Scale-Crossing Brokers and Network Governance of Urban Ecosystem Services: The Case of Stockholm

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ABSTRACT. Urban ecosystem services are crucial for human well-being and the livability of cities. A central challenge for sustaining ecosystem services lies in addressing scale mismatches between ecological processes on one hand, and social processes of governance on the other. This article synthesizes a set of case studies from urban green areas in Stockholm, Sweden—allotment gardens, urban parks, cemeteries and protected areas—and discusses how governmental agencies and civil society groups engaged in urban green area management can be linked through social networks so as to better match spatial scales of ecosystem processes. The article develops a framework that combines ecological scales with social network structure, with the latter being taken as the patterns of interaction between actor groups. Based on this framework, the article (1) assesses current ecosystem governance, and (2) develops a theoretical understanding of how social network structure influences ecosystem governance and how certain actors can work as agents to promote beneficial network structures. The main results show that the mesoscale of what is conceptualized as city scale green networks (i.e., functionally interconnected local green areas) is not addressed by any actor in Stockholm, and that the management practices of civil society groups engaged in local ecosystem management play a crucial but neglected role in upholding ecosystem services. The article proposes an alternative network structure and discusses the role of midscale managers (for improving ecological functioning) and scale-crossing brokers (engaged in practices to connect actors across ecological scales). Dilemmas, strategies, and practices for establishing this governance system are discussed.

Key Words: *adaptive governance; ecological scales; ecosystem management; ecosystem services; scale mismatch; social network structure; urban ecology*

INTRODUCTION

Urban green areas, although representing the most human-dominated ecosystems, are increasingly being recognized for their role in generating critical ecosystem services that are important for human well-being and society at large (Daily 1997, Bolund and Hunhammar 1999, McGranahan et al. 2005). Services from green areas such as parks, wetlands, cemeteries, and urban forests range from providing shade and space for recreation, filtering of aerosols, and absorption of 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, access to green areas within walking distance could prove crucial in enhancing broad-based public support for the general protection and governance of ecosystems (Pyle 1993, Millennium Ecosystem Assessment 2005, Miller 2005). In contrast to other urban services like medical care and public transport, there has been a deep neglect of research and theorization regarding the governance of ecosystem services in urban landscapes.

This article has two objectives: one is to offer a framework for assessing urban ecosystem governance and derive suggestions for improvements, and the other is to contribute to the theoretical discussion on what type of social network structures and social practices that seem needed to match social and ecological scales towards adaptive governance (Folke et al. 2005). Based on a set of case studies from the urban landscape of Stockholm, Sweden, the empirical focus lies on the ecosystem

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services of pollination and seed dispersal. These services have been selected because they depend on spatially explicit processes that are key for the regeneration of urban ecosystems, which makes them extremely good focal services for addressing spatiality, complexity, and resilience in governance. Other ecosystem services are also discussed.

Governance and management of urban ecosystem services face several challenges. Urban landscapes are characterized by heterogeneity, highly contested land use, rapid social change, limited capacity for ecological renewal, and a high concentration of administrative units (Pickett et al. 2001, 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 for ecosystem management (Folke et al. 1998, Cumming et al. 2006, Olsson et al. 2007). Although studies in urban ecology have embraced cities as social-ecological systems, the studies have mainly focused on exploring how the heterogeneity of land-use patterns affect ecosystem function (Alberti 2005, Cadenasso et al. 2006, Grimm et al. 2008, Pickett et al. 2008), and have focussed less on actual management. Humans have tended to be regarded as part of larger groupings (of class or ethnicity), or as part of anonymous drivers of pollution and urban development. Few studies have focused on groups of humans that intentionally interact with urban ecosystems and how such actor groups could be drawn upon in governance to sustain and/or modify ecological processes so as to maintain ecosystem services in larger urban landscapes. This paper focuses on such actor groups, from allotment garden associations, bird-watching groups, and cemetery and city park managers, to urban planners.

Social networks are important in ecosystem governance and management. Adaptive governance implies different forms of collaboration that involve processes of coordination, social learning, knowledge integration, trust building, and conflict resolution (e.g., Folke et al. 2005, Manring 2007, Olsson et al. 2007), which to various extents depend on creating and sustaining social relations in networks of information sharing. Especially, networks between actor groups that are active at different scales and have different and often scale-specific knowledge and information about the ecosystem are seen as crucial, as this could nurture social learning processes towards understanding

nonlinear dynamics and cross-scale linkages (Bandura 1977, Ashby 2003, Olsson et al. 2007).

Literature addressing social networks in co-management is found in the writings on bridging organizations (Hahn et al. 2006, Olsson et al. 2007, Schultz 2009), institutional entrepreneurs (Westley and Vredenburg 1991), and network brokers (or net-brokers) (Manring 2007). Although rich on the social practices and skills of such actors, this literature analyzes and theorizes social networks from within the horizon of single (but very active) actors, and consequently fails to fully acknowledge that actors are always inscribed in social network structures, i.e., in patterns of shared relations (Wasserman and Faust 1994). In this paper, the structure of networks is central, which means that the behavior and knowledge of actors are seen as dependent, not just on themselves and their closest contacts but also on the contacts of their contacts and consequently on the whole network structure that affects both individual actors and the performance of the whole network (Wasserman and Faust 1994). By shifting the point of theorization, the basic idea pursued is that the patterns of information flows can bring greater clarity in how social networks influence both decentralized processes of social learning and more centralized collective action. Also, moving from individual actors to network structures will inform us about which social practices can support the emergence of purposeful social network structures for ecosystem governance.

The paper consequently builds on scholarly works that have used structural social network analysis in analyzing natural resource management problems (Schneider et al. 2003, Bodin and Norberg 2005, Crona and Bodin 2006, Ernstson et al. 2008, Newig et al. 2010, Prell et al. 2009, Bodin and Crona 2009). Here we take these efforts further by explicitly trying to combine analyses of social network structure with analyses of ecological scales. This approach better articulates the complexity of the resource, i.e., that ecosystem services are generated from spatially distributed ecosystems. As a result, the paper explores a more spatially explicit governance model on overcoming scale mismatches than previous attempts (Folke et al. 1998, Cumming et al. 2006, Borgström et al. 2006, Olsson et al. 2007). Furthermore, by stressing the importance of relations between actor groups, this article draws upon network governance (Sørensen and Torfing 2003, Duit and Galaz 2008) which is seen as part of

adaptive governance (Dietz et al. 2003, Folke et al. 2005). Governance is, in this paper, understood to be the structures and processes by which collective action among a diversity of social actors (state, private, and civil society) is coordinated towards upholding certain publicly held values and resources (cf. Stoker 1998, Lebel et al. 2006).

The paper is organized as follows. First a theoretical network model of governance is constructed that can assist in synthesizing the case studies and assessing current governance of Stockholm's green area ecosystems. This is followed by a short description of the case studies, and then by a presentation of the results. These demonstrate the presence of several scale mismatches. Importantly, one ecological scale is not addressed by any actor group. Furthermore, there is a lack of practices in sharing information between actor groups, and a failure to draw upon the place-specific and in-depth ecological knowledge held by allotment gardens and other civil society groups. Given these findings, the discussion aims to identify social network structures capable of sustaining ecosystem functioning and maintaining management flexibility, which especially centers on the network position of scale-crossing brokers.
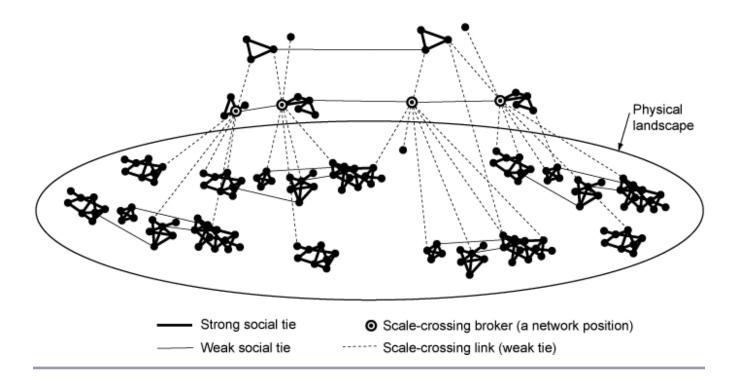
THEORETICAL MODEL AND METHODS

A governance framework that merges ecological scales and social network structure

To synthesize individual case studies and assess current governance, we developed a framework that merges ecological scales with social network structure. This framework is captured in a social network model (Fig. 1) and provides, in the words of Manring (2007), a "conceptual map" of a well-working network governance structure, and a set of "diagnostic tools" that will aid in assessing current governance. As discussed further below, the framework is built to meet two fundamental criteria of ecosystem governance derived from the literature on adaptive co-management and adaptive governance (Holling 1996, Gunderson and Holling 2002, Berkes et al. 2003, Olsson et al. 2004a, Folke et al. 2005). This literature argues that in order to support ecosystem services in the face of rapid and slow change, governance processes should: (1) sustain ecosystem functioning, i.e., increase the ability for urban ecosystems to regenerate through ecological processes and structures at multiple scales (rather than focusing on single-species or a few selected variables); and (2) create and maintain flexibility, i.e., have the ability to switch between two basic modes of governance in order to prepare for change (by enhancing decentralized processes of social learning) and respond to change (by more centralized collective action). Our framework is in line with other approaches for analyzing governance in 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), although it does not explicitly cover issues of institutional redundancy, polycentrism, and conflict resolution (Berkes et al. 2003, Low et al. 2003, Ostrom 2005, Olsson et al. 2007).

The framework, in the form of a social network model (Fig. 1), is based upon three basic notions: ecological scales, social network structure, and how actor groups can be seen as linked to ecological scales.

Ecological scales are those scales deemed suitable for purposeful monitoring of ecosystem dynamics (Cumming et al. 2006). The guiding principle is to use scientific methods to identify the spatial scale of ecological processes that support the ability of urban ecosystems to regenerate, especially through pollination and seed dispersal. This view can be linked to theoretical ideas in which ecological scales are viewed as hierarchically and dynamically linked (Gunderson and Holling 2002); ecosystem interactions 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 (Gunderson and Holling 2002, Pickett and Cadenasso 2008). This means that different species interactions will be important on distinct scales, e.g., interactions such as competition are local while resource use and population dynamics occur on landscape or regional scales. With this in mind, relatively lower ecological scales can be assessed by analyzing patch quality and interspecies and intraspecies interactions, while greater scales depend on where habitats are located in space with aspects such as landscape supplementation and complementation, and neighboring effects (e.g., Dunning et al. 1992). At relatively larger spatial and temporal scales, dispersal corridors and sink-source dynamics become of importance. The dynamics of disturbances also need to be considered, which in an urban context tend to be caused and controlled by humans (Pickett and Cadenasso 2008).

Fig. 1. The figure shows a stylized image of an ideal social network model for ecosystem governance, as discussed in the main text. Scale-crossing brokers are network positions that link otherwise disconnected actor groups which, through their social practices, interact with ecosystem processes at different ecological scales, and through that gain scale-specific and place-specific knowledge and information. At the local scale—and spread out in the physical landscape—local actor groups interact with local green area ecosystems, e.g., cemetery managers or allotment garden associations. On greater spatial scales, actor groups can be municipal ecologists and planners who interact with the urban landscape through GIS and longer-term urban planning instruments.

To capture social dynamics we take the idea from sociology that, just as ecological patches are part of greater scale patterns, social actors are part of emergent social network structures that constrain and shape social dynamics (Wasserman and Faust 1994). One way to understand this is through the widespread notion that all social relations come with a cost, first for establishing them and then for sustaining them (Granovetter 1973), which tends to direct information flows through already established patterns of interaction because such information transfer entails lower transaction costs (Degenne and Forsé 1999, Schneider et al. 2003). (Costs could, for instance, be the effort it takes to arrange joint meetings and events, or the time it takes for actors to develop a common language of communication that allows for more effective coordination of activities.) From this viewpoint, social network patterns are consequently an outcome of localized interactions between pairs of actors, and no actor can fully control the emergent structure. This conceptualization of social networks allows for human agency, but an agency constrained and mediated through the network structure itself (Emirbayer and Goodwin 1994)—single actors can certainly change part of the network structure by redirecting their internally scarce resources to interact with new actors, but they cannot influence all relations. This conceptualization demonstrates the inertia of social network patterns, and why we refer to them as "structure" (Degenne and Forsé 1999).

These notions of ecological scales and agency and structure are integrated in our network model that consists of multiple actor groups arranged in a

pattern or interaction that enhances adaptive co-management (see also proposed model by Bodin et al. (2006a), and similar suggestions by Newman and Dale (2005) and Newig et al. (2010)). Drawing on Granovetter (1973), this conducive model for adaptive co-management is composed of actor groups in which the strength of social ties (amount of time, emotional intensity, intimacy, and reciprocity) within and between actor groups differs —internally actor groups have strong ties (of high cost), and bridging between them they have weaker ties (of low cost). Whereas strong ties can support trust building and long-term capturing of place-specific social-ecological information (Barthel et al. 2010), weak ties are important in spreading information over greater distances in the network (Granovetter 1973). Weak ties would therefore play a crucial role in coordinating the network and in preparing for innovation and adaptation to new situations (Granovetter 1973), while possibly also breaking up closed group thinking (Oh et al. 2004, Scheffer and Westley 2007).

Importantly, we complement this model by clearly conceptualizing how social actor groups are linked (or not linked) to ecological scales. This is done by focusing on the social practices by which actor groups interact with ecosystem processes and locating at what spatial scale these practices take place. This conceptualization also clarifies that the spatiality of governance as (local) actor groups, and their learning practices, can be located in space to specific locations and (local) green areas. Thus, by accounting for the structure of social networks between actor groups, and how they link to ecological scales, our resulting model consists of actor groups interacting both with each other and with ecosystem processes at different spatial scales, and at spatially separate sites (Fig. 1).

A final central aspect of our model is the network position of scale-crossing broker. In social networks, brokerage positions often emerge that link otherwise disconnected actors, which in effect means they mediate social relations, or "social capital", between groups (Burt 1992, 2002, 2005). In order to meet the two governance criteria from above, we posit that a specific type of brokerage position is needed in adaptive governance that bridges across ecological scales. We therefore define scale-crossing broker as a social network position that links otherwise disconnected social actor groups which, through their social practices, interact with ecosystem processes at different
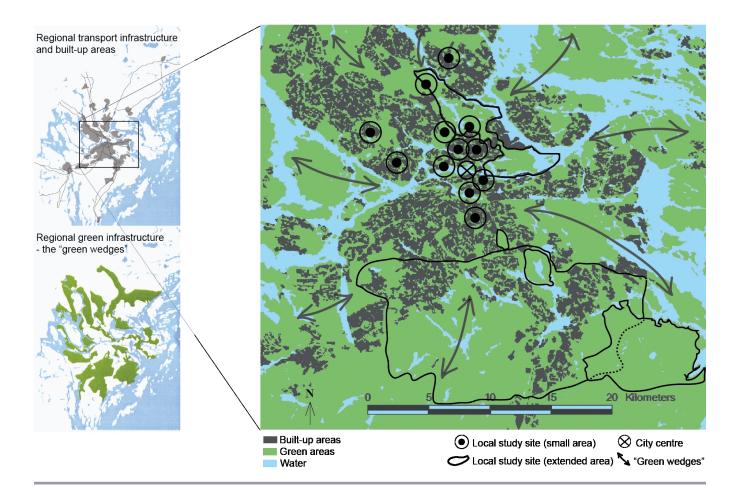
ecological (and spatial) scales and at different physical sites. In the discussion section we will develop further how this social network position is crucial in facilitating the sharing of captured and retained scale-specific information and in coordinating the network towards social learning processes. For now it suffices to motivate this position by noting that in cultural/urban landscapes that depend on continued management, it seems beneficial if civic groups and organizations which continuously interact with (or manage) local patches learn about each other's activities and about the activities of governmental agencies, planners, and scientists. As they interact with ecological processes at different scales, they potentially hold complementary knowledge about the (urban) ecosystem.

This proposed network model facilitates adaptive governance by striking a balance between centralization (for effective collective action in response to change) and decentralized modularity (for a distributed diversity of autonomous and localized knowledge generation in preparation for change). Furthermore, because actor groups are spread out in space, coordination to enhance ecosystem functioning across space is facilitated. The model brings forth a set of diagnostic tools— ecological scales, actor groups, social networks (with strong and weak ties), and scale-crossing brokers—that together form an analytical lens by which to identify and bring together different features of the case studies, and to facilitate our assessment of the current governance of Stockholm's green area ecosystems.

DESCRIPTION OF THE SET OF CASE STUDIES

Our synthesis is based on seven case studies from the urban landscape of Stockholm, Sweden (Fig. 2) published in separate papers (Table 1). The individual studies were carried out at 17 local study sites with a great variety of green areas ranging from protected areas and urban forests, to allotment gardens, urban parks, cemeteries, domestic gardens, and golf courses (exemplified by photos in Fig. 3). The studies focused on different aspects of green area management in Stockholm and both social and ecological data were generated in order to capture the dynamics of social-ecological processes (Table 1). Ecological data focused on functional groups (especially pollinators, seed dispersers, and

Fig. 2. The maps show the study area in the Stockholm Metropolitan Area, Sweden. The right map is marked with 17 local study sites (small and extended areas), alongside the system of large "green wedges" in-between areas of development and transport infrastructure. 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, followed by cultural human practices and it consists of fissured bedrock, clay-covered valleys, and a small-scale rough terrain with a range of habitats conveying a relatively high biodiversity. Stockholm hosts a current population of 1.2 million people; it is the most rapidly growing and most densely populated region in Sweden with 2500 inhabitants/km² (SCB 2007).
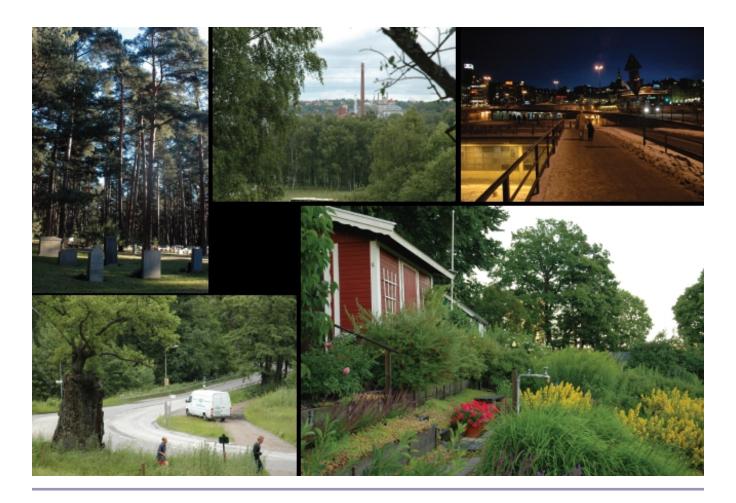

insectivores) and were generated through field surveys of birds and bumblebees, and were complemented with ecological landscape analysis based on land cover structure from satellite images and network models. Social data were generated by engaging with actors at different scales using text analyses, questionnaires, and interviews. 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 empirical case studies used in this paper. Numbers VI and VII were carried out primarily by colleagues from the same research group as the authors. Scales addressed ranged from: (1) local scale green area, (2) city scale green network, and (3) regional scale green infrastructure (see main text).

Study no.	Publications	Short description of study	Type of data	Scale addressed in study
I.	Barthel et al. 2005 Barthel 2006 Barthel et al. 2010	Ecological and historical land-use analysis and stakeholder analysis of a large green area, the National Urban Park (NUP). *Method*: Text analysis of documents and maps, paired with semi-structured interviews and participatory observations.	Social -	1. Local scale 2. - 3. -
II.	Borgström et al. 2006	Comparative study of ecosystem management in five local green areas: one large green area (NUP), a large cemetery, a nature reserve, an urban forest, and a watershed. *Method*: Text analysis of planning documents, paired with interviews with managers.	Social -	1. Local scale 2. - 3. -
III.	Andersson et al. 2007	Comparative study of ecological effects of management practices between different actor groups: cemetery managers, urban park managers, and allotment gardeners. *Method*: Combining field survey of birds and bumblebees with questionnaire and semi-structured interviews.	Social Ecological	1. Local scale 2. City scale 3. -
IV.	Ernstson et al. 2008 Ernstson and Sörlin 2009	Analysis of the social network structure of a local urban movement protecting a large urban green area (NUP), alongside the analysis of arguments for protection. *Method*: Social network survey, paired with interviews, document analysis, and participatory observations.	Social -	1. Local scale 2. City scale 3. -
V.	Andersson and Bodin 2008	Ecological network analysis of bird species movements. *Method*: GIS analysis of land cover, paired with empirical bird observations.	- Ecological	1. - 2. City scale 3. -
VI.	Lundberg et al. 2008	Mobile link analysis of the Eurasian Jay and oak forest regeneration, focusing on a large urban green area (NUP). *Method*: GIS-analysis of land cover, paired with empirical bird observations.	- Ecological	1. - 2. City scale 3. -
VII.	Colding et al. 2006	Spatial assessment of different types of urban green areas, focusing on allotment gardens, domestic gardens, golf courses, and protected areas. *Method*: GIS-analysis of land cover and analysis of planning documents.	Social Ecological	1. Local scale 2. - 3. Regional scale
	Focus of interviews Scale mismatch Social networks Local management practices	20 interviews of duration 30–120 min. 7 interviews of duration 60–90 min 26 interviews of duration 60–90 min.		

Fig. 3. Photos of Metropolitan Stockholm. From the upper left corner: a cemetery with pine trees, deciduous forests, the city center (in the winter), an old oak tree, and an allotment garden. Photos by H. Ernstson.

RESULTS

The results section aims to describe relevant ecological scales and scale mismatches that our studies have exposed and suggested. It is important to initially recognize that ecosystem services are distributed at different spatial scales. They can be confined to the area where they are generated (e.g., recreational values or decomposition), spill over to surroundings (e.g., pollination, pest control, and noise reduction), or connect separate areas (e.g., via seed dispersal or recolonization). As already stated, our studies focused on pollination and seed dispersal, the cases of which were selected for their spatial complexity.

A general temporal feature of Stockholm is that most green areas have been shaped by human cultural usage since the last ice age. Actors have over time generated increasing habitat diversity affecting species composition and ecological functions, and consequently the production of ecosystem services (see case studies I, II, III, VI, and VII in Table 1), suggesting that present ecosystem services have developed from a long-term social-ecological interaction or coevolution (I). Human relations across scales therefore seem key in upholding ecosystem services.
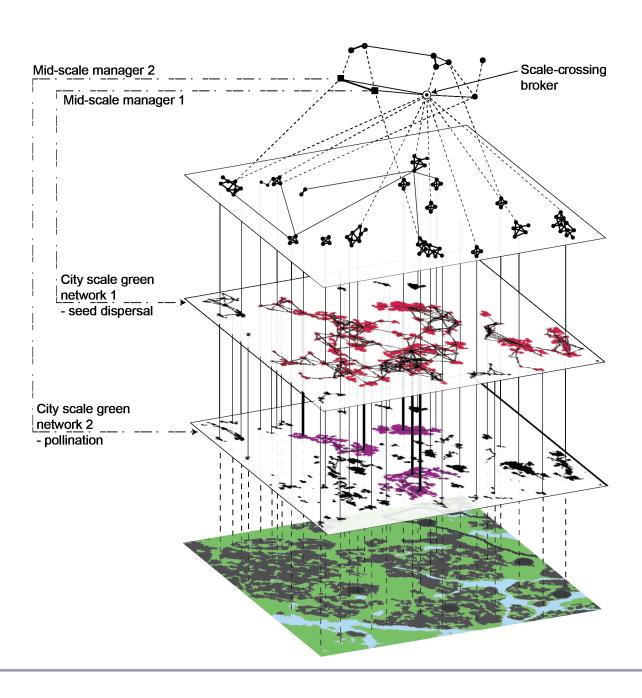
Ecological scales for governance

To achieve and maintain functioning ecosystems, governance needs to be fitted to and deal with different ecological scales. Based on our results below, we suggest three scales of ecological processes relevant to governance in Stockholm: local scale green areas, city scale green networks, and a regional scale green infrastructure. Local green areas are the focus of much of the current management, and an embryo of a regional scale green infrastructure is recognized in planning that is known as the "green wedges". These wedges are large undeveloped areas shaped by and located between the spokes of transport infrastructure stretching outward from the city center (Fig. 2), and they include larger forests, lakes, rivers, but also farm land, holiday cottages, and golf courses that could provide the foundation for co-management across municipal borders. City scale green networks, being less recognized in planning, link hierarchically between the other two scales. We define city scale green networks as selected sets of local green areas, including the patches in between that serve to functionally link these local green areas through landscape ecological processes, e.g., seed dispersal, pollination, waterways, etc., vis-à-vis certain ecosystem services (see illustration in Fig. 4).). The aim with defining city scale green network is to functionally group networks of small green areas and patches within the city into larger ecological management units; while there may be hundreds of local green areas and patches in Stockholm, there would only be a few city scale green networks. In the following we describe and support the validity of these ecological scales for governance.

Access to ecosystem services generated within the city depends on solving two ecological problems: the long-term persistence and the spatial distribution of "ecosystem service providers", i.e., the species, functional groups, and habitat types that sustain ecological functions (Kremen 2005). As our results demonstrate, the small scale and heterogeneity of green areas in Stockholm (and many other urban areas) therefore require governance to address spatial structure because the habitat suitability of a patch is, to a large extent, dependent on its surroundings (V, VI).

Locally, within each green area, governance should aim at improving habitat quality and integrating the area into the larger landscape mosaic (I, II, III, and

Colding 2007). This means to recognize, or even create, city scale networks by planning for the best use and placement, and/or protection, of different green areas to increase the area of functionally connected habitats and the spatial coverage of the desired ecosystem services. To illustrate: planning for pollination in Stockholm would mean providing pollinators with suitable habitat (often clusters of qualitatively different green areas, see VII) and investing in creating these habitat patches so that pollinators can reach as much of the target area (city, part of city) as possible (cf. Bodin et al. 2006a). Seed dispersal, instead of the patch-matrix perspective used for pollination, demands a focus on interpatch relationships that would generate a different city scale network. Here our bird studies (V) show that patches too small to offer habitat individually, may together sustain bird populations (being important seed dispersers) if patches are connected and their combined area exceeds habitat demands. The service itself could be targeted by addressing the habitat requirements of certain species. In Stockholm a keystone species is the oak tree, whose acorn seeds are effectively spread by Eurasian Jays that collect acorns for food and hide them underground. A city scale network for the continued dispersal of acorns would consist of providing and protecting old oaks (located centrally in the city and producing acorns) and denser spruce stands (located at the city outskirts and providing nesting grounds for jays) (VI). At greater spatial scales, governance needs to deal with the fact that the small size of green areas in Stockholm (and many other cities) increases the probability that organisms—including pollinators and seed dispersers—will exhibit local extinction. Long-term persistence then depends on the presence of other areas from where recolonization could occur, i.e., so-called metapopulation dynamics (demonstrated by other studies in Stockholm (Mörtberg 2001) and elsewhere (Reale and Blair 2005)). In relation to this scale, the larger structure of "green wedges" in Stockholm seems to be of vital importance to address through intermunicipal collaboration. Although being contested as sites for new development, the green wedges are also recognized by state agencies and civil society organizations as providing ecological connectivity to outlying green areas (RTK 2008, SNF 2009), thus potentially replenishing sink populations of city scale networks and local and inner city green areas (cf. Sandström et al. 2006b, Crooks et al. 2004). The green wedges also provide ecosystem services like carbon sequestration and spaces for recreation.

Fig. 4. The figure demonstrates how one could identify the city scale green networks of pollination and seed dispersal in a particular area of Stockholm (suggested here by using digital mapping and ecological network analysis (cf. Andersson and Bodin 2008)). Note how certain local green areas are shared between the two city scale green networks, which give rise to network overlap (purple areas with bold vertical lines in city scale green network 2). Furthermore, it is suggested that midscale managers can take responsibility for particular city scale green networks. Taken as a whole, the figure demonstrates how particular ecosystem services can be viewed as embedded both in the physical landscape and within social networks of local actor groups (managing local green areas), scale-crossing brokers, and municipal to regional actors.

In comparison to the other two ecological scales, the mesoscale of city scale networks is understudied in Stockholm, and we found no actors that explicitly address it. However, with a somewhat changed focus, municipal agencies, municipal ecologists, and/or umbrella organizations from civil society could become midscale managers. Note that we so far have just established the scale of these green networks; we will later discuss how to handle the notion that empirically defined city scale networks will differ depending on which ecosystem service is in focus.

Scale mismatches

Taken together, the case studies indicate several possible factors that give rise to scale mismatch. Apart from the unattended scale of green networks from above, another factor is that management of urban green space in Stockholm is formally organized by the municipalities according to user purposes. This has influenced the way managers (like park and cemetery managers) employed by the municipalities perceive their local green area. Instead of viewing their green areas as part of an ecologically linked landscape, they are seen as belonging to a group of spatially distant areas assigned to the same user classification (II, cf. Sandström et al. 2006a). Cemetery managers for example, tend to form stronger social ties with other cemetery managers, and less—if any—with actor groups from adjacent green areas (II, III). The same is true for allotment garden associations that have less contact with adjacent green area managers, but strong local ties within the same association and weaker ties to other allotment associations through their umbrella organizations (I). This lack of social ties between actor groups of adjacent green areas indicates a limited ability to synchronize management across space, for instance in providing complementary habitats for functional groups such as pollinators and seed dispersers (cf. Colding 2007). Although our studies of a selected set of urban parks and nature reserves in Stockholm indicate that there is awareness amongst managers of the need for management at a range of spatial scales, there is less acknowledgement of the need to be able to understand interactions across scales (II). This focus at a particular scale indicates lack of capacity in the governance system to learn about cross-scale ecosystem dynamics (Gunderson et al.

1995a). Another factor of spatial mismatch is that municipalities hold the monopoly of spatial planning, which sharpens the borders between municipalities and hinders cross-border cooperation; an area zoned for recreation in one municipality may be scheduled for industrial development across the border.

One central finding is that a large proportion of urban green areas are ecologically undervalued due to a narrow definition used by authorities of what is considered a "green area" (VII, Lundgren Alm 2001). Local green areas such as allotment gardens, golf courses, and private home gardens tend to be classified as "developed land" and are not recognized as green areas sustaining landscape ecological processes (VII). This reflects similar findings from Baltimore (Pickett et al. 2008). It seems that this limiting definition of green areas limits the dialogue between managers and planners employed by state agencies (who focus on protected land and urban parks) and actor groups in so-called "developed land". This gives rise to scale mismatches because the role that such local green areas play in sustaining species movements across space is ignored in governance processes (III).

Other elements of scale mismatches have their roots in the goals and methods used by management authorities. Although regional authorities articulate the importance of facilitating large-scale ecological flows, authorities' objectives at the local scale are narrowly focused on endangered species and biodiversity conservation (VII), and thus fail to address how local green areas sustain greater scale processes. Moreover, in park and protected area management there is a general lack of monitoring and evaluation, which impedes trial-and-error learning (II, Gunderson et al. 1995b).

Another cause for scale mismatch in governance pertains to not drawing on experience of local change. We identified local green area managers who, in spite of their important role in supporting the generation of ecosystem services, are more or less unrecognized by state agencies (I, III). Because on almost a day-to-day basis they monitor ecosystem processes, allotment gardeners, bird-watching associations, park and 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 (cf. Holling 1978). In pressing this further, one case study made an interesting finding when comparing volunteers from allotment gardeners with employed personnel of cemeteries and urban parks. The former group exhibited greater local ecological knowledge and the widest range of management practices that offered protection of species and improved habitat to sustain pollination and seed-dispersal processes (III). Further studies showed that allotment gardens have through time evolved into communities of practices (I, Wenger 1998) which, through their rules-in-use and strong social ties, have created means by which knowledge, experience, and practices about how to manage a local ecosystem are retained, stored, modified, and transmitted. Barthel et al. (2010, I) define this as social-ecological memory, and note that a prerequisite for its emergence is long-term property rights because social-ecological memory depends on the length of time of lived collective experience. Social-ecological memory is further seen as a quality of communities of practices that engage in place-specific management on the ground, and it enables actor groups to adapt to gradual change and retain experiences and modify practices in relation to a constantly changing world (I, III, cf. Scott 1988). Importantly, and partly because allotment gardeners care for flowers, vegetables, fruits, and berries, their practices underpin processes for sustaining pollination and seed dispersal. Actor groups with such qualities are consequently of crucial importance for urban ecosystem governance, and could serve as examples for how to further develop social-ecological learning arenas (Colding in press).

Moreover, our studies showed how civil society groups attached to local green areas have organized to protect the green areas from exploitation, thus influencing ecosystem functioning by changing the patterns of urban development (IV, cf. Alberti 2005). Our studies suggest that protection partly rests upon the capacity of actors to articulate values for green areas in competition with other land-use interests such as infrastructure, offices, and housing (IV). Areas attracting a high diversity of interest and user groups seem to stand higher chances of being protected because this increases the possibility of collective action, as exemplified in other studies (Diani 1995, Ansell 2003).

Local actor groups that sustain social-ecological memory and mobilize protective capacity are important for green area governance, both for capturing and retaining knowledge to prepare for ecosystem disturbance (I, IV), and for protecting key green areas. However, our studies also indicate that local actor groups tend to ignore ecological processes transcending their focus area (I, II). Given the finding from above that municipal managers and urban planners have a wider landscape perspective (III), this indicates that by combining and negotiating the knowledge and experience of local groups and planners, complementary knowledge for governance can be constructed.

Collaborative attempts

Municipal and regional agencies hold a key role in planning and managing urban green areas. Several efforts to engage in collaboration with nonstate actors concerning urban biodiversity have been launched by the Stockholm municipality, 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 (Östergård 2003, SNF 2009). Further examples of green area co-management consists of wetlands, urban forests, local neighborhoods, and gardens managed by way of user-group contracts (in Swedish, "brukaravtal") (I). However, our studies indicate that these efforts seem to lack an overall strategy of how emergent social networks can be harnessed for dealing with scale mismatches and the management of ecosystem services across the landscape. In the case of user-group contracts, which are short-term management rights granted by state agencies to local actors, their implementation rarely involves meeting in arenas of dialogue and negotiation, or sharing of experiences. In the discussion section we elaborate on strategies towards creating more purposeful networks for ecosystem governance.

DISCUSSION

Based on our findings, and from a view that ecological processes are key in supporting ecosystem services, we argue that the current governance of Stockholm's green area ecosystems does not fully appreciate the connection between land-use and ecological functions, that current governance neglects cross-scale dynamics, and that

actors involved in green area management need to engage in closer dialogue. While actors on the regional scale do recognize ecological functions within the landscape and include them in planning to some degree, actors on other scales do not hold this holistic landscape view. Certain local actors, such as allotment gardens and cemetery and park managers, are valuable for sustaining practices that support ecosystem services but they are currently often neglected in governance. The municipalities, in turn, mainly define and manage green areas from a socially informed viewpoint as user-areas, thus downplaying ecological dimensions. This constrains action to account for landscape ecological processes and seems to give rise to homogenous social networks that do not bridge to other actor groups.

In Table 2 we have summarized the effects of these findings and provided suggestions for how to improve governance. In the following we discuss important components of an improved governance regime for Stockholm. Furthermore, we take our findings as the departure point for a theoretical discussion on how to nurture social network structures capable of bridging scales and sustaining ecosystem services, especially those linked to pollination and seed dispersal.

Envisioning a social network structure for improved ecosystem governance

The priority of a new adaptive governance regime should be the provision of ecosystem services, i.e., the capacity of ecosystems to deliver benefits to citizens. This would recognize already existing recreational, cultural, aesthetic, and open space values, but would need complementation by addressing landscape ecological processes that support ecosystem renewal. Based on our results we argue that governance should be organized at the three ecological scales suggested earlier. Given that there are already actors at the local green area scale and at the green infrastructure scale (Fig. 5), the emergence of midscale managers are of central importance, especially for increasing ecosystem functioning across scales. We will further argue for the need of actors aiming for the network position of scale-crossing broker, especially for enhancing flexibility in governance. This preferred transformation would represent a move towards deliberative partnership with civil society and is sketched in Fig. 5.

Enhancing ecological functioning: midscale managers, city scale green networks, and scale-crossing brokers

Midscale managers should focus on facilitating ecosystem management of city scale networks. They should provide actor groups engaged in local green area management with an ecological context so that the latter could adapt some of their management practices to strengthen landscape ecological processes, especially pollination and seed dispersal. Midscale managers should hold a more dynamic view of 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., cattle grazing, cutting down patches of trees, or even using fire, might be opposed by certain groups and could therefore be difficult to apply. Thus, to reach their objective of fine tuning the landscape matrix in space and time, midscale managers should be the ones identifying, in deliberative consultations and negotiations with interest groups, which green areas could be used for such practices.
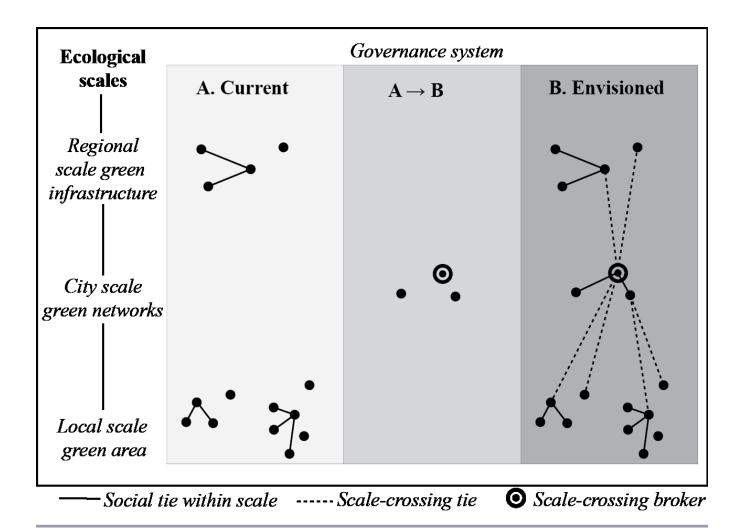
City scale networks consist of a selected set of local green areas and their dispersal corridors. Tools for identifying them as species-specific networks for pollination and seed dispersal exist, e.g., by modeling species movement using digital mapping and network theory, paired with biodiversity ground truthing (V, Keitt et al. 1997, Urban and Keitt 2001, Löfvenhaft et al. 2002). A complicating matter is of course that city scale networks will be different for different ecosystem services. Pollinators and seed dispersers simply do not move in the same patterns, or have the same habitats, and the city scale network of noise reduction will not be the same as that of recreation. However, we would argue that by basing governance on city scale networks of pollination and seed dispersal—being spatially complex processes—governance could support a whole bundle of other ecosystem services that are less dependent on the spatial configuration of green areas. For instance, by selecting shrubs and trees that offer good noise reduction and flower at different points in time, both pollination and noise reduction could be supported.

City scale networks could overlap to different degrees by sharing green areas and dispersal corridors. This would require different governance

Table 2. The table summarizes findings, their effects on current governance, and recommendations for improvements.

Analysis		Description
Findings from case-studies	1.	Management is formally divided between separate sectors, state agencies, and municipalities, and is based upon preserving certain user-classified values rather than on sustaining ecosystem processes in the landscape.
	2.	Many urban green areas are ecologically undervalued due to a narrow definition of "green area", especially allotment gardens, golf courses, and private home gardens are classified as "developed land".
	3.	Actor groups from civil society with capacities for management and protection of local green areas are not sufficiently acknowledged, nor engaged with, by state agencies. The few examples of engagement that exist are made on an ad hoc basis.
	4.	Some social networks span across space, but tend to stretch only within the same actor group (e.g., cemetery managers do not communicate with allotment gardeners).
	5.	At least three relevant ecological spatial scales of importance for governance were identified: local scale green areas, city scale green networks, and the regional scale green infrastructure. City scale green networks are defined as sets of local green areas and their dispersal corridors.
Effects on current governance	1.	The midscale of city scale green networks is not addressed by any actor group, and cross-scale dynamics are missed due to: (a) a lack of information flows between actor groups engaged at different spatial scales, and (b) a general lack of awareness of the importance of ecological cross-scale dynamics.
	2.	Low flexibility for adapting to changes in ecosystems due to: (a) rigid sector divisions and strong administrative borders hampering cross-border cooperation between municipalities, and (b) poor communication between most actors, which undermines social learning and collective action in response to rapid changes.
Suggestions for improved governance	1.	Align governance along three spatial scales—local scale green areas, city scale green networks, and regional scale green infrastructure—and let the generation of ecosystem services be a more pronounced goal in green area management.
	2.	(a) Include local actor groups from civil society, and (b) introduce scale-dependent responsibilities for all actor groups, while (c) appointing/nurturing midscale managers responsible for the governance of city scale green networks.
	3.	Facilitate for certain actors to gain the network position of scale-crossing broker. It is necessary for these actors to hold a holistic landscape view and knowledge of ecological processes. The strategy of a scale-crossing broker would be to: (a) link disconnected actor groups on multiple spatial scales, (b) sustain and support local actor groups (i.e., sustain network diversity), and (c) coordinate collaborative action across scales for social learning and in response to disturbance.

Fig. 5. The figure shows a simplified image of the findings, and of the relations and actors that seem desirable to drive a transformation of current governance. Currently in Stockholm (A) there are actors at the lowest and highest ecological scale. By introducing (in A→B) midscale managers responsible for city scale green networks, and scale-crossing brokers focusing on networking across ecological scales, a new social network structure for governance could emerge (B) that could better handle scale mismatch between social and ecological processes.

arrangements. In cases of marginally overlapping, organism-specific processes—as in pollination and seed dispersal—midscale managers can work quite independently in generating a looser governance network of high modularity (i.e., several loosely connected groups). However, if city scale networks strongly overlap, a more tightly connected governance network would be required with lower modularity. The social ties between midscale managers would be vital in regulating this network modularity. It could, however, also be that a midscale manager is responsible for the city scale networks of both pollination and seed dispersal, thus giving maximum social connectivity. Figure 4 illustrates two city scale networks in the same physical area and how they are associated to different midscale managers. The figure furthermore suggests how these particular ecosystem services are embedded in the social networks of local actor groups (managing local green areas), scale-crossing brokers, and municipal to regional agencies and organizations.

To increase the systemic ability of the governance network to prepare and respond to change, we posit that scale-crossing brokers are needed in Stockholm. Analytically, scale-crossing brokers are positions in the network that link across ecological scales (as in Fig. 1), but actors (i.e., persons or organizations) can occupy or attain such positions by strategically networking with other actors. However, this also means that actors can fail to sustain this position, either through fault of their own, or because the rest of the network changes (cf. Burt 2005). We could thus talk about actors as scale-crossing brokers (when they are in position), but we need to remember that this designation is relational (and not essential) because it is derived from the relations in the network. Remembering this, scale-crossing brokers can be viewed as agents that continuously strive to create and sustain a purposeful network structure for ecosystem governance, while sustaining their own position.

The required strategy to attain and sustain a scale-crossing broker position would be to network with many actors, with different types of actors, and with actors at different ecological scales, while simultaneously striving to sustain and increase actor diversity. This strategy needs to be translated into a "scale-crossing practice" through which enough legitimacy can be built to influence and engage other actors in social learning, while holding on to the structural position (cf. Burt's (2005) discussion on "structural holes" and their dynamics). The empirical literature on bridging organizations and institutional entrepreneurs can inform this practice because the literature stresses skills like trust building and social contracting (Westley and Vredenburg 1991, Kooiman 1993, Westley et al. 2002, Hahn et al. 2006, Manring 2007, Olsson et al. 2007). However, because this literature does not consider the structure of social networks it tends to overlook the cost of having social relations. This is grave because it misses a fundamental dilemma: to sustain many social ties means they are weak and provide less opportunity for trust and social learning, while to invest in stronger and more costly ties means to lose other ties and thus the brokerage position. More research is needed here in the context of ecosystem management, although an answer might lie in the possibility that scale-crossing brokers can be organizations of collaborating individuals. Another basic quality of actors attaining a scale-crossing broker position is ecological knowledge, and a holistic landscape view is needed if the broker is to capture and build

understanding out of the diverse information received from different actors at different ecological scales.

Midscale managers and actors sustaining scale-crossing broker positions could have similar traits and might work in the same organization. However, the former has a clearer spatial responsibility, with focus on ecological dynamics for particular city scale networks, while the latter focuses on social networking to bridge across ecological scales.

Enhancing the flexibility of governance with scale-crossing brokers

Ecosystem governance, as part of our earlier criteria, needs to be able to switch between two basic modes of action: preparing for disturbance, and responding to disturbance. Whereas the first mode is about nurturing actor diversity, i.e., to allow for spatially distributed and diverse ways of capturing and storing place-specific information of local social-ecological dynamics, the latter means to initiate effective collective action through more centralized forms of decision-making (Crumley 1994, 2000; van der Leeuw 2000; Crumley 2003; Folke et al. 2005; Duit and Galaz 2008). Theoretical insights on how to uphold these modes of governance simultaneously can be provided by considering the structure of social networks and the practices of scale-crossing brokers.

The number of possible ways of collective action in a social network depends on the patterns of actor diversity, i.e., on the structure of the social network (Leavitt 1951, Diani 2003, Burt 2005, Ernstson et al. 2008). In that sense, scale-crossing brokers, by linking otherwise unconnected actors, become exceptional crossroads of possibilities (Burt 2005). Scale-crossing practices should thus be seen as the practice of creating new and unique pathways for a diversity of actor groups to meet and exchange experiences, with the aim of nurturing arenas of innovation so as to make possible a greater range of purposeful collective actions. Through such arenas, captured experience of change and successful adaptations from various and spatially distributed parts of the landscape can be negotiated and debated for how to prepare for ongoing change and uncertain futures. In relation to pollination, an example from Stockholm would be the information about the location of nests of wild bees known by allotment gardeners, which can be passed on to municipal

employees to avoid the destruction of nests when bush lands are cleared. Several such learning arenas (Berkes et al. 2003, Olsson et al. 2004b, Fazey et al. 2006, Hahn et al. 2006) could be initiated and promoted by scale-crossing brokers as part of their practice, although the responsibility to sustain and nurture these learning arenas—or even close them down—could be passed to other actor groups (Danter et al. 2000, Manring 2007).

The ability in governance processes to recognize gradual changes in ecosystem dynamics depends on the engagement 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. Consequently, and as part of their strategy to remain in their position, scale-crossing brokers should strive to sustain or even increase the diversity of actors in the network (cf. Olsson et al. 2006). One strategy might be to lobby for more local management rights to user groups. However, to sustain actor diversity requires awareness of the general tendency of powerful actors (including the scale-crossing broker) to superimpose top-down ideas and practices on other actors (Agrawal and Ostrom 2001, Ostrom 2008). It is not the diversity of actor groups per se that is of value here, rather it is the diversity by which actor groups interact with ecosystems, i.e., the diversity of social practices mobilized through the governance network. Our idea of a decentralized network for green area governance should therefore be accompanied by robust property rights that can generate self-organization in communities of practice (Agrawal and Ostrom 2001, Barthel et al. 2010, Colding in press).

Scale-crossing brokers can also enhance the ability of governance to switch modes and respond to disturbances by initiating and coordinating collective action (Burt 1992, Westley et al. 2002, Burt 2005, Olsson et al. 2006). Situated in a unique network position where diverse and up-to-date flows of information and knowledge can meet, including scientific and local experiential knowledge, the scale-crossing broker will have greater potential than other actors to create novel understandings and see new innovative opportunities (cf. Burt 2002, 2005). Further, through knowing many different actors, the broker will tend to know which actors to connect (and not to connect), how to connect them, and when, thus bringing an ability to take earlier and case-appropriate action to find

new collaborative solutions for novel situations; this is an ability named "adaptive implementation" by Burt (2002). In great part, it is the position in-between other knowledgeable and resourceful actors at different ecological scales that bring these abilities to the scale-crossing broker, i.e., these abilities have a relational foundation. For example, if a pest outbreak or a new invasive species is recognized and responded to locally by an allotment gardener, and it threatens to diffuse over wider landscapes, the scale-crossing broker would be best positioned to find financial means, engage experts, and guide further collective action using its many and diverse social ties. 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.

Scale-crossing brokers can, as argued above, be seen as agents for nurturing the emergence of a purposeful social network structure, and for switching between a centralized collective action mode and a decentralized mode of social learning among a diverse set of local autonomous actor groups. Although scale-crossing brokers become key for producing this "switching capacity", the ability to switch modes could also be facilitated by collaborative scenario-building exercises, for instance the construction of maps and narratives aiming to generate an holistic landscape view among actors to help coordinate collective action (cf. Ernstson and Sörlin 2009). However, we, along with others (Folke et al. 2005, Duit and Galaz 2008), believe that the mechanisms and practices of switching between modes need further research. More in-depth studies are required to investigate how social practices, world views, power relations, and networking capabilities of different actor groups are interrelated to create barriers for social learning and collective action outside the group (Wenger 1998, Westley et al. 2002, Folke et al. 2003).

Emergence and accountability of scale-crossing brokers

The question of how midscale managers and scale-crossing brokers emerge—or are incentivized to emerge—along with issues of legitimacy, power, and accountability in network governance, are problems in themselves and lie outside the scope of this paper. However, because social network

structure is a product of localized interactions, it can never be as easy as just "placing" oneself, or another actor, in the scale-crossing broker position; all actors, from allotment gardens to state agencies, need to act through and within the network—there is no "outside" nor any external "control knobs". This paper has merely clarified certain strategies and practices for how actors could reach a scale-crossing broker position. Authorities (e.g., the environmental department at the city) could possibly create incentives in the form of project funding, or even salaries, to invest in individuals or organizations so they can learn and develop these practices, and have access to extra resources so as to meet with local actor groups and formal authorities to build and sustain their network. Based on such public funding, a certain institutional embedding could be created around actors striving for a scale-crossing broker position, which could be joined with defined discretional power. This would not only create mechanisms for periodic evaluation, but also possibly aid in sustaining a scale-crossing broker over time. In Stockholm, local authorities, civil servants, and certain civil society organizations would possibly be willing to receive extra funding to develop the position of scale-crossing broker, partly as a way to gain influence and prestige. From empirical studies (although from less urbanized areas) examples also exist of how single actors, partly supported by authorities, have been able to forge new social ties and expand institutional space for ecosystem management (Olsson et al. 2004b, Olsson et al. 2008), thus apparently having attained brokerage positions. Nonetheless, because scale-crossing brokers become influential through their network position, mechanisms of their accountability remain to be explored (cf. McLaughlin and Dietz 2007).

CONCLUSION

How do we identify social networks of governance able to navigate the dynamic nature of multilevel and multiscale social-ecological systems so as to secure the flow of urban ecosystem services? In this article we have shown how this question can be addressed by synthesizing a set of case studies from Stockholm and comparing them with a theoretical framework combining ecological scales and social network structure. We have aimed to provide an analytical lens to assess governance and come up with suggestions for improvements; the main analytical components of this lens are ecological

scales, actor groups, social networks (with weak and strong social ties), and scale-crossing brokers. Furthermore, based on our findings, we have worked out theoretical insights for what seems to be suitable social network structures for ecosystem governance, and proposed principles for scale-crossing practices on how to nurture and sustain such structures. We believe this framework could also be fruitfully applied to other case studies.

We stress that our framework explicitly strives to identify ecological scales that have been less rigorously pursued by others (Manring 2007, Pahl-Wostl et al. 2007, Grimm et al. 2008), but have been argued as crucial by many (e.g., Nyström and Folke 2001, Cumming et al. 2006). As was discussed earlier, the mesoscale of city green networks influenced our exploration of the governance network. Furthermore, whereas other governance frameworks have dealt less explicitly with space— e.g., polycentric structures (Ostrom 1998); multilevel, collaborative, and adaptive governance (Folke et al. 2005, Pahl-Wostl et al. 2007, Duit and Galaz 2008); and learning networks (Manring 2007) —our framework attempts to articulate that ecosystem governance necessarily "takes place", i.e., that the physical location of ecosystems, their associated actor groups, and their arrangement in space do influence ecological processes.

However, this spatial concern should be further developed. An exciting challenge lies in developing robust ways of analyzing spatial social-ecological networks, where nodes could be both social and ecological entities (Cumming et al. 2010). Also needed are criteria for how to allocate city scale networks in space (i.e., which green areas to include and exclude from management units), and ways to determine their overlap. A promising approach is to base city scale networks on mobile links such as pollinators and seed dispersers that connect habitats in space and time and are important for ecosystem renewal after disturbance (Nyström and Folke 2001, Lundberg and Moberg 2003, Bodin et al. 2006b, Lundberg et al. 2008). A mobile link approach could be combined with ideas on how ecosystem services can be spatially managed as "bundles" in multi-use landscapes (Goldman et al. 2008).

Given the rapidity of world-wide urbanization, and based on our multiple studies in Stockholm, we call for a greater appreciation of urban green areas. Besides being seen as public open spaces and as parts of green patterns that generate and distribute

ecosystem services, urban green areas should also be recognized as sites of learning and interaction between humans and ecosystems. As such they become physical sites of social-ecological interaction, which in turn allows for intentional human action in modifying and sustaining urban ecological processes. As our studies show, urban green areas that allow for citizens to engage in ecosystem management can nurture place-specific learning of ecosystem dynamics that have crucial importance for adaptive ecosystem governance.

Responses to this article can be read online at:
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responses/

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