Hedblom M., 2010. Long term monitoring of biodiversity and recreational values in Swedish urban green areas – methodology development.
The Problems of Landscape Ecology, Vol. XXVIII. 171–179.

Long term monitoring of biodiversity and recreational values in Swedish urban green areas – methodology development

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Abstract: In Sweden 84% of the population live in urban areas. The demographic trend of people moving from the country and smaller urban areas into larger cities is continuing, e.g. the metropolitan area of Stockholm increase with 30 000 people a year. Large parts of green areas in the city and the adjacent landscapes are exploited due to building of infrastructure. Although urban green areas are important to biodiversity, ecosystem services, human recreation and health, no national long term monitoring of the qualities of urban green areas exists in Sweden or elsewhere. In Sweden a methodological development program called Urban NILS (Urban National Inventory of Landscapes in Sweden) is initiated. The purpose with Urban NILS is to establish a long-term monitoring program of biodiversity and human perception in urban green areas using a multiple hierarchical scale method. The suggested methodology is a combination of satellite images and field surveys including the 100 largest cities. Parts of the methodology could be used from existing monitoring programs but the costs and monitoring of e.g. recreational values without using interview techniques need further studies. A monitoring program of urban green areas could provide urban planners and decision makers with adequate information and support national policy decisions.

Key words: *Biodiversity, Geographical Information System, city, urban green area, stakeholder*

Introduction

Urbanization, together with agriculture, is the most significant threat to biodiversity worldwide (Ricketts, Imhoff 2003). Most likely, urbanization is going to top agriculture as the dominating agent of loss, fragmentation and degradation of habitats caused by an increasingly urbanized human population (Marzluff, Ewing 2001). Urbanization will have a major effect on biodiversity since urban areas are projected to increase by more than 500 000 square kilometers in industrialized cities by the year 2030 (Angel et al., 2005). The demographic trend of people that leave smaller towns in rural areas and move into larger towns is significant in Sweden. Stockholm County, for example, increased with more than 30 000 people during 2008 (statistics Sweden 2008a) and is predicted to increase with 500 000 people by year 2030 (RUFS 2010). This building of infrastructure and residential areas has led to a loss of urban green area both within cities and in their adjacent landscape. In the 10 largest cities in Sweden there have been a constant

densification and approximately 5% loss of green areas per decade (statistics Sweden 1992). There is no per definition urban sprawl in Sweden affecting adjacent landscapes, but cities do expand on green areas that are shown to have high biodiversity potential (Hedblom, Söderström, 2010). Moreover, people traditionally settle in areas with highly productive ecosystems and large natural resources, therefore many cities are located in areas important for biodiversity conservation, so called ecological hotspots (Cincotta et al., 2000; Ricketts, Imhoff 2003; Luck 2007). Urban green areas as habitat can thus be of direct importance to flora and fauna within cities but can also be beneficial to humankind. Urban green areas have been highlighted as important for human well being and also to have direct increase in psychological benefits with higher biodiversity (Fuller et al., 2007; Grahn, Stigsdotter, 2010). The increased awareness of biodiversity loss has led to political policies such as the Swedish Environmental Quality Objectives. Recently there have been suggestions to include urban biodiversity within these objectives.

A long term goal for urban ecology should be to uncover the factors regulating the success or failure of species in inhabited areas and use these factors to develop principles for the design of urban landscapes compatible with nature (Turner 2003). In order to reveal why species richness and abundance fluctuate in urban ecosystems there is a need to have long term data of species abundance, habitat quality and habitat quantity. Programs to monitor biodiversity on a national scale started fairly recently e.g. the Swedish bird survey started in 1972 and the NILS program (National Inventory of Landscape in Sweden; Essen et al., 2008) started in 2003. NILS is a nation-wide environmental protection program that monitors the conditions and changes in the Swedish landscape and how these changes influence the conditions for biodiversity. Nevertheless, only 3.8% of the total urban area are included within the NILS program and cannot accurately provide data of biodiversity changes in Swedish urban areas. Moreover, studies of human perception of urban green areas have been irregular questionnaires mostly conducted in one or a few cities. Thus, up to date no national monitoring program of urban green areas connected to biodiversity and human perception of green areas exists.

The Urban NILS project was funded to 1) investigate the need of information among potential stakeholders about biodiversity aspects in urban green areas 2) develop sufficient methods for long term monitoring of biodiversity and human perception of urban green areas 3) investigate potential indicators for biodiversity and human perception 4) estimate costs and benefits with different survey methods.

Stakeholders interest concerning long-term monitoring of urban green areas

The initiative of the Urban NILS project came from the Swedish Environmental Protection Agency (SEPA) and the board of NILS. Although issues' concerning biodiversity and nature conservation are handled by SEPA the Board of Housing, Building and Planning (BHBP) have the main responsibility for the Swedish Environmental Quality Objectives in urban areas. Within Urban NILS stakeholders were asked about the need for long term data related to urban green areas (Hedblom, Gyllin 2009). Stakeholders were primarily governmental agencies such as the SEPA, BHBP, Swedish Forest Agency, the Swedish National Heritage Board and country boards (see Hedblom, Gyllin 2009). The purpose of Urban NILS was to investigate the interest of providing data on changes of urban environments in a national perspective. However, questions were also appointed to larger municipalities (< 100 000 inhabitants) since they work with urban green areas in local perspective and researches.

The results from the questioned governmental agencies and the municipalities showed an apparent and divers interest of information about long-term monitoring of urban green areas. Seemingly the interest in area changes and spatial configuration varied from long term fragmentation effects including whole cities and their peri-urban landscape (surrounding landscape) to solitary trees. Even more specifically knowledge about butterfly abundance and huts made by children were asked for (Hedblom, Gyllin 2009). Municipalities were mainly interested of national data in order to compare their own efforts preserving and managing green areas with mean data of urban green areas in other Swedish cities. However, most municipality data asked for was very detailed and could not be included in a national monitoring program.

Surprisingly, there was a large interest of human perception of urban green areas in the cities and in the peri-urban areas from all stakeholders. Moreover some of the data asked for could only indirectly be provided in a future monitoring program such as e.g. distances to urban green areas from residential areas. It is then needed to combine Urban NILS data with e.g. population data.

Measuring fragmentation of urban green areas

In Sweden, 84% of the population lives in 1940 urban areas. The definition of a Swedish urban area is that it lives at least 200 people not further than 200 m from each other (statistics Sweden 2001). Approximately 7 800 000 of the Swedish inhabitants live in urban areas with this definition. However, the Swedish statistics often use the definition of > 10 000 inhabitants for urban areas. By this definition approximately 55 percentages of the population and 100 cities are included.

The present NILS program uses a combination of RS and field studies (Fig 1, Ståhl et al., 2010). In NILS an aerial picture is taken over a 5 km^2 landscape square. NILS cover 631 of these landscape squares) which are randomly scattered (stratified in certain regions) in all terrestrial landscapes in Sweden. Every 5th year an aerial picture is taken and field studies are conducted. Thus, a statistical representative part of Swedish landscapes and their potential to harbor biodiversity is measured. The Urban NILS program primarily intended to use the same method using landscape squares of 5 km^2, manually interpreted aerial pictures and field studies every 5th year (fig. 1) in the 100 largest cities in Sweden. The landscape squares could be randomly placed anywhere from the centre of a city up to 3 kilometer from the city border in order to include the peri-urban areas. However, not covering the whole city and the surrounding area could lead to a misrepresentation of the special local conditions that exists in some cities such as green corridors that are common in the Stockholm region. Another suggestion would be to cover all urban and peri-urban areas in 100 cities. However, although cities only cover 1.3 percentage of the Swedish surface it would be costly and time consuming to cover all urban and peri-urban areas using aerial pictures. Instead, satellite pictures ought to be used that covers the whole city and the peri-urban areas and thereby not only a representative part of a city (statistics Sweden, 2008b). Although the resolution on the satellite pictures are a bit less than the areal pictures, 10 m vs. 1.5–5 m meter (Allard et al., 2003, statistics Sweden 2008b) the satellite pictures are automatically interpreted which is time and cost efficient. However, using manual interpretation of aerial pictures is advantageous since it allow special focus on e.g. vulnerable biodiversity hotspots such as smaller ponds. Using satellite pictures would provide information of landscape changes such as fragmentation, new building structure and uses of land.

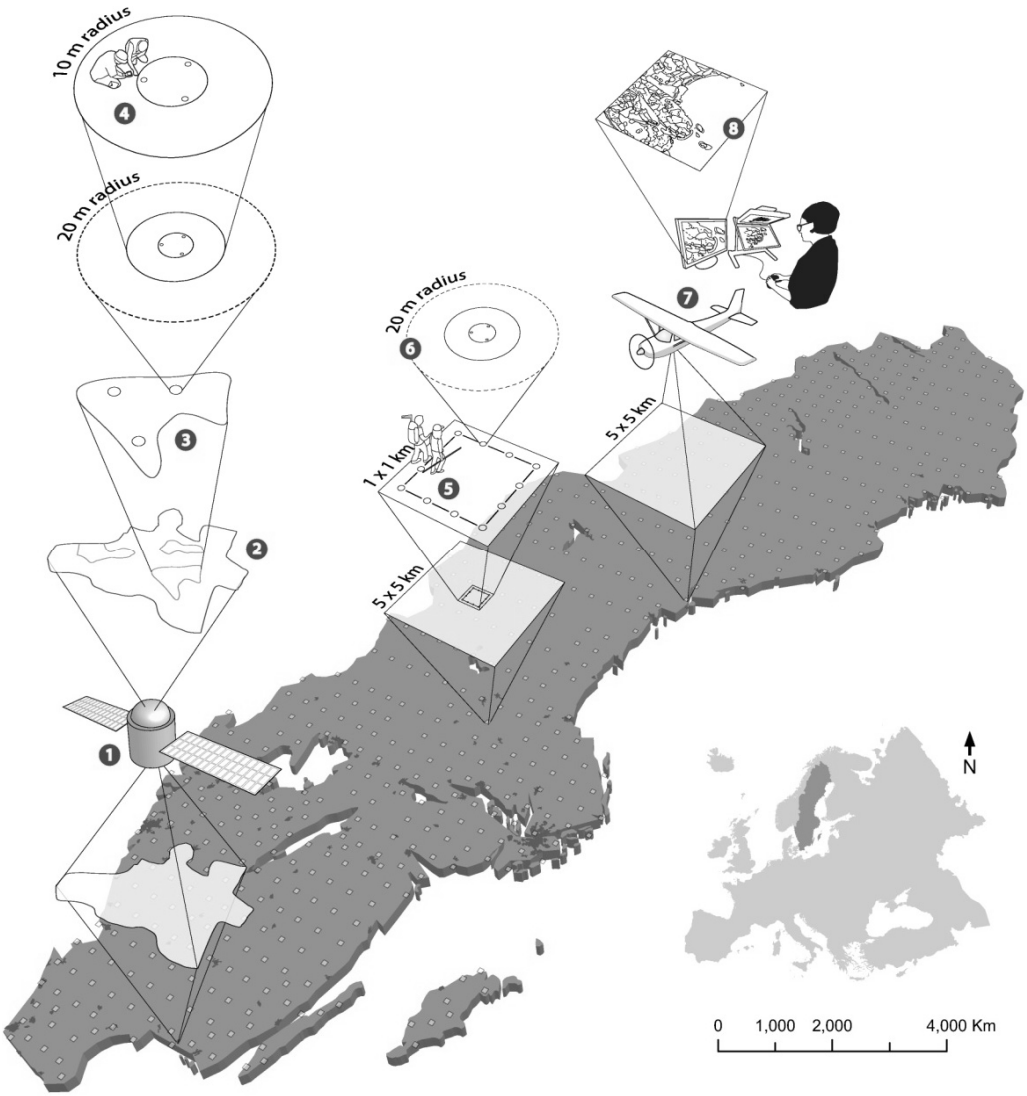

Fig. 1. Illustration of two different long term monitoring methods in Sweden

1–4 represent the suggested monitoring method of urban areas within the Urban NILS project; 5–8 represent the present running NILS (National Inventory of Swedish Landscapes) monitoring programme. (1) A satellite image that covers the whole city and the peri-urban (surrounding) area. (2) Green areas e.g. parks, churchyards, recreation areas, golf courses, urban woodlands etc. that are accessible to the public are chosen on the basis of the satellite image. The size of a green area could vary but not be smaller than 1 hectare. One hectare is also the suggested sampling unit in which 3 sample plots are placed (3). Each sample plot have a radii of 20 m (3, 6). (4) Field surveys of biodiversity and perception values are conducted within each of the plots in circles with different radii (Essen et al. 2007). (5) In the NILS programme, 12 sample plots (radii 20 m) in each central landscape square are chosen for survey. (6) Field surveyng is conducted the same way as in the Urban NILS except recreational values are not recorded. (7) Aerial photographs are taken for each 5km^2 landscape square. (8) Digital aerial photos are interpreted with the aid of a polarised screen and special glasses. It is possible to see a three dimensional picture using two aerial photos in a so called stereo model (Allard et al. 2003)

(Created by Erik Cronvall, 2010)

Measuring biodiversity

Since one of the purposes with Urban NILS is to estimate changes in qualities such as biodiversity on a national basis, a random sample of all green areas in the 100 largest cities are chosen. Urban green areas are identified using satellite pictures (fig. 1). The definition of urban green area is vaguely defined in literature but Urban NILS will inventory green areas as suggested and defined in statistics Sweden (2008b) including all public areas that are not hard surface (e.g. infrastructure such as roads). These samples could either be based on whole green areas or using green areas as a unit. Since there is a large variation in green area sizes both within and between cities a suggestion is to divide green areas into units of one hectare (fig. 1). Green areas smaller than one hectare are omitted. In order to considerate the variation in sizes of cities and make the sample more proportional, all test units (one hectare green areas) will have the same probability to occur in one of all the selected green areas.

A suggested number of green areas would be 650 sample units that are chosen from all cities. Within every unit three sample plots are placed randomly. At every sample plot a NILS standard plot (20 m radii) placed (fig. 1, Ståhl et al. 2010). Every sample plot is then inventoried according to NILS-scheme but also a number of new indicators for urban areas including recreation, perception and biodiversity (Hedblom, Gyllin 2009). For monitoring purposes are sample plots permanently marked as in the NILS project. The permanent plots should be kept secret for the managers in order to avoid bias in quality because special treatment from managers. A certain amount of green areas could be created and lost during the development of a city and thereby some numbers of test units have to be changed during the 5 year period.

One suggestion is to investigate the quality of green areas in one or a few cities more accurate. Thus, provide information that would be of greater importance to local decision makers and managers in single cities. Tentatively the 10 largest cities could be tested for this purpose, although the selection could be based on other criteria than size. The same test unit as in Urban NILS should be chosen (one hectare). 30 test units in one city are then chosen with three sample plots in each. This method to locally increase test units is tested in NILS (Rygne 2009). The sample plots are permanently marked as in Urban NILS.

Biodiversity indicators for urban areas

Indicators show changes in factors that are important for monitoring environmental quality objectives and their goals. The indicators will follow up the results of environmental work, demonstrate that the environmental work is going in the right direction and in the right pace, show how the environment is doing and finally provide a basis for actions and decisions. For targets relating to green areas in cities there are no specific indicators in Sweden although some suggestions are proposed. In today's NILS methodology could several indicators be suitable for use in urban areas. Particularly measurements conducted from present NILS methodology the plots could be used in the indicator system. For recreation and perception only indirect methods of surface area and individual objects could be used.

Suggestion on new indicators

The organisation of Swedish municipalities are working together with Statistics Sweden on an indicator which measures the distance from housing to urban green areas of at least one hectare. The purpose of the project is to develop a method to define the green space in urban agglomerations and neighbourhood

and to monitor changes in these green areas. This creates a basis to calculate the urban population's access to green space of varying size in different distances.

Many Swedish municipalities manage grasslands extensively to promote biodiversity and to keep low management costs. In e.g. the city of Uppsala it is even a happening watching the grass get cut since it is made with horse in a traditional manner. This type of more extensive cutting of grass most probably favours butterflies, although no measurements on butterflies are made in cities. Grasslands in cities consist to a large extent of road verges that showed to be important for butterfly movements (Söderström, Hedblom 2007). To monitor butterflies and the network of road verges with high qualities would provide good indicator on species richness in a city.

Present NILS landscape squares are to a large extent placed in the same squares as the Swedish Bird Survey (Ståhl et al. 2010, Lindström et al. 2009). The birds are monitored in 716 routes including point counts all over Sweden since 1972. However, only 9.5% of the routs are close to urban areas and a few of them actually have points in the city. This is not enough to provide information about bird species as indicators in urban areas but they could give trends on how the bird abundance varies in peri-urban landscapes in Sweden (Hedblom et al., 2010); e.g. forest birds are decreasing in forests close to cities in southern Sweden (fig. 2).

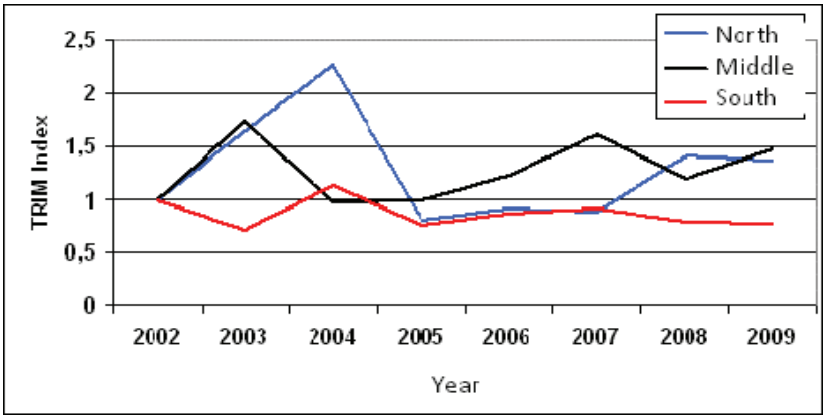

Fig. 2. Monitoring of bird abundances in peri-urban areas at different longitudes in Sweden between year 2002–2009. The sampling is conducted at a distance within 100 meters from the urban area border. The bird's samples are indicators for the environmental quality objective Living forests. The indicator species are: North: coal tit (*Periparus ater*), willow tit (*Parus montanus*), crested tit (*Parus cristatus*), Treecreeper (*Certhia familiaris*), Bullfinch (*Pyrrhula pyrrhula*). Middle and South: Stock pigeon (*Columba oenas*), green woodpecker (*Picus viridis*), marsh tit (*Parus palustris*), coal tit (*Periparus ater*), willow tit (*Parus montanus*), crested tit (*Parus cristatus*), treecreeper (*Certhia familiaris*), bullfinch (*Pyrrhula pyrrhula),* Long tailed-tit (*Aegithalos caudatus*)

TRIM is a program used to combine data: Trends and Indices for Monitoring data.

Human perception

Previous measurements of how human perceive nature or urban nature have been conducted using questionnaires or deep interviews with people. Mostly this is made in one or a few cities. This method would be very costly to use in a national long term monitoring project since it is time consuming. Instead

field personnel could be educated in how to objectively analyse perception and thereby cover larger green areas than questionnaires would. By using a method developed by Ode et al. (2010) field personnel with basic training showed that they could estimate 9 different perceptions as good as a professional landscape architectures (Hedblom at al., 2010). The field personnel took pictures in four directions when estimating the perceptions on plots in urban green areas and these pictures were later estimated by professional landscape architectures. Some examples of perception are the perceived complexity of the environment, naturalness, historical connection and disturbance (Hedblom et al. 2010).

Discussion

Although Sweden is still a sparsely populated country more than 55% live in urban areas with >10 000 inhabitants. Swedish cities have large proportions of the urban areas covered with green areas compared to southern and western Europe (Hedblom, Söderström, 2008) An urban planning trend in Sweden during the last decades is to condense cities (at the costs of urban green areas to a certain part). This has been intensively discussed in local newspapers, especially in larger cities where the pressure to built infrastructure is larger than in smaller cities. The demographic trend in Sweden (and to most part of the world) is to move from the country to cities. The increased pressure has lead to that cities expands cities into the peri-urban land and thereby indirectly urban sprawl. Arguments to keep the urban green areas are health, perception, local farming, ecosystem services, recreation and biodiversity. Although urbanizing is predicted to continue or even increase in the future no comprehensive monitoring program of the amount urban green areas and their qualities exists.

Monitoring could provide future decision makers and city planners with information of how cities evolved, what type of landscape that is fragmented, how green areas used to be managed and how this affected flora and fauna. Monitoring could also provide information of how people perceived their environment prior to exploration and how people change their ways of perceiving nature through time. By using this knowledge it would also be easier to predict how cities develop in the surrounding environment, create sustainability according to ecosystem services and create environments that appreciated for human recreation and perceiving.

No national monitoring programs exist of both biodiversity and human perception of green areas in urban areas. However, there are many programs under development, all of which cover biodiversity but none including human recreation and human perception. In the Netherlands have voluntary monitoring of birds in urban areas been running since 2008 (Monitoring Network Urban Species). The method differs from that used in Swedish birds survey but could be used in other countries due to the effective way of combining self reports on internet. Monitoring of birds in one city has also been conducted by Turner (2003) also using volunteers. The interest of bird watching in Sweden is large and it would most probably it would not be a problem to find people that could volunteering for to provide long term urban bird monitoring information. Moreover, indexes for monitoring biodiversity is under development and have been tested in a number of large cities such as Curitiba, Joondalup, Edmonton, Brussels, Montreal, Nagoya and Singapore (The Singapore index on Cities Biodiversity, CBI). The CBI could be used as a frame in further development of Urban NILS.

Urban areas include many land owners and also many stakeholders, a combination that make urban green areas potentially more complex to monitor than than other habitats such as forests and agricultural areas. Moreover, at least in Sweden, it is difficult to get response for the urge of monitoring urban green

areas since no governmental organization sees the urban green areas as their main responsibility. The governmental organizations consider municipalities to have the main responsibility for urban green areas. The municipalities on the other hand cannot alone afford to develop a monitoring method for urban green areas and neither afford to cover enough area within the single city to get enough data for statistically robust systems. A suggestion is therefore to first develop a national Urban monitoring program with samples of urban green areas within the city and secondly offer the developed methods to municipalities where the municipalities themselves could increase their samples by own payment. This has previously been done in regions within the NILS program (Rygne 2008).

Finally, it will be impossible to cover all interests wished for in one single in future monitoring program. There will alwaysbe a need to prioritise costs, benefits and possibilities accordingly to what actually can be delivered.

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