

One way of avoiding loss of biodiversity is the identification and conservation of ecologically valuable biotopes. In Sweden, one biotope of ecological significance is the common oak (*Quercus robur*) with up to 1500 species acquainted with it (Hultgren et al. 1997). Over 400 of these are on the Swedish Red List (Sandström et al. 2015). The reasons why oaks harbor such species diversity is because of the variation between individuals in populations as well as the ability to grow very old, with some examples with an estimated age over 900 years (Almgren et al. 2003). The oak has many different microhabitats and microclimates that develop and change through its life cycle. The roots and the stem hold a variety of fungi, many different lichens and moss grows on the bark and the leaves and branches household numerous insect and bird species (Hultgren et al. 1997). The more unique habitats such as deep bark crevices and tree hollows occur much more frequently on older trees (Ranius et al. 2008; Ranius et al. 2009). The deep bark crevices are important habitats for lichens, with many of them on the Swedish Red List that occurs mainly on oaks older than 200 years (Ranius et al. 2008). Tree hollows are created when branches brake of the stem and the wound becomes infected by fungi. In time the fungi molder the inside of the oak and it becomes hollowed, and it is in these hollows many different species of invertebrates, birds and mammals take refuge.

For a healthy oak dominated biotope that can sustain a high biodiversity there must be more than single individuals. Mörtberg et al. (2007) has concluded four criteria what is needed in an oak population for it to sustain species richness:

- A closeness between oaks due to that many species bound to the trees have a limited motility.
- Space between trees due to high sunlight requirements for oaks and other species bound to the oaks.
- Large continuous populations of oaks due to the variation of habitats between oaks, so the right type of habitat for a species can be offered at all times.
- To have oaks in different stages of its life cycles due to that every stage has its unique habitat.

Oak population that fulfill these criteria have declined dramatically during the last centuries, mainly because of changing land use as well as changes in the legislation concerning oaks. I addressed and focused on the last criteria for this study. To maintain the high biodiversity that these oak populations have, when an oak perishes there must be another oak nearby that can harbor the species associated to the perished oak. This is especially true for old giant oaks because of the unique nature of the habitats they offer. It is the successor-oaks future role to succeed these giant oaks, and the new recruits will succeed the successors. If there are no gaps between the generations and all oaks have a potential successor, loss of species acquainted to oaks is minimized. Due to these oak populations' critical nature, conscious long-term management is needed if the declination is to stop and for the populations to continue to sustain a high biodiversity through time.

A brief history about the oak in Sweden

The hardwood of oaks has been highly valuable in Sweden through time and has mainly been used as material for shipbuilding (Hultgren et al. 1997). As well as the hardwood, the acorn was a cherished resource used as fodder. Ever since the 14th century there has been regulations concerning oaks in Sweden (Hultgren et al. 1997). In 1558 the king Gustav Vasa established a ban against cutting down oaks for personal use and plantations were set up at the end of the century to secure harvest in the future (Almgren et al. 2003). For every oak that was cut down by the state, two new should be planted. The oaks were now seen as property of the king, even though the nobility had free disposition on their lands. On the other hand, the farmers had growing contempt against oaks on their lands due to additional labor and degrading crops close to the trees (Hultgren et al. 1997). As a result, the seedlings were quickly removed and the trees was mistreated in the farmlands. It was not until 1830 that taxed homesteads could buy the rights to the disposition of oaks on their lands and in 1875 the rights to disposition was given to every homestead (Hultgren et al. 1997). After the new regulations the amount of giant oaks in Sweden declined drastically. Many of the oaks still preserved today are on cemeteries and public commons, since these were still under property of the crown until 1930 (Almgren et al. 2003). In 1909 the first environmental protection law in Sweden surpassed and made it possible to protect single giant oaks from being cut down (Almgren et al. 2003). Today the remaining giant oaks from these times stands as monuments of its past and is managed due its biological value and contribution to biodiversity.

A brief history about the oaks on Östermalm

The oak populations in Östermalm is unique because of its large amount of giant oaks, this is especially true for what today is the Royal National City Park. The park stretches mainly through districts of Norra Djurgården, Ladugårdsgärdet and Djurgården, and continues outside Östermalm north to Ulriksdal and east to Haga (Länsstyrelsen i Stockholm 2019). Due to its exclusive land use history, few areas of this size have such high biodiversity as Östermalm and the Royal National City Park (Barthel et al. 2006).

The reasons why this unique oak population still exists can be dated back to 15th century when most of the land was used for agriculture (Barthel et al. 2005). In this open agricultural landscape and with oaks held as valued material, this is the fundament of today's oak population on Östermalm. In the 16th century, reformations by the king Gustav Vasa led to that most of Östermalm became property of the crown (Länsstyrelsen i Stockholm 2019) and in 1579 Djurgården was set up as royal hunting grounds for the crown and the nobility (Andersson 1975). Around 100 years later the hunting grounds included most of Östermalm (Andersson 1975) and this resulted in intense grazing and restricted rejuvenation of oaks. This land use continued until the 19th century. In 1808 an inventory record of the oaks was made to have an overview in the war-ridden times (Andersson 1975). The records are lost, but summary letters to the king say that there was a total of 8221 oaks listed; 888 were good for building ships, 1886 blighted by rot, 2283 were "retained for promenades" and 3164 saved for continued growth (Andersson 1975). Those blighted by rot was kept as well for the dwellers. In 1930 an inventory report was made that registered 76 giant oaks above 5 meters in circumference and 140 slightly smaller oaks (Sernander et al. 1935).

Today much of the area of Östermalm still is within the crown's property and the Royal National City Park received legal status in 1995, as the world's first national urban park (Länsstyrelsen i Stockholm 2019). With the long continuity as property of the crown and management that favored oak through time, the oak populations of Östermalm still exist and harbor such biodiversity as seen today.

AIM OF THE STUDY AND RESEARCH QUESTION

The aim of this study is to investigate if there are gaps through generations in oak populations and if these gaps could affect biodiversity. In order to reach the aim, I have developed a method that reveals if and where these gaps exist. It is necessary to identify where these generational gaps are, so right actions to conserve these biotopes can be made. The methods derive from giant oaks, because their unique contributions to biodiversity (Hultgren et al. 1997; Ranius et al. 2008; Ranius et al. 2009). Eventually every growing oak will die and that is why long-term planning and management of oak populations is necessary in order to not lose their biological values. Further, I also research and discuss how long it takes for oaks to grow between different generational categories, as well as if the possible gaps could affect the species acquainted to the giant oaks in the studied populations.

STUDY AREA

The area for this study is in the borough of Östermalm in Stockholm, Sweden (fig. 1). The borough contains the districts Norra Djurgården, Ladugårdsgärdet, Östermalm, Hjorthagen and Djurgården.

As both the borough and a district are called Östermalm, hence forth the use of the word Östermalm will refer to the borough of Östermalm, and the district will be called the district of Östermalm.

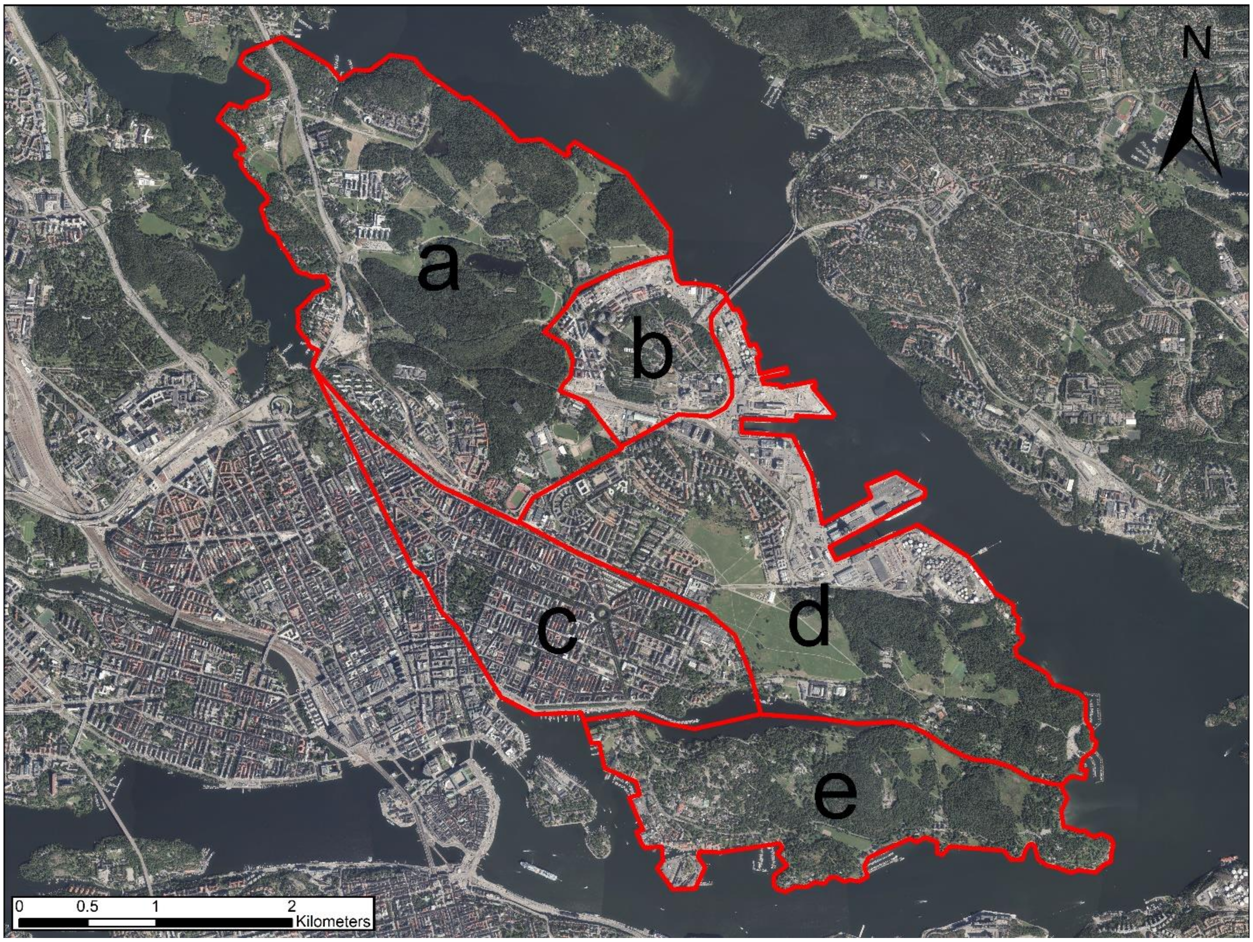


Figure 1. *The borough of Östermalm, Stockholm, where the oak populations for this report has been studied. The labeled areas in the figure are: (a) Norra Djurgården, (b) Hjorthagen, (c) district of Östermalm (d) Ladugårdsgärdet, and (e) Djurgården.*

METHOD

To examine if there are potential gaps in the generations of oaks, I have used data that originates from Ekdatabasen (“The oak database”). Ekdatabasen was created by Ekologigruppen AB in 2007 on the request by Exploateringskontoret in the city of Stockholm. The goal was to sustain and develop the existing oak populations in Stockholm and the species acquainted with them. Within the database one finds data about giant oaks and oak populations with parameters concerning biodiversity, population dynamics, locations, health and more. The database was updated and supplemented in 2018 by Geensway AB on request by Miljöförvaltningen in Stockholm.

This study has used details collected about giant oaks above 100 cm in diameter in Östermalm. The diameter is the trunk measured at chest height. For every giant oak there are two categories in

Ekdatabasen investigated in this report; new recruits and successors. The new recruit-category shows the amount of oaks with 10 to 50 cm in diameter within viewing distance (max 500 m) of the giant oak and is divided into three subcategories depending on the number of new recruits: None, 1-10 or >10. The successors-category shows the amount of oaks between 50-99 cm in diameter in viewing distance and is divided in the same subcategories as the recruitment category. If the data about giant oaks had been categorized differently in the datasets from 2007 and 2018, the most recent data has been used. Some giant oaks in Ekdatabasen have no input data in either the new recruit- or successor-category and was therefore not included in this report. Since most of the oaks in Ekdatabasen have been recorded through infrared aerial imagery, there could be oaks e.g. in dense forest areas, that is still unrecorded.

To calculate how much time it takes for oaks to grow between generations, a growth rate of 2.2 mm/year is used. This growth rate is the highest recorded mean growth rate in an oak population from a study done by Ranius et al. (2009). The growth rate is measured on mainly old oaks, so it is probable that younger trees has higher growth rate. The mortality rate of oaks used in this study is between 1.04% (Ozolincius et al. 2005) and 1.3% annually (Ranius et al. 2009). Ozolincius et al. mortality rates apply on oaks older than 90 years. Ranius et al. rates apply on oaks with hollows, which all studied oaks do not have, though here it is used at an upper limit for mortality rates. The equation to calculate how long it could take for any number of trees to be succeeded is following:

$$\frac{Number\ of\ trees}{Number\ of\ trees * Annual\ mortality\ rate} = Years\ for\ the\ trees\ to\ perish$$

To see if the acquainted species could be affected by the generational gaps, 100-meters and 250-meters buffer zones were used to show connectivity (fig. 4) between giant oaks for low motility species as well as areas of special biological importance. The 100-meter buffer zone was chosen due to that the hermit beetle, *Osmoderma eremita,* has a dispersal distance recorded of below 200 meters (Ranius & Hedin 2001). It is probable that there are several species that has similar dispersal distances, but extensive studies in this area is lacking. The 250-meters buffers were chosen as Sverdrup-Thygeson et al. (2017) study shows that patches of veteran trees within 500 meters of each other is of particular importance for maintaining biodiversity.

ESRI ArcMap 10.6 (2017) was used to analyze the data from Ekdatabasen and visualize where generational gaps and different ecological buffer zones were.

RESULTS

A total of 1306 giant oaks have been studied. The distribution of new recruits around giant oaks is that 12% has none, 51% has 1-10 and 37% has above 10 individuals (fig. 2). For the successors there are 7% of the giant oaks that has none, 51% has 1-10 and 42% has above 10 (fig. 2).

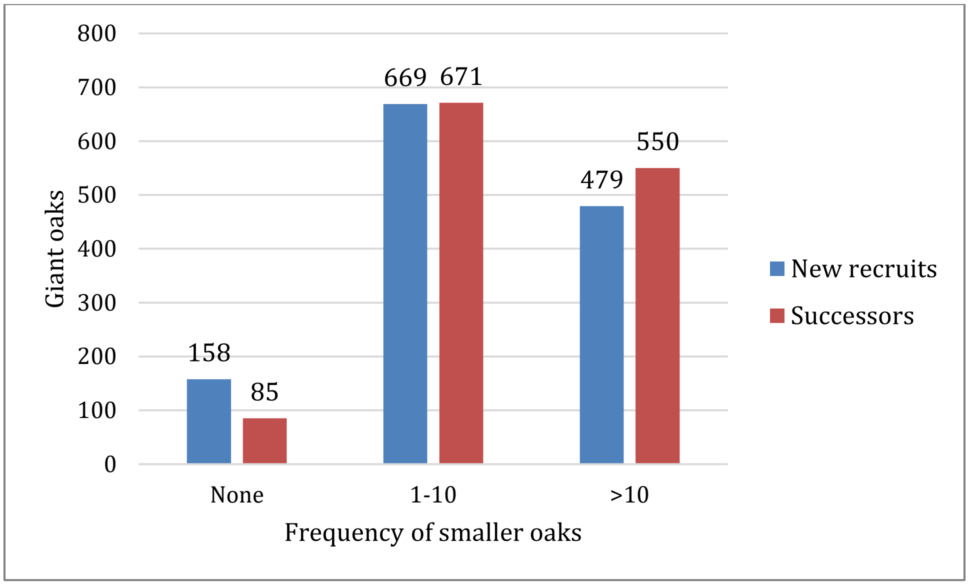


Figure 2. *This graph shows the distribution of smaller oaks in Östermalm within eyesight from a giant oak. The new recruits that have a trunk diameter of 10-50 cm and successors with 50-99 cm and represents different generational stages in an oak population. Data from Ekdatabasen (Ekologigruppen 2007; Greensway 2018).*

The distribution of the giant oaks with new recruits and successors around Östermalm is seen in figure 2 and figures 3a-b. In figures 3a-b we can identify where possible gaps in the generations could be in the oak population.

The studied districts

Norra Djurgården

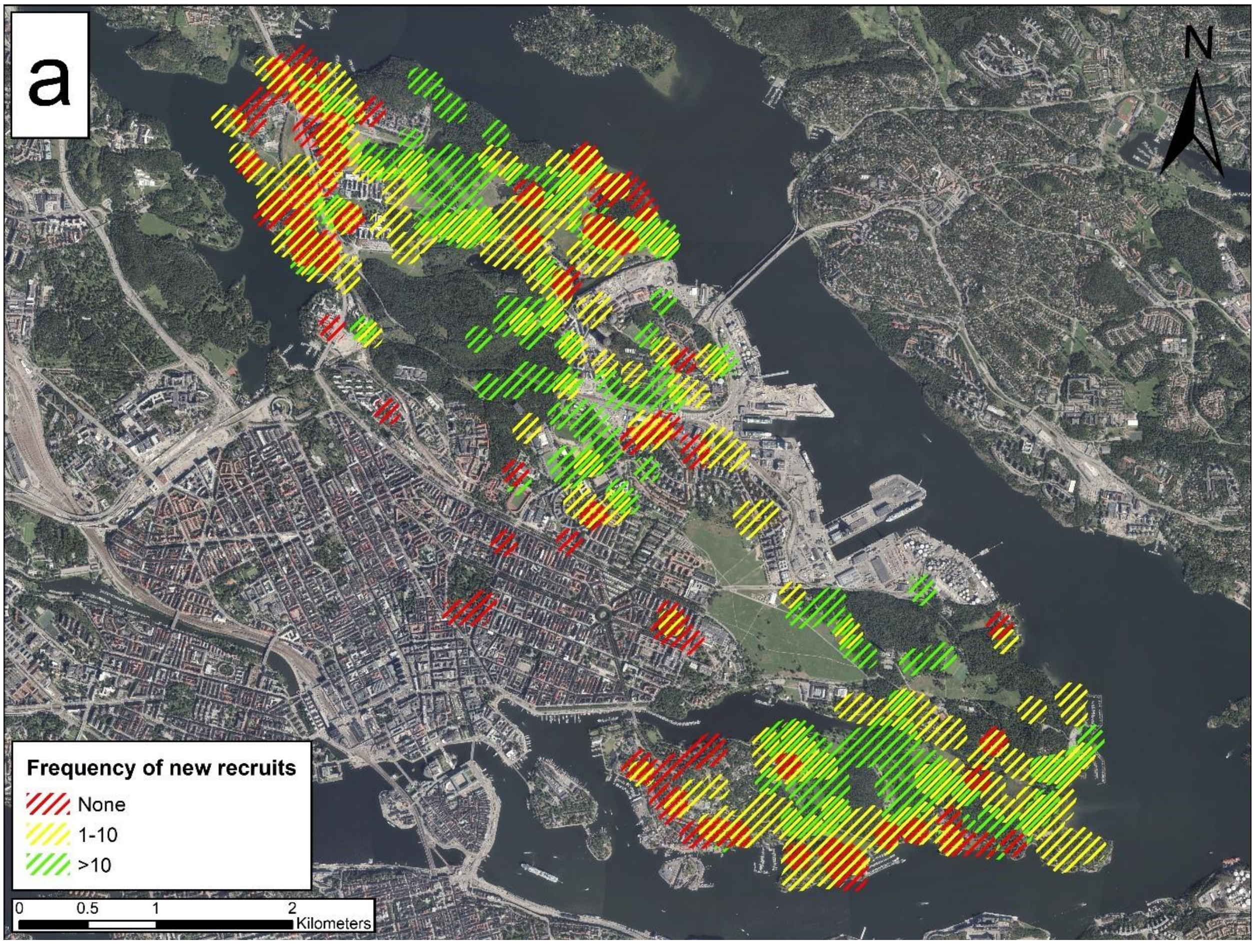
There is a lack of new recruits in the western parts and some in the outer eastern parts of Norra Djurgården (fig. 3a). In the southern parts there is an area that have no successors (fig. 3b), though if these giant oaks were to perish the species acquainted to these have good connectivity to nearby giant oaks (fig. 4).

Hjorthagen and the district of Östermalm

A lack of successors exists in the eastern parts of Hjorthagen, that’s a part of the outer rims of the northern oak population (fig. 3b). In the district of Östermalm a solitary oak population in the central parts has a lack of both successors and new recruits (fig. 3a-b). A few giant oaks in the eastern parts is by a cemetery that is in need of new recruits (fig. 3a).

Ladugårdsgärdet and Djurgården

In Ladugårdsgärdet there is a wedge that connects the northern oak populations with the southern populations of Östermalm (fig. 4). There are only a few giant oaks that stands in this critical area, and with low numbers of successors (fig. 3b). Djurgården has a quite healthy oak population, though a lack of new recruits in the western part and the southern rim of the island (fig. 3a).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Frequency of new recruits
None
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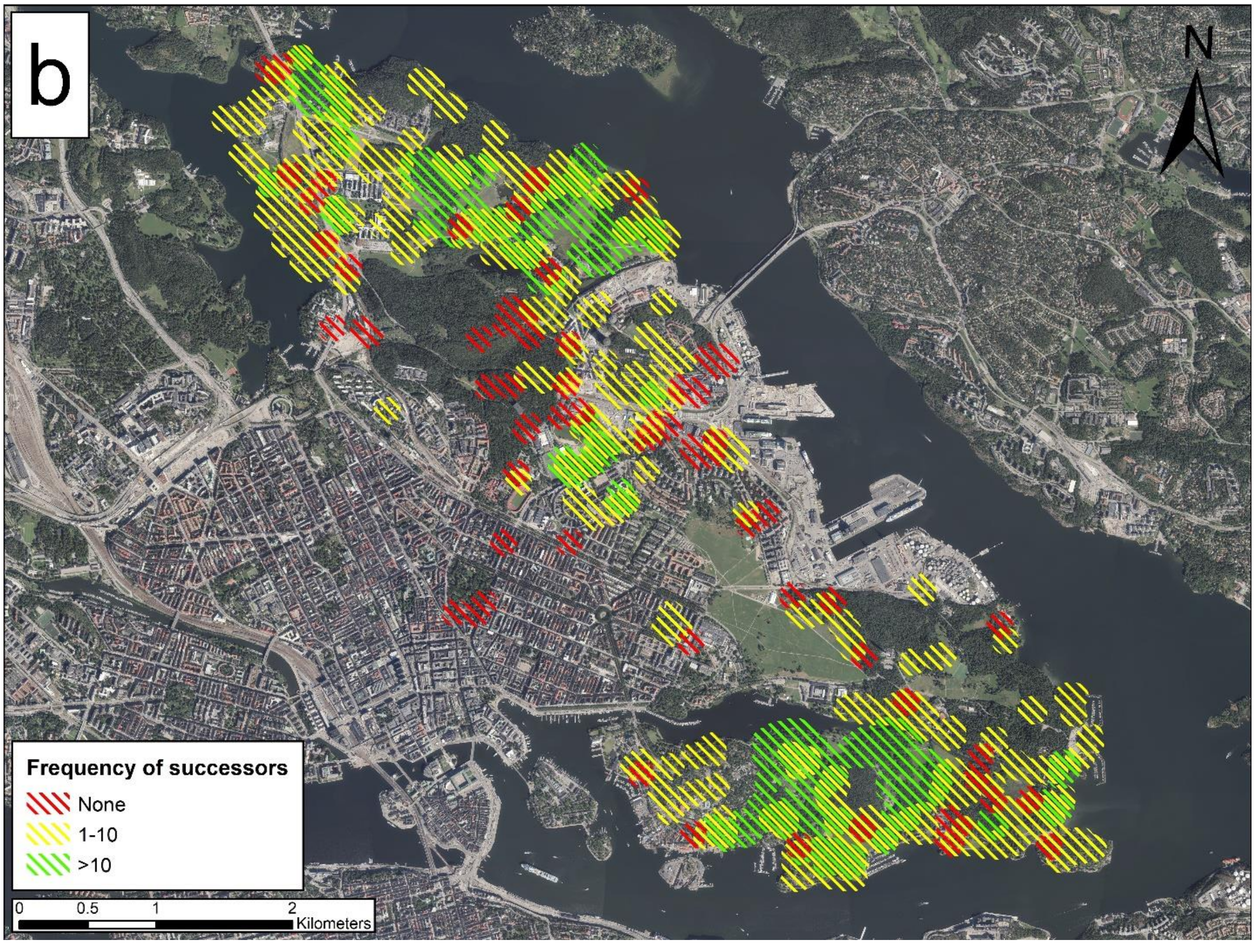

Figures 3a-b. *Giant oaks and the surrounding smaller oaks portrayed in the studied areas to visualize where possible generational gaps in the oak populations could exist. Figure (a) shows the frequency of new recruits within eyesight of a giant oak, and figure (b) shows the frequency of successors. New recruits are trees with a trunk diameter of 10-50 cm and successors has 50-99 cm. Orthophotos from © Lantmäteriet (2015).*

Growth and mortality rates

With an annual mortality rate between 1.04% and 1.3% annually means that the 1306 giant oaks of Östermalm would have to be succeeded in 77 to 96 years. Calculating with a growth rate at 2.2 mm/year, a tree to grow from seedling to fit in the successor-category (50-99 cm) would take at least 227 years. For a seedling to grow to a new recruit (10-50cm) would take 45 years. With these calculations, to fill the generational gap with new recruits to successors would take 1 to 182 years and from successors to giant oak 1 to 227 years.

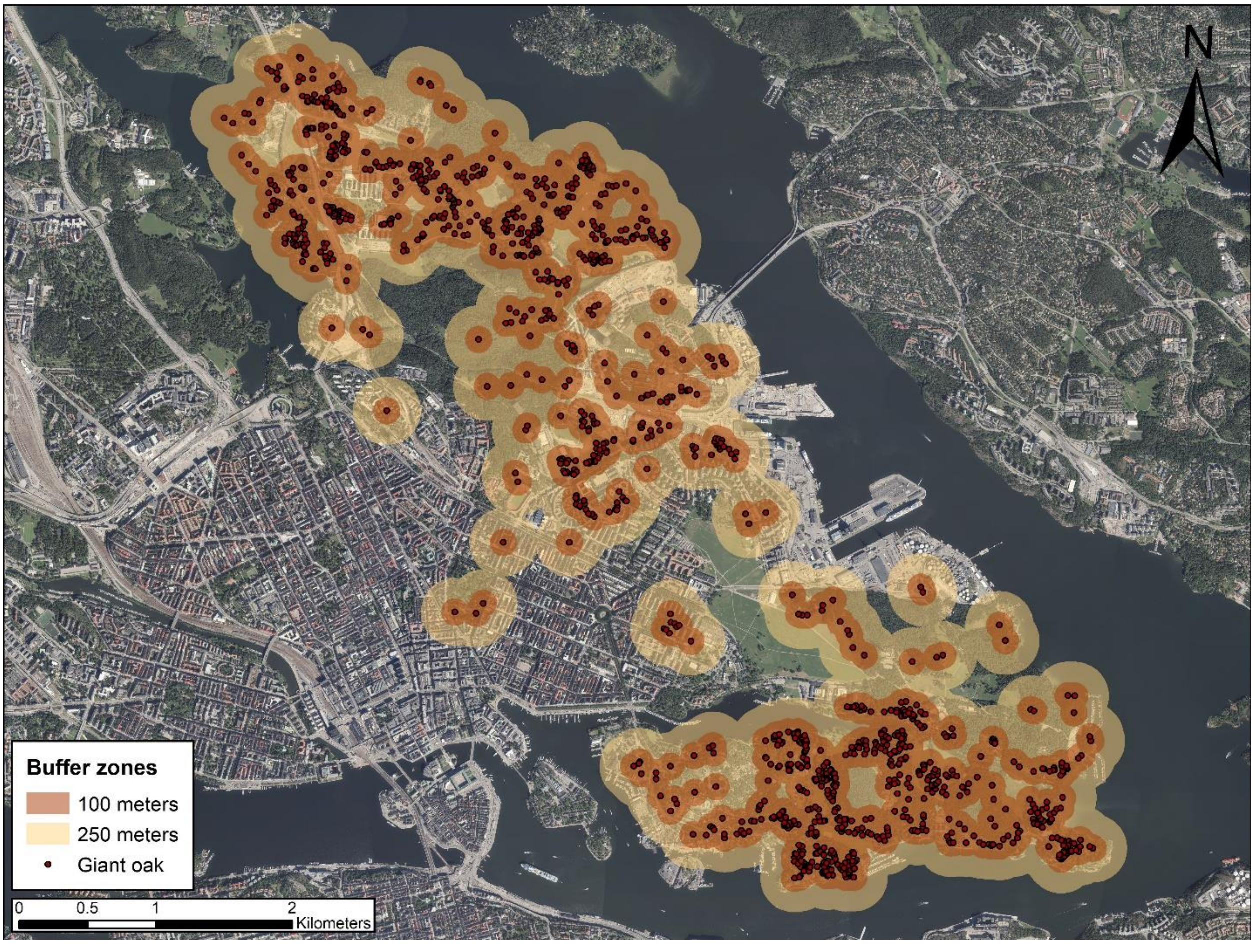

Figure 4. *Connectivity between giant oaks in Östermalm. The 100-meters buffer zone represent low motility species possible dispersal (Ranius et al. 2001) and the 250-meters zones is to show areas with particular importance to maintain high biodiversity (Sverdrup-Thygeson et al. 2017). Every buffer zone originates from a giant oak, and if buffer zones interconnects there should be good connectivity. Orthophoto from © Lantmäteriet (2015).*

DISCUSSION

158 of the 1306 studied giant oaks have no new recruits within eyesight, and 85 oaks have no successors (fig. 2). Most of these oaks that lacks either new recruits or successors lies within a greater community (red circles in fig. 3a-b) with good connectivity (fig. 4). This shows that the oak population in Östermalm are not in grave danger. Though some of them are in the outer rims of the communities, which indicate that the populations could be diminishing. With time this could lead to further fragmentation and loss of connectivity, that ultimately will lead to loss of biodiversity (Sverdrup-Thygeson et al. 2017).

The results presented in this study is a gross simplification of how the dynamics of nature works, but it gives us a picture of where and how action could be directed to have long-term preservation for oak populations. The perfect oak populations from an ecological view has a large interconnected oak community with many old giant oaks, no generational gaps and a closeness of 200-500 meter between the giant oaks. With this in mind, there are some identified areas of greater risk and here presented with possible solutions to avoid loss of biodiversity.

Predictions and proposed solutions in the studied districts

Norra Djurgården

The lack of new recruits in Norra Djurgården should be managed by planting new oak seedlings in these areas as soon as possible to avoid a too far of a gap between generations. The new recruits in the southern parts should be carefully managed to secure the future giant oak population in the area.

Hjorthagen and the district of Östermalm

With the few successors that exist in Hjorthagen can indicate a diminishing northern population. Since Hjorthagen is an expanding residence area which could contribute to stress on the local oak population. Not only long-term management is needed but also protection of the giant oaks so they will not be cut down in favor of infrastructure. The solitary oaks inside of the district of Östermalm will quite certainly cease to exist in due time due to the lack of both new recruits and successors. The giant oaks in the eastern part of the district, by the cemetery, should be cared for and new recruits planted to withhold both biodiversity and cultural history.

Ladugårdsgärdet and Djurgården

Close management of the giant oaks here and much effort should be made to increase the much-needed connectivity in this wedge. This to secure the possibility for low motility and specialist species to disperse between the northern and southern populations. If this connection would lessen and finally be lost, there will most likely lead to fragmentation of the populations. But if better connectivity should be established, there could be beneficial for the diversity in both populations. The lack of the new recruits in Djurgården could lead to a generational gap if not tended to by planting seedlings in a near future.

The larger picture and further studies

The calculations of how long it could take to fill generational gaps shows that areas that need new recruits should be planted with seedlings as soon as possible. This could eliminate the generational gap in 45 years, though young trees grow probably faster than considered here. It is possible to eliminate the gap of no successors from seedling, but for that to happen the giant oaks that need these need to survive at least 227 years. By that time the categorical generational gaps could be closed, but in reality, the successor and the giant oak is probably too far apart in their life cycles to benefit from each other. This also shows the importance of long-term planning.

The model presented here has a low resolution, but it shows indications of where generational gaps could exist. In these areas where gaps exist, efforts should be made to get a more detailed overview of the local situation in the oak population. This detailed overview could for instance be the health of the giant oaks and the area around it, if there is Red Listed species associated to them or what type of characters the oak has (e.g. if it's hollow, has an especially large crown, etc.). The study was concentrated to the oak population of Östermalm and did not take in account the areas and oaks that exists outside the borough's borders. With additional information like this long-term plan could be made for the local populations to avoid gaps between generation and loss of biodiversity.

As seen with the calculations and the discussion there is much work to sustain a healthy population of giant oaks that can harbor high biodiversity, and it takes time. Long-term planning is truly necessary if these types of biotopes are to sustain and have resilience. To conserve this kind of biologically valuable biotopes is one small but essential contribution needed to change the negative trend that biodiversity is experiencing in these crucial times.

CONCLUSIONS

The oak populations of Östermalm is in no grave danger to loss of biodiversity, but if not managed the population could lose connectivity and lead to fragmented. The areas of Östermalm that are more critical is especially the wedge in Ladugårdsgärdet, which interconnects the northern and southern oak populations. Other areas of interest are the west and eastern parts of Norra Djurgården, the solitary population by the cemetery in the district of Östermalm, the south-western parts of Djurgården. It is recommended to focus on these areas and take forth area-specific long-term conservation plans to secure that Östermalms oak population can sustain the high biodiversity it has today even in the future.

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