Urban woodland ecology

–methodological perspectives and empirical studies

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Academic dissertation

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Contributions

The following table shows the contributions of authors to the original articles. The authors are referred to by the first letters of their names, and the articles by their roman numerals.

	I	II	III	IV	V	VI	VII
Original idea	SL	SL	SL, HR	SL	SL	SL	SL
Design				SL	SL	SL	SL, MM, JN
Methods				SL	SL	SL	MM, JN
Data collecting				SL	SL	SL	MM
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Original articles and manuscripts

The thesis is based on the following articles and manuscripts

I Lehvävirta S 2004. The natural regeneration dynamics of indigenous urban woodlands. Manuscript.

II Lehvävirta S and Kotze DJ 2004. Why and how to conduct comparative urban ecological research. In McDonnell MJ, Breuste J and Hahs AK, Ecology of Cities and Towns: A Comparative Approach. Cambridge University Press, Cambridge. Accepted.

III Lehvävirta S and Rita H 2004. When and how to use one-tailed statistical hypotheses – improving the epistemic clarity of results. Manuscript.

IV Lehvävirta S 1999. Structural elements as barriers against wear in urban woodlands. Urban Ecosystems 3: 45-56.

V Lehvävirta S & Rita H 2002. Natural regeneration of trees in urban woodlands. Journal of Vegetation Science 13: 57-66.

VI Lehvävirta S, Rita H and Koivula M 2004. Barriers against wear affect the spatial distribution of tree saplings in urban woodlands. Urban Forestry and Urban Greening 3: 3-17.

VII Lehvävirta S, Kotze DJ, Niemelä J, Mäntysaari M and O'Hara B 2004. Effects of fragmentation and trampling on carabid beetle assemblages in urban woodlands in Helsinki, Finland. Submitted manuscript.

For my beloved Grandmother
who wished to see me defend my thesis

Her last evening
she barely had the strength to breath

Yet she lifted her eyelid
when I told her
I had just finished the script

Look, Mother.

Introduction

In 1996, I was the mother of three daughters, one, four and eight years old, living next to an urban woodland and enjoying the recreational and psychological values it provided for my family. I also steered the Forest Club of Helsinki of the Finnish Nature Conservation Association. At the time, the aim of this club was to preserve the indigenous woodland ecosystems and the species that had established there before the city grew and embraced the patches. As forestry alone is responsible for the majority of species losses in Finland (Heliövaara and Väisänen 1984, Niemelä 1997, Rassi and Väisänen 1987), the club raised discussion with the city foresters about when, where, how and if the urban woodlands should be logged. There is no demand for economic productivity of city woodlands, yet the foresters sincerely felt that their activities were needed to guarantee the regeneration of trees in the woodlands, because of the high anthropogenic pressure in the city. The Forest Club of Helsinki in turn argued that the woodlands could do with minimal maintenance that should include only cutting down old or damaged trees that might pose a danger to the public, collecting of rubbish, maintenance of trails, control of wear caused by recreational use, and patrolling. The arguments from either side were not based on scientific information but rather on personal opinion.

It was the lack of evidence on the (dis)ability of urban woodland trees to regenerate that took me back to university. As an environmental biologist I found it an extremely absorbing question what the disturbance regime, natural regeneration and succession would be like in urban woodlands. How much has the extremely dense human population and settlement changed the urban woodland ecosystems, and what factors are behind the possible changes?

I took tree regeneration as the main focus of my studies (papers I, V and VI), as trees are a key element in a forest ecosystem: they define the habitat conditions (at least within the limits of climate and soil) for other forest species. The regeneration of trees is also at the heart of urban forestry. The other focus of my studies was the anthropogenic factors that change urban woodland ecosystems. To study anthropogenic effects I focussed on trampling, woodland patch size and edge effects using path cover (IV), tree regeneration (I, V, VI) and ground beetles (*Coleoptera*, *Carabidae*; paper VII) as indicators of the possible effects. A number of follow-up studies are still going on, and also new study designs have been employed, widening and deepening our understanding of tree regeneration on one hand, and anthropogenic ecosystem effects on the other hand.

Science can never (or at least should never!) be done without careful philosophical and methodological thinking. In the thesis I included three review papers that synthesise information (paper I) or develop methods (papers II and III) that could be applied to urban ecosystems and their research. When methods are developed along with empirical work, they are seldom reported as results per se. Instead, they are seen as tools and briefly mentioned in the methods section of an empirical paper. This way new methodological developments may remain undiscovered for the readers, and the ways methods get developed remain implicit. This a pity as methodological developments are often a prerequisite for increasing understanding of the focal study object – and at the same time this understanding is always dependent on the methods used. Further methodological development is still needed, and I wish it will never come to an end. I see science as an ever-developing field, both factually and methodologically.

The papers in this thesis show one novice scientist's work on a selection of issues that are linked together. The ideas presented here were 'born of each other': one would not exist without the other. The links between the papers are shown in Fig. 1.

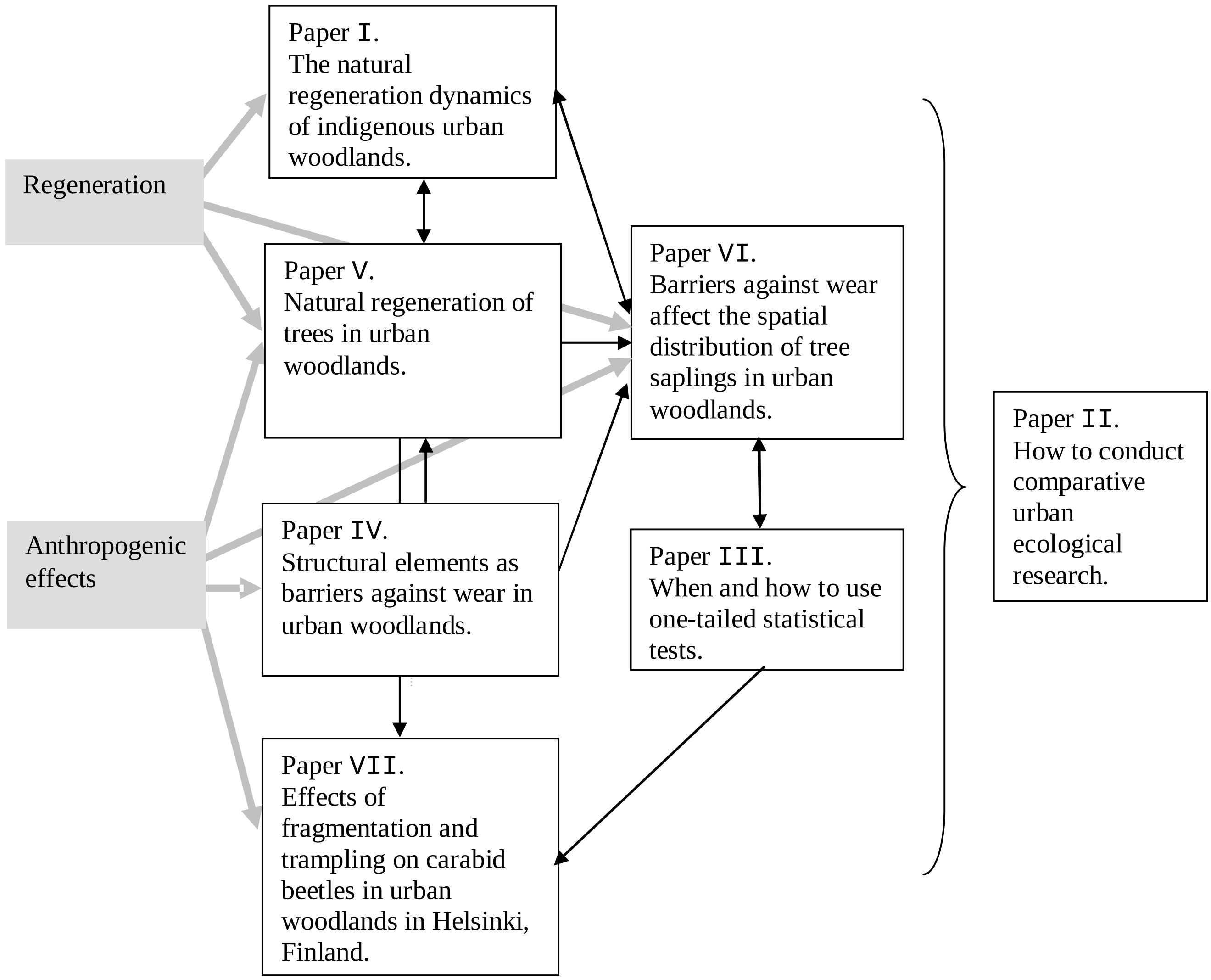

Figure 1. A schematic presentation of the linkages between different papers of the thesis. The grey boxes and arrows represent the background and its links to the papers, and white boxes refer to the papers by their roman numerals.

The review and methodological papers

The review on natural regeneration dynamics of indigenous urban woodlands (paper I) was at the basis of everything. It was started first and finished last, being always at the background, representing the initial reason for starting my empirical studies. In this paper I examined changes in the non-anthropogenic factors that drive the ecosystem dynamics of urban woodlands, from the point of view of the preservation of indigenous species. I summarised disturbance dynamics and tree regeneration in boreal forests, focusing on urban woodlands, and defined research needs for future work. My point is, that if we understand the dynamics of the urban ecosystems, we can make choices (within the limits given by nature) about what to preserve or 'let live'. It is proposed that understanding and mimicking the natural dynamics in forestry is a good basis for preservation of biodiversity (e.g. Angelstam 1998, Kuuluvainen et al. 1998). When studying urban woodlands, natural dynamics is a good starting point, as nature is basically similar in urbanised areas as in the surroundings (discussed e.g. in Niemelä 1999).

The second paper (II) gives some perspectives on how urban ecological comparative research should be conducted. These issues I learned along with my empirical work and philosophical studies, so it was born from empirical research and philosophical hobby. In the paper we discussed the usefulness of urban theory and comparative research. We examined methods necessary for the successful performance of such research, building on the foundation of ecological philosophy laid by e.g. Ford (2000), Peters (1991) and Underwood (1990). In particular, we stressed the need for clear concept definition, hypotheses generation and explicit testing, along with the necessity of quantification.

The paper on one-tailed testing (III) is purely methodological. It is a child of my empirical research, the other parent being the philosophy study circles I participated. The joint effect of my empirical work and philosophical interests was a mind-puzzling conflict: at the research hypothesis level we presented directional postulates, so it would be logically invalid to test them as two-tailed. This paper looked at the controversial issue of one-tailed statistical testing from a new perspective: we immersed the problem of one-tailed hypotheses into the general framework of scientific, empirical inference. This paper is most closely linked to paper VI, and used its contents as case-material to present the logic.

The empirical work

The empirical studies were conducted in 'wild' urban woodlands, to reveal the regeneration dynamics and anthropogenic effects in unmanaged woods (with the ideas presented in paper I at the background). Initially, I selected 158 forest compartments with trees older than 84 years, by using data from the Green Area Divisions of the cities of Helsinki and Vantaa, examined them in the field, and classified them according to their management intensity. The classification method was adapted from Lindholm and Tuominen (1993). Systematic distribution of the trees, uniform stand height structure, lack of snags or fallen trees, ditches and stumps were taken as signs of management, reduscing the stand's suitability as a study site. To minimise the effects of management on regeneration, the 30 least managed sites in Helsinki and Vantaa were chosen as study sites for tree regeneration. These sites represented a gradient in the intensity of anthropogenic effects, with varying degree of recreational use, patch size, distance from the woodland edge, and population density in the surroundings. From the 30 sites, a subset of 15 was chosen for the ground beetle study.

Within the sites, sample plots were randomly positioned. Randomisation was done by first standing at the centre of the study site (the cross point of the longest diameter and a line perpendicular to it), and from there locating the first sample plot according to a compass direction and a distance taken from tables of random numbers created for this purpose. The second sample plot was located similarly, standing at the edge of the first sample plot, etc. The ground beetle traps were placed into zigzag lines, allowing for a 10 m distance between the traps while staying within the boundaries of the study site.

My first empirical paper (IV) was on human trampling in the urban woodlands. Recreational use of the woodlands causes wear and tear of vegetation and erosion of the forest soil (Bhuju and Ohsawa 1998, Kellomäki and Saastamoinen 1975, Liddle 1997). The main question was whether natural barriers such as bushes, thickets or fallen trees could limit the area being trampled upon. To answer this, area of trails and the amount of structures that might act as natural barriers (like topography, stones, trees and bushes) were measured in the 30 study sites. Data on the number of potential recreationists (=recreational pressure in the surroundings) were derived from the Helsinki City regional database (Vuori, pers. comm.).

In the second empirical paper (V) I investigated tree regeneration and the effect of several anthropogenic factors on it. Hannu Rita shared the philosophical and statistical delights with me. Our hypothesis and design included the testing of the following factors as determinants of regeneration success of trees: the presence of propagule sources, growing space, fragmentation, recreational and other uses of the woodland sites, natural barriers, the substrate and pollution (paper V and references therein). We used the number of saplings (height 30–200 cm) per study site as the response, with 1) the number of potential parent trees, 2) number of other trees, 3) size of the forest area that included the study site, 4) the summed longest horizontal length (or diameter) of potential natural barriers, 5) path area, 6) the number of potential recreationists, and 7) an air pollution load classification as independent variables.

In the third empirical paper (VI) we studied regeneration microhabitats within the woodlands, with the aim of 1) testing the hypothesis that with increasing wear tree saplings survive best next to natural barriers where they are sheltered from trampling and 2) defining favourable microhabitats. We described the microhabitat of saplings and random points within sample plots of 50 cm by radius. We then compared the sapling microhabitats to those available (as measured by the random points). In the hypothesis testing we faced the problem of solving the logical contradiction between a directional research hypothesis and the widely preferred use of two-tailed testing; so this paper is the empirical parent of paper III. We agreed with Cooligan (1999) who noted that a theory is of not much use if the indication of an effect in either direction could be taken as support for it (c.f. also Clarke 1980).

Finally, paper VII is the twin of the second empirical paper (V). Looking at anthropogenic effects on tree regeneration had its larger background in the idea of looking at anthropogenic effects on urban woodland ecosystems. I was conscious of the problem that even if dramatic changes are happening, it might not yet show in the regeneration pattern of trees. Carabids have been named as good indicator species (e.g. Rainio and Niemelä 2003), and having expertise on this group available (in the form of my supervisor Jari Niemelä) it was natural to look at such an indicator taxon, to determine whether there was an effect of fragmentation or trampling on these beetles.

Main results and discussion

Lessons from philosophy and methodology of science

The first lesson to learn was that one should always be critical of the methods that others use. There are several papers or books that show how scientists can go wrong if they are content with, or abide by, generally used, traditional methods and lines of thinking (discussed for example in Peters 1991, Preece 1984 and Underwood 1991).

The main outcomes of papers II and III are that careful *a priori* thinking and restrictive hypotheses are an efficient tool in scientific work. In paper II we concluded that explicit quantitative theories and models are necessary when comparing between cities and countries. Scientists should not hesitate to make clear predictions and test their validity, as it is an effective way for the development of theory (Romesburg 1981, Underwood 1990, Peters 1991). We argue that the most efficient way to study urban ecosystems is to investigate a small set of factors at a time, and to control for other factors, preferably in the field or laboratory, or if this is not possible, then statistically (Shipley 2000). We make the case that quantitative reporting of variables and effect sizes or other results is a necessity for making meaningful comparisons.

Explicit, strong and quantitative theory statements often produce directional research hypotheses. In paper III we showed that with a directional research hypothesis, a directional statistical hypothesis is needed to preserve the logical consistency in inference and clarity of the epistemic status of the results. We separated the two tails of the sampling distribution of the test statistic according to their different epistemic roles in the testing and, based on this separation, suggested a notation to improve the epistemic clarity of the results in scientific papers.

Personally, the greatest lesson I learned was patience. Think once, think twice – and once again through every detail of the planned research procedure (Ford 2000). What is the original research question? What is the theory or model? What kind of observations would reveal whether the theory holds or not? What kind of data generation procedure is needed to produce these observations? Do the data allow for an appropriate statistical test – or is statistical testing needed at all? And even if you do your best, there may always lie a surprise on the next step…

Lessons from urban woodland dynamics and its driving forces

Human activity affects urban woodlands both directly (papers IV-VII) and indirectly (paper I). With indirect effects I refer to changes in the dynamic factors (e.g. in wind or fire regime). Changes in them might be as consequential for the urban woodland ecosystem as direct anthropogenic ecosystem effects (such as trampling or pollution effects, for example). An example of a possible change in a dynamic factor comes from increased insect outbreaks due to nitrogen load – although information on this is sketchy. The main finding of paper I was that strong empirical evidence about changes in dynamic factors in urban environment is practically non-existent. Thus the role of paper I is to present a framework within which future studies should be conducted in order to understand the consequences of changes in the dynamic factors. I suggested that the dynamics of tree populations may turn out to be highly variable, hampering simple generalisations; however, useful patterns and cause-effect relationships will surely be found.

To summarise the findings of paper I, it appears that in urban areas successional pathways may be changed, but woodlands as ecosystems defined by trees seem to persist (paper I, Airola and Buchholz 1982, Florgård 2000, Kellman 1996, McBride and Jacobs 1986). This conclusion was supported by our empirical work (papers V and VI): regeneration was not threatened in the urban woodlands of Helsinki and Vantaa in general, but it is possible that the species composition is changing slowly, as different tree species responded differently to anthropogenic effects. For example, regeneration of Picea abies decreased with increasing fragmentation of the forest landscape, while many deciduous species increased.

Among the most obvious direct threats to tree regeneration is trampling (papers V and VI, Bhuju and Ohsawa 1998) caused by the intensive recreational use of urban woodlands in Helsinki and the surroundings (paper IV). With an increase in the density of visits per unit area of green space, the sustainability of urban forests may be threatened if people trample all over the forest floor. However, trampling and the consequent wear and tear of the forest floor vegetation might be restricted by natural barriers (paper IV). These barriers provide shelter for tree seedlings and saplings from trampling (paper VI, Tonnesen and Ebersole 1997). This implies that the future horizontal structure in worn out woodland patches is shaped by wear and the present horizontal structure i.e. by the location of barriers.

Though the effects of both fragmentation and trampling were obvious when investigating tree regeneration, results concerning ground beetles (Carabidae) were somewhat surprising. All the carabid species, even the ones classified as forest species, decreased from the woodland edge towards the interior. Furthermore, the response of carabids to trampling, measured as path cover, was not as clear as we expected. We suggest that the urban species pool may be 'pre-adapted' to urban conditions.

Lessons for urban forestry

Understanding natural dynamics of an ecosystem is a good starting point to evaluate and develop sustainable management methods for it (Franklin et al. 2002, Harvey et al. 2002, Hunter 1999, Kuuluvainen 2002, Lähde et al. 1999, Seymour et al. 2002). The characteristics of the natural vegetation and the dynamic factors regulating its succession need to be understood in order to maintain biodiversity. Preservation of urban biodiversity is important because of its educational value to urban residents.

It appears that we could rely more on natural colonisation and succession in urban woodlands, and focus on maintenance rather than management (papers I and V). This maintenance could include the removal of garbage, erecting signs informing the public about nature, building paths through the woodland and patrolling. When there is a possibility of overuse that could cause excessive wear of vegetation and death of tree regeneration, trees can be cut down to form subtle natural barriers that limit the area being trampled upon (papers IV and VI). This practice would resemble that suggested by deVos and Bailey (1970), who proposed campsite rotation for maintaining an acceptable recreational quality of the campsites. This kind of rotational limitation of the trampled area would affect the future horizontal structure of an urban woodland patch as tree saplings would survive best in the vicinity of the barriers. Future studies might also show a differentiation between tree species' saplings in relation to microhabitats created by downed logs of different species or stage of decay. With this knowledge the horizontal structure and species assemblage of future canopy might be subtly guided.

Natural regeneration of urban woodlands is usually adequate to ensure continuity, but tree species assemblages may change in the long term, as various anthropogenic factors affect different species differently. The possible changes in the dynamics do not necessarily have to be seen as threats, but also as fascinating sources of information. The possibly changed ecosystems will still provide us with scenic, aesthetic, recreational and scientific values.

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Without my dear friends outside the university, I would not have finished this thesis. They kept me going, both mentally and physically. Particularly I want to mention my oriental dancing team, led Kirsi Bergdahl: dancing was such a delight mentally, and importantly, helped me physically endure working hours and hours with the computer.

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