Red squirrels (*Sciurus vulgaris*) and Siberian chipmunks (*Tamias sibiricus*) in Tilburg, the Netherlands

Optimization of visual counts

Serena Nelissen

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Red squirrels (*Sciurus vulgaris*) and Siberian chipmunks (*Tamias sibiricus*) in Tilburg, the Netherlands

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PREFACE

In the period from March until September 2014 I worked with pleasure on my internship at the Dutch Mammal Society (Bureau van de Zoogdiervereniging). This internship was very instructive and I learned how to set up fieldwork and work with the data afterwards. I had the opportunity to be independent in doing things, which was nice.

During my fieldwork in Tilburg more and more people started to recognize me and asked me what I was doing. Most of them were interested and asked me the next time they saw me how it was going and how many squirrels I saw that day. One day, when it was raining very hard, I could even shelter in the cafeteria 'De Grotto' in the middle of Oude Warande without any problem. The squirrels came very close and were not very afraid of people, which makes it more fun to do the fieldwork.

First of all I want to thank Vilmar Dijkstra and Hans Hollander for their guidance through the whole process during my internship. Second, I am grateful to Sanne Winkel, Nora Nelissen, Ramon Nelissen and Theo Peeters for helping me with my field work. Furthermore, I want to express my thanks to Henk Siepel for his guidance from the university. Last but not least, I want to thank all employees and other interns for their help and the good times.

SUMMARY

In a mixed forest south-west of Tilburg, red squirrels (*Sciurus vulgaris*) and Siberian chipmunks (*Tamias sibiricus*) seem to live together without disturbing each other too much. Different studies suggest a possible negative effect of Siberian chipmunks on forest communities. To research these populations, both squirrels need to be monitored. The main question of this study is therefore 'What is the best method of visual counts to have the highest probability of detecting red squirrels and Siberian chipmunks?'

In a literature study the possibility of food and habitat competition was researched. Vegetation mapping was used to show the percentage dead wood and shrubs and the density of each tree species in each section. With visual squirrel counts the effect of time since sunrise, weather, temperature, wind speed, wind direction, vegetation, presence of people and dogs and number of people counting during visual counts was determined.

Literature study shows that food competition between the red squirrel and Siberian chipmunk can occur. Food competition can also occur between squirrel species and different animals (i.e. birds, muroidea, rabbits). Habitat competition can take place between red squirrels and Siberian chipmunks for activity time and forest type, but not for hiding place for food and nest space.

The relative ratio showed a higher activity of red squirrel in the morning and this is confirmed by the result of a significant detection peak from four to six hours after sunrise and literature. Siberian chipmunks were active all day, which also is found in other studies. With clear weather more red squirrels were detected in Wandelbos, which could not be explained because clear weather can also mean a higher temperature or more light. A trend is found in the effect of temperature on the detection probability of red squirrels. However, also a confounding factor of temperature is found, namely time since sunrise. Wind speed and wind direction give no significant effect on the probability of detecting red squirrels and Siberian chipmunks. Dead wood shows a significant effect and the number of tree species a trend on the presence of Siberian chipmunks. Trees species that are important for the presence of squirrels are different per area and per species. On a busy day with people in Wandelbos less Siberian chipmunks were seen. Because of the petting zoo and playground in Wandelbos, many people could also mean more children, who can unsettle chipmunks more, because they are louder and more active. No significant effect of counting with one or two people is found. Nevertheless, only five times there was counted with two people and every person reacts different on sounds and movement and has a different sight. So counting with two people should be done several more times with different people to say for sure there is no difference between counting with one or two people. The needed sample size to get the same result differs a lot per area and per squirrel species. Because of the low density and the counting frequency no accurate sample size can be calculated for Vredelust-Heidepark yet. Approximately 16% of the observations of Siberian chipmunks is auditory.

To conclude, time since sunrise and weather have an effect on the probability of detecting red squirrels and dead wood and number of tree species have an effect on detecting Siberian chipmunks. Time since sunrise is important for the visual counts of red squirrel, while no of the researched factors is important for the visual counts of Siberian chipmunks. Therefore, when counted both squirrels species at the same time, visual counts should be done between two to six hours after sunrise and with the same frequency each season to see differences per season.

1 INTRODUCTION

In nature reserves 'Oude Warande', 'Wandelbos', 'Vredelust-Heidepark', 'De Blaak' and 'De Kaaistoep' in Tilburg (Netherlands) the red squirrel (*Sciurus vulgaris*) and the Siberian chipmunk (*Tamias sibiricus*) seem to live together without disturbing each other too much. The Siberian chipmunk stayed behind after a zoo in Tilburg was closed and established a population in 'Oude Warande' and spread to the other reserves in Tilburg. From different studies, it is known that non-native species can become invasive to the native species. The grey squirrel is the most discussed invasive squirrel (Bertolino, 2008; Bertolino, 2009; Bertolino et al., 2000; Bertolino et al., 2014; Wauters et al., 2002). When species live in the same niche, species are competing with each other. Competing can negatively affect fecundity, growth or survival of one or both species (Wauters et al., 2002). By different ecological processes (e.g. competition, predation, parasitism, disease vectoring and hybridization), introduced species interact with native species (Bertolino, 2008). Non-native species can change ecosystem functioning by altering materials and energy flows. Litter decomposition rates can be affected by animal invasions in different ways, for example direct consumption and displacement. Secondary production can be increased and growth and biomass can be decreased. Denitrification rates can be altered by animal invasions (Ehrenfeld, 2010; Strayer, 2012). To become invasive in non-native environment, species need to be introduced, need to establish and need to spread. According to the 10% rule, approximately 10% of the introduced species establish and approximately 10% of these spread (Williamson, 1996). Jeschke & Strayer (2005) disprove this rule. Approximately 50% of vertebrates, introduced in Europe and North America, establishes and spreads in non-native environment (Jeschke & Strayer, 2005).

In different studies authors suggest that there is a possible negative effect of Siberian chipmunks on other forest communities, like birds and woodland rodents, because of the size of the populations of Siberian chipmunk in Europe. However, this topic is never studied. By monitoring squirrels in a park in Rome, Benassi & Bertolino (2011) found out that 20 years after introduction of Siberian chipmunks, the red squirrel is still more abundant in the park (Benassi & Bertolino, 2011). In the native area of Siberian chipmunks, they bring heavy damage to grain crops. This damaging is never reported in Europe (Bertolino & Genovesi, 2005).

To see how the populations red squirrels and Siberian chipmunks in Tilburg behave, the squirrels need to be monitored. The main question of this study is: 'What is the best method of visual counts to have the highest probability of detecting red squirrels and Siberian chipmunks?' The sub-questions for this main question are:

1. Which of the factors: time since sunrise, weather, temperature, wind speed, wind direction, vegetation, presence of people and dogs and number of people counting during visual counts have an effect on the probability of detecting red squirrels and Siberian chipmunks?
2. Which factors are of interest for visual counts of red squirrels and Siberian chipmunks?
3. What is the relative ratio between red squirrels and Siberian chipmunks in the study areas?
4. Can there be food competition between the red squirrel and the Siberian chipmunk?
5. Can there be habitat competition between the red squirrel and the Siberian chipmunk?
6. What is the best sample size to determine the average number of squirrels in the research areas?

First, in chapter 2, I will discuss some characteristics of the red squirrel and the Siberian chipmunk and whether there can be food or habitat competition. In chapter 3, the methods used for this study are described, namely vegetation mapping and visual counts. Furthermore, in chapter 4, the results of the field research and analyses will be described. Finally, in chapter 5, the results will be discussed.

2 LITERATURE STUDY: CHARACTERISTICS, FOOD AND HABITAT COMPETITION

2.1 Red squirrel (*Sciurus vulgaris*)

Figure 1: Red squirrel (*Sciurus vulgaris*)

The red squirrel (Figure 1) is native in Europe and Asia, where it has a globally spread in the Palaearctic, from the United Kingdom to the Pacific coast. The squirrel is most abundant in large habitats of coniferous forests. However, it also occurs in deciduous woods, mixed forests, parks, gardens and small stands of conifers. Squirrels prefer older forests, because there are more opportunities for food and nesting. In summer they are most active in the early morning and late in the afternoon. In winter they are active when the weather permits (Bosch & Lurz, 2012; Kalwij & van der Linden, 1995). Densities of the red squirrel differs between less than 0.1 to 1.5 animals per hectare (Bosch & Lurz, 2012). Red squirrels live solitary and home ranges of males are bigger than home ranges of females. It mostly eats seeds, acorns, fungus, buds, shoots and flowers. Sometimes it takes animal prey, like insects, young birds and eggs (Bosch & Lurz, 2012; Kalwij & van der Linden, 1995). The colour of this squirrel is light red to dark brown with a white belly. The sound of this squirrel is rattling or a quick squeaking at two alternately heights (Bertolino *et al*., 2000; Bosch & Lurz, 2012). Without the tail (14-22 cm), red squirrels are 21-25 cm. They build their nest high in a tree. The breeding period is from December till February and from May till June. Gestation is 5-6 weeks and only the female raise the young. Young squirrels are suckled for 10 weeks. (Bosch & Lurz, 2012; Kalwij & van der Linden, 1995). Red squirrels have no hibernation, they are just less active during the winter (Wiltafsky, 1993). The main threat to this species is habitat loss and habitat fragmentation. Predators of the red squirrel are pine marten, wild and feral cat, fox, lynx, owls and other large birds of prey (Bosch & Lurz, 2012).

2.2 Siberian chipmunk (*Tamias sibiricus*)

Figure 2: Siberian chipmunk (*Tamias sibiricus*)

The Siberian chipmunk (Figure 2) is native in Asia. It is a small squirrel of 12-17 cm with a tail of 8-12 cm. The colour of this squirrel is tints brown and grey. It has five dark stripes on its back and two stripes near its eyes. The sound of this species is a high squeak, which can be quick (several times per second) or slow (ones per second/two seconds). The squirrel lives in coniferous forests, deciduous woods and mixed forests (Thissen, 1992). It lives in holes in the ground, so often sand is the best ground for it to live in. They are active at daylight. In general, it does not climb higher than 7 metres. However, it can climb till 30 metres. Its diet is very diverse and mostly vegetable. However, it also eats snails, amphibians, reptiles, bird eggs and young

birds (Thissen, 1992). This squirrel builds its nests below ground (Kawamichi, 1989). Mostly it has one breeding period, but sometimes two. The first one is in April-May and the second is in August-September. Gestation is 5-6 weeks and young squirrels are suckled for 4-6 weeks (Thissen, 1992). Hibernation is from October/November till March/April (Krapp, 1993). Densities of the Siberian chipmunk change during and per year. At the start of the breeding period populations have a density of ten squirrels per hectare and in summer it will be between 26-40 squirrels per hectare. The predators in the Netherlands are weasel, stoat, polecat and other mustelids, fox and birds of prey (Peeters, 2013).

2.3 Food competition

Red squirrels and Siberian chipmunks can outcompete each other when there is competition for food or habitat. Red squirrels have a very extensive diet. The vegetable part consists of coniferous seeds (pine and spruce), hazelnuts, acorn, walnuts, beechnut, sweet chestnuts, *Aesculus* nuts, common hornbeam seeds, different berries, fruits, buds, shoots, flowers, green plant material and sometimes bark of trees. The other part consists of fungi, bird eggs, young birds, snails, invertebrates (like insects) and lichens (Table 1) (Bosch & Lurz, 2012; Broekhuizen, 1991; Kalwij & van der Linden, 1995; Lurz *et al*., 2005; Shuttleworth, 2000; Wiltafsky, 1993). Siberian chipmunk also have an extensive diet. The vegetable part consists of coniferous seeds, deciduous seeds, different berries, fruits, buds, leaves, flowers, wheat, oats, buckwheat and other field fruits. The other part consists of fungi, bird eggs, young birds, snails, amphibians, reptiles, insects and arthropods, like mealworms and cricket (Table 1) (Krapp, 1993; Peeters, 2013; Verbeylen & Matthysen, 1998).

Table 1: Diet of red squirrels and Siberian chipmunks.

Red squirrel	**Siberian chipmunk**
Vegetable	
Coniferous seeds	Coniferous seeds
Hazelnuts, acorn, walnuts, beechnuts, sweet chestnuts, *Aesculus* nuts, common hornbeam seeds	Deciduous seeds
Berries	Berries
Fruits	Fruits
Buds	Buds
Shoots	-
Flowers	Flowers
Green plant material	Leaves
Bark	-
-	Wheat
-	Oats
-	Buckwheat
-	Field fruits
Other food	
Fungi	Fungi
Bird eggs	Bird eggs
Young birds	Young birds
Snails	Snails
Invertebrates (worms, insects)	Insects and arthropods
Lichens	-
-	Amphibians
-	Reptiles

There are many similarities in food of the red squirrel and the Siberian chipmunk and only a few differences (Table 1). The red squirrel eats sometimes bark and lichens, while

Siberian chipmunks eat wheat, oats, buckwheat, field fruits, amphibians and reptiles. The rest of the mentioned food is the same. By this there can be said that food can be a deciding factor whether the squirrels can live together. For food they can compete with each other. However, when there is enough food available for both populations, they do not have to compete for food.

Other animals can also compete with squirrels for food. Coniferous seeds are also eaten by mice (Muridae), voles (Microtidae), woodpeckers (Picidae), nutcrackers (*Nucifraga caryocatactes*) and crossbills (*Loxia curvirostra*), hazelnuts, both ripe and unripe, are also food for great tits (*Parus major*), edible dormouse (*Glis glis*), wood mouse (*Apodemus sylvaticus*), yellow-necked mouse (*Apodemus flavicollis*), hazel dormouse (*Muscardinus avellanarius*), European water vole (*Arvicola amphibius*), bank vole (*Myodes glareolus*), striped field mouse (*Apodemus agrarius*), Corvidae, Eurasian magpie (*Pica pica*), woodpeckers, Eurasian nuthatch (*Sitta europaea*) and nutcrackers. Beechnuts are, besides squirrels, also eaten by mice, voles, Eurasian nuthatch and other birds, like greenfinch (*Carduelis chloris*), brambling (*Fringilla montifringilla*) and chaffinch (*Fringilla coelebs*). Acorn are also food for mice, voles, birds like Eurasian jay (*Garrulus glandarius*), nutcrackers, Corvidae, rook (*Corvus frugilegus*), Western jackdaw (*Corvus monedula*) and small birds, like great tits and Eurasian blue tit (*Cyanistes caeruleus*). Walnuts are also eaten by mice, voles, raccoons, edible dormouse, great tit and other small birds, Western jackdaw, Eurasian jay and Corvidae. Sweet chestnuts and *Aesculus* nuts are also food for rodents, like mice, voles and rats (*Rattus*), and birds. Rose hips are also eaten by greenfinch, chaffinch, thrush (Turdidae), wood mouse, yellow-necked mouse and bank vole. Fruits are also food for mice, voles, rats, thrush, common blackbird (*Turdus merula*) and crossbills. Fungi are also eaten by mice, voles, rabbits (*Oryctolagus cuniculus*), Eurasian woodcock (*Scolopax rusticola*) and other birds, wild boar (*Sus scrofa*), European badger (*Meles meles*) and roe deer (*Capreolus capreolus*). Flowers of trees and bushes are also eaten by wood mouse and yellow-necked mouse. Twigs are also eaten by rabbits, European hare (*Lepus europaeus*), roe deer, deer (Cervidae) mice and voles. Buds is also food for bank vole, wood mouse, yellow-necked mouse, garden dormouse (*Eliomys quercinus*), hazel dormouse and edible dormouse. Debarking is also done by deer, European hare, rabbits, edible dormouse, hazel dormouse, field vole (*Microtus agrestis*), common vole (*Microtus arvalis*), bank vole, European water vole, Eurasian beaver (*Castor fiber*), coypu (*Myocastor coypus*), great spotted woodpecker (*Dendrocopos major*), black woodpecker (*Dryocopus martius*), European green woodpecker (*Picus viridis*) and great tits. Bird eggs is also food for Corvidae, Gulls (Laridae), Eurasian magpie, Eurasian jay, European hedgehog (*Erinaceus europaeus*), fox (*Vulpes vulpes*), beech marten (*Martes foina*), pine marten (*Martes martes*), polecat (*Mustela putorius*), weasel (*Mustela*) and stoat (*Mustela erminea*). Snails are also eaten by brown rat (*Rattus norvegicus*), wood mouse, garden dormouse, song thrush (*Turdus philomelos*), European hedgehog, shrew mouse (Soricidae), common blackbird, Corvidae and Eurasian magpie (Table 2 and Table 3) (Van Diepenbeek, 1999).

So a lot of other species eat food that squirrels eat too. By searching waarneming.nl for observed species in Tilburg, all mentioned birds are observed in Tilburg, except the nutcracker (Table 2). Muroidea observed in Tilburg are bank vole, common vole, field vole, shrew mouse and wood mouse (Table 3). Other of the mentioned animals which are observed in Tilburg are European hedgehog, fox, polecat, rabbits and roe deer. For 'De Blaak', Mustelidae was mentioned as observation. This can be beech marten, European badger, pine marten, polecat, stoat and weasel (Table 3). By this there can be said that competition between different animal species and squirrels in possible in the study areas in Tilburg.

Table 2: Birds which eat the same as squirrels. Furthermore, for each study area in Tilburg, the presence of the species is displayed.

	Birds																						
	Birds (general)	**Black woodpecker**	**Brambling**	**Chaffinch**	**Common blackbird**	**Corvidae**	**Crossbill**	**Eurasian blue tit**	**European green woodpecker**	**Eurasian jay**	**Eurasian magpie**	**Eurasian nuthatch**	**Eurasian woodcock**	**Great spotted woodpecker**	**Great tit**	**Greenfinch**	**Gulls**	**Nutcracker**	**Rook**	**Song thrush**	**Thrush**	**Western jackdaw**	**Woodpecker (general)**
Coniferous seeds							X											X					X
Hazelnuts						X					X	X			X			X					X
Beechnuts	X		X	X								X				X							
Acorn	X					X		X		X					X			X	X			X	
Walnuts	X					X				X					X							X	
Sweet chestnuts and *Aesculus* nuts	X																						
Rose hips				X												X					X		
Fruits					X		X														X		
Fungi	X												X										
Flowers																							
Twigs																							
Buds																							
Debarking		X							X					X	X								
Bird eggs						X				X	X						X						
Snails					X	X					X									X			
Oude Warande	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X
Wandelbos	X	X	X	X	X	X		X	X	X	X	X		X	X	X	X			X	X	X	X
Vredelust-Heidepark	X	X	X	X	X	X		X	X	X	X	X		X	X					X	X	X	X
De Blaak	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X
De Kaaistoep	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X

Table 3: Muroidea and other animals which eat the same as squirrels. Furthermore, for each study area in Tilburg, the presence of the species is displayed.

	Muroidea													**Other animals**																			
	Mice (general)	**Voles (general)**	**Bank vole**	**Common vole**	**Edible dormouse**	**European water vole**	**Field vole**	**Garden dormouse**	**Hazel dormouse**	**Shrew mouse**	**Striped field mouse**	**Wood mouse**	**Yellow-necked mouse**	**Beech marten**	**Brown rat**	**Coypu**	**Deer**	**European badger**	**Eurasian beaver**	**European hare**	**European hedgehog**	**Fox**	**Pine marten**	**Polecat**	**Rabbits**	**Raccoons**	**Rats (general)**	**Roe deer**	**Squirrels**	**Stoat**	**Weasel**	**Wild boar**
Coniferous seeds	X	X																											X			
Hazelnuts			X		X	X			X		X	X	X																X			
Beechnuts	X	X																											X			
Acorn	X	X																											X			
Walnuts	X	X			X																				X				X			
Sweet chestnuts and *Aesculus* nuts	X	X																								X			X			
Rose hips			X									X	X																X			
Fruits	X	X																								X			X			
Fungi	X	X																X							X			X	X			X
Flowers												X	X																X			
Twigs	X	X															X			X					X			X	X			
Buds			X		X			X	X			X	X												X				X			
Debarking			X	X	X	X	X		X							X	X		X	X					X				X			
Bird eggs														X							X	X	X	X					X	X	X	
Snails								X		X		X			X						X								X			
Oude Warande	X	X	X	X								X										X			X				X			
Wandelbos	X									X											X	X			X			X	X			
Vredelust-Heidepark																					X				X			X	X			
De Blaak	X	X					X							x				x			X	X	x	x	X				X	x	x	
De Kaaistoep	X									X												X		X	X			X	X			

2.4 Habitat competition

Red squirrels and Siberian chipmunks are both active during daylight. Both species are more active in the morning and evening hours (Broekhuizen, 1991; Krapp, 1993; Peeters, 2013; Wiltafsky, 1993). Red squirrels and Siberian chipmunks life in coniferous, deciduous and mixed forests (Broekhuizen, 1991; Lurz *et al*., 2005; Peeters, 2013; Wiltafsky, 1993). However, red squirrels prefer old coniferous trees, because there is more proteins and energy in pine and spruce seeds of older trees (Broekhuizen, 1991; Wiltafsky, 1993). Siberian chipmunks need sandy soils to build their burrows (Peeters, 2013). Red squirrels bury food or hide it in hollow trees, in bark or in tree forks (Wiltafsky, 1993). Siberian chipmunks store food in their nest and bury it 5 cm in the soil (Peeters, 2013). Red squirrels spend most time in trees, while Siberian chipmunks spend more time at the ground (Benassi & Bertolino, 2011; Krapp, 1993; Verboom & van Apeldoorn). Red squirrels build their nest high in trees and Siberian chipmunks below ground (Table 4) (Verbeylen & Matthysen, 1998; Verboom & van Apeldoorn; Wiltafsky, 1993).

Table 4: Similarities and differences in habitat use of red squirrels and Siberian chipmunk.

	Red squirrel	**Siberian chipmunk**
Activity	Daylight	Daylight
Habitat	Coniferous, deciduous and mixed forests	Coniferous, deciduous and mixed forests
	Old trees	Sandy soils
Hiding food	Burying, in hollow trees, in bark or in tree forks.	Food storage and burying
Nest	High in trees	Below ground

Both squirrel species live in the same forest types and are active during the same times. The nest of the species are at very different places. Red squirrels have different ways of hiding food, while Siberian chipmunks mostly store their food. Red squirrels spend more time in trees than Siberian chipmunks. For forest type and activity times the squirrel species can compete with each other. However, for hiding place for food and nest space no competition occur.

3 METHODS

In the methods the study area will be described, followed by a description of the vegetation mapping, visual counts of squirrels and the analyses.

3.1 Study areas

The areas where both species, red squirrels and Siberian chipmunks, live, are 'Oude Warande', 'Wandelbos', 'Vredelust-Heidepark', 'De Blaak' and 'De Kaaistoep' (Figure 3). It is a forest south-west of Tilburg. Wandelbos is in the north of the nature reserve. Oude Warande can be found south of Wandelbos. Between Bredaseweg and Gilzerbaan, Vredelust-Heidepark can be found. South of the Gilzerbaan, De Blaak and De Kaaistoep are established. This research took place in Oude Warande, Wandelbos and Vredelust-Heidepark.

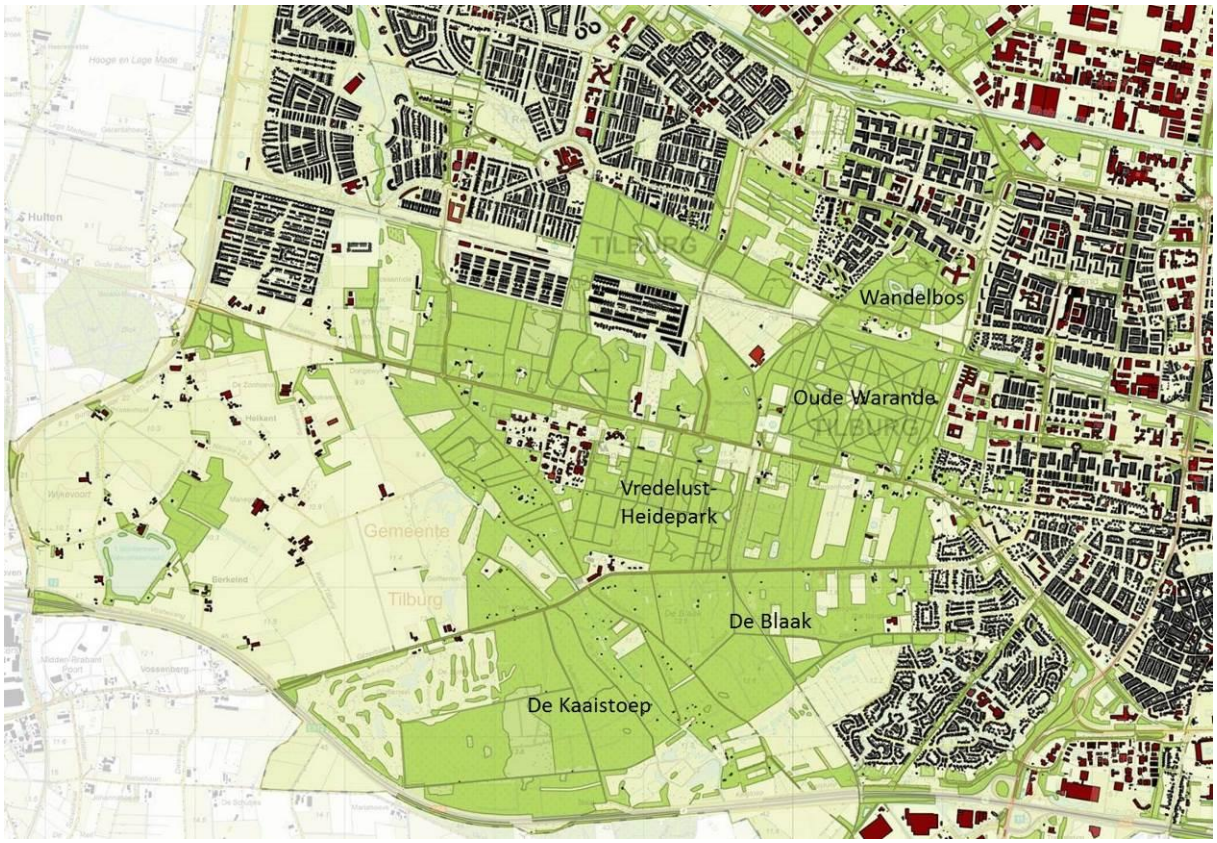

Figure 3: Research area in Tilburg with the areas Wandelbos, Oude Warande, Vredelust-Heidepark, De Blaak and De Kaaistoep.

3.2 Vegetation mapping

In the areas Wandelbos, Oude Warande and Vredelust-Heidepark the trees were mapped for each section to examine whether vegetation, and thus presence of food, is important to observe a squirrel in a certain section (Figure 4). Wandelbos was divided into 26 sections, Oude Warande into 46 sections and Vredelust-Heidepark into 38 sections.

Figure 4: Sections for vegetation mapping in the areas Wandelbos (A), Oude Warande (B) and Vredelust-Heidepark (C).

For each section the percentages dead wood on the ground and shrubs were estimated. Contiguously, the percentage cover, density (0-10) and relevé (Braun-Blanquet, 1965) of each present tree species were noted. A density of 1 represents a very low density, while a density of 10 represents a very high density. A density of 0 means a planted tree lane. In Table 5 relevé codes are defined. The findings were written at a form named 'Vegetation mapping' (Attachment 1).

Table 5: Relevé codes by Braun-Blanquet (1965).

Relevé	**Abundance**	**Cover**
r	Very few	<5%
+	Few	<5%
1	Numerous	<5%
2m	Very numerous	<5%
2a	Arbitrary	5-12.5%
2b	Arbitrary	12.5-25%
3	Arbitrary	25-50%
4	Arbitrary	50-75%
5	Arbitrary	75-100%

3.3 Visual counts of squirrels

The visual squirrel counts were carried out during spring and summer of 2014. Transects were marked within suitable squirrel habitat in Wandelbos, Oude Warande and Vredelust-Heidepark (Figure 5). The transects were divided in sections based on easy to recognize reference points on the transect.

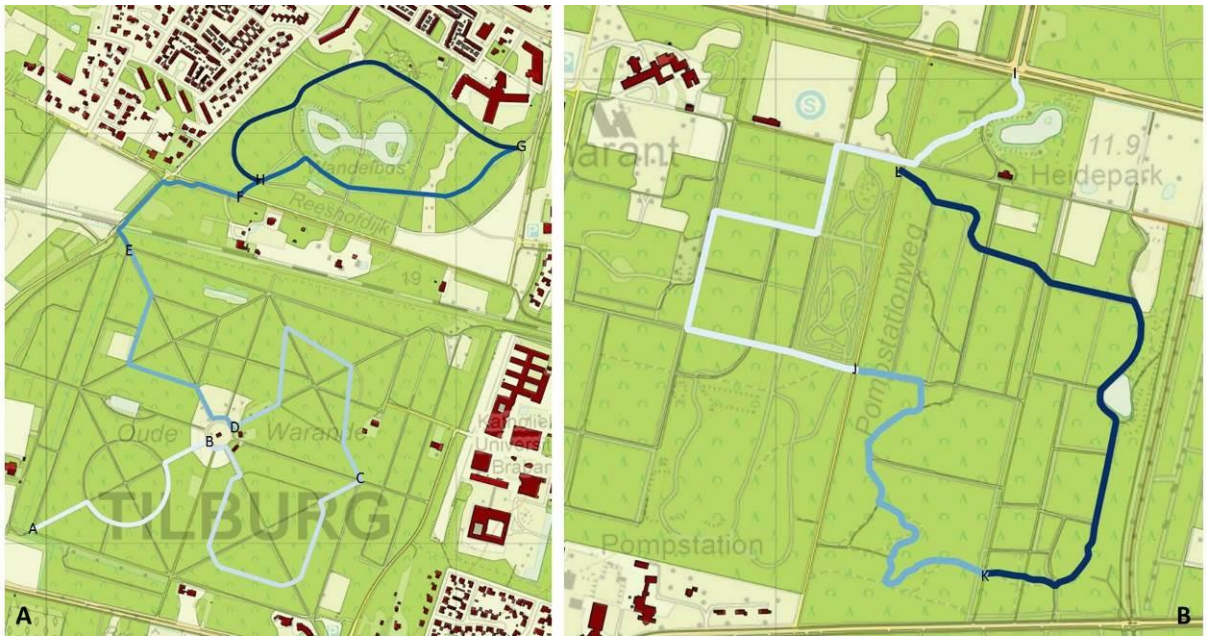

Figure 5: Transect and sections in Oude Warande and Wandelbos (A) and in Vredelust-Heidepark (B).

The transects were walked at three moments of a day with a speed of approximately 2 km/h. In the morning it was walked from about 9:00h till 11:30h in Oude Warande-Wandelbos or till 10:30h in Vredelust-Heidepark. In the early afternoon it was walked from about 12:00h till 14:30h in Oude Warande-Wandelbos or till 13:30h in Vredelust-Heidepark. In the late afternoon it was walked from about 14:30h till 17:00h in Oude Warande-Wandelbos or till 16:00h in Vredelust-Heidepark. In Table 6 the length of the sections is defined with the time it takes to walk that part. In Oude Warande four sections were walked with a total length of 2928.7 meters. In Wandelbos the total length of the three sections was 2119.8 meters and in Vredelust-Heidepark the total length of the three sections was 3060.5 meters.

Table 6: Transect sections with its length and time to walk.

Area	**Sections**	**Length (m)**	**Time (min.)**
Oude Warande	A-B	595.3	18
Oude Warande	B-C	907.4	27
Oude Warande	C-D	790.7	24
Oude Warande	D-E	635.3	19
Wandelbos	E-F	415.5	12
Wandelbos	F-G	759.9	23
Wandelbos	G-H	944.4	28
Vredelust-Heidepark	I-J	1185.4	36
Vredelust-Heidepark	J-K	736.0	22
Vredelust-Heidepark	K-L	1139.1	34
	Total	8109.0	243

During the walk all squirrels were noted including time, estimated distance from the transect line in meters, behaviour and location. Behaviour was divided into foraging, passing, fighting, playing, hiding, fleeing, cleaning, digging and searching. Foraging included eating and walking with food in the mount. Fleeing meant that a squirrel was running away very fast. Sounds of squirrels were also recorded including time and location, but only if a squirrel was heard and not seen. The amount of people and dogs in the area were noted in three categories: Quiet, Average and Busy.

3.3.1 Weather

A record of the weather(s) during the count was made (clear, veil clouds, scattered clouds, partly cloudy, mostly cloudy, overcast, fog, drizzle, light rain, moderate rain and heavy rain) (Bryce *et al*., 1997; Fimbel & Freed, 2008; Gurnell *et al*., 2004; Gurnell *et al*., 2009; Squirrel Census Methods, n.d.; Verbeylen & Matthysen, 1998; Verbeylen, 2001). The weather was clear, when there were no clouds in the sky. Scattered clouds meant that approximately one fourth of the sky was covered with clouds. Partly cloudy meant that approximately half of the sky was covered with clouds. Mostly cloudy meant that approximately three quarters of the sky was covered with clouds. Overcast meant that the sky was completely covered with clouds (KNMI, 2013; Science NetLinks, n.d.). Light rain was less than 2.5 mm in one hour. Moderate rain was between 2.5 mm and 7.6 mm in one hour. Heavy rain was between 7.6 mm and 10 mm in one hour (Haby, n.d.) (Table 7).

Table 7: Weather with its definitions.

Weather	**Definition**
Clear	No clouds
Veil clouds	Veil clouds
Scattered clouds	¼ clouds
Partly cloudy	½ clouds
Mostly cloudy	¾ clouds
Overcast	Fully cloudy
Fog	Fog
Drizzle	Drizzle
Light rain	< 2.5 mm/hour
Moderate rain	2.5 mm/hour – 7.6 mm/hour
Heavy rain	7.6 mm/hour – 10 mm/hour

Afterwards, temperature, wind speed, wind directions and sunrise was looked up for every hour. Temperature, wind speed, wind directions and rainfall were measured in Gilze-Rijen (Latitude: 51° 34'; Longitude: 04° 56' (KNMI, 2013-2)). This was the closest measure point to Tilburg, namely 10.4 km (KNMI, 2014; KNMI, 2014-2). Temperature, wind speed and wind direction do not differ much between Tilburg and Gilze-Rijen and therefore these data are used for the research areas. However, rainfall can differ quickly areas. Therefore, rainfall is classified in light rain, moderate rain and heavy rain.

3.3.2 Frequency

Three times a week for thirteen weeks, the transects were walked. In Attachment 2 information about the visual count days is described. When the weather was unsuitable, the survey was delayed, because squirrels hide in their nest by violent rain (>50 mm in one hour), strong winds (wind speed >17,1 m/s) or when it is very cold (below 0°C at daytime). Oude Warande and Wandelbos were counted fourteen times in the morning, nine times in the early afternoon and six times in the late afternoon. Vredelust-Heidepark

was counted three times in the morning, three times in the early afternoon and three times in the late afternoon. The findings were written at the form named 'visual counts' (Attachment 3) during the walks. The transects were walked alternately clockwise and counter clockwise (Bryce *et al*., 1997; Fimbel & Freed, 2008; Gurnell *et al*., 2004; Gurnell *et al*., 2009; Squirrel Census Methods, n.d.; Verbeylen & Matthysen, 1998; Verbeylen, 2001).

3.4 Analyses

3.4.1 Mapping

By using the maps with numbers of recorded squirrels and the estimated distance of each squirrel from the transect line, maps were made of the visual counts in QGIS 2.2.0 Valmiera. With the location of the squirrel sounds, maps were made of the squirrel sounds. Furthermore, the vegetation was mapped per section and per tree species. This generates in three types of maps.

3.4.2 Data processing

The collected data were sorted per walk. The average temperature, wind speed and wind direction of each walk was considered by calculating each average of one hour as part of the walk. For example, one walk lasted for 75 minutes in three different hours. The walk was for five minutes in the first hour, 60 minutes in the second hour and ten minutes in the third hour. 5/75 part of the temperature of first hour plus 60/75 part of the temperature of the second hour plus 10/75 part of the temperature of third hours made the average temperature of that walk. Next, the results were divided into categories. Temperatures were divided into six categories (1: 5 – 10, 2: 10 – 15, 3: 15 – 20, 4: 20 – 25, 5: 25 – 30 and 6: 30 – 35 °C). Wind speeds were divided into five categories (1: 0.3 – 1.5, 2: 1.6 – 3.3, 3: 3.4 – 5.4, 4: 5.5 – 7.9 and 5: 8.0 – 10.7 metres per second). Wind directions were divided into seventeen categories (1: North, 2: North-North-East, 3: North-East, 4: East-North-East, 5: East, 6: East-South-East, 7: East-South, 8: East-South-South, 9: South, 10: South-South-West, 11: South-West, 12: West-South-West, 13: West, 14: West-North-West, 15: North-West, 16: North-North-West and 17: Variable).

The time since sunrise was calculated with the median of the time of the walk. The median minus the sunrise gave the time since sunrise. Subsequently, time since sunrise was divided into six categories (1: 0 – 2, 2: 2 – 4, 3: 4 – 6, 4: 6 – 8, 5: 8 – 10 and 6:10 – 12 hours after sunrise). For weather, general weather of the day was used for the analysis. Generally, this was the weather that was most present that day. To standardise the number of squirrel per walk in time. The number of squirrel per minute was calculated by dividing the number of squirrel by the duration of the walk.

3.4.3 Statistics

To prove a possible difference between the detection of both squirrels species and the number of people or dogs present in the areas an unifactorial variance analysis (Microsoft Excel, Analysis ToolPak) was used. When the data were not normally distributed the data were log-transformed. The possible differences in detection of both squirrel species with different time since sunrise, weather, temperatures, wind speed, wind direction and number of people counting was verified with one way ANOVA in IBM SPSS Statistics Version 22 (IBM Corp, 2013). First the data were tested on normal distribution. If the data were not normally distributed, a transformation was used. If the data could not be normally distributed with transformation, a Kruskal-Wallis test one-way analysis of

variance was used in IBM SPSS Statistics to see possible differences between the categories.

Linear regression in IBM SPSS Statistics was used to prove possible regression between the number of squirrels in each section and the percentage dead wood or shrubs or the number of tree species. The relevé of Braun-Blanquet was converted to a continuous scale (1 – 9). A Negative Binomial Generalized Linear Model (Package MASS; Venables & Ripley, 2002) was built in the program R statistics, where red squirrels or Siberian chipmunks was plotted against tree species. The tree species which occurred in less than three sections were excluded of the model. The Variance Inflation Factors (package car; Fox & Weisberg, 2011) and correlations (package stats; R Core Team, 2014) were checked. The model was corrected for Variance Inflation Factors higher than ten and correlations higher than 0.7. The optimal model was chosen by AIC in Stepwise Model Selection (package RcmdrMisc; Fox, 2014) using the backward direction.

The optimal sample size was calculated for the average number of squirrels in each research area with three different errors: 0.5 squirrel, one squirrel and two squirrels. This sample size was based on the collected data and is calculated for spring and summer together. The z-value was based on a confidence level of 95%. Sample sizes were calculated by the square of z-value times standard deviation divided by the error and rounded up.

4 RESULTS

4.1 Observations

During the visual counts, in Wandelbos the most red squirrels and in Oude Warande the most Siberian chipmunks were observed. In Vredelust-Heidepark only a few squirrels of both species were observed (Table 8). In all areas more Siberian chipmunks than red squirrels were seen. In attachment 4 the number of squirrels per count is given. The maximum number of red squirrels seen during one count is eight in Oude Warande, eleven in Wandelbos and two in Vredelust-Heidepark. The maximum number of Siberian chipmunks seen during one count is thirteen in Oude Warande, twelve in Wandelbos and two in Vredelust-Heidepark.

Table 8: Total result of visual counts of squirrels.

		Species			
		Red squirrel		Siberian chipmunk	
	Sample size	Total number	Average	Total number	Average
Oude Warande	29	35	1.214	191	6.786
Wandelbos	29	87	2.964	143	4.929
Vredelust-Heidepark	9	3	0.333	8	0.889

In Oude Warande most red squirrels were seen in the morning, while Siberian chipmunks were mostly seen in the early afternoon. Most red squirrels were seen in the morning and most Siberian chipmunks were seen in the late afternoon in Wandelbos. In Vredelust-Heidepark most red squirrels and Siberian chipmunks were observed in the morning (Table 9). Overall, the highest detection of red squirrels is in the morning, while the highest detection of Siberian chipmunks differs per area.

Table 9: Result of visual counts of squirrels at different day times (morning, early afternoon and late afternoon).

			Species			
			Red squirrel		Siberian chipmunk	
	Day time	Sample size	Number	Average	Number	Average
Oude Warande	Morning	14	28	2.000	79	5.643
	Early afternoon	9	6	0.667	71	7.889
	Late afternoon	6	1	0.167	41	6.833
Wandelbos	Morning	14	63	4.500	65	4.643
	Early afternoon	9	15	1.667	50	5.556
	Late afternoon	6	9	1.500	28	6.833
Vredelust-Heidepark	Morning	3	2	0.761	5	1.903
	Early afternoon	3	0	0.000	3	1.142
	Late afternoon	3	1	0.381	0	0.000

Figure 6 shows the distribution of the seen squirrel species during the visual counts in Wandelbos, Oude Warande and Vredelust-Heidepark.

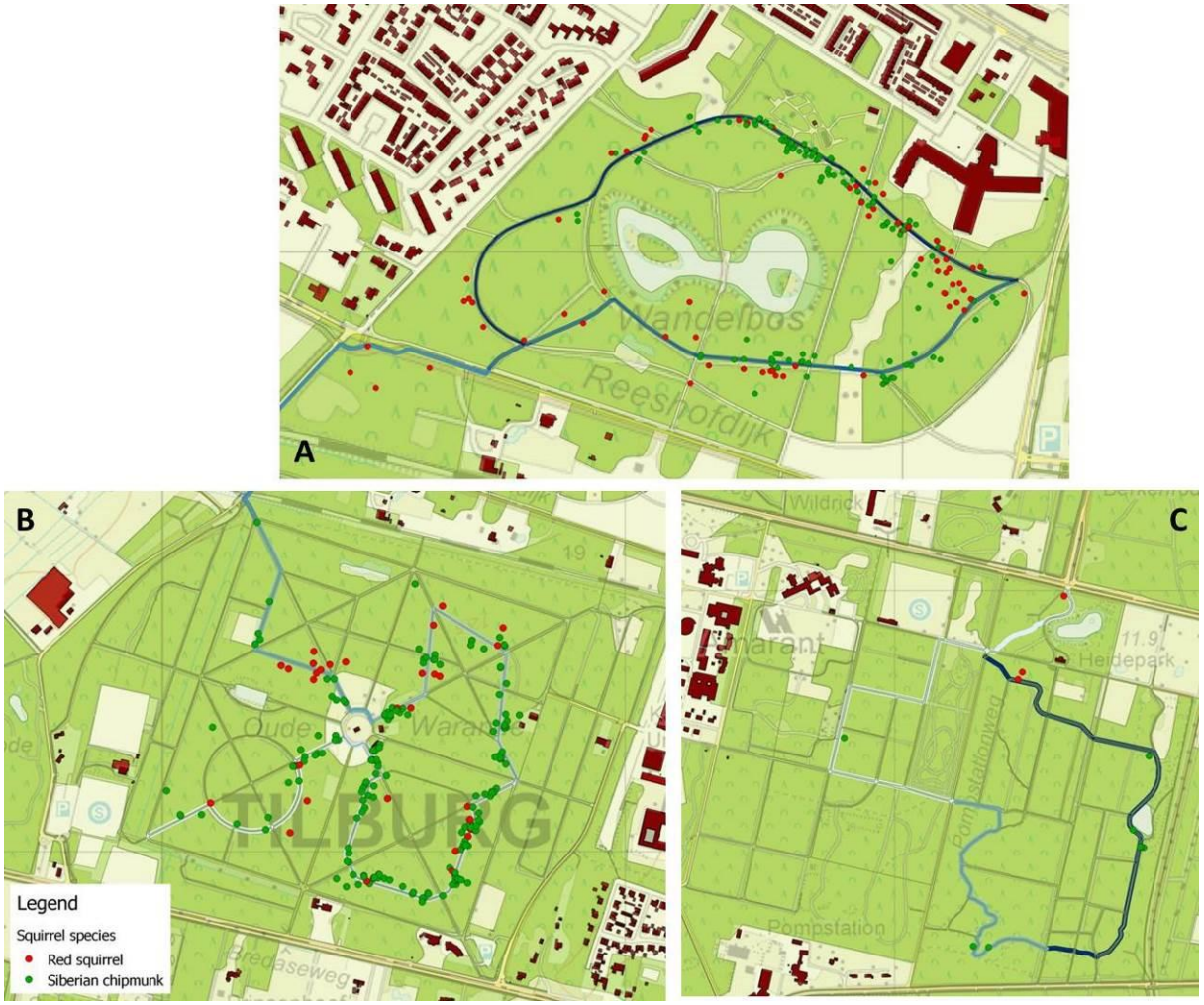

Figure 6: Distribution of seen squirrel in Wandelbos (A), Oude Warande (B) and Vredelust-Heidepark (C).

During the visual counts, the sounds of squirrels were also noted but only if the squirrel could not be seen. Table 10 shows that most Siberian chipmunks were heard in Oude Warande, followed by Wandelbos and only a few sounds were heard in Vredelust-Heidepark. The approximate place of the sound was mapped (Figure 7). The noted and mapped sounds were all from Siberian chipmunk. When the sound of a red squirrel was heard, the squirrel was also visible. In Oude Warande 15.9% of the observed Siberian chipmunks was a sound. In Wandelbos this is 16.9% and in Vredelust-Heidepark 42.9%.

Table 10: Sounds of squirrels only heard during visual counts.

	Species			
	Red squirrel		**Siberian chipmunk**	
	Total sounds	Average	Total sounds	Average
Oude Warande	0	0.000	36	1.714
Wandelbos	0	0.000	29	1.381
Vredelust-Heidepark	0	0.000	6	0.667

Figure 7: Squirrel sounds heard during visual counts in Wandelbos (A), Oude Warande (B) and Vredelust-Heidepark (C).

4.1.1 Behaviour

During the visual counts some interesting squirrel behaviour was seen. On 25th April 2014 two magpies were fighting with a red squirrel in a tree in Wandelbos. Both animals were making lots of noises. The magpies were poking the squirrel. Finally, the red squirrel flees by jumping to other trees. The magpies followed the squirrel for a few seconds and returned to their tree. In Oude Warande two red squirrels were playing with each other on the 28th of April 2014. They were running around and following each other. At a certain moment, a Siberian chipmunk came running and collided one of the playing red squirrels. Both species were perplexed for a moment, but continued with what they were doing. Sometimes a red squirrel and a Siberian chipmunk were seen about 1 meter from each other without disturbing each other. These examples show that the two squirrel species do not seen to disturb each other, but other animals can disturb the squirrels.

Siberian chipmunks were seen at the same place at different days, while red squirrel were most times seen at different places. Figure 8 shows that passing is the behaviour which was seen most for both red squirrels and Siberian chipmunks. This behaviour was followed by foraging and thereafter searching and playing.

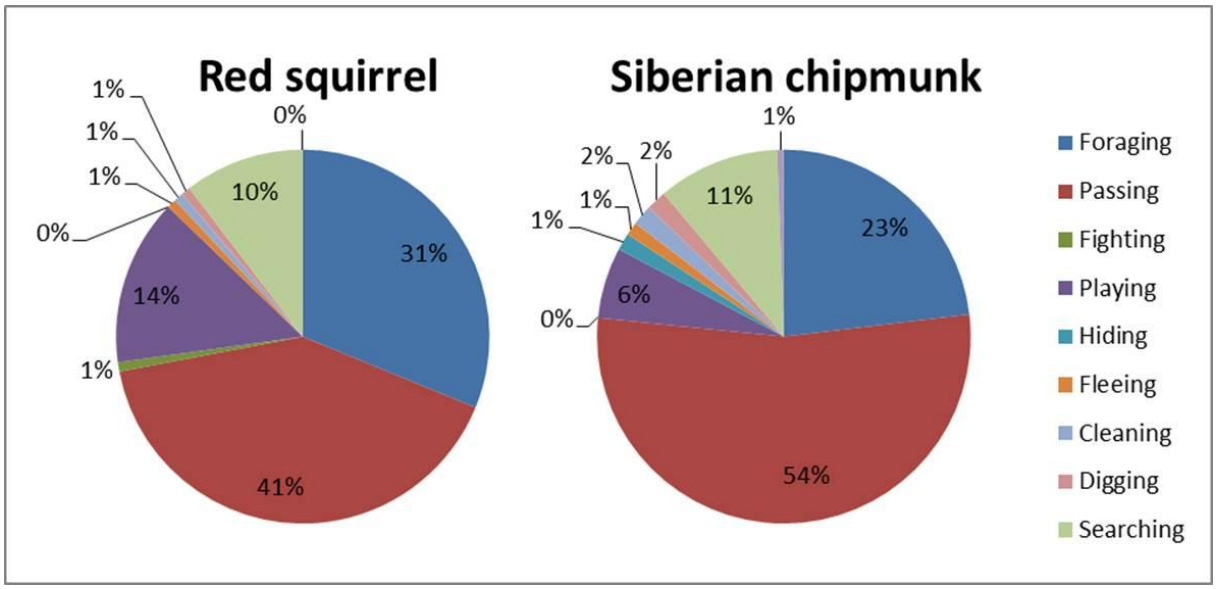

Figure 8: Behaviour of red squirrels and Siberian chipmunks during the visual counts.

4.2 Relative ratio

Differences in detection of red squirrels and Siberian chipmunks at different times of the day are found in the research areas. The relative ratio red squirrels to Siberian chipmunks in Oude Warande over the day is 1:5.46. In the morning this ratio is 1:2.82, in the early afternoon the ratio is 1:11.83 and in the late afternoon it is 1:41. In Wandelbos the relative ratio red squirrels to Siberian chipmunks over the day is 1:1.64. In the morning the ratio is 1:1.03, in the early afternoon the ratio is 1:3.33 and in the late afternoon it is 1:3.11. Over the day the relative ratio red squirrels to Siberian chipmunks in Vredelust-Heidepark is 1:2.67. In the morning this ratio is 1:2.50, in the early afternoon the ratio is 0:3 and in the late afternoon it is 1:0.

4.3 Vegetation

Vegetation mapping of the sections of each areas (Attachment 5) and linear regressions show that dead wood (Oude Warande: p=0.752, Wandelbos: p=0.693), shrubs (Oude Warande: p=0.454, Wandelbos: p=0.257) and the number of tree species (Oude Warande: p=0.914, Wandelbos: p=0.979) does not affect the presence of red squirrels in Oude Warande and Wandelbos. The presence of Siberian chipmunks is not affected by shrubs in Oude Warande (p=0.738) and Wandelbos (p=0.686). The number of tree species shows a trend for Siberian chipmunks in both Oude Warande (p=0.070) and Wandelbos (p=0.075). Dead wood give a significant effect for Siberian chipmunks in Oude Warande (p=0.042), but not in Wandelbos (p=0.588).

Negative binomial Generalized Linear Models show that the presence of red squirrels is positive influenced by Norway spruce (p=0.023), beech (p=0.008) and sweet chestnut (p=0.033) and negative influenced by hemlock (p=0.074), birch (p=0.016) and *tilia* (p=0.084) in Oude Warande. The presence of Siberian chipmunks is positive influenced by Norway spruce (p=0.039) and beech (p=0.053) and negative influenced by Weymouth pine (p=0.044) in Oude Warande. In Wandelbos the presence of red squirrels is positive influenced by scots pine (p=0.126), Douglas fir (p=0.003), beech (p<0.001) and native oak (p<0.001) and negative influenced by Weymouth pine (p=0.002) and

maple (p=0.001). The presence of Siberian chipmunks is positive influenced by scots pine (p=0.006), hemlock (p=0.032), birch (p=0.090) and native oak (p<0.001) and negative influenced by northern red oak (p<0.001) and maple (0.032) in Wandelbos.

4.4 Effects of different factors

The effect of time since sunrise, weather, temperature, wind speed, wind direction, presence of people and dogs and number of people counting was tested with ANOVA or Kruskal-Wallis test for Oude Warande and Wandelbos. For Vredelust-Heidepark these tests were not performed because of the low amount of data in this area.

4.4.1 Time since sunrise

Kruskal-Wallis test shows no significant difference in detection of the red squirrel between the categories (2 – 4, 4 – 6, 6 – 8, 8 – 10 and 10 – 12 hours) of time since sunrise in Oude Warande (p=0.143). Also for Siberian chipmunk in Oude Warande there is no significant difference found between the categories (ANOVA, p=0.115). However, a significant effect in detection of the red squirrel is found for time since sunrise in Wandelbos (ANOVA, p=0.015). The difference is seen between the category 4 – 6 hours and 8 – 10 hours after sunrise. The detection of Siberian chipmunk is not significantly affected by time since sunrise (Kruskal-Wallis, p=0.747). In Figure 9 the average number of squirrels at different categories of time since sunrise is shown.

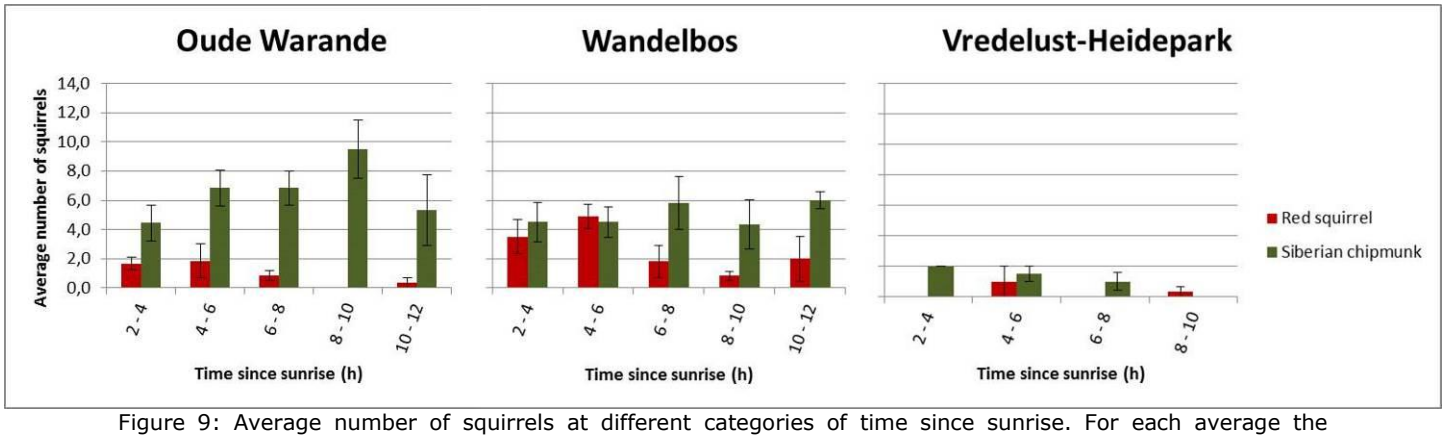

Figure 9: Average number of squirrels at different categories of time since sunrise. For each average the standard errors of the mean are shown.

4.4.2 Weather

No significant effect of weather on the detection of red squirrels (Kruskal-Wallis, p=0.731) and Siberian chipmunk (ANOVA, p=0.479) is found in Oude Warande. However, in Wandelbos, a significant effect of weather on the detection of red squirrels is found (Kruskal-Wallis, p=0.027). With clear weather there are more red squirrels visible then with other weather types. The detection of Siberian chipmunks is not affected by weather (ANOVA, p=0.720). Figure 10 shows the average number of squirrels with different weather.

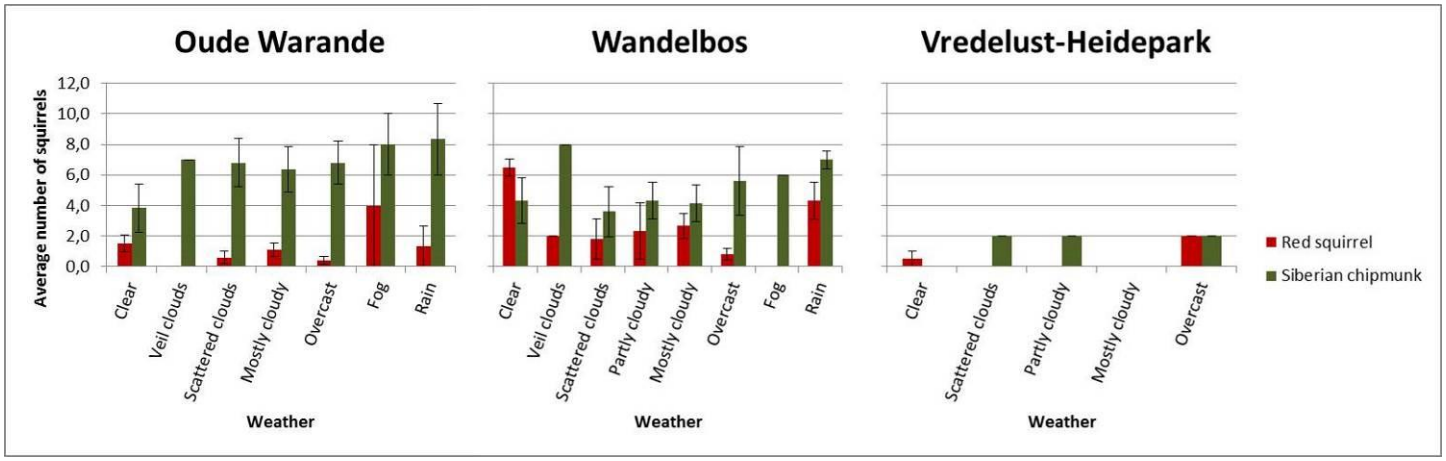

Figure 10: Average number of squirrels at different weather categories. For each average the standard errors of the mean are shown.

4.4.3 Temperature

The detection of red squirrels is not significantly affected by temperature in Oude Warande (Kruskal-Wallis, p=0.064), however there is a trend found. No significant difference is found of the detection of Siberian chipmunks in Oude Warande between the categories (10 – 15, 15 – 20 and 20 – 25 °C) of temperature (ANOVA, p=0.729). Wandelbos shows the same result as Oude Warande. For red squirrels there is a trend (Kruskal-Wallis, p=0.082) and no significant effect for Siberian chipmunks (ANOVA, p=0.286) between the categories. Figure 11 shows the average number of squirrels seen in the time categories.

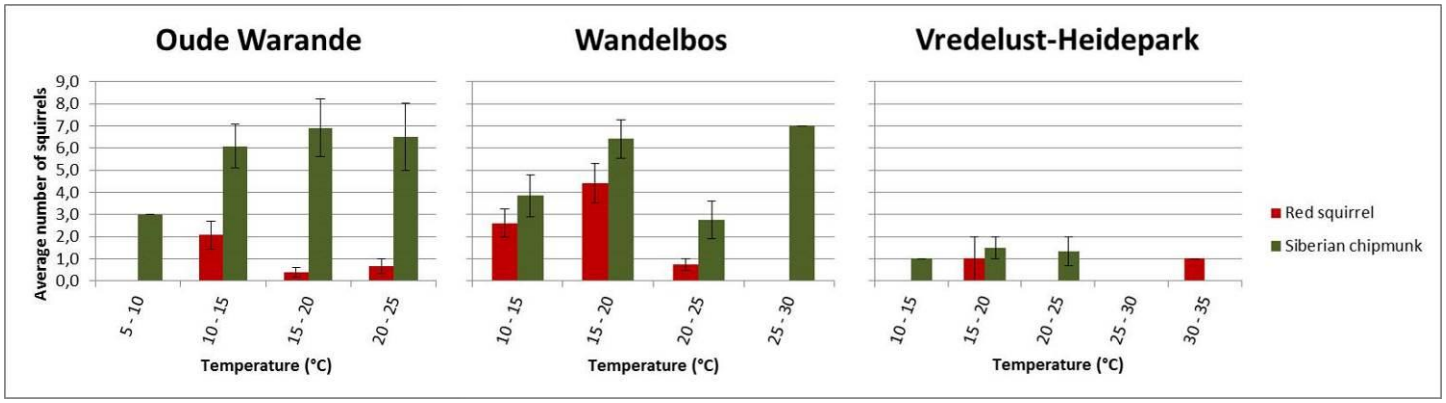

Figure 11: Average number of squirrels for different categories of temperature in degrees Celsius. For each average the standard errors of the mean are shown.

With the result of a trend, a test was done for a confounding variable. A positive correlation is found between temperature and time since sunrise (Oude Warande, p<0.001; Wandelbos, p=0.005).

4.4.4 Wind speed

In Oude Warande there is no significant effect found between the wind speed categories (0.3 – 1.5, 1.6 – 3.3, 3.4 – 5.4, 5.5 – 7.9) for the detection of red squirrels (Kruskal-Wallis, p=0.229) and Siberian chipmunks (ANOVA, p=0.686). Wandelbos gave the same results. ANOVA shows no significant effect for red squirrels (Square root transformation, p=0.564) and Siberian chipmunk (p=0.333). In Figure 12 the average number of squirrels in shown for wind speed in the research areas.

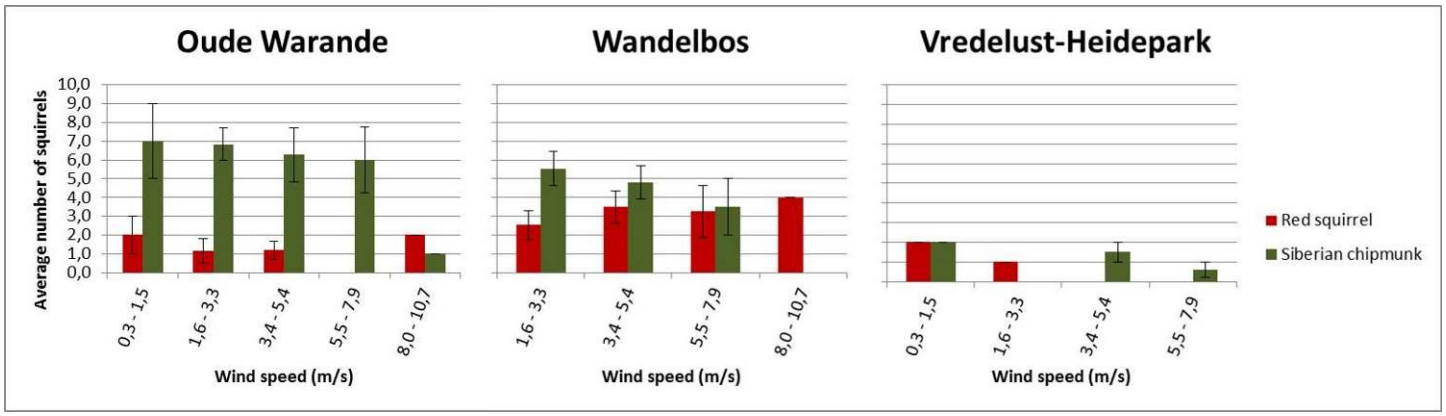

Figure 12: Average number of squirrels for different categories of wind speed in meters per second. For each average the standard errors of the mean are shown.

4.4.5 Wind direction

For Oude Warande, Kruskal-Wallis test shows no significant difference in detection of red squirrels (p=0.579) and Siberian chipmunks (p=0.257) between different wind directions. In Wandelbos, also no significant effect of wind direction was found for red squirrels (Kruskal-Wallis, p=0.282) and Siberian chipmunks (Kruskal-Wallis, p=0.444). Figure 13 shows the average number of squirrels with different wind directions.

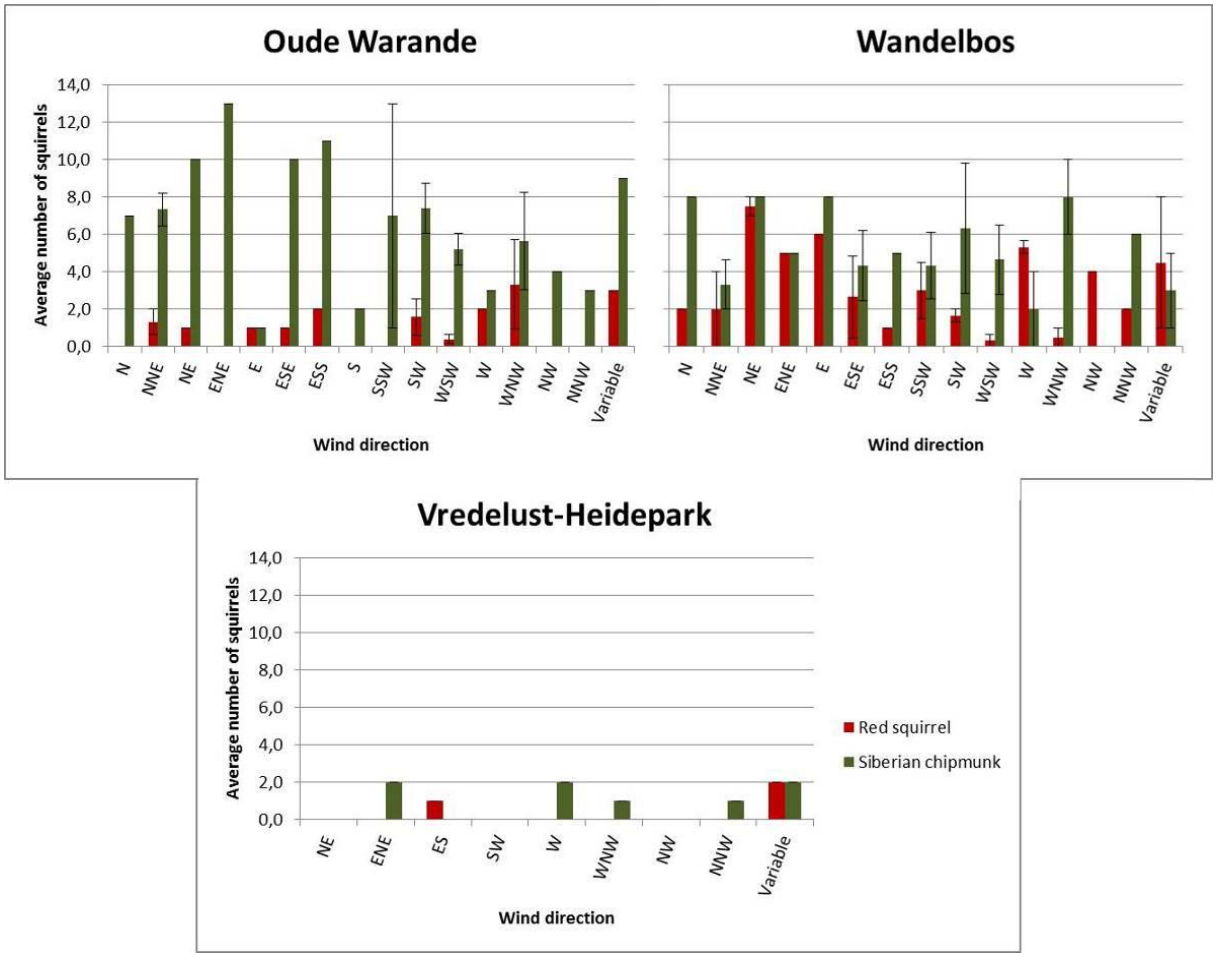

Figure 13: Average number of squirrels for different wind directions. For each average the standard errors of the mean are shown.

4.4.6 Presence of people and dogs

During the walks, for every area the amount of people and dogs was noted. For red squirrels there is no significant difference between the categories quiet, average and busy for both people (Oude Warande: p=0.436, Wandelbos: p=0.620, Vredelust-Heidepark: p=0.670) and dogs (Oude Warande: p=0.527, Wandelbos: p=0.222, Vredelust-Heidepark: p=0.801) in the three research areas. For Siberian chipmunks no significant difference between the categories for people (Oude Warande: p=0.390, Vredelust-Heidepark: p=0.661) and dogs (Oude Warande: p=0.626, Vredelust-Heidepark: p=0.840) is found in the areas Oude Warande and Vredelust-Heidepark. Also, no significant difference is found for dogs in Wandelbos (p=0.398). A significant difference is found between the categories for people in Wandelbos (p=0.035). When there was a higher amount of people, a slightly lower number of Siberian chipmunk was seen in comparison with the categories quiet and average (Figure 14).

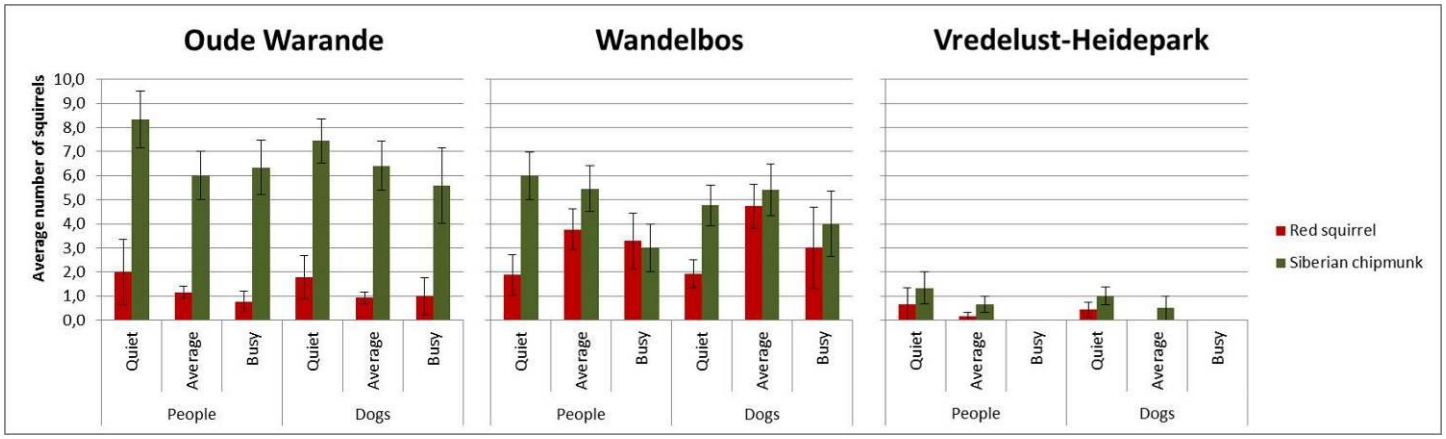

Figure 14: Average number of squirrels with different categories of presence of people and dogs. For each average the standard errors of the mean are shown.

4.4.7 Number of people counting

No significant difference is found between walks with one or two people for red squirrels (Kruskal-Wallis, p=0.929) and Siberian chipmunks (ANOVA, p=0.992) in Oude Warande. Wandelbos gave the same result, no difference for red squirrels (ANOVA, p=0.222) and Siberian chipmunk (ANOVA, p=0.490). Figure 15 shows the average number of squirrels with one or two people counting. Vredelust-Heidepark is only counted with one person.

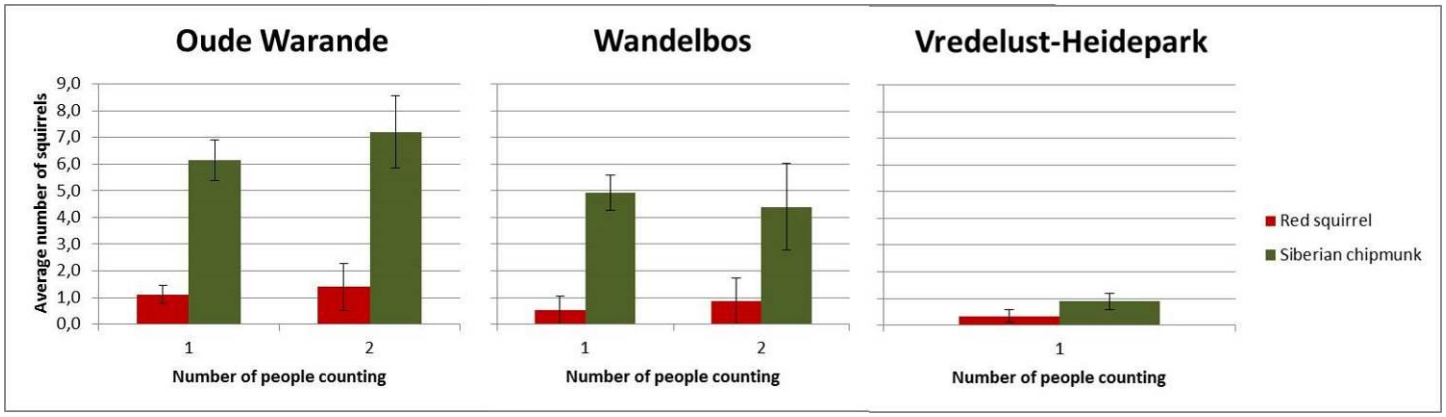

Figure 15: Average number of squirrels with different number of people counting. For each average the standard errors of the mean are shown.

4.5 Sample size

The best sample size was calculated for the average number of squirrels in each research area. In Oude Warande the sample size with an error of 0.5 squirrel in the average of red squirrels is 48 counts. With an error of one squirrel the sample size is twelve and with an error of two squirrels the size is three. For Siberian chipmunk in Oude Warande the sample size with an error of 0.5 squirrel is 206 counts, with an error of one squirrel is 52 counts, and with an error of two squirrels is thirteen counts. In Wandelbos the sample size with an error of 0.5 squirrel is 116 counts for red squirrels. With an error of one squirrel the sample size is 29 counts and with an error of two squirrels the size is eight counts. For Siberian chipmunk in Wandelbos the sample size with an error of 0.5 squirrel is 167 counts, with an error of one squirrel is 42 counts and with an error of two squirrels is eleven counts. In Vredelust-Heidepark the sample size for red squirrels with an error of 0.5 squirrel is eight counts, with an error of one squirrel is two counts and with an error

of two squirrel is one count. For Siberian chipmunk the sample size with an error of 0.5 squirrel is fourteen counts, with an error of one squirrel is four counts and with an error of two squirrels is one count (Table 11).

Table 11: Sample size for the average number of red squirrels and Siberian chipmunk in each research area with different errors in the average.

Research area	**Squirrel species**	**Error in average**	**Sample size**
Oude Warande	Red squirrel	0.5 squirrel	48
		1 squirrel	12
		2 squirrels	3
	Siberian chipmunk	0.5 squirrel	206
		1 squirrel	52
		2 squirrels	13
Wandelbos	Red squirrel	0.5 squirrel	116
		1 squirrel	29
		2 squirrels	8
	Siberian chipmunk	0.5 squirrel	167
		1 squirrel	42
		2 squirrels	11
Vredelust-Heidepark	Red squirrel	0.5 squirrel	8
		1 squirrel	2
		2 squirrels	1
	Siberian chipmunk	0.5 squirrel	14
		1 squirrel	4
		2 squirrels	1

5 DISCUSSION

In general, the detection of red squirrels increases with time since sunrise and clear weather and seem to increase with temperature increase. The detection of Siberian chipmunks does not seem to react on any of the examined factors. The effect of different factors on detection level was researched with the questions 'Which of the factors have an effect on the probability of detecting red squirrels and Siberian chipmunks?' and 'Which factors are of interest for visual counts of red squirrels and Siberian chipmunks?' The factors time since sunrise, weather, temperature, wind speed, wind direction, vegetation, presence of people and dogs and number of people counting during visual counts do not always seem to have the same effects in different areas.

Time since sunrise gave a significant effect for red squirrels in Wandelbos but not in Oude Warande. In Wandelbos more red squirrels were detected than in Oude Warande, which could make the effect of time since sunrise clearer. Red squirrels do react on sunrise according to other articles. In summer the activity peaks ones in the morning and ones late in the afternoon or in the evening (Lurz *et al*., 2005; Tonkin, 1983; Wiltafsky, 1993). In Wandelbos the first peak is visible at four to six hours after sunrise and a second peak starts at ten to twelve hours after sunrise, but does not seems to be at its highest point. No effect of time since sunrise was found for the probability of detecting Siberian chipmunks. During the visual counts, Siberian chipmunks seem to be active during the entire day, which was confirmed by literature (Krapp, 1993; Verbeylen & Matthysen, 1998).

In Wandelbos an effect of weather was found for red squirrels. More red squirrels were detected with clear weather than with other weather types. However, this effect was not found in Oude Warande. This difference between the areas could again be explained by the density of red squirrels in the different areas. An explanation for a higher probability of detection with clear weather cannot be given, because clear weather can also mean a higher temperature or more light, which can mean a different activity level of the squirrel. Although, it could be important to set up a model in which the detection of squirrels is corrected for weather. In both Oude Warande and Wandelbos no effect of weather was found on the detection of Siberian chipmunks. Despite, other studies suggest less activity of squirrels with extreme weather, like heavy rain (>7.6 mm/h) (Gurnell *et al*., 2009). During this study no walks with extreme weather were performed, so this could not be confirmed.

A trend was found in temperature for red squirrels in Oude Warande and Wandelbos. Red squirrels seem to be more active between ten to twenty degrees Celsius. Hamilton (1939) found a decrease of the activity of red squirrels with higher temperatures. Wunder & Morrison (1973) found a higher run activity with temperatures around ten degrees Celsius to minimize the heat loss. Heat loss might explain the trend found in temperature for detecting red squirrels. Time since sunrise is positive correlated with temperature, which means that time since sunrise is a confounding variable for both temperature and number of red squirrels. This trend is therefore negligible. For Siberian chipmunks there was no effect found of temperature on the detection of the squirrels in both research areas. However, this result is different from literature. Verbeylen *et al*. (1999) and Verbeylen & De Bruyn (2000) showed a lower detection level of Siberian chipmunks with average temperatures above 20 degrees Celsius.

Wind speed does not have an effect on the detection of both red squirrels and Siberian chipmunks. Similarly for wind direction, no effect on the detection of both squirrels

species was found. In winter, this could be different, because wind from the north could be cold then. The number of people counting during visual counts gave no significant effect on the probability of detecting the squirrel species. However, there was counted only five times with two people and this were four different people. Every person can have a different detection level, because not every person sees equally clear or reacts the same on movement. More people should be tested to conclude that there is no difference in counting with one or two people.

Presence of people and dogs in the research areas gave no significant effect on the detection of red squirrels and Siberian chipmunks in Oude Warande, Wandelbos and Vredelust-Heidepark. Only a significant difference on the detection of Siberian chipmunk was found between the categories for people in Wandelbos. A lower number chipmunks was seen when there was a high amount of people. Because this difference was only found in Wandelbos and not in the other areas, this might be a coincidental result. There was no difference made between children and adults in the category people. In Wandelbos there is a playground and a petting zoo, which can mean that the most people on a busy day are children. Children are louder and more active than adults, which can unsettle the squirrels more. However, Verbeylen & Matthysen (1998) found that higher recreation provides a higher number of visual counts, which could mean that the chipmunks were used to the people and dogs. In this study also no difference was made between children and adults.

Dead wood, shrubs and number of tree species gave no significant effect on the presence of red squirrels in both Oude Warande and Wandelbos. Red squirrels spend most time of their foraging in trees (Shuttleworth, 2000), so therefore dead wood and shrubs are not that important for them. If the squirrels are mostly foraging in tree canopies, the squirrel travels not much per month (Shuttleworth, 2000). This might explain that many different kind of tree species is not necessary. Dead wood gave a significant effect for Siberian chipmunks in Oude Warande, but not in Wandelbos. In Oude Warande more Siberian chipmunks were detected and more dead wood was present, which could make the effect of dead wood clearer. Shrubs did not give a significant effect on the presence of Siberian chipmunks. Siberian chipmunks live mostly on the ground and build their nests entrance near or under dead wood or shrubs (Kawamichi, 1989; Thissen, 1992). Only the effect dead wood was confirmed in this study. Though, the effect of shrubs is not found. The number of tree species gave a trend for Siberian chipmunks in both areas. This could mean that Siberian chipmunks need a very diverse diet of different tree seeds. A diverse diet is described in different literature (Krapp, 1993; Peeters, 2013; Verbeylen & Matthysen, 1998).

A difference is found between areas in which trees have an influence on the presence of both squirrel species. Some tree species which have a low density the research area still seem to have an influence on the presence (sweet chestnut, *tilia*, maple). Because the density of these trees is so low, the influence could not be very high. Some of the trees species have an influence, however this influence is not always significant (beech, birch, hemlock, scots pine, *tilia*).

Another question of this study was 'What is the relative ratio between red squirrels and Siberian chipmunks in the study areas?' The ratios indicate a higher probability of detecting red squirrels in the morning. In every research area more Siberian chipmunk than red squirrels were seen, nevertheless there were no indications in behaviour seen for possible competition between red squirrels and Siberian chipmunks. By answering the questions 'Can there be food competition between the red squirrel and the Siberian chipmunk?' was found out that food competition between the squirrel species and

between the squirrels and other animals can occur. However, this year was a good mast year with lots of food for the squirrels. If there is enough food for both squirrel species, they will not compete very easily because of food, but in a bad mast year with less food they might. Gurnell (1983) shows that in a good mast year squirrels are more abundant than in bad mast years, which can mean that both squirrel species adapt in number to the abundance of tree seeds. While answering the question 'Can there be habitat competition between the red squirrel and the Siberian chipmunk?', there was concluded that for hiding place for food and nest space no competition occurs. Only for forest type and activity time competition is possible.

In Oude Warande most Siberian chipmunks and least red squirrels were seen compared to Wandelbos. Although, competition is not seen in behaviour, the low numbers of red squirrels in the area with many Siberian chipmunks may indicate competition between the species. Another explanation can be the suitability of the habitat in Oude Warande for red squirrels. Habitat fragmentation can also be an explanation, though this is not known for this area.

The best sample size to determine the average number of squirrels differs a lot between research areas and between squirrel species. Because of the density of squirrels in Vredelust-Heidepark, it is difficult to say whether the calculated sample size is correctly. Vredelust-Heidepark should be counted for approximately twenty times more to calculate a precise sample size. Oude Warande and Wandelbos were counted for 29 times, so this sample size should be more or less correct. The difference in sample size between the two squirrel species also means that if the species are counted at the same time, the highest sample size should be taken as minimum. The accuracy of an error in the average number of squirrels needs to be determined per area separately, because one squirrel on an average of two squirrels is high, but one squirrel on an average of ten squirrels is not that high.

Both visual as auditory observations of squirrels were done in this study. The percentage auditory observations of all observations is different between the areas. Nevertheless, the percentage sounds in Oude Warande and Wandelbos are more or less the same. Because Vredelust-Heidepark is not counted enough to calculate the precise percentage of sounds in observations, there could be said that approximately 16% of the observations of Siberian chipmunks is auditory. This is not completely in accordance with the result of an average of 31% in the study of Verbeylen & Matthysen (1998). Although, they found a difference between areas and linked this to recreation. Less alarming sounds were heard with more recreation. In the area with more recreation, 18% of the observations were auditory. Whereas Oude Warande and Wandelbos have a high recreation level, the 16% is in accordance with the results of Verbeylen & Matthysen (Verbeylen & Matthysen, 1998).

Red squirrels (*Sciurus vulgaris*) and Siberian chipmunks (*Tamias sibiricus*) in Tilburg, the Netherlands

6 CONCLUSION AND RECOMMANDATIONS

6.1 Conclusion

The main question of this study is 'What is the best method of visual counts to have the highest probability of detecting red squirrels and Siberian chipmunks?' To answer this main question some sub-questions were formed. Two of these questions are 'Which of the factors: time since sunrise, weather, temperature, wind speed, wind direction, vegetation, presence of people and dogs and number of people counting during visual counts have an effect on the probability of detecting red squirrels and Siberian chipmunks?' and 'Which factors are of interest for visual counts of red squirrels and Siberian chipmunks?' Time since sunrise and weather have an effect on the probability of detecting red squirrels. Probably, only time since sunrise is of interest for visual counts of red squirrels. Dead wood and number of tree species have an effect on the probability of detecting Siberian chipmunks. This is probably not of interest for visual counts of Siberian chipmunks itself.

Two other sub-questions are 'Can there be food competition between the red squirrel and the Siberian chipmunk?' and 'Can there be habitat competition between the red squirrel and the Siberian chipmunk?' Food competition is possible between red squirrels and Siberian chipmunks. Habitat competition is only possible for forest type and activity time. For hiding place for food and nest space no competition can occur.

Another sub-question is 'What is the relative ratio between red squirrels and Siberian chipmunks in the study areas?' The ratio red squirrels to Siberian chipmunks is 1:5.46 in Oude Warande, 1:1.64 in Wandelbos and 1:2.67 in Vredelust-Heidepark. The last sub-question is 'What is the best sample size to determine the average number of squirrels in the research areas?' The best sample size is 52 counts in Oude Warande and 42 counts in Wandelbos. The best sample size in Vredelust-Heidepark should be specified after more visual counts.

The best method of visual counts to have the highest probability of detecting red squirrels and Siberian chipmunks is counting between two to six hours after sunrise and with the same frequency each season.

6.2 Recommendations

If visual counts are performed for both red squirrels and Siberian chipmunks at one time, the counts should take place between two to six hours after sunrise. This is a peak of red squirrel activity. To prove differences in squirrel number per year, the sample size in each season should be approximately the same.

A recommendation is to count Vredelust-Heidepark each year for more times than this year is done to say for sure that the density in this area is much lower than in Oude Warande and Wandelbos. In De Blaak and De Kaaistoep the squirrels should be counted to show the distribution and differences in density. The best sample size for Oude Warande and Wandelbos is quite high, which is difficult to achieve in practice if there are not many volunteers to observe. To solve this problem, the sample size can be calculated for each transect section (Table 6) separately, in which is corrected for the length of the section. Perhaps, this will lower the sample size. Another recommendation is counting the areas with many different observers in different seasons to decrease the observers' effects as much as possible. With this data of many observers a relative density of red

squirrels and Siberian chipmunks can be calculated for each area. Furthermore, the relative density should be corrected for discernment from the transect line. To calculate the absolute density, a capture-mark-recapture study and transmitting could be done. The density could differ between seasons, so all studies should be done in all seasons. However, in winter the activity of red squirrels is low and Siberian chipmunks are in hibernation, so this is perhaps not necessary.

Before saying something about competition, the reason why there are more Siberian chipmunks and fewer red squirrels in Oude Warande should be researched. For habitat fragmentation, there should be looked at the history of the area. To research whether there is competition between the red squirrel and the Siberian chipmunk, comparison of the areas in Tilburg and control areas (with only red squirrels) should be done. A recommendation for this research is to take areas with mixed forest and preferably a bit shaped like a park. Several control areas have to be chosen, because climate can change very quickly over the Netherlands. If possible, the climate should be as comparable as possible with Tilburg.

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ATTACHMENT 1: FORM VEGETATION MAPPING

Date			**Date**	
Counting area			**Counting area**	
Section			**Section**	
Dead branches/ trees (%)			**Dead branches/ trees (%)**	
Shrubs (%)			**Shrubs (%)**	

Tree species	**Present?**	**Density**	**Cover (%)**		**Tree species**	**Present?**	**Density**	**Cover (%)**
Scots pine				G	Scots pine			
Weymouth pine				W	Weymouth pine			
Black Pine				Zd	Black Pine			
Douglas fir				D	Douglas fir			
Norway spruce				F	Norway spruce			
Fir				Zs	Fir			
Hemlock				Hs	Hemlock			
Beech				B	Beech			
Birch				Be	Birch			
Acacia				A	Acacia			
Common hazel				H	Common hazel			
Sweet Chestnut				Tk	Sweet Chestnut			
Aesculus				Pk	Aesculus			
Native oak				Ie	Native oak			
Northern red oak				Ae	Northern red oak			
Maple				Es	Maple			
Alder				E	Alder			
Honey locust				Vc	Honey locust			
Elm				I	Elm			
Tilia				L	*Tilia*			
Walnut				Wn	Walnut			
Thuja occidentalis				Wl	*Thuja occidentalis*			

Density: 1=low, 10=high, 0=planted/tree lane

ATTACHMENT 2: INFORMATION VISUAL COUNT DAYS

Date	Counting time	Area	Sunrise	Time	Temperature (°C)	Wind speed (m/s)	Wind direction (°)	Time	Weather
2-4-2014	Morning 8:55 - 11:30	Oude Warande to Wandelbos	07:13	8:55 - 8:59	10,5	1,0	40	8:55 - 11:30	Clear
				9:00 - 9:59	14,6	2,0	100		
				10:00 - 10:59	17,2	2,0	110		
				11:00 - 11:30	19,1	2,0	100		
7-4-2014	Morning 8:54 - 12:35	Oude Warande to Wandelbos to Oude Warande	07:02	8:54 - 8:59	14,4	4,0	190	8:54 - 11:29	Mostly cloudy
				9:00 - 9:59	15,6	4,0	210	11:30 - 12:35	Clear
				10:00 - 10:59	17,4	4,0	200		
				11:00 - 11:59	19,1	5,0	190		
				12:00 - 12:35	20,3	6,0	190		
9-4-2014	Morning 8:48 - 12:21	Wandelbos to Oude Warande to Wandelbos	06:57	8:48 - 8:59	7,9	2,0	250	8:48 - 12:21	Clear
				9:00 - 9:59	10,3	3,0	260		
				10:00 - 10:59	12,1	4,0	270		
				11:00 - 11:59	13,4	6,0	280		
				12:00 - 12:21	13,1	6,0	270		
14-4-2014	Morning 9:53 - 12:12	Oude Warande to Wandelbos	06:46	9:53 - 9:59	9,6	7,0	290	9:53 - 12:12	Mostly cloudy
				10:00 - 10:59	10,3	8,0	300		
				11:00 - 11:59	10,6	8,0	310		
				12:00 - 12:12	12,5	9,0	300		
17-4-2014	Morning 9:01 - 11:58	Wandelbos to Oude Warande to Wandelbos	06:39	9:01 - 9:59	12,1	5,0	210	9:01 - 11:29	Clear
				10:00 - 10:59	12,9	5,0	220	11:30 - 11:58	Scattered clouds
				11:00 - 11:58	14,5	4,0	240		
18-4-2014	Morning 9:13 - 11:44	Oude Warande to Wandelbos	06:37	9:13 - 9:59	9,5	6,0	350	9:13 - 9:59	Clear
				10:00 - 10:59	9,2	6,0	340	10:00 - 10:29	Partly cloudy
				11:00 - 11:44	10,4	7,0	340	10:30 - 11:44	Mostly cloudy
22-4-2014	Morning 9:08 - 11:28	Wandelbos to Oude Warande	06:29	9:08 - 9:59	11,9	4,0	210	9:08 - 11:28	Mostly cloudy
				10:00 - 10:59	13,2	4,0	230		
				11:00 - 11:28	14,8	4,0	230		

Date	Counting time	Area	Sunrise	Time	Temperature (°C)	Wind speed (m/s)	Wind direction (°)	Time	Weather
23-4-2014	Morning 8:51 - 11:19	Oude Warande to Wandelbos	06:27	8:51 - 8:59	11,1	1,0	220	8:51 - 9:29	Scattered clouds
				9:00 - 9:59	14,2	1,0	250	9:30 - 11:19	Clear
				10:00 - 10:59	16,5	2,0	990		
				11:00 - 11:19	17,1	2,0	170		
25-4-2014	Early afternoon 10:56 - 13:20	Wandelbos to Oude Warande	06:23	10:56 - 10:59	17,7	5,0	100	10:56 - 13:20	Clear
				11:00 - 11:59	19,7	5,0	70		
				12:00 - 12:59	21,1	5,0	90		
				13:00 - 13:20	23,2	6,0	110		
28-4-2014	Morning 8:50 - 11:46	Oude Warande to Wandelbos	06:17	8:50 - 8:59	11,6	1,0	80	8:50 - 9:44	Overcast
				9:00 - 9:59	14,3	1,0	990	9:45 - 9:59	Mostly cloudy
				10:00 - 10:59	16,5	1,0	990	10:00 - 10:59	Veil clouds
				11:00 - 11:46	17,2	2,0	50	11:00 - 11:46	Clear
30-4-2014	Morning 8:56 - 11:17	Wandelbos to Oude Warande	06:13	8:56 - 8:59	11,8	3,0	290	8:56 - 11:17	Fog
				9:00 - 9:59	12,2	3,0	290		
				10:00 - 10:59	12,7	3,0	300		
				11:00 - 11:17	13,4	2,0	280		
30-4-2014	Early afternoon 11:19 - 13:46	Oude Warande to Wandelbos	06:13	11:19 - 11:59	13,4	2,0	280	11:19 - 12:29	Fog
				12:00 - 12:59	14,5	2,0	300	12:30 - 13:46	Overcast
				13:00 - 13:46	15,0	3,0	280		
2-5-2014	Early afternoon 11:52 - 14:23	Oude Warande to Wandelbos	06:09	11:52 - 11:59	11,2	6,0	10	11:52 - 14:23	Overcast
				12:00 - 12:59	11,1	7,0	10		
				13:00 - 13:59	11,8	7,0	20		
				14:00 - 14:23	12,5	6,0	30		
7-5-2014	Late afternoon 14:28 - 16:40	Wandelbos to Oude Warande	06:00	14:28 - 14:59	13,8	5,0	240	14:28 - 14:39	Overcast
				15:00 - 15:59	14,1	4,0	240	14:40 - 15:59	Mostly cloudy
				16:00 - 16:40	14,6	5,0	270	16:00 - 16:40	Overcast

Date	Counting time	Area	Sunrise	Time	Temperature (°C)	Wind speed (m/s)	Wind direction (°)	Time	Weather
9-5-2014	Late afternoon 14:33 - 16:55	Oude Warande to Wandelbos	05:56	14:33 - 14:59	15,3	7,0	240	14:33 - 14:39	Mostly cloudy
				15:00 - 15:59	15,3	7,0	250	14:40 - 14:49	Overcast
				16:00 - 16:55	12,1	7,0	260	14:50 - 14:57	Mostly cloudy
								14:58 - 15:14	Overcast
								15:15 - 15:59	Moderate rain
								16:00 - 16:19	Mostly cloudy
								16:20 - 16:29	Overcast
								16:30 - 16:55	Light rain
12-5-2014	Morning 9:01 - 11:13	Wandelbos to Oude Warande	05:51	9:01-9:59	10,3	4,0	220	9:01 - 9:54	Light rain
				10:00 - 10:59	11,6	5,0	230	9:55 - 10:34	Overcast
				11:00 - 11:13	11,9	4,0	230	10:35 - 10:44	Light rain
								10:45 - 10:59	Overcast
								11:00 - 11:13	Drizzle
15-5-2014	Morning 8:57 - 11:21	Oude Warande to Wandelbos	05:46	8:57 - 8:59	10,9	3,0	10	8:57 - 9:19	Partly cloudy
				9:00 - 9:59	10,6	4,0	10	9:20 - 10:19	Mostly cloudy
				10:00 - 10:59	11,0	4,0	20	10:20 - 11:21	Partly cloudy
				11:00 - 11:21	12,9	4,0	30		
16-5-2014	Early afternoon 12:01 - 14:21	Wandelbos to Oude Warande	05:45	12:01 - 12:59	15,9	3,0	10	12:01 - 14:21	Veil clouds
				13:00 - 13:59	16,9	3,0	360		
				14:00 - 14:21	17,4	4,0	30		
19-5-2014	Early afternoon 11:50 - 14:08	Oude Warande to Wandelbos	05:41	11:50 - 11:59	22,7	3,0	170	11:50 - 12:09	Clear
				12:00 - 12:59	23,2	2,0	150	12:10 - 14:08	Scattered clouds
				13:00 - 13:59	24,4	3,0	120		
				14:00 - 14:08	24,9	3,0	90		
21-5-2014	Late afternoon 14:24 - 16:44	Wandelbos to Oude Warande	05:38	14:24 - 14:59	20,3	3,0	120	14:24 - 16:44	Overcast
				15:00 - 15:59	20,2	2,0	90		
				16:00 - 16:44	20,6	3,0	110		
23-5-2014	Late afternoon 14:24 - 16:45	Oude Warande to Wandelbos	05:36	14:24 - 14:59	19,1	4,0	200	14:24 - 15:14	Mostly cloudy
				15:00 - 15:59	19,6	4,0	190	15:15 - 16:45	Partly cloudy
				16:00 - 16:45	20,5	3,0	160		

Date	Counting time	Area	Sunrise	Time	Temperature (°C)	Wind speed (m/s)	Wind direction (°)	Time	Weather
26-5-2014	Early afternoon 12:03 - 14:31	Wandelbos to Oude Warande	05:32	12:03 - 12:59	19,6	4,0	90	12:03 - 12:44	Overcast
				13:00 - 13:59	18,4	4,0	60	12:45 - 12:54	Light rain
				14:00 - 14:31	17,0	3,0	60	12:55 - 12:59	Overcast
								13:00 - 13:24	Light rain
								13:25 - 13:29	Overcast
								13:30 - 13:49	Light rain
								13:50 - 13:59	Overcast
								14:00 - 14:09	Light rain
								14:10 - 14:31	Overcast
28-5-2014	Early afternoon 11:54 - 14:22	Oude Warande to Wandelbos	05:30	11:54 - 11:59	15,1	2,0	230	11:54 - 14:22	Overcast
				12:00 - 12:59	15,2	3,0	250		
				13:00 - 13:59	16,5	2,0	230		
				14:00 - 14:22	15,8	3,0	190		
23-6-2014	Morning 9:03 - 11:41	Oude Warande to Wandelbos	05:20	9:03 - 9:59	17,0	1,0	40	9:03 - 9:29	Clear
				10:00 - 10:59	19,0	3,0	40	9:30 - 11:41	Scattered clouds
				11:00 - 11:41	19,8	4,0	50		
25-6-2014	Early afternoon 11:47 - 14:11	Oude Warande to Wandelbos	05:21	11:47 - 11:59	16,3	4,0	50	11:47 - 12:59	Mostly cloudy
				12:00 - 12:59	18,0	4,0	20	13:00 - 14:11	Partly cloudy
				13:00 - 13:59	17,4	4,0	20		
				14:00 - 14:11	18,5	4,0	40		
27-6-2014	Morning 8:51 - 10:18	Vredelust-Heidepark	05:22	8:51 - 8:59	16,1	1,0	990	8:51 - 10:18	Overcast
				9:00 - 9:59	17,7	1,0	990		
				10:00 - 10:18	20,3	3,0	170		
30-6-2014	Early afternoon 11:30 - 12:55	Vredelust-Heidepark	05:24	11:30 - 11:59	15,3	3,0	320	11:30 - 11:39	Light rain
				12:00 - 12:55	16,1	5,0	360	11:40 - 11:44	Overcast
								11:45 - 11:59	Mostly cloudy
								12:00 - 12:55	Overcast
2-7-2014	Late afternoon 14:27 - 16:53	Wandelbos to Oude Warande	05:25	14:27 - 14:59	20,9	2,0	990	14:27 - 16:53	Scattered clouds
				15:00 - 15:59	22,2	2,0	320		
				16:00 - 16:53	21,3	3,0	300		

Date	Counting time	Area	Sunrise	Time	Temperature (°C)	Wind speed (m/s)	Wind direction (°)	Time	Weather
4-7-2014	Late afternoon 14:32 - 15:55	Vredelust-Heidepark	05:27	14:33 - 14:59	28,9	5,0	200	14:32 - 14:44	Scattered clouds
				15:00 - 15:55	27,4	6,0	220	14:45 - 15:29	Mostly cloudy
								15:30 - 15:55	Overcast
7-7-2014	Morning 9:03 - 11:24	Wandelbos to Oude Warande	05:29	9:03 - 9:59	16,1	3,0	200	9:09 - 11:24	Mostly cloudy
				10:00 - 10:59	17,8	2,0	210		
				11:00 - 11:24	19,2	2,0	230		
9-7-2014	Morning 8:56 - 10:20	Vredelust-Heidepark	05:31	8:56 - 8:59	13,2	6,0	300	8:56 - 10:20	Light rain
				9:00 - 9:59	13,5	6,0	300		
				10:00 - 10:20	14,3	7,0	300		
11-7-2014	Early afternoon 11:57 - 14:44	Wandelbos to Oude Warande	05:33	11:57 - 11:59	17,2	2,0	220	11:57 - 14:44	Overcast
				12:00 - 12:59	18,8	2,0	250		
				13:00 - 13:59	19,8	3,0	230		
				14:00 - 14:44	21,1	2,0	250		
14-7-2014	Early afternoon 11:53 - 13:27	Vredelust-Heidepark	05:37	11:53 - 11:59	21,2	5,0	290	11:53 - 12:54	Scattered clouds
				12:00 - 12:59	21,6	6,0	260	12:55 - 13:14	Partly cloudy
				13:00 - 13:27	22,3	6,0	270	13:15 - 13:27	Scattered clouds
16-7-2014	Late afternoon 14:15 - 16:54	Oude Warande to Wandelbos	05:39	14:15 - 14:59	24,8	3,0	230	14:15 - 16:54	Scattered clouds
				15:00 - 15:59	25,5	3,0	230		
				16:00 - 16:54	25,0	3,0	260		
18-7-2014	Late afternoon 14:37 - 16:06	Vredelust-Heidepark	05:42	14:37 - 14:59	31,8	4,0	150	14:37 - 16:06	Clear
				15:00 - 15:59	31,9	3,0	140		
				16:00 - 16:06	32,5	4,0	120		
21-7-2014	Late afternoon 14:36 - 16:04	Vredelust-Heidepark	05:46	14:36 - 14:59	21,2	7,0	310	14:36 - 14:44	Light rain
				15:00 - 15:59	21,0	6,0	310	14:45 - 15:19	Overcast
				16:00 - 16:04	20,2	6,0	310	15:20 - 15:24	Light rain
								15:25 - 15:29	Overcast
								15:30 - 16:04	Light rain
23-7-2014	Early afternoon 11:52 - 13:18	Vredelust-Heidepark	05:48	11:52 - 11:59	25,4	5,0	50	11:52 - 12:29	Scattered clouds
				12:00 - 12:59	26,5	6,0	50	12:30 - 13:18	Clear
				13:00 - 13:18	27,5	6,0	70		

Date	Counting time	Area	Sunrise	Time	Temperature (°C)	Wind speed (m/s)	Wind direction (°)	Time	Weather
25-7-2014	Morning 8:50 - 10:23	Vredelust-Heidepark	05:51	8:50 - 8:59	19,5	4,0	50	8:50 - 9:44	Partly cloudy
				9:00 - 9:59	20,6	4,0	80	9:45 - 10:23	Mostly cloudy
				10:00 - 10:23	21,4	5,0	60		

ATTACHMENT 3: FORM VISUAL COUNTS

Name(s)	
Date	
Start time	
End time	
Weather	
Number of people	
Name/Number counting area	

Vegetation

Nr.	Species	Section	Estimated meters from transect	Time	Behaviour

Other observations
Specialities/details
Comments

Behaviour:

1. Foraging
2. Passing
3. Fighting
4. Playing
5. Hiding
6. Fleeing
7. Cleaning
8. Digging
9. Searching
10. Alarming
11. Different (explain)

ATTACHMENT 4: NUMBER OF SQUIRRELS AT VISUAL COUNT DAYS

Date	Day time	Area	Number of red squirrels	Number of Siberian chipmunks
2-4-2014	Morning	Oude Warande	1	1
		Wandelbos	7	8
7-4-2014	Morning	Oude Warande	0	3
		Wandelbos	6	5
9-4-2014	Morning	Oude Warande	2	3
		Wandelbos	11	0
14-4-2014	Morning	Oude Warande	2	1
		Wandelbos	4	0
17-4-2014	Morning	Oude Warande	4	11
		Wandelbos	1	0
18-4-2014	Morning	Oude Warande	0	3
		Wandelbos	2	6
22-4-2014	Morning	Oude Warande	0	10
		Wandelbos	1	1
23-4-2014	Morning	Oude Warande	1	5
		Wandelbos	8	5
25-4-2014	Early afternoon	Oude Warande	1	1
		Wandelbos	5	5
28-4-2014	Morning	Oude Warande	3	9
		Wandelbos	8	8
30-4-2014	Morning	Oude Warande	8	6
		Wandelbos	0	6
30-4-2014	Early afternoon	Oude Warande	0	10
		Wandelbos	1	10
2-5-2014	Early afternoon	Oude Warande	0	9
		Wandelbos	0	2
7-5-2014	Late afternoon	Oude Warande	0	2
		Wandelbos	1	6
9-5-2014	Late afternoon	Oude Warande	0	6
		Wandelbos	5	6
12-5-2014	Morning	Oude Warande	4	6
		Wandelbos	2	7
15-5-2014	Morning	Oude Warande	2	6
		Wandelbos	6	6
16-5-2014	Early afternoon	Oude Warande	0	7
		Wandelbos	2	8
19-5-2014	Early afternoon	Oude Warande	2	11
		Wandelbos	0	2
21-5-2014	Late afternoon	Oude Warande	1	10
		Wandelbos	1	3
23-5-2014	Late afternoon	Oude Warande	0	13
		Wandelbos	1	5
26-5-2014	Early afternoon	Oude Warande	0	13
		Wandelbos	6	8
28-5-2014	Early afternoon	Oude Warande	1	6
		Wandelbos	2	12
23-6-2014	Morning	Oude Warande	1	10
		Wandelbos	7	8

Red squirrels (*Sciurus vulgaris*) and Siberian chipmunks (*Tamias sibiricus*) in Tilburg, the Netherlands

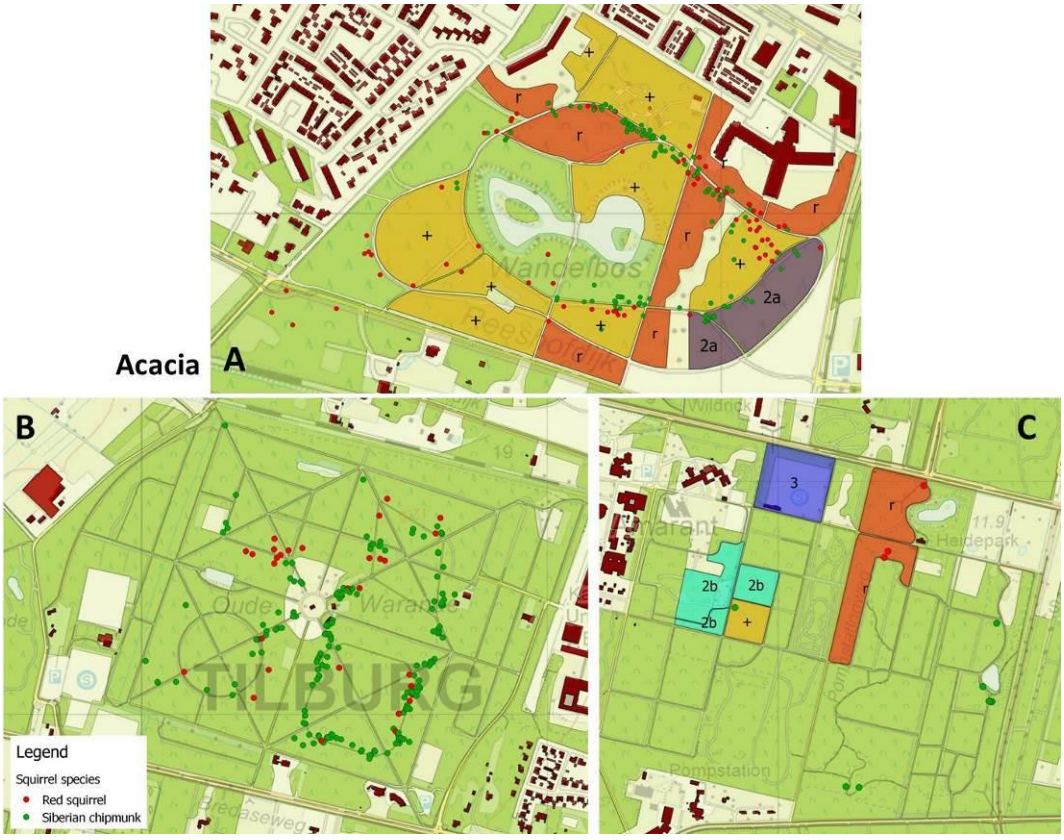
Date	Day time	Area	Number of red squirrels	Number of Siberian chipmunks
25-6-2014	Early afternoon	Oude Warande	2	7
		Wandelbos	0	2
27-6-2014	Morning	Vredelust-Heidepark	2	2
30-6-2014	Early afternoon	Vredelust-Heidepark	0	1
2-7-2014	Late afternoon	Oude Warande	0	4
		Wandelbos	1	1
4-7-2014	Late afternoon	Vredelust-Heidepark	0	0
7-7-2014	Morning	Oude Warande	0	4
		Wandelbos	2	7
9-7-2014	Morning	Vredelust-Heidepark	0	1
11-7-2014	Early afternoon	Oude Warande	0	7
		Wandelbos	0	1
14-7-2014	Early afternoon	Vredelust-Heidepark	0	2
16-7-2014	Late afternoon	Oude Warande	0	6
		Wandelbos	0	7
18-7-2014	Late afternoon	Vredelust-Heidepark	1	0
21-7-2014	Late afternoon	Vredelust-Heidepark	0	0
23-7-2014	Early afternoon	Vredelust-Heidepark	0	0
25-7-2014	Morning	Vredelust-Heidepark	0	2

ATTACHMENT 5: VEGETATION AND SQUIRRELS

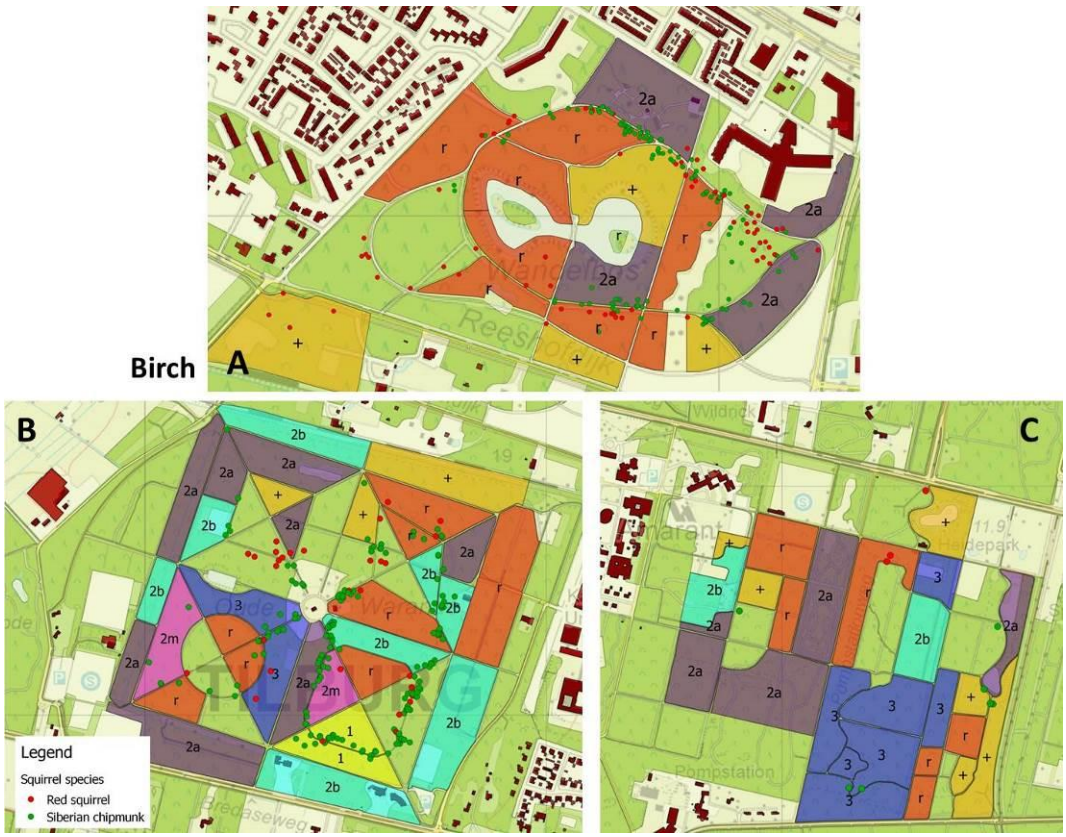
For each tree species the densities are given for each section in Braun-Blanquet codes with colours and the squirrels are shown.

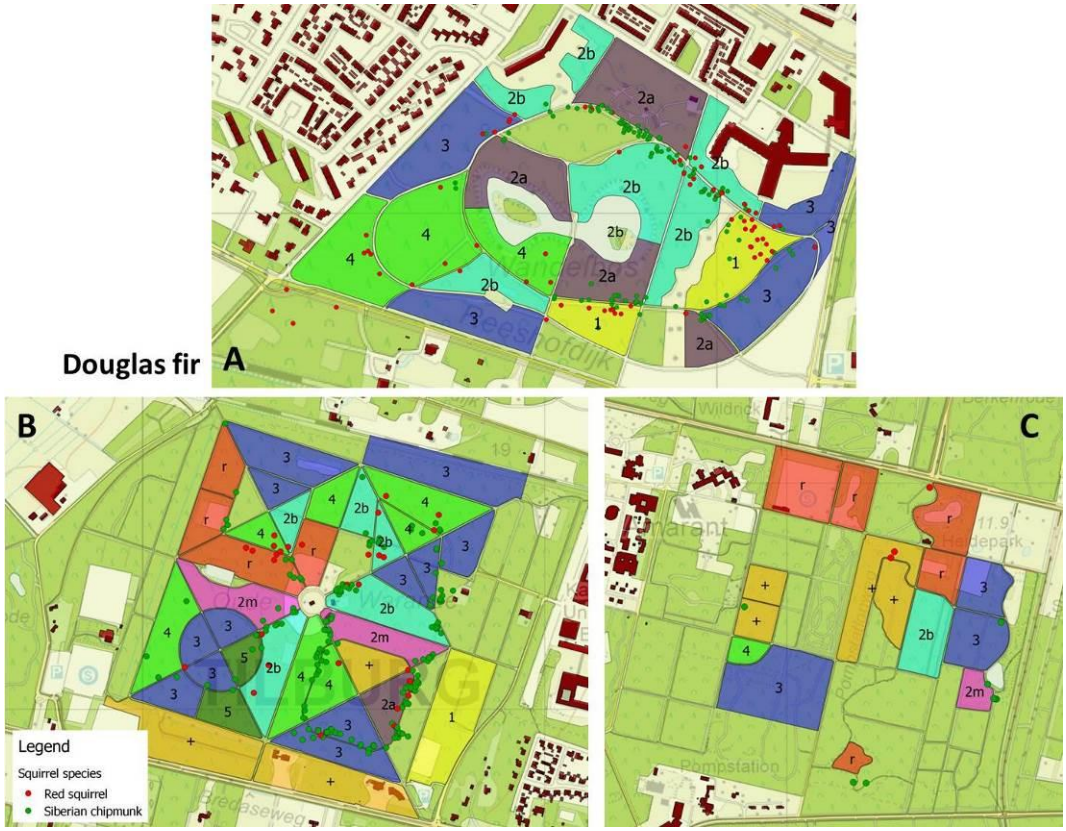
Relevé	Colour
r	Red
+	Orange
1	Yellow
2m	Pink
2a	Purple
2b	Light blue
3	Blue
4	Light green
5	Dark green

The percentage dead wood and shrubs is also given for each section.

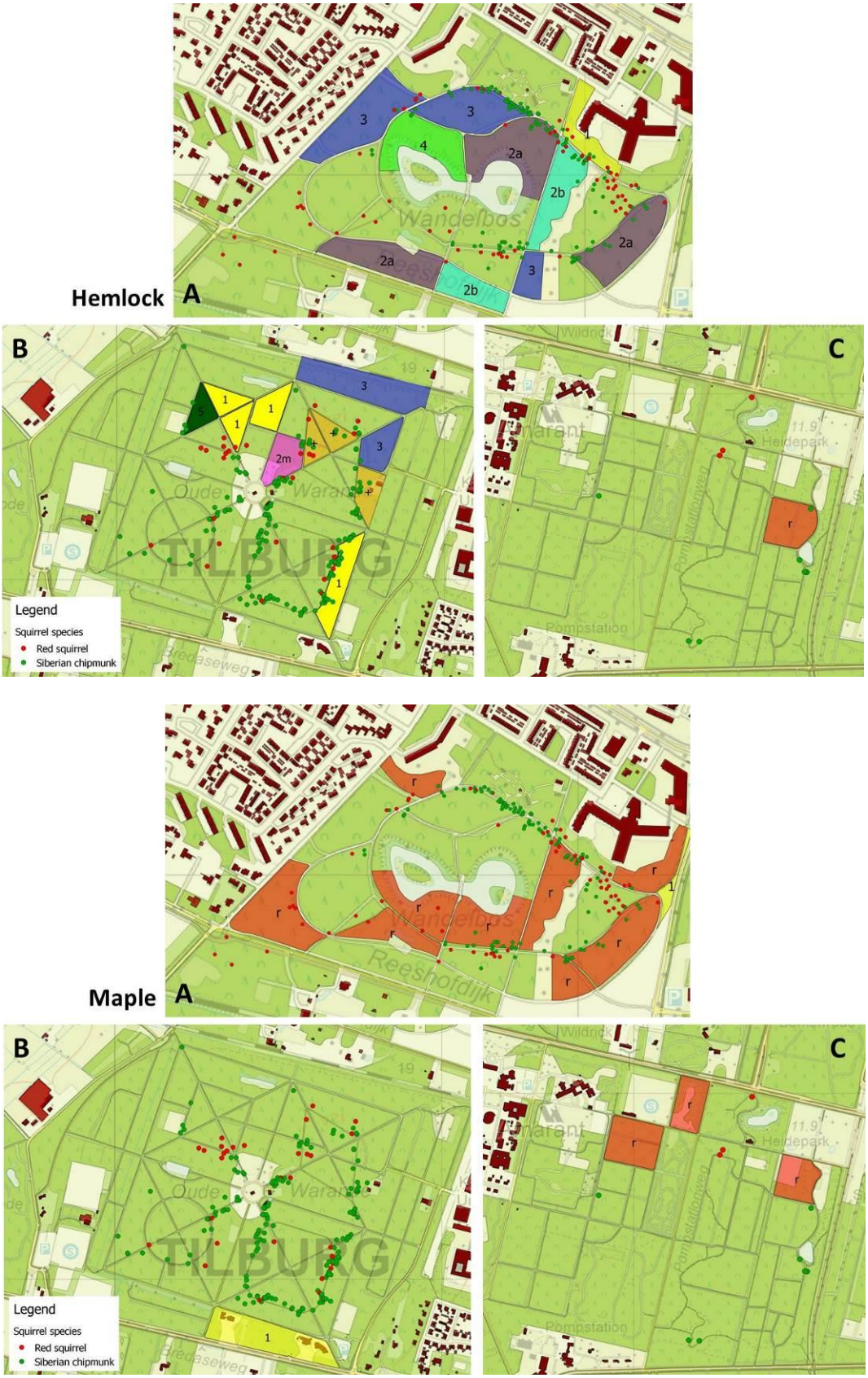


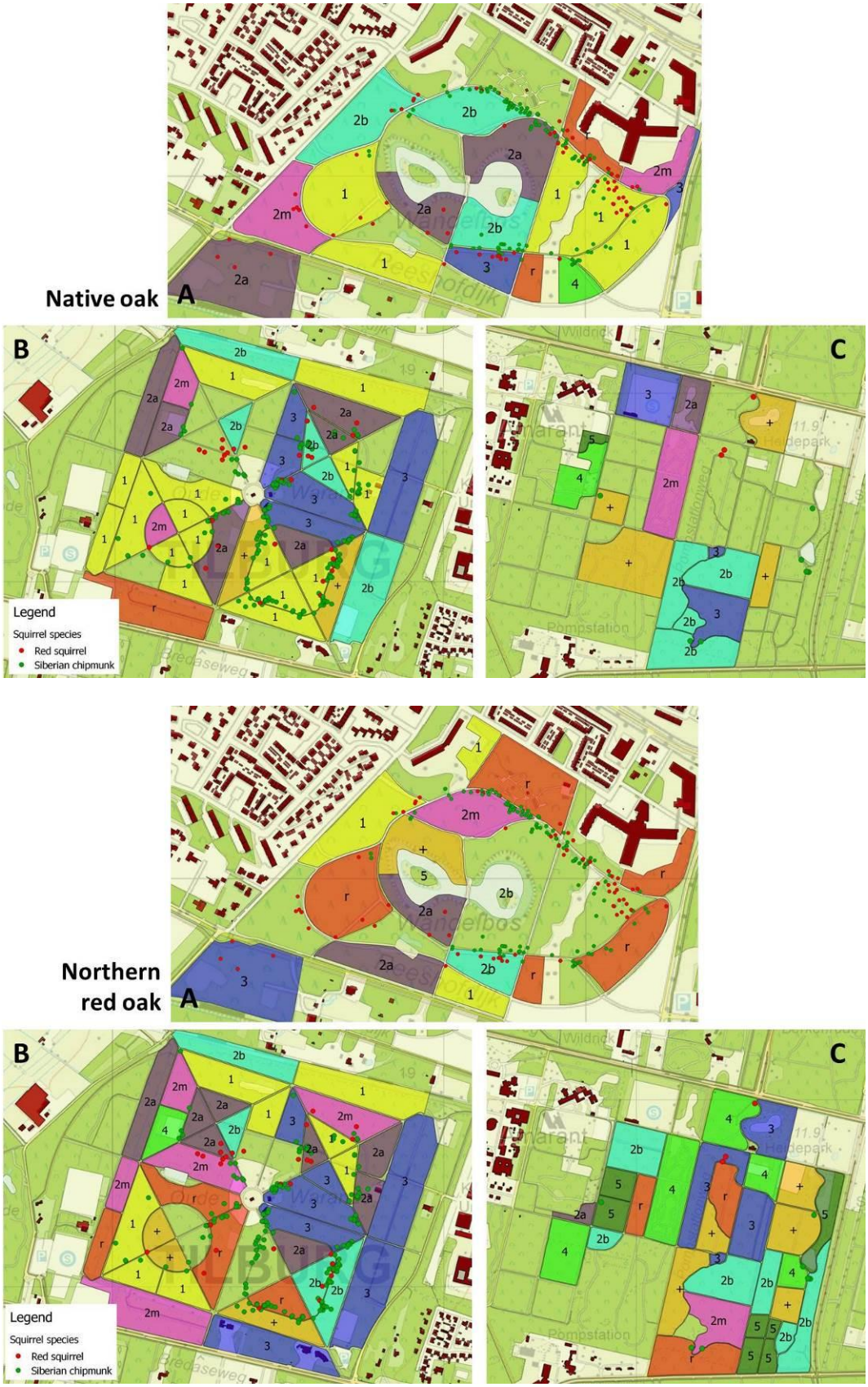

Beech
A
B
C
Legend
Squirrel species
Red squirrel
Siberian chipmunk

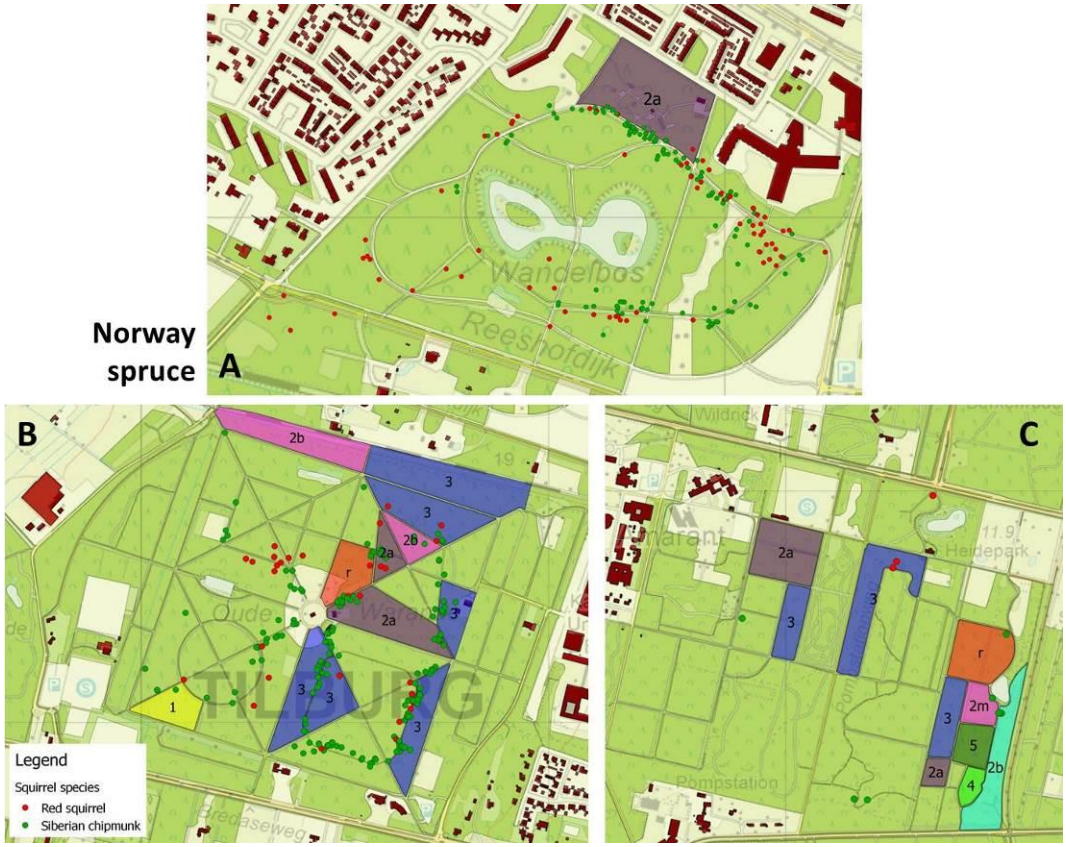

Birch
A
B
C
Legend
Squirrel species
Red squirrel
Siberian chipmunk

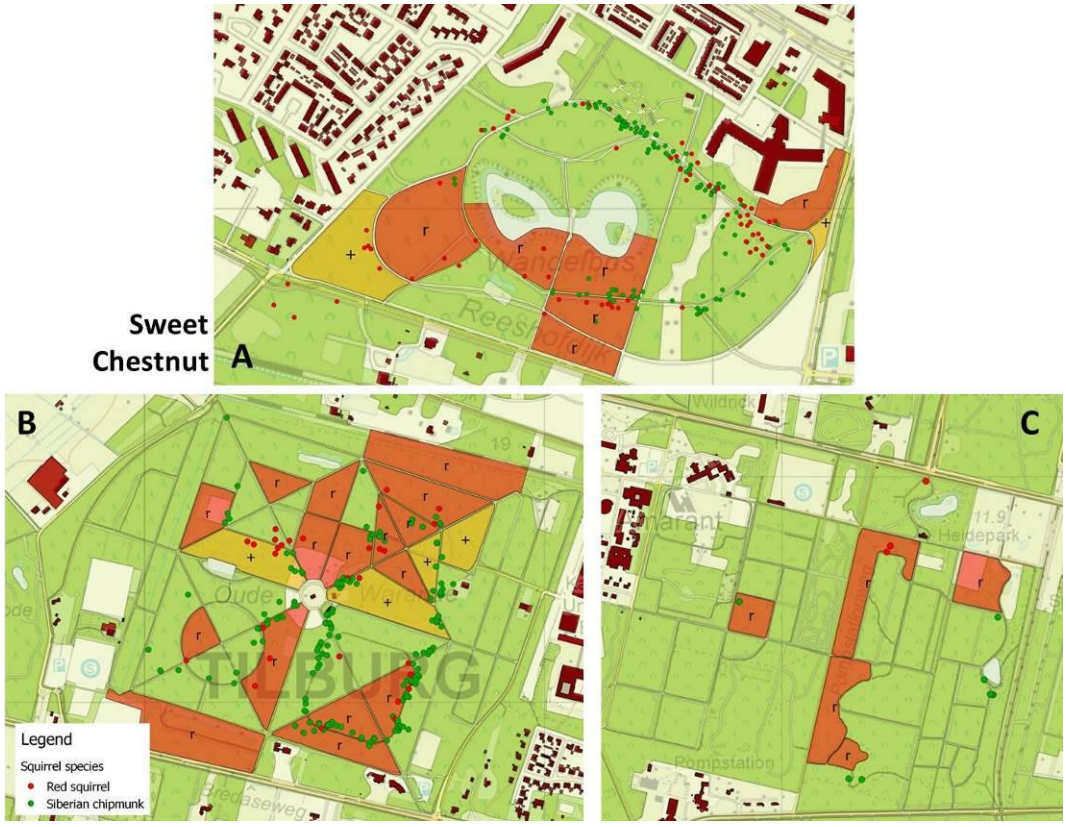

Douglas fir
A
B
C
Legend
Squirrel species
Red squirrel
Siberian chipmunk
Elm
A
B
C
Legend
Squirrel species
Red squirrel
Siberian chipmunk

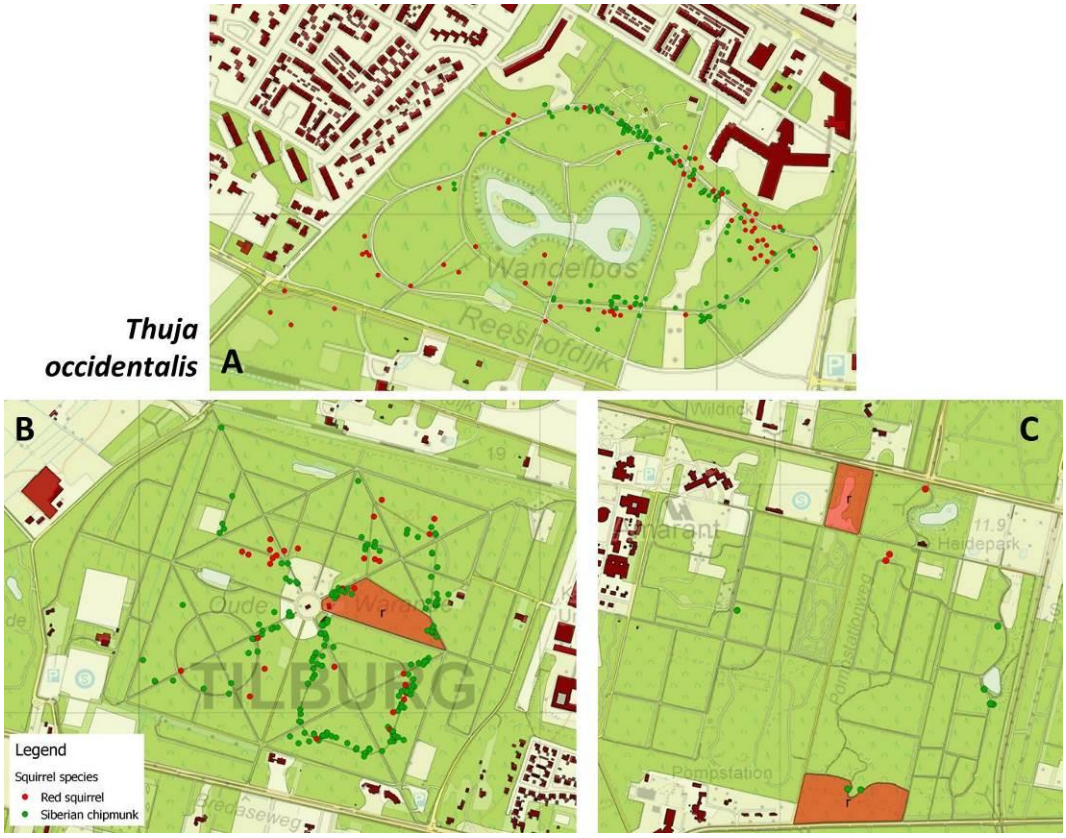
Red squirrels (*Sciurus vulgaris*) and Siberian chipmunks (*Tamias sibiricus*) in Tilburg, the Netherlands

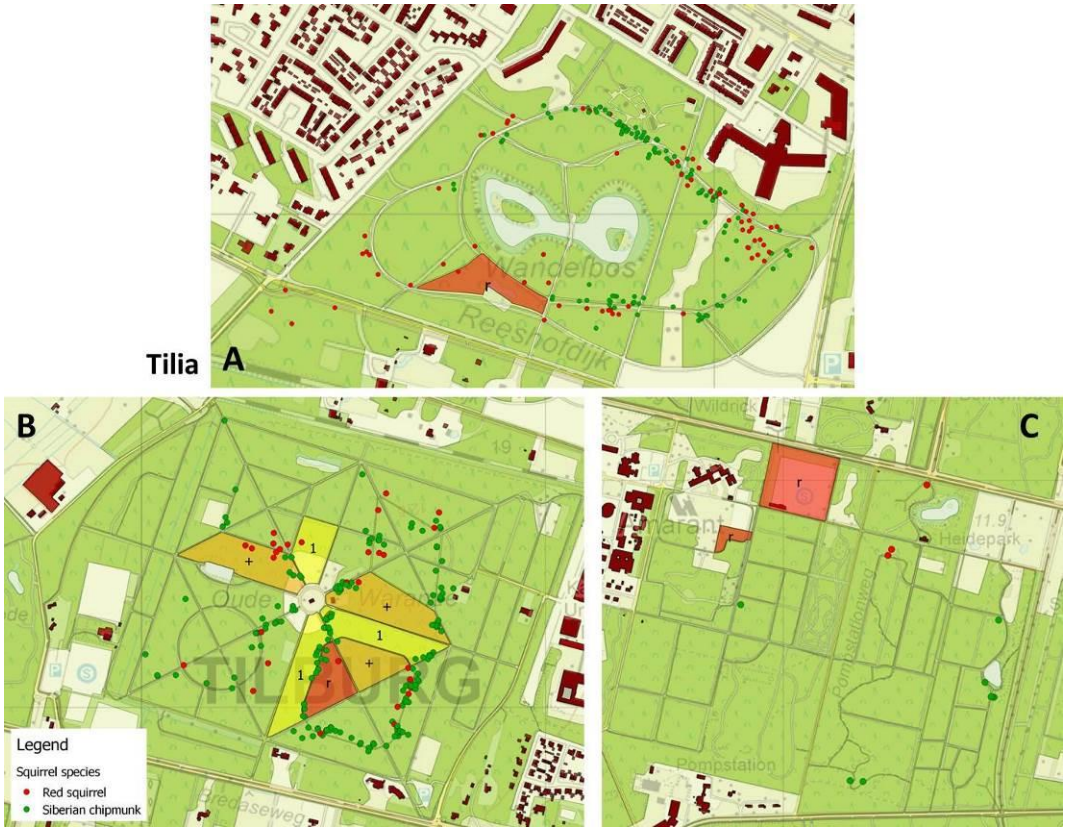



Native oak
A
B
C
Legend
Squirrel species
Red squirrel
Siberian chipmunk
Northern red oak
A
B
C
Legend
Squirrel species
Red squirrel
Siberian chipmunk

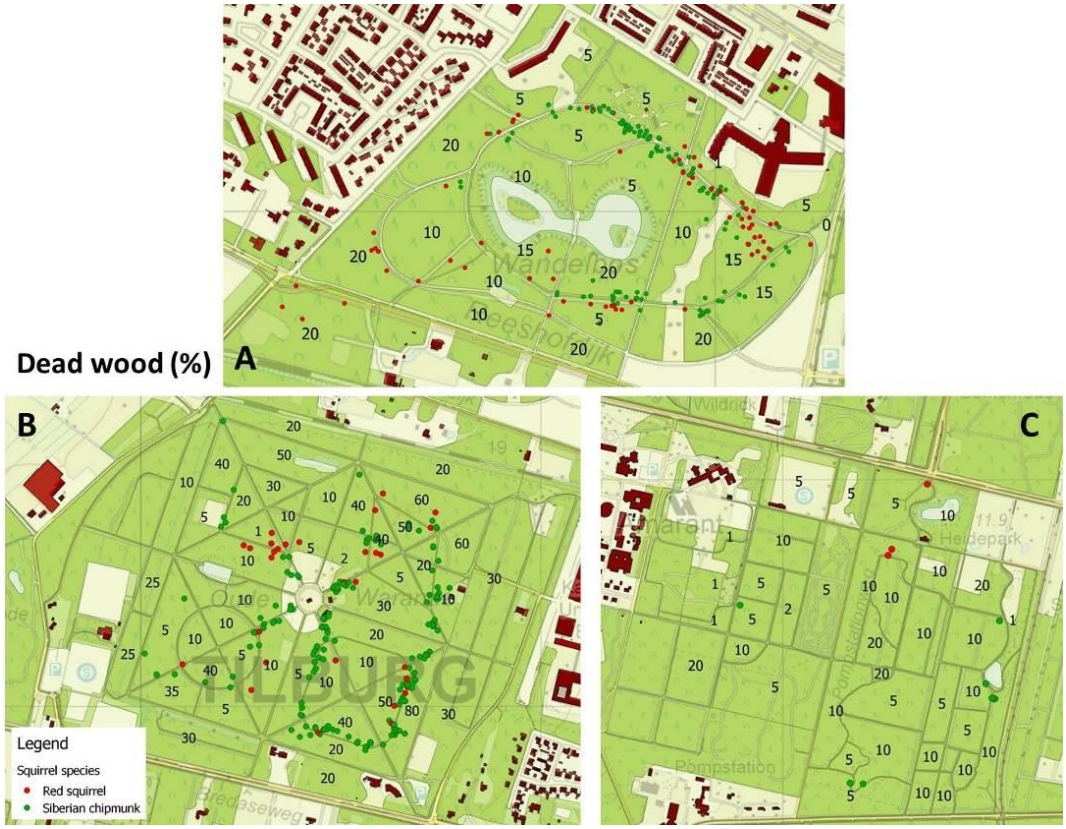

Norway spruce
A
B
C
Legend
Squirrel species
Red squirrel
Siberian chipmunk
Scots pine
A
B
C
Legend
Squirrel species
Red squirrel
Siberian chipmunk

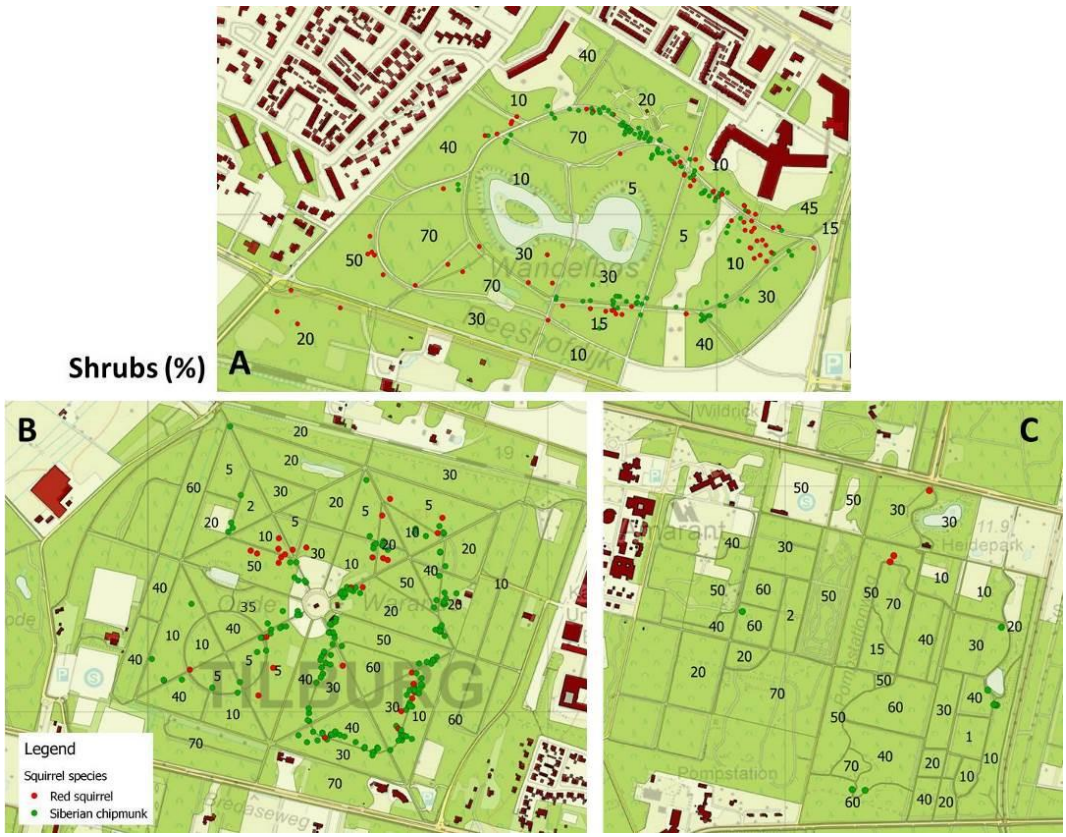

Sweet Chestnut
A
B
C
TILBURG
Legend
Squirrel species
Red squirrel
Siberian chipmunk


Thuja occidentalis
A
B
C
TILBURG
Legend
Squirrel species
Red squirrel
Siberian chipmunk


Tilia
A
B
C
Legend
Squirrel species
Red squirrel
Siberian chipmunk
TILBURG


Weymouth pine
A
B
C
2a
2b
3
4
Legend
Squirrel species
Red squirrel
Siberian chipmunk
TILBURG


Dead wood (%)
A
B
C
Legend
Squirrel species
Red squirrel
Siberian chipmunk
TILBURG


Shrubs (%)
A
B
C
Legend
Squirrel species
Red squirrel
Siberian chipmunk
TILBURG