Recalling Urban Nature

- linking city people to ecosystem services

Stephan Barthel

“During the course on interdisciplinary research methods, the professor went for a walk by the lake with her students. She stopped on a meadow in front of a large Aspen, and asked them-*what do you observe?*
One student quickly responded - *leaves are moving.*
Another one, who tried to outsmart the first, said- *wind is moving.*
The third student long gazed at the tree in silence.
Then he talked. -*Mind is [co-] moving.*”
(Modified Zen-story)

To Leo and Rosa-Linn

Abstract

People, society and ecosystems are embedded in social-ecological systems, and societal development ultimately is dependent on the generation of ecosystem services (ES) to sustain it. Many ES are degrading however, reflected for instance in the world wide crisis in the pollinator service. Related to this urgent issue, the objective of this thesis is to investigate how actors and actor groups, as well as their governance context, shape the generation of ES. Focusing on social-ecological features behind management practice, the empirical basis are a number of case studies in Stockholm, Sweden, including allotment areas, cemeteries, city parks, as well as a large urban national park. The thesis uses a theoretical lens of complex adaptive systems theory and resilience thinking for the interdisciplinary approach. Methods include ecological inventories of birds and bees and studies of maps, field observations, questionnaires, deep interviews, literature analysis, as well as synthesis writing. It consists of four papers, where results suggest new issues explored in subsequent papers. ***Paper I*** shows that the urban landscape owes it's current flow of ES to co-evolutionary processes and that green governance with the aim of sustaining such ES must take into account historical property and management rights and the involvement of a diversity of actor groups, as well as ecological processes of the larger landscape. ***Paper II*** studies allotment gardens, cemeteries and city parks in relation to the generation of pollination, seed dispersal and pest regulation. Differences in social mechanisms behind management practice are reflected primary as higher abundance of pollinators in the informally managed allotment gardens and as differences in the compositions of seed dispersers and insectivores' birds. Thus, voluntary, informal and often ignored actor groups, motivated by sense-of-place, play an important role for the generation of some ES here. ***Paper III*** shows how local management practice, linked to ES generation, is retained and stored among allotment gardeners, and modified and transmitted through time, by means of social-ecological memory (SE-memory). SE-memory is an emergent property of a dual process of participation and reification in communities of allotment practice. It facilitates monitoring of local change and seems to link practice, often in habits, to place specific processes that underlie prime ES. ***Paper IV*** explores how spatial scale mismatches between ecological process and processes of management can be bridged by a spatially explicit and flexible social network structure of governance. Policy recommendations for how to strengthen the flow of ES are provided, including appointing mid-scale actors with focus on ecosystem management of the ignored mid-scale, and of scale-crossing brokers with focus on creating relations between disconnected actor groups on multiple spatial scales. Urban ES are a product of complex and human driven co-evolution, consequently sustaining ES in urban landscapes is not about conservation without people, but shaped by and dependent on management practice by people. Practice that links to generation of ES are facilitated by SE-memory of local communities of ecosystem practice of physical sites in the landscape, which also is where meaning and motivation of voluntary management is created. Long term management rights that allow for such qualities to emerge are crucial in this regard. Consequently, local actor goups, which contribute to the production of ES, should explicitly be integrated with green governance of Stockholm, which could be put in practice by facilitating emergence of actor groups engaged in scale crossing brokering that provides collaborative platforms, supports a diversity of actor groups and cultivates features that enable local self-organization.

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List of papers

Paper 1	Barthel S., Colding J., Elmqvist T., and Folke C. 2005. History and local management of a biodiversity rich, urban, cultural landscape. *Ecology and Society* **10**:10.
Paper 2	Andersson, E., Barthel, S. and Ahrné, K. 2007. Measuring social-ecological dynamics behind the generation of ecosystem services. *Ecological Application* 17(5): 1267-1278.
Paper 3	Barthel S., Folke, C., and Colding J. Social-ecological memory for management of ecosystem services. *Manuscript*
Paper 4	Ernstson, H., Barthel, S., Andersson, E., and Borgström, S. Ecological scales and social network structure in urban landscapes: management and governance of urban ecosystem services in Stockholm, Sweden. *Manuscript*

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Swedish Summary/Svensk Sammanfattning

Endast en bråkdel av jordens biologiska mångfald existerar idag inom skyddade områden, den största delen har funnits i ekosystem som är mänskligt förvaltade. Den här avhandlingen handlar om förvaltning, vård och utveckling av biologisk mångfald och ekosystem i stadslandskap. Den undersöker mänskliga aktörer och aktörsgrupper som är engagerade i förvaltning, med fokus på sammanlänkade social-ekologiska processer som möjliggör en förvaltning som är anpassad till dynamiska ekosystem. Ett grundläggande antagande är att civilisation och ekosystem är sammanlänkade i *social-ekologiska system*, och att samhällsutveckling i grunden är beroende av biosfärens kapacitet att möjliggöra den. *Ekosystemtjänster* (ES) är hela frekvensen av tillstånd och processer genom vilka ekosystem möjliggör mänskligt liv, inkluderat provianterande tjänster (t.ex. mat och kläder), reglerande tjänster (t.ex. luft rening och sjukdomsreglering), kulturella tjänster (t.ex. rekreation och estetiska upplevelser), samt stödjande tjänster som underligger produktionen av alla övriga ES. Slutsatsen av den globala utredningen *Millennium Ecosystem Assessment* var att många av jordens ES är försämrade, reflekterat bland annat i en världsomfattande kris rörande pollinering för odling och för biologisk mångfald. Relaterat detta brådskande faktum är målsättningen för denna avhandling att undersöka hur aktörsgrupper, samt den sociala kontexten av ledning och beslutsfattande som de tillhör, formar genereringen av urbana ES. Den empiriska basen är en rad fallstudier i Stockholms urbana landskap, inkluderat kolonilottsområden, kyrkogårdar, stadsparker samt Nationalstadsparken. Avhandlingen använder en teoretisk lins, bestående av komplexitets teori i kombination med resiliens tänkande, för att analysera information som fångats genom ämnesövergripande metoder. Dessa inbegriper ekologiska inventeringar av fåglar och humlor, studier av historiska och moderna kartor samt biotopkartor, observationer i fält, frågeformulär, djupintervjuer, litteraturstudier och synteser. Avhandlingen består av fyra uppsatser där resultat leder till nya frågor som adresseras i efterföljande uppsatser. ***Uppsats I*** är en fallstudie av Nationalstadsparken, som är ett stort och centralt beläget grönområde i Stockholm. Den visar att flödet av ES här beror på processer av samevolution mellan människa och ekosystem, och att ledning och beslutsfattande med målet att bevara detta flöde av ES, behöver ta i beräkning historiska äganderätter och förvaltningsrätter, deltagandet av en mångfald av aktörsgrupper, samt processer som sammanlänkar parken med omkringliggande ekosystem. ***Uppsats II*** studerar kolonilottsträdgårdar, kyrkogårdar och stadsparker i relation till generering av tre ES; pollinering, fröspridning och naturlig skadedjursreglering. Variation i bakomliggande sociala kvaliteter och processer; institutioner, lokal ekologisk kunskap och platskänsla (*sense-of-place*), förklarar skillnader i förvaltningspraxis mellan dessa typer av områden. Dessa skillnader reflekterades i flödet av ES, primärt i en högre abundans av pollinerande humlor i de informellt förvaltade koloniträdgårdarna, och i skillnader i kompositionen av fågelarter som sprider frön i rummet och av fågelarter som äter insekter. Sålunda, frivillig och informell förvaltning motiverad av platskänsla, och ofta undervärderad i dessa sammanhang, spelar en viktig roll for genereringen av ES i detta landskap. ***Uppsats III,*** fokuserar på kolonilottsodling och bygger på resultat från uppsats två. Uppsatsen frågar sig hur förvaltningspraxis inom självorganiserade grupper, och som stödjer flödet av ES, bevaras och lagras, och hur de modifieras och överförs i tiden.

Svaret utvecklas här genom iden om *social-ekologiskt minne*, vilken är en upplevelse baserad och framväxande egenskap genom deltagandeprocesser och reifikationsprocesser i grupper med gemensam social praktik *(Communities-of-practice)*. Exempel på deltagandeprocesser är imitation av kroppsarbete och vardagliga samtal om odling, och reifikations processer kan vara ordspråk, fotografier och fysiska objekt, så som fågelholkar och fruktträd. Social-ekologiskt minne stödjer odlare i övervakningen av lokal förändring och det verkar som om det länkar praxis, ofta genom vanor, till platsspecifika processer som underligger önskade ES. ***Uppsats IV*** undersöker hur sådana lokala kvaliteter kan integreras i ledning, förvaltning och beslutsfattande rörande ES i det större stadslandskapet och hur förvaltning kan anpassas till ekologiska processer i rummet. Den fjärde uppsatsen är en syntes av sju fallstudier utförda i Stockholm och som genomförs med en kombination av ett strukturellt nätverksperspektiv och ett skaltänkande baserat på ekologiska processer. Pappret tillhandahåller en linje för hur förvaltningen av ES kan förbättras, genom att införa ett tydligt skaltänkande och genom att öka flexibilitet i styrning så att en förvaltning som är anpassad till dynamiska ekosystem görs möjlig. Detta kan förverkligas genom att främja framväxten av aktörsgrupper med målsättningen att sammanlänka aktörer som idag ignorerar varandra. Denna avhandling hävdar att urbana ES är en produkt av komplexa och aktörsdrivna samevolutions processer, och därför handlar bevarande av ES i stadslandskap inte om skydd *från* människor, utan om hur de är beroende av fortsatt förvaltning *av* människor. Förvaltningspraxis som stödjer ES främjas av social-ekologiskt minne inom lokala grupper som är aktiva i vård och förvaltning i det fysiska landskapet, och det är också här som mening och motivation för frivillig förvaltning skapas. Långtidsavtal rörande förvaltningsrätt som tillåter sådana lokala kvaliteter att växa fram är centralt i detta samanhang. Sådana skapar incitament för stadsmänniskan att aktivt delta i förvaltningen av ekosystem, aktiviteter som i sin tur kan påverka det allmänna stödet för naturvård och en ekologisk hållbar utveckling. Följaktligen, lokala aktörsgrupper, vilka främjar flödet av ES, bör aktivt tas in vid beslutsfattande och ledning rörande stadens grönområden, exempelvis genom att skapa samverkansarenor där aktörs grupper som idag inte har några relationer kan träffas och lära av varandra. Detta medför utmaningar då grupper med olika intressen möts. En linje om hur det ska förverkligas inkluderar att främja framväxten av skalövergripande medlare *(scale-crossing-brokers)* med målet att föra samman aktörsgrupper som är aktiva inom förvaltning av olika rumsliga skalor, samt är aktiva inom olika samhällsnivåer. Dessa medlare bör verka för att skapa ett socialt nätverk med en mångfald av aktörsgrupper, de bör verka för lokal självorganisering och samtidigt vara uppmärksamma på toppstyrda lösningar och blåkopior vilka tenderar att uppkomma. Decentralisering för självorganisation verkar bygga mångfald och ökad resiliens inför ekologisk förändring och därför bör system av adaptiv styrning och beslutsfattande, med möjlighet att växla mellan toppstyrning och decentralisering, införas vid förvaltning av stadens ekosystem. Upplevelsebaserade kvaliteter hos lokalt verkande aktörsgrupper, så som platskänsla, identitet och mening och social-ekologiskt minne är viktiga komplement till generella ekologiska teorier när vi gemensamt ska verka för en ekologiskt hållbar utveckling på den här planeten.

Introduction

This thesis is about actor and actor groups in relation to on the ground management of biodiversity and ecosystem services in urban landscapes, with a focus on social-ecological features behind management practice. A dominant proportion of all species live in ecosystems that are managed by humans and only a small fraction of biodiversity exists in protected areas (Pimentel et al. 1992; Hoekstra et al. 2005). The Millennium Ecosystem Assessment concluded that ecosystems of the world are degrading, reflected in a worldwide crisis in many ecosystem services for human wellbeing (MA 2005). Knowledge and understanding of the role of urban landscapes in this context needs to be developed (Grimm et al. 2008). Time is ripe to consider urban landscapes for their potential role in sustaining species richness and for generating ecosystem services (MA 2005; iclei 2008, http://www.iclei.org/index.php?id=6803).

This thesis assumes that ecosystems, society and people are embedded in social-ecological systems (SES) (Berkes and Folke 1998) with societal development ultimately being dependent on the life-support capacity of the biosphere to sustain it (Odum 1989). Ecosystem services (Folke 1991; Daily 1997) are generated in SES and they are defined as the conditions and processes through which ecosystems sustain and fulfill human life, including provisioning services (products like food and fiber); regulating services (e.g pest regulation and air filtration); cultural services (e.g spiritual enrichment, recreation, and aesthetic experiences); and supporting services being necessary for generation of all other ecosystem services (MA 2005).

Urbanization is a global trend (UN 2007), and a main driver for the drastic and persistent changes in habitats and landscapes both around and within urban landscapes (Rees 1997; Folke et al. 1997; Alberti et al. 2003; Antrop 2004; McKinney 2006). As more people are projected to live in urban landscapes (UN 2007), the wellbeing of a growing proportion of humanity will depend on urban ecosystems for enjoying services such as recreation, aesthetic experiences, health regulation, as well as services like air filtration, water retention and pollination (Pyle 1978, 1993; Bolund and Hunhammar 1999; Jansson and Nohrstedt 2001; Grahn and Stigsdotter 2003; Chiesura 2004; Takano et al. 2002; Miller 2005).

The purpose of the thesis is to investigate how actors and actor groups as well as their governance contexts shape the generation of ecosystem services in the urban landscape of Stockholm, Sweden. Actors and actor groups are here used as both stakeholders and/or stewards that actively may take part in on-the-ground management of ecosystems, as well as such individuals or groups that may indirectly facilitate or constrain practical management and the generation of ecosystem servcies. The departure is a study of historical land uses and current “local stewards” (Schultz et al. 2007) of urban green areas and their management rights of the National Urban Park of Stockholm (see Figure 1). Results highlight that biodiversity of this cultural landscape is a reflection of a co-evolutionary process of humans and nature (Norgaard 1994), and that the reasons for the relative rich flow of ecosystem services there, relate to past land use and current management of the land (***Paper I***).

The second section moves on to analyze social-ecological processes behind the generation of three ecosystem services; pollination, seed dispersal and pest regulation. Interdisciplinary studies of three types of intensively managed urban green areas: city parks, cemeteries and allotment areas, show that rules-in-use, ecological knowledge and sense-of-place diverge considerably between managers of the different types of areas, with consequences for the generation of the three ecosystem services. The study highlights the significance of the different governance contexts within which they operate (***Paper II***).

The third section digs deeper into social features behind management practice in relation to ecosystem services in one of these land uses, namely allotment gardens. We explore the concept of social-ecological memory (SE-memory). SE-memory is defined as the means by which knowledge, experience and practice about how to manage a local ecosystem is retained and stored among a group of people, and modified and transmitted through time. SE memory of communities of practice like allotment gardens seems to be paramount for management of regulating and supporting ecosystem services underlying many prime resources (***Paper III***).

How such place specific qualities in management can be brought into adaptive governance structures for management of ecosystem services of the whole urban landscape is developed in the last study of this thesis. Tentative policy recommendations for how to strengthen the flow of urban ecosystem services in the urban landscape of Stockholm are provided (***Paper IV***) (se figure 1).

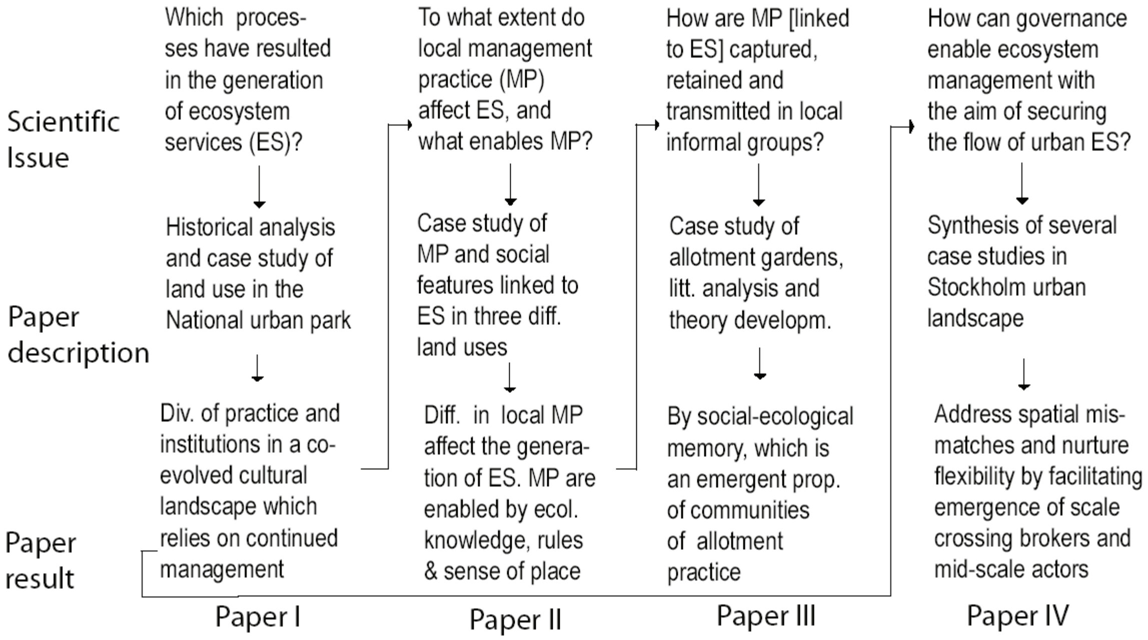

Figure 1. *Scientific issues lead to papers, and paper results suggest new issues explored in subsequent papers.*

The approach of the thesis

The thesis is explorative in nature, and each paper has generated questions and hypotheses for the next (figure 1). We applied a diversity of methods to investigate social-ecological features and management practices of urban ecosystem services. Field studies were conducted in Stockholm, focusing on allotment areas, cemeteries, city parks, as well as on a park legally classified as being of national interest, called the National Urban Park (NUP).

Stockholm is situated at the boundary between the northern hemisphere boreal zone and the mid-European nemoral zone, and at the outlet of the freshwater lake Mälaren into the brackish Baltic Sea (59º20’N, 18º05’E). The physical landscape is shaped by the last glacial period 10.000 years ago and consists of fissured bedrock and clay covered valleys. The City was founded during the mid 1200s and the surrounding landscape has a long history of human-nature interactions. Stockholm city hosts a current population of 1.2 million people, which is growing with ca. 20.000 inhabitants per year, and the region holds 2500 inhabitants/km^2 (***Paper I***).

The first study is on the National Urban Park ***(Paper I)***. This park is located next to the inner city of Stockholm and covers 2,643 ha, of which 813 ha is open water. Few areas of equivalent size in Sweden show such a high biodiversity and the large populations of oak (*Quercusrobur* and *Q. petrea*) in the park make it unique from an international perspective. We asked ourselves how such rich levels of biodiversity and the generation of relatively high abundance and quality of ecosystem services (see Table 2 of Paper I) was possible in a green area that is located close to the centre of a large capital.

In this park we conducted field observations, along with studies of historical and modern maps of the area as well as analyses of relevant written accords. In addition we did a telephone survey with stakeholders in the park, asking questions about their activities and where in the landscape they are active. Finally, three deep interviews were conducted with people that were central during the establishment of the park in 1995. This exploration generated a hypothesis for Paper II, which was whether some of the identified stakeholders or local stewards actually supported biodiversity and the ecosystem services that were generated.

In ***Paper II*** we test whether local management of urban areas actually supports ecosystem services. Here we focused on three types of land uses that can be found in the National Urban Park; allotment gardens, cemeteries and city parks and their management relations to pollination, seed dispersal and pest regulation. During field studies we combined ecological inventories of bumble bees and small birds in these three classes of land use, with interviews and questionnaires with the managers of these areas. The research led to another question; how are practices that generate and sustain ecosystem services stored and transmitted through time and between people? This became the overarching question for ***Paper III*** (see figure 1).

Paper III focuses solely on allotment gardens. Allotment areas are reserved for horticulture, containing tiny pieces of garden plots with individual or family management rights to land, which is usually owned by a local municipality. They are mostly located in urban or semi-urban areas, and appear as patches of intensively-managed flower rich areas, some considerably old, up to 100 years. Currently allotment gardens occupy 210 ha of land and involve about 24,000 people in the urban landscape of Stockholm.

Here we explore the concept of social-ecological memory for carrying ecologically benign management practices through time and between people. It builds on the data collected for Paper II and also employs deep interviews and questionnaires, in combination with literature studies on social memory (e.g. Halbwachs 1926 [1950]; Olick and Robbins 1998; Wenger 1998; McIntosh et al. 2000; Misztal 2003). Besides results and conclusions about social-ecological memory in relation to local management of ecosystem services, it also critically reflects on whether the concept is of value for governance of ecosystem services on larger spatial scales.

All three papers in combination lead to the fourth and last paper ***(IV)*** of this thesis, which again is explorative in nature. ***Paper I*** and ***II*** both recognizes gaps in the social network of governance for enabling ecosystem based management in Stockholm, and ***Paper III*** shows the importance of including local management for capturing processes of ecosystem service generation (see figure 1). ***Paper IV*** explores a multilevel and adaptive governance system with the capability of addressing three separated spatial scales of ecosystem processes, crucial for maintaining the flow of urban ecosystem services in Stockholm.

This last paper is a synthesis of seven case studies of ecosystem service management conducted in Stockholm and the frame of the synthesis is a combination of theory about ecosystem ecology and management (Holling 1978; Gundersson and Holling 2002; Bengtson et al. 2003) and structural network theory (Wasserman and Faust 1993; Burt 2002), which in combination are used to synthesize the findings of the case studies, and to suggest improvements.

The overall lens that is used for interpreting reality draws on *complex adaptive systems theory* (Byrne 1998; Levin 1998, 2003; Cilliers 1998; Crumley 2003; Lansing 2003; Norberg and Cumming 2008), and *resilience thinking* (Holling 1973, Walker and Salt 2006). The concept of resilience describes how a complex adaptive system can assimilate disturbance and continue to develop without crossing critical thresholds that would tip it into another domain of attraction, with different controls on structure and function (Carpenter et al. 2001; Folke 2006). Social-ecological systems (SES) (Berkes and Folke 1998) are prototypes of complex adaptive systems since ecosystem and societal processes are interlinked in evolving, non-linear relations (Gundersson and Holling 2002; Lansing 2003).

This lens of the thesis is used for applying an interdisciplinary approach, drawing on insights developed in *systems ecology and ecosystem management* (e.g. Holling 1978; Odum 1989a,b; Bengtsson et al. 2003; Folke et al. 2003), *anthropology* (Crumley 1994, 2000; McIntosh et al. 2000; Nazarea 2006) and other *social sciences* (e.g. Ostrom 1990; Hollis 1994; Hanna et al. 1996; Harvey 1996; Wenger 1998; Misztal 2003; North 2005).

Management of urban ecosystem services

With the goal of illuminating how social-ecological features affect management of urban ecosystem services this section will discuss findings of the individual papers in relation to different theories. I will end by synthesizing the major findings generated in this thesis with the hope to contribute to increased understanding of how to incorporate the complexity of ecosystem service generation into governance of urban systems and their development.

Scope of thesis for the on-going discussion

This thesis attempts to explore social-ecological features in relation to on the ground management of ecosystem services (MA 2005; Daily and Matson 2008). These include the role of actor and actor groups, with a focus on stewards of ecosystems services, their level of participation, collaboration and social networks, and how and where they generate, sustain and develop ecological knowledge and practice. The novel approach here is the combination of a long term perspective, interdisciplinary methods and the exploration of the role of social-ecological memory in relation to urban ecosystem services. Specific aims are 1) to analyze effects of past land use and of local current management practice on the generation of urban ecosystem services, 2) to explore how management practices, which are linked to ecosystem services, are retained and stored among a group people, and modified and transmitted through time, and 3) to suggest an organizational structure of governance that enables management of ecosystem services in the larger urban landscape.

The complex adaptive system and resilience perspectives emphasize that it is crucial to increase understanding of how to relate to ‘tipping points’ and multiple trajectories that may challenge or enhance essential ecosystem services (Folke et al. 2002; Folke, et al. 2004; Norberg and Cumming 2008). How can we design governance systems in relation to complex systems and tipping points? One strategy for dealing with complexity is to strike a balance between, on the one hand centralized power and responsibility, for effective collective action, and on the other, decentralized governance with diverse ways of monitoring and understanding the social-ecological system, with the potential to increase adaptive capacity for the whole (Duit and Galaz 2008; ***Paper IV)***.

Often lacking is the adaptive capacity of governance in relation to ecosystem services (Folke et al. 2003; Folke et al. 2005), which is one reason for putting forward decentralization of responsibility and power, and active involvement of stakeholders in adaptive co-management approaches (e.g. Gadgil et al. 1993; Christenssen et al.1996; Pomeroy and Berkes 1997; Dale et al. 2000; Gadgil et al. 2000; Dietz et al. 2003; Olsson et al. 2004; Selman 2004). Diverse and decentralized social networks of information and power (Crumley 1994, 2000, 2003), which are rich in ‘weak links’ (Granovetter 1973), may be less effective at mobilizing collective action in times of rapid change, but seem to be good at capturing information and prepare prior the change. The reason is that decentralized social networks seem inherently equipped for monitoring and capturing of local change and for cross-scale sharing of information (Berkes et al. 2003; Folke et al. 2005). This is partly due to lower transaction costs, most notably costs incurred for describing and monitoring the ecosystem, designing regulations, coordinating users and enforcing regulations (McCay and Jentoft 1996; Johannes, 1998). Yet, the approach has encountered opposition in conceptualizing the complexity of current governance of social-ecological systems (Berkes 2004; Carlsson and Berkes 2005; Batterbury and Fernando 2006).

There are a number of challenges for humanity and society in relation to decentralization in co-management approaches, including ethical issues of fairness and distribution (Duffy 2006; Eakin and Luers 2006; Fennell et al. 2007; Ernstson 2008; McLaughlin and Dietz; *in press;* Cowling et al. 2008). Critique of research and implementation has been raised in relation to who is gaining or loosing in such systems of governance (Batterbury and Fernando 2006; Blakie 2006; Lebel et al. 2006). In Stockholm, there are obvious trade-offs between ecosystem services generated from the National Urban Park, especially between recreational and supporting services, and contest for land is sometimes intense ***(Paper I and III)***. A co-management project here would need to fully take into account the contested nature of the past (Castro and Nielsen 2001; Misztal 2003).

One argument for decentralization of power and responsibility is that rules, discourses and meaning in relation to ecosystem service management, must be negotiated between local actors on the ground, since these will have to live and deal with local outcomes (Lyotard 1984; Cilliers 1998; Norton and Hannon 1996). From a holistic systems perceptive (Hollis 1994), equally important is to take into account the tendency of powerful actors to superimpose top down practises on less powerful actors (Agrawal and Ostrom 2001; Ostrom et al. 2007**)**. Decentralized governance increases the adaptive capacity for social networks when there is autonomy for actor groups and where localized dynamics are allowed to self organize and evolve (van der Leeuw 2000; Crumley 2003; Bodin et al. 2006), like in communities of practice **(*Paper III)***. However, as stressed in the adaptive and multilevel governance literature, such learning processes often need to be facilitated and supported by institutions at broader levels (e.g. Young et al. 2008), sometimes referred to as framed creativity (Folke et al. 2003).

History and contemporary examples show that if rare events and slowly changing ecosystem processes, underlying the resources, are ignored, unpleasant surprise may follow (McGovern 1994; van der Leeuw 2000; Huitric 2005; Steneck et al. 2008). Consequently, it is not enough to assume that ‘good governance’, will automatically result in sustainable use of resources, while simultaneously ignoring the ecology of SES (Pretty 1995; Acheson et al. 2000; Brown 2003; Pound et al 2003). This thesis takes on the challenge of exploring social features that captures, retains and develops social-ecological processes, underlying desired ecosystem services.

The landscape of the National Urban Park in Stockholm ***(Paper I)*** owes its current flow of ecosystem services to co-evolutionary processes of people and nature, ignited several thousand years ago as land for people was first provided by the land-uplift. When enough fine sediment soil was exposed, people used them for agriculture and continuously transformed the landscape according to secure their needs. Since then major transformations of the relationship between the inhabitants and the environment have occurred driven by rapid social changes. Physical structures in the landscape, such as giant oaks, meadows, and urban gardens can be considered as legacies of these transformations (Foster et al. 2003) representing habitats from where desired ecosystem services flow today.

In an historical account of land uses of the National Urban Park it became clear that the resilience of this landscape to produce ecosystem services is linked to surrounding ecosystems as well as to historical property and management rights, and the involvement of a diverse set of stewardship groups that take active part in practical management of the park. The high species diversity currently found there relates to past activities in land use, and thus, relies on continued management. Hypothetically, sustaining the flow of ecosystem services there will depend on governance that is sensitive of slowly changing variables of land use, of social diversity of actor groups involved in management and of management rights. Hence, sustaining ecosystem services in urban areas is not about conservation without people, but shaped by and dependent on management practice by people.

Paper II shows that the analyzed social features of management; rules-in-use, ecological knowledge and sense-of-place, differ significantly, and that this affects practices, linked to the three functional groups of ecosystem service providers. The results show the ecological affects of these social differences, primarily in terms of higher abundance of pollinators in the informally managed allotment gardens (see figure 2 of paper II), and as differences in the composition of seed dispersers and insectivores. Thus, voluntary management motivated by sense of place, which is normally undervalued by planning authorities, is important for the generation of ecosystem services in the urban landscape. Furthermore, this paper suggests that management has an important secondary function: it may be crucial during periods of instability and change by promoting risk reducing practices that address ecological processes that are important for responding to disturbances, such as enhancing habits for ecosystem service providers of pest regulators. The research generated questions whether, participation of citizens in management of green areas which now are managed solely by employed personnel, such as city parks, could result in similar positive results as allotment gardens, and if practices that supports ecosystem services can be retained and stored among such self organized management groups, and transmitted through time?

Paper III builds on findings of paper II and explores *social-ecological memory* in relation to management practice that sustains ecosystem services, and investigates where and how social practice of local social-ecological systems is retained and transmitted.

Social practice (Bourdieu 1978; Ortner 1984), implies an actor centered perspective as an important complement to a holistic systems perspective (Giddens 1979), and ultimately it is about how we experience the world and our engagement in it as meaningful (Wenger 1998). We found that the allotment gardens function as communities-of-practice (ibid.), where participation and reification interact and social-ecological memory is an emergent structure that persists by being both perturbable and resilient. Community of practice is here used as informal groups of people characterized by dense relations and mutual engagement, as well as shared stories, jargon and ways of doing things together.

Social-ecological memory in the urban gardening is retained and transmitted through participation in mimicking practices, learning processes, oral communication and collective gatherings. Is also resides in structures of chalets and garden plots and other physical forms and artifacts as well as a number of rules-in-use (institutions) of allotment gardening. Finally, a wider social context provides an external support structure, through various forms of media, social networks, collaborative organizations, and legal structures. We conclude that social-ecological memory holds a role in sustaining ecosystem services in times of crisis and change and that it enables resource users and managers to address slow underlying, and therefore often ‘hidden’ ecosystem processes of many resources and ecosystem services, and that it determines success or failure of navigating away from complex tipping points of undesirable trajectories.

Although physical sites that allows for stewards on the ground to engage in local management are important for the reasons above, it is equally important to engage in management of the whole landscape for the production of ecosystem services since its spatial configuration is critical to the supply of many services (Goldman et al. 2007). The final paper of this thesis ***(Paper IV)*** attempts to up-scale the findings of the previous papers for addressing how qualities of local management can be brought into governance, and how to design a social network structure of governance in order to overcome spatial scale-mismatches. This paper is visionary as it gives policy directions of governance that allows for ecosystem based management of the whole urban landscape with the aim of sustaining the flow of ecosystem services, and as such, it is recognizing imagined futures as objectives of human actions. This implies dealing with settings of actors that differ quite substantially in terms of preferences, social, economical and political resources and social practices (Wenger 1998; Galaz 2005). High heterogeneity of actors in management of ecosystem services often increases potentials for distrust and conflict (Castro and Nielsen 2001; Walters 1997). Institutional entrepreneurship like brokering between actors is suggested to serve as a bridge over such troubled waters (Westley and Vredenburg 1991*;* Granovetter 1973; Burt 1992; Hahn et al. 2006).

Brokering according to a structural network perspective, is about structural position in social networks, or more precisely about actors occupying positions that enable them to create relationships between disconnected clusters of actors. However, brokerage is not just about structural position; it is also about social practice (Wenger 1998; Westley 2002; Hahn et al. 2006). It requires enough legitimacy to influence the evolution of practice of different actors, to address conflicting interests and to build trust (Wenger 1998; Olsson et al. 2004; Hahn et al. 2006).

In ***Paper IV*** we use structural network theory (Granovetter 1973, Wasserman and Faust 1994, Burt 2002) and ecological scales for a discussion of how the practice of scale crossing brokers can increase the flexibility of an spatially explicit adaptive governance, required for overcoming misfits and for an ecosystem based management in this urban landscape ***(Paper IV)***. It provides tentative policy directions including facilitating for the emergence of actors that engage in sale crossing brokering, as well as for appointing actor groups that focus on ecosystem management of the spatial mid-scale. (***Paper IV***).

Large scale processes affecting urban ecosystem services

Why is management of ecosystem services, in urban landscapes, a complex issue? Cities are both endpoints of human domestication of landscapes (Karieva et al. 2007) and simultaneously complex adaptive systems (Byrne 1998). A general difference in the relations between society and ecosystems in rural vs. urban landscapes is that in urban landscapes the faster social dynamics increasingly sets the pace for and dominates ecosystem dynamics (van der Leuuw 2000). This restlessness is partly due to flows enabled by the positions urban landscapes hold in a global network of cities (Castells 1996; Fyfe and Kenny 2005). Urban landscapes are experiencing rapid and continued transformations (***Paper I;*** Cox 2005), putting pressure on remaining urban ecosystems (Collins et al. 2000. Grimm et al. 2000; Kinzig and Grove 2001; Alberti et al. 2003; May 2004, Pickett et al. 2008; Wallace and Wallace 2008) and on physical sites that allow for participation in the actual management of ecosystem services (Colding 2009).

Such continued changes may weaken and erode ideas and values about peoples' dependence on ecosystems also outside cities. This is alarming since it may challenge broad-based public support for combating the decline of ecosystem services (MA 2005) both inside and outside urban landscapes. The estimated reason for this erosion is the decreasing possibilities for city-people of personally engaging with ecosystems (Pyle 1978; 1993; Theodori et al. 1998, McDaniel and Alley 2005). Without first hand personal interaction the motives of learning and care seem to dissolve and ultimately disappear (***Paper II***).

Viewed in this context, this thesis argues that urban governance for management of ecosystem services holds pedagogic responsibility for creating opportunities for citizens to actively engage with ecosystems. This is important not only for building broad based support for stewardship and sustainability, but also for developing important local social-ecological processes of management of ecosystem services on the ground ***(Paper III)***.

Consequences and responses in Stockholm

The ecological consequence in Stockholm is a gradual loss of ecosystems for constructions and development that tends to lead to isolated and small-sized green areas. This means that habitat suitability of a patch, for ecosystem service providers such as bees and small birds, is to a large extent dependent on its surroundings ***(Paper IV)***. Some species become dependent on small scale networks of one type of green areas while others need access to several different types (Colding 2007; Lundberg et al. 2008).

The small sizes of ecosystems also increase the probability that many organisms will exhibit meta-population dynamics with local extinction and re-colonization as shown by other studies in Stockholm (Mörtberg 2001) and elsewhere (Reale and Blair 2005). Hence, managing local ecosystems in isolation will fail ***(Paper I)*** the surrounding city-green-network has got to be taken into account as well ***(Paper IV)***. At the regional scale a system of larger green areas, or "green wedges", as well as areas of national interest are recognized by authorities as providing landscape connectivity thus potentially replenishing sink populations of local green areas (cf. Sandström et al. 2006; cf. Crooks et al. 2004).

Such fragmentation is common in urban landscapes and has been argued to produce a higher tendency of scale mismatch, i.e. when there is a temporal or spatial mismatch between the scales of ecological processes and the processes of governance that frames ecosystem management (Folke et al. 1998; Cumming et al. 2006). Green governance of Stockholm includes land use planning, policy development and practical management on the ground. Despite good intentions there are scale mis-matches, partly because no actor group is purposely addressing the spatial scale between local ecosystems or habitats and regional green wedges, known as the mid-scale, of the urban landscape, which have been stressed as important in urban landscapes (cf. Byrne 1998; Borgström et al. 2006; Cumming et al. 2006). ***Paper IV,*** calls this scale the city-green-network.

At local levels a considerable amount of small ecosystems and their stewards, such as allotment gardens and cemeteries, are classified as "developed land" and not recognized for their ecological roles (Colding et al. 2006). The fair amount of informal and motivated stewardship groups that take direct part in habitat management and conservation, tend therefore to be undervalued by planning and management authorities. However, there is limited knowledge within each local actor group of spatial scales larger than the area that they manage ***(Paper II).*** Management authorities in Stockholm have a landscape perspective, but there is lack of ecological knowledge integration between the landscape managers and the local stewards, which re-produce the tendency of scale mismatch ***(Paper IV)***.

The role of social-ecological memory in communities of practice on the ground

The results of the first three papers show that some local groups that take part in active management on the ground, such as nature enthusiasts, allotment gardeners and cemetery managers, plays a role in the production of urban ecosystem services. Firstly, it shows that their different management practices generate different habitats and biotopes. Secondly**,** it also shows that some local groups support the generation of ecosystem services by enhancing in situ habitat quality for some ecosystem service providers. For instance, management practices in allotment areas positively affect the diversity and abundance of wild bees, which spills over into the urban landscape, and the increased heterogeneity that the gardens have on the urban landscape, also increases the overall diversity of insectivores birds ***(Paper I, II and III)***. Consequently, local informal management plays an important role in management of ecosystems services, but what is it really that motivates informal and often voluntary managers in urban landscapes?

One important factor is the temporal length of engagement. It is the long-term engagements in physical sites that allow for participation of citizens in the actual management of ecosystem services that create motives for voluntary management (***Paper III***). Rights to engage in the long term are incentives for managers to invest in rules-in-use, as well as in physical objects. Such 'objects' tend to outlive the repertoire of practices that first created them and they load the place with shared histories of ongoing processes of learning and negotiation about meaning. This results with time in an emotional attraction, referred to here as sense of place. Continued labor and participation deepens the sense of place further (Norton and Hannon 1996).

Sense of place is estimated as crucial for keeping urban actors in civil society motivated to engage in practical management of urban ecosystem services, as people are not economically reliant on them ***(Paper II)***. The feedbacks between an urban ecosystem and its stewards are indirect or weaker than in most rural SES. Usually, it is not feedbacks related to livelihood, such as food, fiber and material products (Berkes et al. 2003) that motivate urban local stewards of ecosystems, but it is rather social features, such as the recreation, sense of place or employment, as for park- and cemetery managers.

Long term engagement in urban landscapes requires enabling legislation (Olsson et al. 2004), more precisely robust property rights (Ostrom 1990), since contest for land is intense here (***Paper I and III)***. Allotment areas in Stockholm, for example, hold leaseholds on long-term basis. Renewable leaseholds up to 25 years between a local allotment association and the local municipality are common. Not surprising then is that these associations contain well managed cottages, gardens and long lived organisms, such as fruit trees, as well as they hold most of the characteristics described for communities of practice, including a high degree of freedom in decision making (***Paper III***).

Long term engagement is important not only for motivating local managers to continue their management, but also for developing place specific SE-memory (***Paper III;*** Gunn 1994; cf. Wenger 1998; Muchagata and Brown 2000; Ballard and Huntsinger 2006)***.*** Social-ecological systems not only evolve through time, but their past is often reflected in their present functions (cf. Levin 1998, 2003; cf. Foster et al. 2003). Hence, in order to respond successfully to changes, any ecosystem manager must be able to capture information and experiences and continuously learn about the social-ecological system, and store it for future use (Gunn 1994; Cilliers 1998; Folke et al. 2003).

SE-memory related to allotment gardening is an emergent structure of their community of practice ***(Paper III).*** This emergent structure is created in a dual process of participation and reification. Participation is a source of social-ecological remembering and also of building identities and thus deals with our need to recognize ourselves in our past. Participation ignite reification processes that generate 'things' that functions as shortcuts to communication, and which tend to persist, such as metaphors, artifacts and physical objects, and also of which some will change according to their own laws, such as shared jargon. The 'things' that are generated in reification processes are linked to ecological dynamics which they tend to reflect.

However, SE-memory is constantly modified not only because we forget and remember partially, but also because the world is in constant motion and since our forms of participation change. The consequence is that any practice must constantly be reinvented even though it remains ‘the same practice’ ***(Paper III)***.

The emergent structure of SE-memory enables resource users and managers to be exposed to slow changing processes and rare events, such as changes in pollination capacity and pest out-breaks, via positive feedback cycles of practice and monitoring, where monitoring is facilitated by SE-memory ***(Paper III).*** It has been suggested that slow variables are defining the underlying structure of social-ecological systems, whereas fast variables reveal the dynamics of this underlying structure (Carpenter et al. 2001; Carpenter and Turner 2001). A narrow focus on faster dynamics only, will always undermine a system, since ignorance of slow variables that play out on the longer-term automatically leads to accumulation of potential risks (Holling and Meffe 1996; van der Leeuw 2000). This is a reason why captured and stored information of slowly changing processes is of importance for ecosystem management.

Drawing on the notion that acquisition of novel practice typically follows resource crises (Folke et al. 2003; Berkes and Turner 2006) and in combination with the theory of SE-memory developed in this thesis, it is reasonable to think that information about environmental events is retained in reification processes. In allotment gardens, such information is reflected in risk reducing practices, for instance by habitat improvement for service providers ***(Paper II),*** which subconsciously prepares gardeners for up-coming disturbances **(*Paper III*).** Such features of SE-memory often lies beyond the cognitive and rational, as it is carried in habits (Misztal 2003), and it functions as mental maps for decision making in a complex world, and can be reflected in practices that build local social-ecological resilience ***(Paper III)***.

Concluding remarks

The Millennium Ecosystem assessment concluded that the capacity of ecosystems to generate important services has deteriorated as a consequence of human action. But that humanity, through improved governance systems, has the potential to advance our management of ecosystems and secure their resilience for the future (MA 2005).

In democratic societies improved governance for management of ecosystem services requires motivated citizens, of which over 50% now live in urban landscapes. The thesis exemplifies that personal experiences with green area management in urban landscapes facilitate citizens to develop meaningful and emotional motivation for engaging in ecosystem management ***(Paper II)***. It also highlights that there are actors and actor groups that already function as local stewards of urban ecosystem services, a role seldom recognized in urban planning or governance (***Paper I***). The thesis makes the point that urban ecosystem services are a product of co-evolution of people and nature, and analyzes the role of local stewards and communities of practice in management of ecosystem services. Results illuminate how urban ecosystem services are generated in complex and actor driven social-ecological processes.

It does so by applying a long term perspective of such processes, starting by a historical description of interdependent social-ecological processes and by exploring how current actor groups are linked to the generation of ecosystem services ***(Paper I)***. It continues through interdisciplinary analyzes of contemporary land uses in cemeteries, allotment gardens, and city parks and their local management and governance ***(Paper II)***, and stretches into the human sphere, by illuminating how social-ecological memory enables practices of local management that links to ecosystem services, such as pollination, seed dispersal and pest regulation, and that such practices simultaneously create experiences of meaning ***(Paper III)***.

The thesis illustrates the benefits of creating incentives for ecologically engaged people that are aware of the significance of ecosystem services for societal development to participate in their management. This calls for governance to appreciate and actively include citizens in on the ground management of urban ecosystem services, whether it is about sustaining urban green areas or developing new ones. Creating opportunities for urban people to actively engage with ecosystems should be prioritized in urban governance, for example through creating platforms or arenas of collaboration, such as co-management arrangements and connecting uncoordinated actor groups and social networks. Decentralization for self organization seems to build diversity and resilience for responding to change. Adaptive governance schemes that support such processes in multilevel governance systems could be developed and implemented for urban ecosystem management (***Paper IV***). It would provide opportunity for centralized cross-level coordination and collaboration, of particular significance when periods of major crises or challenges arise (e.g. Olsson et al. 2008). This thesis also illustrates that robust long term property and management rights are crucial in this respect ***(Paper I and III)***.

Consequently, local communities of ecosystem practice in civil society, which contribute to the production of ecosystem services, should explicitly be taken into account in urban green governance of the urban landscape of Stockholm. Their participation could be realized by training and appointing scale crossing brokers that enable information flows between management on the ground and state agencies, without superimposing top-down practices by suggesting ‘blueprint’ management and planning (Holling and Meffe 1996; Ostrom et al. 2007). This is one possible way to overcome present scale-mismatches, and a possibly intelligent network structure of urban green governance ***(Paper IV)***.

Identity, sense of place and social-ecological memory motivate local communities of practice, and link their practices to place specific processes. Such kind of qualities of local communities of practice complement the general ecological knowledge held by scientists and management authorities, and need to be considered when negotiating governance of ecosystems of the world for securing its benefits for the generations of people that will follow us (Gunderson et al. 1995; Becker and Ghirnire 2003; Chalmers and Fabricius 2007).

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Ecological scales and social network structure:
management and governance of urban ecosystem services in Stockholm, Sweden[1]

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Abstract

Continued management and protection of ecosystems in urban landscapes are crucial for the generation of ecosystem services. One central challenge to sustain the generation of urban ecosystem services is to address scale mismatches between ecological processes on the one hand, and the social processes of governance on the other. In this article we synthesize a set of case studies from Stockholm, Sweden, and discuss how actor groups engaged in ecosystem management can be linked to each other through social networks so as to match spatial scales of ecosystem processes. This paper highlights the importance of management practices of informal actor groups that take part in ecosystem management on the ground. It also identifies gaps in current green area governance, and therefore suggests an alternative network structure organized around three ecological scales; local green areas, city-green networks and the regional green infrastructure. We discuss governance of resilience with the aim of securing the flow of ecosystem services in this urban landscape. A diversity of actor groups including civil society groups and state agencies are each recognized as having roles and responsibilities on different spatial scales. For this to be realized there are needs to facilitate the emergence of actor groups that address the ignored city-green network and of scale-crossing brokers engaged in practices with the main objective to connect actors that currently ignore each other.

Keywords Ecosystem management · adaptive governance · scale mismatch · resilience · social network structure · ecosystem services · urban ecology

1. Introduction

Urban landscapes represent an end point of a gradient of social-ecological systems in which human activities effect ecosystem processes (Collins et al. 2000; Grimm et al. 2000; Pickett et al. 2008). At the same time, urban green areas are recognized for their role in generating ecosystem services critical for human well-being and sustainable development (Daily 1997; Bolund and Hunhammar 1999; McGranahan et al. 2005; MA 2005). Services range from providing shade and space for recreation, filtering of aerosols and absorbing CO_2 emissions, to pollination, pest regulation and seed dispersal processes that support biodiversity and the ability to maintain ecological function (Alberti 2005; Andersson et al. 2007). Furthermore, in a rapidly urbanizing world (UN 2007), access to green areas could prove crucial in enhancing broad-based public support for environmental governance of degrading ecosystem services (Pyle 1993; Miller 2005; MA 2005). This paper addresses the urgent research area put forward by the millennium ecosystem assessment, which is governance of ecosystem services in urban landscapes (MA 2005).

Urban governance of social-ecological systems faces several challenges. Urban landscapes are characterized by heterogeneity and contested land use, by rapid social change, limited capacity for ecological renewal, and by the many administrative units (Collins et al. 2000; Pickett et al. 2001; Borgström et al. 2006; Heynen et al. 2006; Grimm et al. 2008). These characteristics have been argued to produce a tendency for scale mismatch (Borgström et al. 2006), i.e. a temporal or spatial mismatch between the scale of ecological processes and the scale of social organization of governance (Folke et al. 1998; Cumming et al. 2006; Olsson et al. 2007; Galaz et al 2008).

This paper is about how to develop a social organization of governance that supports ecosystem management. Although studies in urban ecology have analyzed cities as social-ecological systems, they have mainly been focusing on how the heterogeneity of land use patterns affect ecosystem function (Alberti 2005; Cadenasso et al. 2006; Grimm et al. 2008; Pickett et al. 2008). Many studies regard humans as part of larger passive groups (of class or ethnicity), or as anonymous drivers of pollution or of urban development (Alberti 2005; Pickett et al. 2008). Few studies focus on the governance of ecosystem services of larger urban landscapes and regions. In this article we synthesize a set of case studies from the urban landscape of Stockholm, Sweden, with the aim to explore a social network structure for governance that can secure the flow of ecosystem services. The concept of 'network' governance takes into account all actor groups and non-linear relations that may influence outcomes in an uncertain world, including government authorities as well as citizens and groups in civil-society (Sörensen and Torfing 2006; Duit and Galaz 2008; Galaz et al. 2008). Such network governance is part of adaptive governance (Dietz et al. 2003; Folke et al. 2005), and focus here is on how the network structure allows for ecosystem management on the ground, and for dealing with scale mismatches (Olsson et al. 2007). It includes actor groups on multiple levels in society and active on various spatial scales in the landscape, their patterns of interaction, as well as rules-in-use and social practices in policy, planning and ecosystem management.

Adaptive Co-management and Adaptive governance are two analytical frameworks that has been developed to analyze ecosystem management in multi-level governance contexts (Gunderson and Holling 2002; Berkes et al. 2003; Olsson et al. 2004; Folke et al. 2005). These frameworks, which hitherto have been less applied in urban landscapes, argue for a general shift of paradigms towards a focus on social-ecological resilience. Resilience is defined as the ability to assimilate disturbance without crossing thresholds into a different domain of attraction, with different controls on structure and function (Holling 1978; Folke 2006). Instead of single-species and the control of a few selected variables (Holling and Meffe 1996), governance should take holistic approaches that acknowledge the inherent uncertainty of social-ecological systems (Berkes et al. 2003; Folke et al. 2005). Ecosystem management should focus on ecological processes (e.g. nutrient flows and pollination) and on functional groups of species that play complementary roles in facilitating these processes (Nyström and Folke 2001), as well as on processes that transcends scales in space and time (Folke et al. 1998; Cumming et al. 2006). Inspired by this literature two criteria for governance of resilience are used in this paper; 1) *sustaining ecosystem functioning*, i.e. increasing the ability for urban ecosystems to regenerate through ecological processes and structures at multiple scales, 2) *creating and maintaining flexibility*, i.e. the ability to switch between of i) preparing for change, and to ii) responding to change.

Adaptive governance depend on several social processes, for instance trust, conflict resolution, knowledge integration, and vision building (e.g. Folke et al. 2005; Olsson et al. 2007). However, all of these partly depend on creating and sustaining social relations in networks of information sharing (Bodin et al. 2006a; Manring 2007). In this article we therefore focus on social networks, and especially on the structure of social networks, i.e. the patterns of mutual relations (Wasserman and Faust 1994). Although a network in itself does not 'do' or 'learn' anything – only individuals are capable of this (Guenther and Newig *manuscript*) – we can by uncovering the 'architecture' of information flows bring greater clarity into the structural factors that facilitate or constrain governance with the aim to sustain the flow of ecosystem services (Schneider et al. 2003; Bodin and Norberg 2005; Crona and Bodin 2006; Prell et al. forthcoming; Ernstson et al. 2008). This paper combines analyses of the social network structure of governance with an analysis of ecological scales (Cumming et al. 2006; Olsson et al. 2007), and the goal is to explore a spatially explicit model of governance that can overcome scale mismatches, and contribute to solutions of how to battle further erosion of ecosystem services.

The paper is organized as follows; we start by a short description of the case studies that has been synthesized here, followed by an account of the methodology. In the results we show that urban green areas that allow citizens to take active part in the actual management of ecosystem services play important roles in the generation of ecosystem services. However, such arenas are currently undervalued in Stockholm. There are mis-matches here that are caused by many unfortunate features such as that the mid-scale of ecological processes is unattended, and that cross-scale practice in sharing of information between various actor groups is lacking.

The discussion revolves around how to improve a social network structure of governance by facilitating the emergence of *scale-crossing brokers*, which link disconnected actor groups that take part in ecosystem management at different spatial and societal scales, and how their scale crossing practice can enhance flexibility.

Short Description of Case Studies

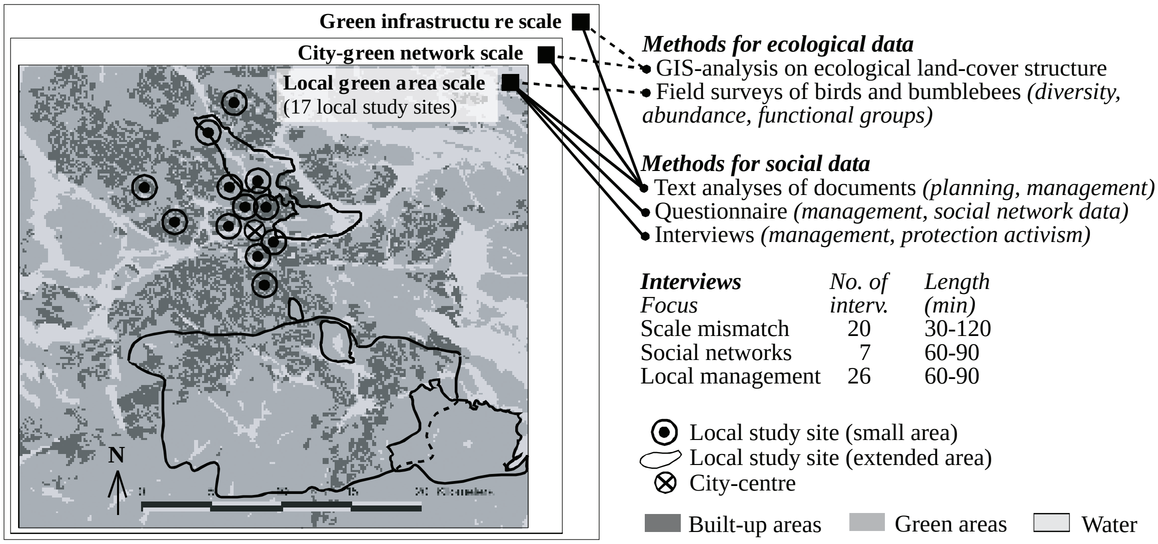
Our synthesis is based on seven case studies from the urban landscape of Stockholm, Sweden (Figure 1) published in separate papers (Table 1). The individual studies focused on different aspects of and management of green areas in Stockholm and generated both social and ecological data in order to capture the dynamics of social-ecological processes. Ecological data focused on functional groups (especially pollinators, seed dispersers, and insectivores) and were generated through field surveys of birds and bumblebees, complemented with ecological landscape analysis based on land cover structure from satellite images and network models. Social data were generated through engaging with different actors at different scales using different methodological tools such as text analyses, questionnaires and interviews (Figure 1). Actors included regional and municipal agencies, cemetery and park managers employed by the public or private sector, and civil society groups such as allotment garden associations, outdoor life associations, boating clubs and cultural-history and nature conservation groups. We refer to individual papers for detailed information. In the results section we refer to the case studies with their Roman numerals (I-VII) as given in Table 1.

Table 1. The table shows the empirical case studies synthesized in this paper. The numbers are used in the main text to clarify results from the case studies. Number VI and VII were primarily carried out by collegues from the same research group.

No.	*Publication*	*Short description of study*
I.	Barthel et al. 2005 Barthel 2006 Barthel et al. *submitted*.	Historical land use analysis of stake-holders, property rights, and management of large urban park (the National Urban Park; NUP), and studies of social-ecological memory in local communities of allotment gardening.
II.	Borgström et al. 2006	Comparative study of ecosystem management in five local green areas: large green area (NUP), large cemetery, nature reserve, urban forest, and a watershed.
III.	Andersson et al. 2007	Comparative study of management practices between different actor groups: cemetery managers, urban park managers, and allotment gardeners.
IV.	Ernstson and Sörlin 2009 Ernstson et al. 2008	Social network analysis of local urban movement protecting a large urban green area (NUP) followed by value creation analysis.
V.	Andersson and Bodin in press	Ecological network analysis of bird species movements.
VI.	Lundberg et al. 2008	Mobile link analysis of the Euroasian Jay and oak forest generation for a large urban green area (NUP).
VII.	Colding et al. 2006	Spatial assessment of different types of urban green areas with focus on allotment gardens, domestic gardens, and golf courses vs. protected areas

2. Methodology: A Framework for Social-Ecological Synthesis

This paper synthesizes a set of results from different case studies conducted in the same landscape (figure 1). Our methodology for synthesizing individual case studies is based on a theoretical framework of social-ecological systems, with focus on spatial scales, and how to govern them (Berkes and Folke 1998; Gundersson and Holling 2002; Folke et al. 2005), in combination with network models conducive for adaptive governance (Newman and Dale 2005; Bodin et al. 2006a; Guenther and Newig manuscript).



Interviews Focus	*No. of interv.*	*Length (min)*
Scale mismatch	20	30-120
Social networks	7	60-90
Local management	26	60-90

Figure 1. The map shows Stockholm Metropolitan Area marked with 17 local study sites and the methods used for data generation. Stockholm is situated at the boundary between the northern hemisphere boreal zone and the mid-European nemoral zone, and at the outlet of the freshwater lake Mälaren into the brackish Baltic Sea (59º20'N, 18º05'E). The physical landscape is shaped by the last glacial period 10.000 years ago and consists of fissured bedrock and clay covered valleys. The small scale rough terrain and the climatic conditions convey a relatively high biodiversity (CAB 2007). Stockholm hosts a current population of 1.2 million people, and it is the most rapidly growing and most densely populated region in Sweden with 2500 inhabitants/km^2 (SCB 2002). The case studies used different methods to generate data on different ecological scales.

Through this framework, which we elaborate below, we could identify scale mismatches, assess the criteria of ecosystem functioning and flexibility, and come with suggestions of necessary changes. Although the framework is new, it is in line with other approaches to analyze governance of social-ecological systems (e.g. Hanna et al. 1996; Berkes and Folke 1998; Olsson and Folke 2001; Cundill et al. 2005; Hahn et al. 2006; Young et al. 2006). It does not however cover other issues of adaptive governance such as the roles of institutional redundancy, polycentrism and conflict resolution mechanisms (Berkes Low et al. 2003; Dietz et al. 2003; Ostrom et al. 2005; Olsson et al. 2007; Ostrom et al. 2007; Galaz et al. 2008).

Ecological scales are context sensitive and difficult to readily define in practice. Our aim was to identify, guided by theory and empirical measurements, those ecological scales most suitable for purposeful monitoring as outlined by Cumming et al. (2006), and witch are relevant for ecosystem services that support the ability for urban ecosystems to regenerate, including pollination and seed dispersal. In theory ecological scales are viewed as hierarchically and dynamically linked (Gunderson and Holling 2002); interactions between parts in ecosystems are nonlinear and local, and constrained by larger scales, but local interactions may have emergent effects that could influence other scales and the system as a whole (Ibid.; Pickett et al. 2008). Different interactions will be important on different scales, e.g. interactions such as competition are local while resource use and population dynamics occur on landscape or regional scales. One key to finding the relevant scales for management is to understand how different organisms perceive and interact with the landscape (Hostetler and Holling 2001; Farina and Belgrano 2006; Lundberg et al. 2008). With this in mind, lower scales are assessed through analyzing patch quality and inter and intra species interactions, while greater scales are dependent on aspects of configuration, such as landscape supplementation and complementation, and neighbouring effects (e.g. Dunning 1992). At even larger spatial and temporal scales, dispersal corridors and sink-source dynamics become of importance (ibid.). Another issue is the scales and dynamics of disturbances, and in cities these are often caused or controlled by humans and should therefore be addressed from a social-ecological perspective (Pickett et al. 2008).

Just as ecological patches are part of greater scale patterns (Alberti 2005), social actors are part of emergent social network structures (Wasserman and Faust 1994). Bodin, Crona, and Ernstson (2006a) have outlined a network model conducive for adaptive governance. Others have pointed to similar models (Newman and Dale 2005; Guenther and Newig manuscript); what we do is to complement this model with information on ecological scales, so as to engage in a holistic analysis of a linked social-ecological system. Our framework consists of separate actor groups that interact with each other and the ecosystem at different spatial scales. They have strong internal ties, and weaker bridging ties to other actor groups (i.e. they meet less frequently or less intensely with them). Strong ties in communities of practice (Wenger 1998) support long-term capturing of place specific information (Barthel et al., *submitted*), while weak ties are important in spreading information over greater distances in the network (Granovetter 1973). Weak ties therefore play a crucial role in preparing for innovation and adaptation to new situations (ibid.), by breaking up closed group thinking and practice (Oh et al. 2004; Scheffer and Westley 2007).

In social networks there are sometimes brokerage positions between actor groups that are not directly linked (Burt 1992; Bebbington 1997; Olsson et al. 2007). In our framework it is important that these positions are filled by *scale-crossing brokers* that link disconnected actor groups that take part in management at different spatial scales. The main objective of the brokers is to facilitate sharing of captured and retained scale specific information.

The reason for why this network structure can facilitate adaptive governance is that it strikes a balance between centralization (for effective collective action) and decentralized modularity (for a distributed diversity of autonomous and localized knowledge generation), which will be further discussed in section 4.

3. Results from the Synthesis

The main finding from the synthesis is that there are several features of governance that can be improved. Currently, governance of urban green areas is split up with limited sharing of information between separate sectors and state agencies, and goals focus often on to uphold certain user values rather than sustaining ecosystem services that support ecological regeneration. Communication between state agencies and actor groups of civil society can be enhanced. Local actor groups that take part in management practice on the ground, which support the generation of ecosystem services, are not sufficiently acknowledged or engaged with by state agencies, which results in missed possibilities to learn about cross-scale ecological processes. Moreover, and central for the discussion below, the important mid-scale of urban ecosystem processes, referred to here as city-green networks, is not addressed by any actor group engaged in governance (see table 2).

History and current governance

Most of Stockholm’s ecosystems are remnants from cultural usage and shaped by humans over the millennia, and ecosystem services generated today can be considered as emergent from a long-term social-ecological interaction or co-evolution (I). It is thus important to recognize that different actors with different objectives have created different ecological conditions, which in turn has increased the diversity of green areas and affected species composition, ecological functions and consequently the production of ecosystem services (I; II; III; VI; VII). Thus, continued management is needed to uphold the flow of urban ecosystem services (I).

Municipalities (state agencies) hold a key role in planning and management of urban green areas. Several efforts to engage in collaboration in ecosystem management has been launched by the Stockholm municipality (Stockholm Stad 2003), for instance educational projects with park and street managers and private entrepreneurs, as well as restoration projects in collaboration with groups in civil society, including ornithological associations and nature protection organizations. Further co-management examples are wetlands, urban forests, local neighborhoods and gardens managed by way of user-group contracts (*swe.‘brukaravtal’*)(I). However, our case studies indicate that these efforts seem to lack an overall strategy of how emergent social networks could be used for dealing with scale mis-matches and management of ecosystem services across the landscape. For instance user-group contracts are about management rights on short term basis granted by state agencies to local actors which comes with a set of regulations. It rarely involves meeting in arenas of dialogues and negotiation and of sharing experiences. Below we elaborate further features of mismatches in current green governance.

Features of scale-mismatches in Stockholm

There are many possible features for misfits and scale mismatches in Stockholm. One feature is due to the fact that municipalities hold monopoly of spatial planning, which tends to erect barriers that hinder cross-border cooperation between municipalities. Management of urban green space in Stockholm is formally organized by the municipalities according to user purposes. This has influenced the way many managers employed by municipalities, such as park and cemetery managers, perceive their local green area. Instead of seeing them as part of an ecologically linked landscape they are seen as belonging to a group of areas assigned to the same user classification (II; cf. Sandström et al. 2006). Cemetery managers for example, tend to form stronger social ties with other cemetery managers, and interact less with actors from adjacent green areas. The same is true for allotment gardens, which are linked with national and regional allotment unions (I). This indicates low ability to synchronize management to provide complementary habitats of ecosystem service providers, as argued by Colding (2007). Our studies of a selected set of urban parks and nature reserves indicate that there is an awareness of the importance of management at multiple spatial scales, but the tendency is to ignore interactions across scales (II), which we interpret as a limited understanding of cross-scale ecosystem dynamics.

One central finding is that a large proportion of urban green areas are ecologically undervalued due to the narrow definition used by authorities (VII; Lundgren and Alm 2001). Local green areas such as allotment gardens, golf courses and private home gardens are sometimes classified as “developed land” and not recognized for their ecological roles (VII), which goes in accordance with findings in Baltimore (Pickett and Cadenasso 2008). And hence, there is limited dialogue about ecosystem management between managers of ‘developed land’ and mangers and planners employed by state agencies. This result in serious scale-mismatches of current management since local green areas facilitating cross-scale movement of species are ignored (III).

Other features for scale mis-matches are the goal as well as the methods used by management authorities, as they focuses mainly to facilitate large scale ecological flows within the whole green infrastructure, and to preserve selected local green areas where red listed species or high biological diversity have been recorded (VII). Moreover, the general lack of monitoring and evaluation of the management that is performed impedes trial-and error learning (II; Gunderson et al. 1995, Busch et al. 1995).

There are scale mis-matches that relate to capturing of experience of local change. Some local actor groups hold an important role in supporting the generation of ecosystem services but are nevertheless ignored by state agencies (I; III). For instance, allotment gardeners, bird watching associations, cemetery managers (I; III) and even urban golf course managers (VII), have the capacity to capture fine-tuned and continuous ecosystem feedback necessary for engaging in adaptive management, since they continuously monitor ecosystem processes (Holling 1978).

When comparing employed personnel of cemeteries and urban parks with voluntary allotment gardeners, the latter group exhibited greater local ecological knowledge together with the widest range of management practices that offered protection of species and improved habitat to sustain pollination and seed dispersal processes (III). In allotment gardens there are means by which knowledge, experience and practice about how to manage a local ecosystem is retained, stored, modified and transmitted through time. This is an emergent structure of communities of practice (Wenger 1998), and it is defined here as social-ecological memory (I). A pre-requisite for such qualities to emerge is however, long term property rights, as the emergence of social-ecological memory is dependent on the time depth of lived experience (I). Social-ecological memory is a quality of communities of practice that take part in management on the ground, which enables individual managers to address underlying ecosystem processes behind many ecosystem services, and the quality by which they are capable to adapt to gradual change and retain experiences and modify practices in relation to a constantly changing world (I; III; Scott 1988). Moreover civil society actor groups have also shown to influence urban ecosystem by protecting them from exploitation. Indirectly this influences ecosystem functioning by changing the patterns of urban development (IV). It is reasonable to think that such local actor groups are prime candidates for capturing and retaining practices of importance to prepare for ecosystem disturbance (I).

However, even though some of local actor groups hold such qualities, they often seem to be ignorant of ecological processes that transcend their focus area. Municipal managers and planners hold less knowledge on site specific ecological processes compared to some local actor groups, but hold the missing landscape perspective (III).

Connectivity between ecosystems of the urban landscape

An important consequence of the expanding city is that most green areas are small, which increases the significance of spatial structure, i.e. the habitat suitability of a patch is to a large extent dependent on its surroundings. Some species become dependent on small scale networks of one type of green areas (V), while others need access to several different types (VII). The small size of green areas also increases the probability that many organisms will exhibit meta-population dynamics with local extinction and re-colonization as shown by others in Stockholm (Mörtberg 2001) and elsewhere (Reale and Blair 2005). At a larger scale a system of ‘green wedges’, remain partly due to the city’s transport infrastructure and to land allocations. These are recognized by state agencies (Stockholm stad 2003) as providing ecological connectivity at a larger scale thus potentially replenishing sink populations of local green areas (cf. Sandström et al. 2006, cf. Crooks et al. 2004).

Based on empirical ecological inventories and on the possible features for scale mis-matches we suggest that there are at least three relevant ecological scales for governance aiming to facilitate management of ecosystem services; *local green areas*, *regional green infrastructure*, and at the mid-scale, linking hierarchically between the other two, *city-green networks.* Our analysis of the connectivity and complementarities between ecosystem of the urban landscape shows that the mid-scale of the city-green network to a large extent determine whether different species are present or not (V; VI).

In comparison to the other two ecological scales, city-green networks are understudied, and we found no actors that explicitly address them, although candidates exist. With a somewhat changed focus municipal agencies, municipal ecologists, and/or umbrella organizations from civil-society could address the ignored city-green network scale, as well as engage in networking between current dis-connected actor groups

Implications of mis-matches

The above result show many possible features for the scale mismatches in the urban landscape of Stockholm. In Table 2 we have summarized these and the implications they might have for governance of Stockholm's green areas. The table also provide a set of suggestions for how to improve the social network structure of governance. In the following we discuss some features of the alternative governance.

Table 2. The table summarizes features of scale mismatches and the implication for current governance, followed with suggestions for improvements. We believe these suggestions could provide conceptual maps and diagnostic tools for analyzing governance of ecosystem services in other urban landscapes as well.

Findings from synthesis

1. Management is divided between separate sectors and state agencies and based on upholding certain user classified values rather than sustaining ecosystem processes in the landscape.
2. There are at least three separable ecological spatial scales of importance for governance: local green areas, city-green networks, and the green infrastructure.
3. One important ecological scale is not accounted for (city-green networks) and cross-scale dynamics are missed due to lack of information flows between actor groups engaged on different spatial scales and on different levels of society.
4. Actor groups from civil society with capacities for management and protection of local green areas are not sufficiently acknowledged or engaged with by state agencies, or treated on an ad-hoc basis.
5. Some social networks span across space (but tend to stretch only within actor groups).
6. Some candidates for scale-crossing brokers exist.

Effects on current governance

1. Low flexibility for adapting to emergent ecological properties due to rigid sector divisions and strong administrative borders, paralleled with poor communication between most actors.
2. Unawareness of ecological cross-scale dynamics and ignorance of setting ecosystem services as objective for green governance.
3. No purposive governance at the scale of the city-green networks.

Suggestions for alternative social network structure of ecosystem governance

1. Focus on at least three spatial scales; local green areas, city-green networks, regional green infrastructure
2. (a) Include local actors from civil society, and (b) introduce scale-dependent responsibilities for all actors, while (c) appoint mid-scale actors responsible for the governance of city-green networks.
3. Facilitate the emergence of scale-crossing brokers with knowledge of ecological processes and with a holistic landscape view. Their task is to (a) link disconnected actor groups on multiple spatial scales, (b) sustain and support local actors (i.e. sustain network diversity), and (c) coordinate collaborative action for responding to disturbance.

4. Envisioning an alternative network structure for improved ecosystem management

In this section we will analyze and discuss the findings and implications, and explore governance of resilience with the aim to uphold the flow of urban ecosystem services. One new priority of urban ecosystem governance should be the provision of ecosystem services, i.e. the capacity of ecosystems to deliver benefits to citizens. This would acknowledge already existing recreational, cultural and esthetic and open space values, but would need complementation by addressing ecological services that support ecosystem renewal.

A new adaptive governance regime that support ecosystem management should therefore be organized along the three ecological scales as we suggested earlier, in combination with development of means to facilitate exchange of information between actors at the different ecological scales. The aim of such governance is to enable different actors to address ecological objectives at their appropriate scales while simultaneously being open for cross-scale coordination of collaborative activities. We suggest therefore that education and appointment of mid-scale actor groups as well as scale-crossing brokers are of central importance for enhancing the social network structure of green area governance in this urban landscape (Figure 3). We argue below that this would enable scale awareness as well as enhance flexibility of governance (Table 2). These suggestions implicate to open up the current management mainly built around state agencies, for deliberative partnerships with civil-society and thus moving towards shared decision-making in governance of urban ecosystem services.

Mid-scale managers and scale crossing brokers

Since the mid-scale is currently not addressed, we argue for the need to facilitate the emergence of mid-scale actors responsible for the management of city-green networks. A city-green network consists of a mosaic of local green areas and green space that functions as dispersal corridors, which connects local green areas. Tools for identifying species specific city-green networks exist, based on network theory and modeling movement of species, digital mapping and inventories of biodiversity (Löfvenhaft et al. 2002; Andersson and Bodin in press; cf. Keitt et al. 1997; cf. Urban and Keitt 2001). In practice however, city-green networks are difficult to define since the landscape is used differently by different organisms. Thus the delimitation of the networks will depend on the ecosystem service(s) in focus. For instance, the city-green network relevant for pollination might be different from that of pest regulation or seed dispersal.

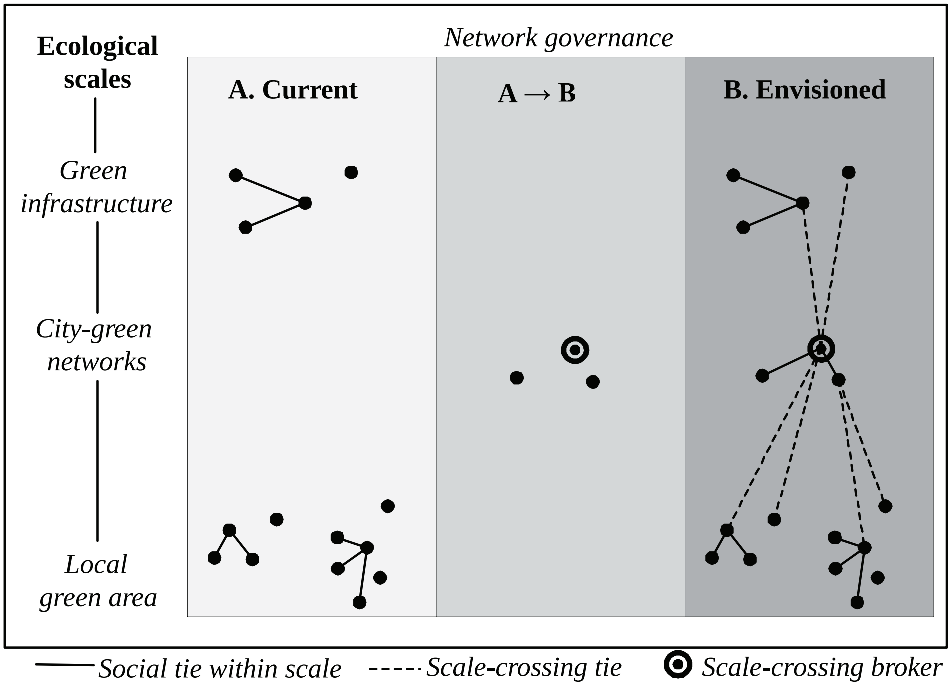


Figure 3. In comparison with the ecological scales we suggested for the studied social-ecological system, our results show that in the current governance (A) there are actors active on the lowest and highest ecological scale. By introducing actors responsible for city-green networks while at the same time introducing scale-crossing brokers (A→B), new governance (B) could emerge that better handle spatial and temporal mismatches between social and ecological processes.

The mid-scale actors should focus on to facilitate ecosystem management of the undervalued mid-scale. On one hand they should provide actor groups engaged on local management with an ecological context that make the most of the local heterogeneity. On the other hand, the mid-scale actors should hold a more dynamic view on landscape ecological functions by managing disturbance regimes, i.e. inducing disturbances to create local ecosystem collapses and allow for succession, consequently regenerating ecosystems and sustaining spatial resilience (Bengtsson et al. 2003). Such practices, e.g. cutting down patches of trees or even using fire, might be opposed by certain neighborhood groups and could therefore be difficult to apply in all local green areas. Thus, areas where such practices could be used should be identified and used to “fine-tune” the landscape matrix in space and time.

The role of the scale-crossing brokers is to focus on social relations of the network of governance. Since network structures cannot be controlled but are emergent, the brokers need to work as agents that strive to create and sustain a network structure that in turn facilitates processes that both prepare governance for change, and also processes that enhances the ability to respond to change. Manring (2007) talks appropriately of brokers as network “caretakers” and Thomas Hahn refer to “bridging organizations” as those actors that create and sustain purposeful social networks for collaboration (Hahn et al. 2006; Olsson et al. 2007). From a structural network perspective we can deepen the understanding of the practices of these actors. The practices of scale-crossing brokers for sustaining purposeful network structures can be divided in two parts.

First, they need to network with *many* actors, with *different types of actors,* and finally, with actors at *different ecological scales*. Second, they should strive to sustain and increase actor diversity. Noteworthy is that these practices coincide with sustaining their own position.

As mentioned, scale-crossing brokerage is not just about social structure; it is also about social practice (Wenger 1998; Westley 2002). It requires enough legitimacy to influence the evolution of practice of different actors and to address conflicting interests (Ibid.). And at the same time it requires skills and practices to hold the structural position. The dilemma is about sustaining many ties, which means they are weak and provide less opportunity for trust and social learning, or to invest in stronger ties, which means to lose other ties and thus the brokerage position (Granovetter 1973). Scale-crossing brokers may well be organizations of many individuals that collaborate in solving this dilemma, in the literature such organizations is referred to as, institutional entrepreneurs (Westley and Vredenburg 1991) or bridging organizations (Hahn et al. 2006; Olsson et al. 2007). Maybe the most important quality of agency that scale-crossing brokers hold is ecological knowledge and a holistic landscape view based on ecological processes. This is needed if the broker is to capture and build understanding out of the diverse information received from different actors at different scales. Other practices important for the broker include leadership skills, trust building and social contracting (Westley et al. 2002; Hahn et al. 2006; Manring 2007; Olsson et al. 2007).

Enhancing flexibility of governance with scale crossing brokers

Ecosystem management requires flexible governance regimes which includes the ability to switch between different modes, for example switching between 1) preparing for disturbance by allowing for spatially distributed and diverse ways of capturing and storing place specific information of locally evolved dynamics, and to 2) igniting effective collective action for response to disturbance (van der Leuuw 2000; Crumley 1994, 2000, 2003; Folket et al. 2005; Duit and Galaz 2008). Such flexibility partly is enabled or constrained by the structure of the social network of governance (Leavitt 1951; Diani 2003a; Ernstson et al. 2008).

Educating and appointing scale-crossing brokers of governance may increase flexibility. First, through linking actors on different scales, the coordination by scale-crossing brokers could decrease ecological mismatches and improve the functioning of ecosystems (Folke et al. 2005). Through such practice new and unique pathways for a diversity of actor groups to meet and exchange experiences can be created, which can nurture arenas of innovation for a greater potential range of purposeful actions (Burt 2003; Hahn et al. 2006). In such areans there is potential to draw on the diversity of social-ecological memories that has emerged in the different actor groups (Folke et al. 2003; Barthel et al, *submitted*). Here captured experience of change and successful adaptations from various parts of the landscape can be negotiated in debate for how to prepare for ongoing change and uncertain futures (Wenger 1998; Folke et al. 2003).

An example of negotiation is about the ecosystem service of pollination were the location of nests of wild bees detected and desired by allotment gardeners can be passed on to municipal employees clearing bush lands. Several such learning arenas (Berkes et al. 2003; Olsson et al. 2004a; Fazey et al. 2006), could be initiated by scale-crossing brokers (Hahn et al. 2006), and then on later stages, other actor groups might continue, or close down such arenas (Danter et al. 2000; Manring 2007).

To draw on diverse social-ecological memories scale-crossing brokers must be able to sustain and increase the diversity of actors in the network (Olsson et al. 2006). This requires awareness of the general tendency of powerful actors to superimpose top down practises on less powerful actors (Agrawal and Ostrom 2001; Ostrom et al 2007), which threatens to erode valuable diversity of social practices in the network of governance. There are reasons to believe that decentralized networks of social diversity prepares the network prior change, only if there is autonomy for local actor groups to self organize (van der Leeuw 2000; Crumley 2003), meaning here self-monitored collective action assumed without being guided or controlled by an outside source (Westley 2002). Decentralized green area governance should therefore be accompanied by robust property rights that gain local actor groups rights and obligations (Agrawal and Ostrom 2001; Barthel et al. *submitted;* Colding 2009), and other conditions that generate self-organization in communities of practice (Wenger 1998). The task of recognizing gradual changes in ecosystem dynamics hence depends on the existence of diverse actors at different scales – from allotment gardeners and municipal ecologists to regional planning offices – that continuously perform their practices and generate lived experiences.

Scale crossing brokers can also enhance ability of governance to respond to disturbances, by taking central leadership for collective action (Leavitt 1951; Lin 1999; Agranoff and McGuire 2001; Westley 2002; Olsson et al. 2006). In fact, the notions of broker and the ones of network-leader, or institutional entrepreneur share similarities such as active ‘networking’ as a practice (Westley and Vredenburg 1991; Bardach 1998; Kooiman 1993; Burt 2003). From Burt (2003) we know that network wide information have a tendency to be concentrated to the broker, which enhances its ability to coordinate collective action in essential ways. Situated in a position where diverse flows of information and knowledge meet, including scientific and local experiential knowledge, the broker will have greater ability to create novel understandings and see new innovative opportunities (Burt 2003). In response to rapid change, it can take earlier action and find new collaborative solutions for novel situations. This effect rests upon that the brokerage position grants the broker more diverse and up-to-date information than any other actor in the network. In part it is the position between other knowledgeable and resourceful actors at different ecological scales that brings out such abilities (Ibid.). For example, if a pest-outbreak or a new invasive species is recognized and responded to locally by a allotment gardener, and which threatens to diffuse over wider landscapes, the broker could find financial means, social capital and engage experts and to guide further collective action. Hence, in such circumstances decision making becomes centralized and the scale-crossing broker takes on a leadership role for collective action in response to ecosystem disturbance. Such social processes have proven to influence the generation of ecosystem services by protection of a large urban park in Stockholm from exploitation (Ernstson et al. 2008; Ernstson and Sörlin; *in press*).

Here a vast diversity of interest and user groups that articulated the values of this park in competition with other land use interest such as infrastructure, office and housing, was facilitated, articulated and expressed by an actor group with a central position in the network (Ibid.) This example also shows that such network leadership differs vastly in practice from conventional command-and-control style of hierarchical management (Agranoff and McGuire 2001; Westley 2002; Galaz et al. 2008).

Scale-crossing brokers are possible agents for navigating the social network structure between centralized collective action on the one hand and decentralized and the preservation of social diversity of local autonomous actor groups (rich modularity), on the other. We believe however, that the issue of how to switch between these modes needs further research. It is possible that such flexibility of governance lies in a combination of social practice, politics and of underlying world views of participants in governance (Wenger 1998; Westley 2002; Folke et al. 2003). It may be facilitated by scenario building exercises, including the construction of artifacts and shared narratives, and other ways that can increase values for such flexibility (cf. Callon 1986; Wenger 2000; Ernstson and Sörlin 2009). However, it may well be that there are trade-offs between the modes of collective action and rich modularity. In network theory, an assumption is that all social relations come with a cost, first for establishing it and then to sustain it (Granovetter 1973), which tends to direct information flows through established patterns of interaction (Diani 2003b).

Social network structure are consequently an outcome of localized interactions and no actor can fully control the whole emergent structure, but scale-crossing brokers may change at least parts of the network structure through interacting with new actors (ibid.). Such new interactions is what partly lies behind transformational changes when for instance an institutional entrepreneur or bridging organization invests time and effort in creating new links (Westley and Vredenburg 1991; Olsson et al. 2004b; Manring 2007). However, the idea that social network structure is an emergent property due to local interaction of costly relations also demonstrates its inertia, and why it is referred to as a 'structure' (Degenne and Forsé 1999). In Stockholm the same network structure that was effective for protection of a large urban park, might have hampered ecosystem management of the same park, as user groups with ecological knowledge were marginalized due to their peripheral network position (Ersntson et al, 2008). This serves as a good example of the duality between network structure and process; a structure effective for solving certain issues might simultaneously constrain solving other types of issues (Diani 2003b).

Although no scale-crossing brokers were identified in Stockholm potential candidates exist. Scale-crossing brokers and the actors responsible of managing city-green networks could appear to have similar positions and might even work in the same organizations. However, the latter has a clearer spatial responsibility with focus on a particular city-green network and engage more profoundly in ecosystem management, while the broker should focus on social networking.

The brokerage position could be held by both individuals, and organizations from civil-society, as well as municipal agencies (Cash and Moser 2000; Olsson and Folke 2001; Westley et al. 2002; Hahn et al. 2006; Olsson et al. 2006; Moss and Wissen 2005) We found that candidates from all categories already exist in Stockholm.

5. Further explorations

How do we identify social networks of governance that is able to 'navigate' the dynamic nature of multilevel and multi-scale interconnected social-ecological systems so as to secure the flow of urban ecosystem services? In this article we have shown how this pressing question can be addressed through synthesizing a set of case studies from Stockholm and compare them with a theoretical framework combining ecological scales and social network structure. To develop interdisciplinary frameworks of governance such as the one discussed here can, in the words of Manring (2007), provide "conceptual maps and diagnostic tools". Generally, cities have predominately been viewed as social entities and produced an organizing logic that constrains urban green governance. We therefore believe that our results could be quite general and apply to urban green governance in other cities as well.

We like to express that our framework is explicit in identifying suitable ecological scales which have been less rigorously pursued by others (Pahl-Wostl et al. 2007; Manring 2007; Grimm et al. 2008), but argued as crucial by many (e.g. Cumming et al. 2006). Our analysis of the city-green network scale determined our exploration the social network structure of governance. But as it is difficult to define the delimitation of city-green networks due to that the landscape is perceived differently by different organisms, we leave it to future research to develop criteria for how to define city-green networks. A promising approach could be to base them on mobile links, i.e. species supporting ecosystem regeneration through their movement between separate areas (Nyström and Folke 2001; Lundberg and Moberg 2003; Bodin et al. 2006b; Lundberg et al. 2008), in combination with ideas on how to manage sets or "bundles" of ecosystem services in landscapes (Goldman et al. 2007; Nelson et al. 2008).

A question left unanswered in our analysis is the one about accountability (e.g. Agrawal and Ribot 1999; Bierman 2007). Scale-crossing brokers will have great social capital and power (Lin 1999; Crona 2006) that potentially can be used for self benefit or to navigate towards maintaining some ecosystem services in front of others or favoring certain types of actor groups and not others (Heynen 2003; Adger er al. 2006; Corbera at al. 2007). If scale-crossing brokers exercise their power in such ways, how and by whom are they held accountable? Who are legitimate scale-crossing brokers? Further intriguing research areas about the emerging field of adaptive governance and the needed flexibility for upholding the flow of ecosystem services may be cross-fertilized by such analyzes (McLaughlin and Dietz 2008; Ernstson 2008).

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