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Research

Strategic Spatial Planning and the Ecosystem Services Concept – an Historical Exploration

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ABSTRACT. This study examines how ecosystem services (ES) have been taken into account historically in strategic spatial plans in Melbourne and Stockholm through a comparative case study analysis of eight strategic spatial plans from 1929-2010. We investigated the types of ES taken into account, and how human-nature relations and the valuation and trade-off discussions regarding ES were framed. An ES coding protocol was developed that categorized and identified 39 ES drawing from the Millennium Ecosystem Assessment and other relevant literature. Only two of the 39 ES were addressed in every plan for both cities, namely freshwater and recreation. While the number of ES referred to in plans has generally increased over time, just under a third of ES in Melbourne and Stockholm were not addressed at all. References to individual ES showed little continuity over time. This variability reveals a time-scale mismatch that has been overlooked in the ES literature with potential urban policy implications. Despite considerable variation in ES addressed across the plans, there is a striking similar pattern in the total numbers of ES addressed over time in both cities. Plans for both cities showed a spike in the late 60s/early 70s, followed by a significant decline in the late 70s/early 80s with the highest number of ES addressed in the most recent plans. Furthermore, our analysis shows that strategic spatial plans generally demonstrate awareness that urban populations are dependent on ecosystems and this framing is an important part of the policy discourse. While specific monetary values were not placed on any ES in the plans, resolution of land-use conflicts requiring tradeoffs between ES and equity of distribution of ES is a central feature of most of the examined plans. We argue that longitudinal policy document analysis represents a useful complement to any attempt to improve understanding of the implications of and opportunities for operationalizing an ES approach in urban practice.

Key Words: *ecosystem services; Melbourne; Stockholm; strategic spatial planning; urban ecology, urban governance*

INTRODUCTION

Urban populations rely on ecosystems within cities for services such as recreation, microclimate regulation, erosion control, and air filtration (Bolund and Hunhammar 1999, Martinez-Arroyo and Jáuregui 2000, Niemelä et al. 2010). City inhabitants also depend on the ecological footprint provided by ecosystems outside of cities for the supply of food, fiber, and other services (Folke et al. 1997). Urban populations are large consumers of ecosystem services (Folke et al. 1997, McGranahan et al. 2005, Grimm et al. 2008) and a key source of global environmental impacts (Bai 2007) in a time when ecosystems are in rapid decline (Millennium Ecosystem Assessment 2005). A key urban governance challenge is to find ways to make visible the dependence that urban populations have on local and distant ecosystems and have this taken into better account through democratic decision making processes. The concept of ecosystem services (ES) is an attempt to articulate this relationship by identifying the services that biodiversity provides for human benefits.

Ecosystem services (ES) can be defined as "the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life" (Daily 1997:3). An ES approach can be advocated for many purposes, although three major reasons stand out in the ecological literature. First, the ES approach identifies a more extensive set of benefits that humans derive from ecosystems in an attempt to make visible more concealed types of ES. To this end, the Millennium Ecosystem Assessment (2005) identifies four categories of ES, depending on the type of benefit they provide humans with:

- Supporting services are the services that underlie all other ES, e.g., water cycling, nutrient cycles, and biodiversity.
- Provisioning services are the services that maintain the production of goods, e.g., food, timber, and freshwater.
- Regulating services are the services that regulate ecosystem processes, e.g., pollination, climate regulation and water purification.
- Cultural services are services that provide humans with intangible benefits and are of significant value for social, psychological, and physical well-being, e.g., aesthetic and recreational values.

Secondly, an ES approach raises awareness that humans are dependent on ecosystems and that the current rate of loss of biodiversity is detrimental to human well-being. The third major purpose of an ES approach is to enable the valuation (monetary and nonmonetary) of ES in order to inform better trade-off decisions through public policy processes. The term ES highlights ecological and economic linkages (Norgaard

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Table 1. Strategic spatial plans included in analysis

MELBOURNE		STOCKHOLM	
Year	Strategic Spatial Plan	Year	Strategic Spatial Plan
1929	Plan of General Development - Melbourne	1936†	Regional plan for Stockholm
1954	Melbourne Metropolitan Planning Scheme 1954	1958	Proposal for regional plan for the Stockholm area
1971	Planning Policies for the Melbourne Metropolitan Region	1966†	Outline 66 for a Stockholm region plan
1980	Metropolitan Strategy (Melbourne Metropolitan Board of Works 1980)	1973	Regional plan 1973 for Stockholm County
1987	Shaping Melbourne's Future	1978	Regional plan 1978 for the municipalities in Stockholm County (Stockholms läns landsting - Regionplane- och näringslivsnämnden 1982)
1992	A Place to Live	1991	Regional plan 1991 for Stockholm County 1990-2020
1995	Living Suburbs: a policy for metropolitan Melbourne into the 21st Century	2001	Regional Development Plan 2001 for the Stockholm region
2002	Melbourne 2030: planning for sustainable development	2010	Stockholm Regional Development Plan 2010 (Exhibition proposal)

† These two plans were not formally adopted but were used in practice (RTK 2002) and thus included in the analysis.

2010) emphasizing economic values of ecosystems and thus facilitating increased consideration of them in economic valuation frameworks (Daily et al. 2009; Gómez-Baggethun et al. 2009). In the 1980s and 1990s, several valuation methods were initiated (e.g., Costanza et al. 1997). Since then, the ES concept has been taken up more broadly in economic related policy arenas, most recently in "The Economics of Ecosystems and Biodiversity" study (Sukhdev et al. 2010). It has also become incorporated in various markets and payment mechanisms (e.g., Bayon 2004).

The importance of improved understanding of urban generation of and demand for ES has been increasingly recognized in the urban ecology literature (Bolund and Hunhammar 1999, Kroll et al. 2005, Andersson 2006, Colding 2007). Recently, the concept of ES has more broadly been advocated as a useful framework for urban planning (Niemelä et al. 2010, Colding 2011). However, no systematic analysis has to our knowledge been conducted to examine in what ways an ES approach has been addressed historically in strategic spatial planning.

We contribute to addressing this gap through a comparative case study of strategic spatial plans from Melbourne and Stockholm during 1929-2010. Strategic spatial planning represents an established urban governance policy tool across most developed countries and articulates government policy regarding land use and development around metropolitan regions (Healey 2006). Hence, it provides a window into how human–nature relations are conceptualized in public policy discourse and how ecologically related matters more generally are taken into account through formulation of integrated policy.

Research questions and overview

Three overarching questions have guided this research: (1) What ES are taken into account in strategic spatial plans, which ones are not considered, and what insights does use of the comprehensive ES framework enable? (2) How do strategic spatial plans frame relations between humans and ecosystems consistent with an ES approach? (3) How are discussions regarding valuation of ES framed in strategic spatial plans? We begin by providing a brief history of the development of the ES concept, followed by an historical account of the way human–nature relations are addressed in urban design and planning practice. This is followed by a description of the methodologies used in the analysis. Results are discussed, followed by a concluding section distilling the broader policy implications of an ES approach in urban practice.

METHODS

A comparative case study analysis of strategic spatial plans from Melbourne (Australia) and Stockholm (Sweden) was conducted in order to probe the relevance of the ES approach in such plans. The two city regions were chosen based on the authors' previous work in them through case studies in urban ecology as well as from experience in planning practice. Moreover, comparison between the two city-regions was enabled due to the fact that plans from both regions share similar history with respect to when metropolitan scale strategic spatial planning commenced. In addition, the number of strategic spatial plans and the broad scope of such plans were generally similar, making comparison less problematic.

All strategic spatial plans addressing the city-region scale from both cities that were officially adopted or had a significant impact in practice according to published accounts were examined. This resulted in eight plans for each city-region, spanning from 1929-2010. Table 1 lists each plan showing the varied frequency of these across both cities. The plans were analyzed using content analysis (Yin 2009), which focuses on the content of communication, as well as interpretive policy analysis (Yanow 2002), which focuses on the meanings of a

policy, including what values are expressed. An ES Coding Protocol was designed to enable consistency of coding across the two cities and between the different plans in each city.

The ES Coding Protocol (see Appendix) is based on the four categories used in the Millennium Ecosystem Assessment (Millennium Ecosystem Assessment 2005), i.e., supporting services (coded A), provisioning services (B), regulating services (C) and cultural services (D). Identified ES were grouped into the four categories, complemented by additional literature analysis (i.e., Daily 1997, Bolund and Hunhammar 1999, Maas et al. 2006, Forest et al. 2011) to make sure that services dealt with in the plans were not missed. The ES Coding Protocol comprises five columns as follows:

ID: the unique code for each ES, e.g., A1, A2, A3, B1, C1, etc.

Ecosystem service: the name of the ES with the primary scientific source in brackets, e.g., water cycling (MA 2005)

Descriptor (MA): descriptor of the ES as referenced in the MA

Descriptor (other): descriptor of the ES as referenced in other scientific literature

Coding formulations: examples how each ES is referenced in the plans.

A draft ES Coding Protocol was piloted with complete data set analysis across Melbourne and Stockholm before being finalized. This pilot process refined the list of ES, the descriptors, and coding formulations to enable coding consistency. The descriptors for each ES clarify the ecological characteristics, based on the scientific literature used (as referenced in the "descriptor" column of Appendix 1). The coding formulations provide examples of how ecological characteristics are referred to in the plans.

Coding of the plans using the ES Coding Protocol involved the following steps: All plans were read through at least twice and quotations containing references to ES were transcribed into a spreadsheet and coded consistently with the ES Coding Protocol. These data formed the basis for addressing our three overarching research questions. The particular methods used to address each question will now be outlined.

Methods for addressing Research Question 1

"What ES are taken into account in strategic spatial plans, which ones are not considered, and what insights does use of the comprehensive ES framework enable?"

The excel spreadsheets generated using the ES Coding Protocol were used to identify which plans made at least one reference to each ES. The "ES Coding" column of the Excel worksheet for each city was examined to identify each unique ES in the ES Coding Protocol. If an ES was referred to in a plan it was marked as present with a cross (X) in each table that summarizes results for this research question (see Tables 2 and 3). We do not present how often each ES was referred to in the plans on the grounds that the plans had different lengths, writing styles, and foci of interest, making a fair interpretation of such quantitative findings difficult. It should be emphasized that reference to an ES in a plan implies only that it has been addressed (sometimes to a limited extent) in the policy discourse and does not mean that the ES has been addressed through detailed implementation. This is an important additional avenue of research but beyond the scope of this study.

Methods for addressing Research Question 2 and 3

"How do strategic spatial plans frame relations between humans and ecosystems consistent with an ES approach? How are valuation discussions regarding ES framed in strategic spatial plans?"

The quotes contained in the Excel spreadsheets forming the ES Coding Protocol were analyzed to identify key analytic categories (after Strauss and Corbin 1998) regarding the framing of human–ecosystem relations and how ES valuation discussions were framed in the plans. This method draws on grounded theory (Strauss and Corbin 1998, Bryant and Charmaz 2007) in which sense is made by the analyst of diverse data through a process known as "conceptual ordering", whereby data are organized into "discrete categories" depending on their "properties and dimensions" (Strauss and Corbin 1998:19). This was done for each city separately. These were then brought together to enable comparison. In some cases an issue was identified for one of the cities that required additional source document analysis of plans for the other city. This sometimes resulted in the identification of additional relevant quotes that discussed human–nature relations or addressed ES valuation generally without reference to the specific ES.

RESULTS

Research Question 1 - ES in examined strategic spatial plans

With regard to research question 1, Tables 2 and 3 summarize the results of the detailed content analysis of which ES were and were not referenced across all of the Melbourne and Stockholm plans.

Only two ES (of the 39 ES coded for) are addressed in every plan for both cities, namely "freshwater" (B4) and "recreation" (D6). Whilst for Stockholm these are the only ES referenced in every plan, for Melbourne "aesthetic values" (D4) is also referenced across all plans. Four ES are not addressed in any of the plans in either city, namely "primary production" (A4), "disease regulation" (C5), "inspirational" (D5) and "spiritual and religious values" (D9). In both Melbourne and Stockholm, just over two thirds of ES are addressed at least once in at least one plan. In Melbourne, 12 ES (just under one third) were not addressed at all (nutrient cycling – sulfur, primary production,

Table 2. Ecosystem services addressed in Stockholm's strategic spatial plans

Strategic Spatial Plans Ecosystem Services	1936	1958	1966	1973	1978	1991	2001	2010	Total
Supporting Services									
A1 Water cycling	X	-	X	-	X	X	X	X	*6*
A2 Soil formation	-	-	-	-	-	-	-	-	-
A3a Nutrient cycling - carbon cycle	-	-	-	-	-	X	X	X	*3*
A3b Nutrient cycling - nitrogen cycle	-	-	X	-	-	X	X	X	*4*
A3c Nutrient cycling - sulfur cycle	-	-	X	-	-	X	X	-	*3*
A3d Nutrient cycling - phosphorus	-	-	X	-	-	X	X	X	*4*
A4 Primary production	-	-	-	-	-	-	-	-	-
A5 Photosynthesis	-	-	-	-	-	X	-	-	*1*
A6 Biodiversity	X	X	X	-	X	X	X	X	*7*
Sub Total - Supporting	*2*	*1*	*5*	-	*2*	*7*	*6*	*5*	
Provisioning Services									
B1 Food - agriculture	-	X	X	X	X	-	-	X	*5*
B2 Food – commercial fishing	-	X	X	-	-	-	-	X	*3*
B3 Food - wild	-	-	X	-	-	-	-	-	*1*
B4a Water - fresh water	X	X	X	X	X	X	X	X	*8*
B4b Water - energy	-	X	X	-	-	-	-	-	*2*
B4c Water - transportation	X	X	X	-	-	X	X	X	*6*
B5 Biochemicals/genetic resource	-	-	-	-	-	-	-	-	-
B6 Fiber	-	-	X	X	X	-	-	X	*4*
B7 Fuel	-	-	-	-	-	-	X	X	*2*
Sub Total - Provisioning	*2*	*5*	*7*	*3*	*3*	*2*	*3*	*6*	
Regulating Services									
C1a Climate regulation - local	-	-	-	-	-	-	-	X	*1*
C1b Climate regulation - global	-	-	-	-	-	-	-	-	-
C2 Air quality regulation	-	-	X	-	-	X	-	X	*3*
C3 Water purificat'n/waste treatment	X	-	X	-	-	-	X	X	*4*
C4 Water regulation	-	-	-	-	-	-	-	X	*1*
C5 Disease regulation	-	-	-	-	-	-	-	-	-
C6 Pest regulation	-	-	-	-	-	-	-	-	-
C7 Natural hazard regulation	-	-	-	-	-	-	-	-	-
C8 Erosion regulation/soil retention	-	-	-	-	-	-	-	-	-
C9 Pollination	-	-	-	-	-	X	X	X	*3*
C10 Seed dispersal	-	-	-	-	-	X	X	X	*3*
C11 Noise regulation	-	-	X	-	-	-	-	-	*1*
Sub Total - Regulating	*1*	-	*3*	-	-	*3*	*3*	*6*	
Cultural Services									
D1 Social relations	-	-	-	-	-	-	-	X	*1*
D2 Cultural landscape, heritage values	X		X		X	X	X	X	*6*
D3 Sense of place	-	-	-	-	-	-	-	X	*1*
D4 Aesthetic	X	-	X	-	X	-	-	-	*3*
D5 Inspirational	-	-	-	-	-	-	-	-	-
D6 Recreation and eco-tourism	X	X	X	X	X	X	X	X	*8*
D7 Educational and knowledge	-	-	-	-	-	-	-	-	-
D8 Health	-	-	X	-	-	-	X	X	*3*
D9 Spiritual and religious values	-	-	-	-	-	-	-	-	-
Sub Total - Cultural	*3*	*1*	*4*	*1*	*3*	*2*	*3*	*5*	
TOTAL	8	7	19	4	8	14	15	22	

photosynthesis, food – wild, climate regulation – local, disease regulation, pollination, seed dispersal, social relations, inspirational, spiritual and religious values). In Stockholm, 11 ES (just under one third) were not addressed at all (soil formation, primary production, biochemical/genetic resource, climate regulation – global, disease regulation, pest regulation, natural hazard regulation, erosion regulation/soil retention, inspirational, educational and knowledge, spiritual and religious values).

Apart from the ES listed which were present or absent across all plans, references to individual ES showed little continuity over time, with the exception of "biodiversity" (A6) and "cultural landscape, heritage values "(D2) in Melbourne which both first appeared in the 1971 plan and then kept being referenced for all later plans, as well as "nutrient cycling – carbon cycle " (A3a) "pollination" (C9) and "seed dispersal" (C10), which appeared in Stockholm in the three latest plans. By contrast every other ES across all plans in both Melbourne

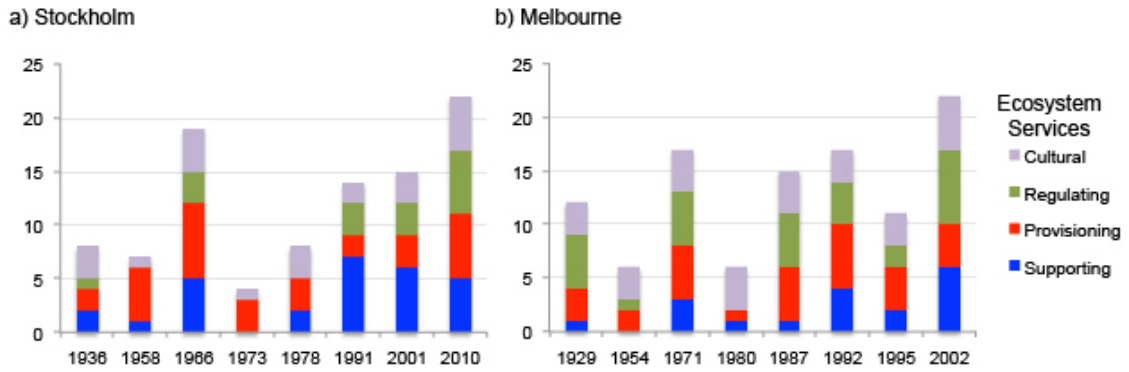
Table 3. Ecosystem services addressed in Melbourne's strategic spatial plans

Strategic Spatial Plans / Ecosystem services	1929	1954	1971	1980	1987	1992	1995	2002	Total
Supporting Services									
A1 Water cycling	X	-	X	-	-	X	-	X	*4*
A2 Soil formation	-	-	X	-	-	X	X	X	*4*
A3a Nutrient cycling – carbon	-	-	-	-	-	X	-	X	*2*
A3b Nutrient cycling – nitrogen	-	-	-	-	-	-	-	X	*1*
A3c Nutrient cycling – sulfur	-	-	-	-	-	-	-	-	-
A3d Nutrient cycling - phosphorous	-	-	-	-	-	-	-	X	*1*
A4 Primary production	-	-	-	-	-	-	-	-	-
A5 Photosynthesis	-	-	-	-	-	-	-	-	-
A6 Biodiversity	-	-	X	X	X	X	X	X	*6*
Sub Total - Supporting	*1*	-	*3*	*1*	*1*	*4*	*2*	*6*	
Provisioning Services									
B1 Food - Agriculture	-	-	X	-	X	X	X	X	*5*
B2 Food – Commercial fishing	-	-	-	-	X	X	-	-	*2*
B3 Food - Wild	-	-	-	-	-	-	-	-	-
B4 Fresh water	X	X	X	X	X	X	X	X	*8*
B4b Water - energy	-	-	X	-	-	-	-	-	*1*
B4c Water - transportation	X	X	X	-	X	-	X	X	*6*
B5 Biochemicals/genetic resource	-	-	-	-	X	X	-	-	*2*
B6 Fiber	X	-	X	-	-	X	X	X	*5*
B7 Biological energy sources/Fuel	-	-	-	-	-	X	-	-	*1*
Sub Total - Provisioning	*3*	*2*	*5*	*1*	*5*	*6*	*4*	*4*	
Regulating Services									
C1a Climate regulation – local	-	-	-	-	-	-	-	-	-
C1b Climate regulation - global	-	-	-	-	-	-	-	X	*1*
C2 Air quality regulation	X	-	X	-	X	X	-	X	*5*
C3 Water purificat'n/waste treatment	X	X	X	-	X	X	X	X	*7*
C4 Water regulation	X	-	X	-	X	X	X	X	*6*
C5 Disease regulation	-	-	-	-	-	-	-	-	-
C6 Pest regulation	-	-	-	-	X	-	-	X	*2*
C7 Natural hazard regulation	X	-	X	-	-	X	-	X	*4*
C8 Erosion regulation - soil retention	X	-	X	-	X	-	-	X	*4*
C9 Pollination	-	-	-	-	-	-	-	-	-
C10 Seed dispersal	-	-	-	-	-	-	-	-	-
C11 Noise regulation	-	-	-	-	-	-	-	-	-
Sub Total - Regulating	*5*	*1*	*5*	-	*5*	*4*	*2*	*7*	
Cultural Services									
D1 Social relations	-	-	-	-	-	-	-	-	-
D2 Cultural landscape, heritage values	-	-	X	X	X	X	X	X	*6*
D3 Sense of place	-	-	-	-	-	-	-	X	*1*
D4 Aesthetic	X	X	X	X	X	X	X	X	*8*
D5 Inspirational	-	-	-	-	-	-	-	-	-
D6 Recreation and eco-tourism	X	X	X	X	X	X	X	X	*8*
D7 Educational & knowledge	-	-	-	-	X	-	-	-	*1*
D8 Health	X	X	X	X	-	-	-	X	*5*
D9 Spiritual and religious values	-	-	-	-	-	-	-	-	-
Sub Total - Cultural	*3*	*3*	*4*	*4*	*4*	*3*	*3*	*5*	
TOTAL	12	6	17	6	15	17	11	22	

and Stockholm was sporadically absent in at least one, but often more than in one later plan.

Moving beyond individual ES, Figures 1a and 1b show the total number of ES addressed by ES category over time for Stockholm and Melbourne respectively. Figures 2a-d shows the proportion of total ES addressed for each ES category comparatively for Stockholm and Melbourne. This indicates that there is considerable variation between the two cities in the attention given to the different categories. In general, Stockholm pays more attention to Supporting Services than Melbourne, and Melbourne pays more attention to Regulating Services than Stockholm. There is a strikingly similar pattern in the total numbers of ES addressed over time in both cities (see Figure 2e). This shows a spike in the late 60s/early 70s, followed by a significant decline in the number of ES addressed in the late 70s/early 80s, followed by a general increase, with the most ES considered in the most recent plans for both cities. However, despite this consistency, there is

Fig. 1. Total number of ecosystem services addressed by category over time for Stockholm (a) and Melbourne (b)



substantial temporal variation in the ES addressed across the plans over time and between the cities. Recently, the similarity of ES considered in subsequent plans has increased, especially in Stockholm (see Figure 2f).

Research Question 2 - Framing of human–nature relations

Human dependency on ecosystem services

One of the central concerns of both the early instigators of the ES concept and those promoting its use in public policy today is to make visible human dependency on ecosystems. With respect to research question two, our findings suggest that Melbourne and Stockholm's strategic spatial plans recognize this dependence in different ways and to varying degrees from the very first plans.

The role ecosystems play in historic patterns of urban development is clearly recognized. The 1954 Melbourne plan, for example, states "thus because of the provisions of nature, we find Melbourne the seat of government, the centre of import and export" (Melbourne Metropolitan Board of Works 1954:27). This is a reference to the fact that "Port Phillip Bay, at the head of which stands Melbourne, [is] the only body of water offering opportunities for large scale harbor development in over 1000 miles of coastline" (MMBW 1954: *a*:27), that extensive timber and pastoral land was present and that a natural freshwater supply existed by virtue of an existing ledge of rock across the Yarra River "sufficient to prevent tidal water from traveling much further upstream" (Presland 2009:20). Provisioning services, including "food" (B1, B2) and "freshwater" (B4a), are thus recognized as critical.

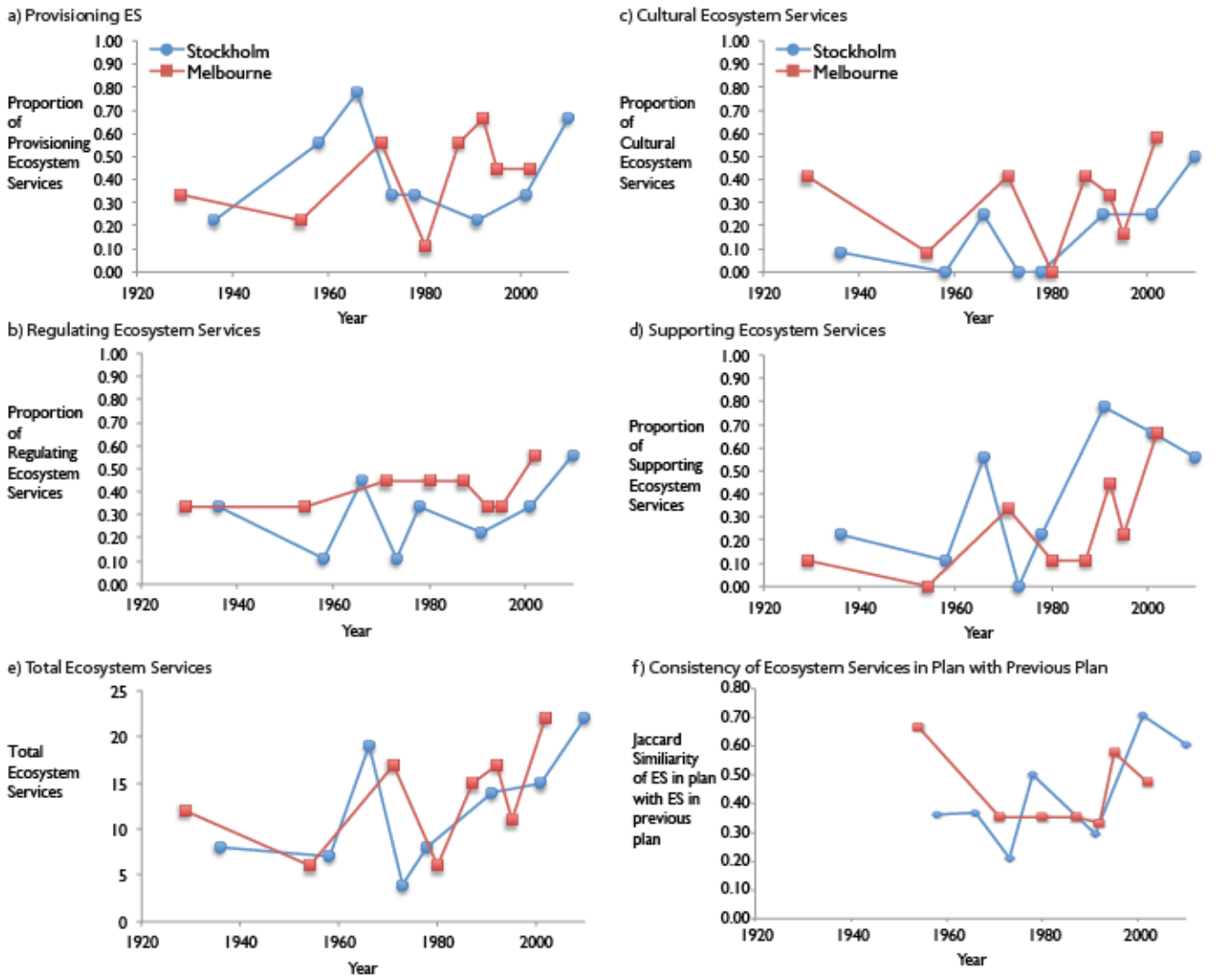
When it comes to water there are examples from both Melbourne and Stockholm of broad awareness of the extent of human dependency on water as an ecosystem service as exemplified by the following two quotes:

> *Water is a dominant part of man's (sic) life support system. It is required for human and animal consumption and agriculture, is a medium for aquatic flora and fauna and a recreational resource. It serves as a raw material and cooling agent in industrial processes, including the generation of power, as a medium for transferring wastes, and is a support medium for ships, swimmers and water skiers...The physical growth of Melbourne ultimately depends on the availability of water for domestic, industrial, stock and agricultural use.* (MMBW 1971:35)

> *The fresh water resources and the natural ecosystems must be preserved. Also, the citizens and tourists must continuously be able to use the water of the region for recreation. The increasing population implies a large demand both on water as a resource and on environments near water. The regional water catchments shall be preserved. Regard must be taken both to ground water incidence as to lakes, as well as to their catchment areas.* (Regionplane- och trafikkontoret 2009:131)

From the earliest plans in both cities there is also awareness that ecosystems have purifying capacities that affect water quality. In the 1929 Melbourne plan for example, there was recognition that "the purification of the sewage of Melbourne and suburbs is affected by filtration and aeration through the natural soil of the farm at Werribee" (Metropolitan Town Planning Commission 1929:106). In the 1936 Stockholm plan there was similar recognition that lakes and water courses possess some "self-purification capacity" and that treatment of sewerage through natural biochemical processes prior to emission was critical to maintain the "practically undrainable Lake Mälaren" (Stockholmsförorternas regionplaneförbund

Fig. 2. Proportion of total ecosystem services addressed for each category, Stockholm and Melbourne compared (a-d); total number of ecosystem services addressed, Stockholm and Melbourne compared (e); consistency of ecosystem services in plan with previous plans (f)



1935:11) as a key fresh water source. Here we see recognition that ecosystems can assimilate and detoxify compounds through processes in the soil, in particular wetland animals and plants can treat sewage water by slowing down the water flow so particles can settle out on the bottom. Within the ES framework this function is a regulating service - "water purification/waste treatment" (C3).

The second ES referred to in every plan is recreation (D6). In Melbourne, the link between recreation and health (D8) is made as early as in the 1929 plan which states, "abundant evidence is available to substantiate the views of city planners, the medical profession, and psychologists that proper outdoor recreation has a most beneficial effect on the health, morals, and business efficiency of communities, and consequently on the national life" (Metropolitan Town Planning Commission 1929:187). The 2001 Stockholm plan goes even further and recognizes the specific value of nature for human health (after Kaplan 1995) as reflected in the following quote.

> *The human being is dependent on rest and recreation. Research has shown that nature is an especially healing power against different states of stress. Measures that aims to preserve and develop the green areas of the region as well as especially cherish silent areas increase the conditions for a good health.* (Regionplane- och trafikkontoret 2002:117)

Broader awareness of human–nature linkages over time

Over time the sophistication of the awareness of humans' dependency on nature generally increases in parallel with scientific knowledge. A general shift can be seen from primarily local, instrumental, and aesthetic concerns to awareness of the broader impact that urbanization has on the regional and global environment. For example in the 1971 Melbourne plan reference is made to international research on the "limits to growth" by "eminent ecologists and scientists, including Dr. Paul Ehrlich and Sir Macfarlane Burnet, [who] maintain that resources are inadequate to provide for the expanding world population, and that action should be taken now to limit population growth in accordance with resource availability" (Melbourne Metropolitan Board of Works 1971:22). The 1971 Melbourne plan states,

> *The industrial revolution of the 18th century was a turning point in man's relation with his environment. The industrial revolution set Western man (sic) on a course of action which on the one hand has brought many material benefits through the development of technology but it has also led to the current situation where this technology is threatening to do irreparable damage to the earth's life support system.* (Melbourne Metropolitan Board of Works 1971:35)

In the early 1990s, after the Brundtland Report, "Our Common Future" (World Commission on Environment and Development 1987), reference is being made in both the Melbourne and Stockholm plans to "ecological sustainable development", and the plans grapple with how to balance social, economic, and environmental concerns. For example, the 1991 Stockholm plan states that "the physical environment should be used so that, from a long-term ecological, social and socioeconomic point of view, good use of resources is fostered" (Stockholms läns landsting 1991:30) and the 2001 Stockholm plan includes "long-term sustainable development" as one of the main goals. This attention to sustainable development reflects changes in Swedish natural resource legislation.

In the 1992 Melbourne plan there is explicit awareness of the disproportionate dependence of urban communities on ES beyond the metropolitan areas. The plan states that "the high concentrations of population and industry in urban areas account for their disproportionate impact on the wider environment. They consume so many resources and produce so much waste that natural systems are in danger of breaking down under the stress of depletion and pollution" (Government of Victoria 1992:25). In the more recent plans, global environmental challenges such as biodiversity loss and climate change come onto the public arena. For example, the 2010 Stockholm plan states, "climate change also affects biodiversity and the natural environment, since a change in the climate affects a whole range of processes that control the structures and functions of ecosystems" (Regionplane- och trafikkontoret 2009:69).

The environment as an economic asset

There are various examples from both Melbourne and Stockholm in which the environment is framed in terms of its economic value, which in some cases becomes the basis for commercialization of the assets. In the 1992 Melbourne plan the significance of genetic diversity per se (B5) is recognized (i.e., existence value) in parallel with increasing expansion of the local biotechnology industries as captured in the following quote:

> *Preserving genetic diversity is important both for its intrinsic value and for its economic potential. Agricultural, fishery, industrial and pharmaceutical activities ultimately rely on the genetic variability of indigenous and naturalised species: such diversity is the raw material for selection and breeding to sustain and improve rural production, and for scientific and industrial innovation.* (Government of Victoria 1992:28)

In the 1995 Melbourne plan, promoting the development of "natural attractions" including open space and coastal assets was the basis for a controversial policy of upgrading commercial venues and day visitor facilities on public land.

The 2010 Stockholm plan encourages inter-municipal cooperation to facilitate accessibility to attractive water recreation sites in order to "market the asset that the water (of Stockholm) constitutes" (Regionplane- och trafikkontoret 2009:74). In both cities, the potential for prospective commercial ventures in the countryside (Stockholm) or "green wedges" (Melbourne) that build on the environmental assets or qualities is recognized. The 2010 Stockholm plan states that "businesses in the countryside can develop tourist as well as 'green' enterprising that make the most of the natural and cultural values of the countryside and its closeness to the city" (Regionplane- och trafikkontoret 2009:73). In Melbourne this is a source of significant policy variation across the plans and the 2002 plan introduced "tougher planning controls over use and development" permitted in green wedges (Government of Victoria 2002:67).

Over time environmental assets and performance are recognized as critical to quality of life, which in turn contributes to the global competitiveness of each city. Protecting those environmental assets and therefore quality of life thus becomes a deliberate economic development strategy. The 1987 Melbourne plan states this explicitly as follows, "the critical links between environmental quality, quality of life and a positive business climate are increasingly recognised by Governments around the world" (Government of Victoria 1987:29). The 1995 Melbourne plan states, "Melbourne's

international reputation for livability and its demonstrated ability to attract investment and tourists are based to a considerable extent on the quality of [the] environment". (Government of Victoria 1995:38). The vision of the 2002 Melbourne plan is to be "one of the most liveable cities in the world". The 2010 Stockholm plan aims to make the greater Stockholm the most "attractive" metropolis of Europe, a task that will be accomplished through the realization of six main strategies. One of these strategies is to "secure values for future needs" (Regionplane- och trafikkontoret 2009:6), including "nature, culture and recreation values", "the climate, energy and transport" and "resource management and sustentation systems" (Regionplane- och trafikkontoret 2009:6). Here we see management of ecosystems serving two purposes, namely, a concern for well-being and a political strategy to improve competitiveness and economic growth of the Stockholm region.

Research Question 3 - Valuation of ecosystem services

Monetary valuation of ES

Specific monetary values are not placed on ES in any of the plans. However, ES marketization processes are referred to in the later Melbourne plans where certain ES are subject to privatization. In the early 1980s "the introduction of water conservation programs and 'user pays' pricing slowed water usage" (Government of Victoria 2002:25). The 1992 Melbourne plan states "in future planning for water supply and sewerage, increased waste recycling will be combined with more emphasis on the user pays principle for waste disposal and the development of polluter pays taxes and charges" (Government of Victoria 1992:9). In the 2002 Melbourne plan reference is made to Victoria's native vegetation management framework that will "guide reversal of the continuing loss of native vegetation, helping achieve a net gain through improvements and habitat creation" (Government of Victoria 2002:140). The "net gain" policy requires proponents to achieve a net gain in all development through purchase of native vegetation "offsets" via newly emerging markets.

Land-use conflicts requiring trade-offs between different ES

While specific monetary values are not placed on any ES in the plans, resolution of land use conflicts requiring trade-offs among ES is central. One obvious trade-off in both cities results from the expansion of cities into surrounding nonurban land. Both Melbourne and Stockholm have expanded significantly since 1920 and the resulting land use changes have dramatically changed ecosystems and resulting ES. The issue of how to address trade-offs is addressed in the plans both generally and specifically. The 1991 Stockholm plan provides a good example of general principles being established for how to deal with trade-offs and states:

> *When knowledge concerning the ecological consequences is scarce, precaution must be taken regarding irreversible change. In the choice between preserving and using natural resources [...] a national economical evaluation must in principle be made considering which measure is preferable. The effect on employment and economic growth shall be given emphasis.* (Stockholms läns landsting 1991:30)

With respect to trade-offs between different ES, there are many examples across the plans. In the 1929 Melbourne Plan there was conflict between the Forests Department and the Melbourne Metropolitan Board of Works (responsible for water supply, etc.) over extensive areas of land on the edge of Melbourne with respect to use of land for timber production (B6) or protection of the water catchment for freshwater supply (B4). The Metropolitan Town Planning Commission resolved in favor of protecting the water supply, as they summarize:

> *The Commission has given consideration to the opposing arguments, and believes that nothing should be permitted which may have the slightest detrimental effect upon areas so suitable as a potential water supply. The Commission is of the opinion that no other use should be considered when the objective is so vital.* (Metropolitan Town Planning Commission 1929:238)

Here we see an example where protection of one ES (in this case, freshwater, B4) is considered non-negotiable and use of the same land for a different ES denied (fiber, B6). In later plans, and by virtue of the original protection, these catchment areas go on to be recognized for additional ES including biodiversity (A6), recreation (D6), aesthetic (D4), and climate regulation (C1a).

Specific trade-offs between ES also appear in the Stockholm plans. For example, in the 1966 Stockholm plan, a three type "leisure zone" is introduced, in which agriculture (B1) and forestry (B6) on the one hand and recreation (D6) on the other hand are prioritized to different extents depending on how close to the city centre the concerned land is situated. By the 1973 Stockholm plan, "valuable landscapes" (D2) are recognized, albeit in the context that "agriculture (B1) and forestry (B6) should generally be pursued in recreational areas (D6) without hindrance" (Stockholms läns landsting – Regionplanenämnden 1976:76).

In other cases land uses that were permitted in early plans become undesirable in subsequent plans because of their detrimental impact on multiple ES. For example, in Melbourne rural living areas (single dwelling on large lots on the edge of metropolitan Melbourne, usually in areas of landscape beauty) were permitted in earlier plans to provide choice to those who wanted to be able to enjoy a semirural lifestyle in areas of natural beauty (D4, D3). However, by the 1987 Plan it was recognized that "residents do not always manage their

properties in sympathy with the delicate surrounding environment. Destruction of native fauna by domestic pets (A6), noxious weed infestation (C13), pollution of watercourses (C3) and an increase of bushfire hazards are common occurrences" (Government of Victoria 1987:8). By the 1992 plan such low-density living was "potentially incompatible" with the need to reduce greenhouse gas emissions (A3a) (Government of Victoria 1992:60). Here we see an increasing awareness of the detrimental impact of low-density semiurban living on a range of ES and a resulting change in acceptable trade-offs and thus policy.

Equity of distribution of ES

Intergenerational equity and intragenerational equity considerations underpin another way some ES are framed. The need for equitable distribution of open space for recreation (D6) and aesthetic (D4) enjoyment is raised across several plans in both Melbourne and Stockholm. The 1929 Melbourne plan recognizes that "proper outdoor recreation has a most beneficial effect on the health, morals, and business efficiency of communities" and that the needs of the poor living in densely populated areas "must be met" (Metropolitan Town Planning Commission 1929:187). It was considered "reasonable" for "the people living in the vicinity of those areas where property is enhanced in value on account of the proximity of the well-developed park lands should contribute to the work causing the enhancement" (Metropolitan Town Planning Commission 1929:232). In the 2002 Melbourne plan it is recognized that "while metropolitan Melbourne and the surrounding region is noted for the quality of its parks, there are gaps in the network of parkland and it is unequally distributed" (Government of Victoria 2002:105) and investment priority for new open space networks is subsequently given to these locations. This is not a case of trade-offs between ES but rather a matter of redressing historical inequities of access.

As Stockholm had comparatively well distributed publically accessibly green wedges throughout the city early on, intergenerational equity is focused more on the means of access to green spaces rather than their geographical distribution per se. This theme runs through many of the plans. For example, the 1936 Stockholm plan states that all citizens have "an interest" in "good suburban transport for recreational trips" (Stockholmsförorternas regionplaneförbund 1935:69). Citizens' "direct contact with nature" through access to open space including leisure areas, open air areas, bathing places, and fields and meadows are considered important (Stockholmstraktens regionplanenämnd 1958:43). In the 1966 Stockholm plan, green space in the outer skirts and in the central parts of the region are considered equally important for the benefit of recreation. In the 2001 Stockholm plan, the region is described as having a structure that consists of "radial transportation network and undeveloped green wedges [that] enable conditions for living with good communication and good access to green areas" (Regionplane- och trafikkontoret 2002:51). In later plans, other ES as well as recreation are used in the argumentation for maintaining closeness to nature. Health (D8) and, as in the 2010 Stockholm plan, certain regulating services (C2, C3), are for instance recognized:

> *Venues for outdoor activities and events in natural environments encourage more interaction between people. The green wedges function as natural treatment plants improving the living environment in the city, for instance through water purification and air cleansing. Proximity to nature for city dwellers is therefore of significant extra value for citizens, and is important from a public health perspective.* (Regionplane- och trafikkontoret 2009:101)

In Melbourne, the 1992 plan was the first to explicitly recognize the interests of future generations, stating that "it is imperative that all development is ecologically sustainable" and thus "development should therefore never be allowed to endanger Victoria's natural assets, the health of its environment or the interest of future generations." (Government of Victoria 1992:19) This plan goes on to clarify that "any loss of genetic diversity [B5] is irreversible; the costs must be borne forever" (Government of Victoria 1992:28), again presumably by future generations. Approaches to intragenerational equity in the Stockholm plans appear in various contexts. The 1966 Stockholm plan focuses on concern for specific issues, such as the consequences that emissions from the pulp industry can have for "the future water supply from Mälaren" (Stockholmstraktens regionplanekontor 1967:167). Future generations in a general ecological context are addressed in the 1991 Stockholm plan through a recognition of the need to maintain "ecological conditions so that functioning ecosystems can be preserved in the long run" (Stockholms läns landsting 1991:32). The Stockholm 2010 plan aims to "manage [...] resources for future generations", especially in order to deal with climate change and the "maintenance and development of robustness and adaptability" (Regionplane- och trafikkontoret 2009:183).

DISCUSSION

Comprehensive framework of ecosystem services

A key public policy challenge is how to handle the complexity of ecosystems through decision making processes. The ES approach provides one way of categorizing characteristics of ecosystems to improve legibility for decision makers in a way that remains more comprehensive in scope. Our analysis shows that even in its most basic form the ES framework is a useful policy analysis tool to expose the specific way in which ecosystem related matters are addressed in the strategic spatial planning policy discourse. Importantly it also reveals which ES are left out of the discourse. The analysis then enables more

informed discussion about why they are not addressed and what alternate policy processes or scales could address them. This is one of many necessary starting points for improved urban ecological governance.

With only some exceptions there is little continuity of attention to ES across the plans in each city, which raises significant issues for ongoing ecological governance, because variation in attention means that ecosystems and ecosystem services are likely to be poorly monitored and less understood. The variability of attention to ES over time revealed in our analysis highlights the limitations of strategic spatial planning per se in addressing matters of ecological concern. Strategic spatial plans are first and foremost political documents (Sandercock and Friedmann 2000) used to articulate ideological positions. How human–nature relations are framed and what particular environmental matters are given attention is an important part of that ideological position. With respect to practice then, the ES framework has potential to make more transparent variable attention to ecological issues and could be used to inform future strategic spatial planning processes, by providing a framework for the systematic incorporation of a more comprehensive ecological understanding in planning.

With respect to future research, many questions are provoked by the analysis, both general and specific. In general, it would be very useful to understand what were the consequences of these plans for ecosystem services and if the implementation of plans varied in any systematic way across ecosystem services. More specifically it would be useful to understand the social processes that produced apparently synchronized variation in the plans' consideration of ecosystem services. For example, why after the 1971 Melbourne plan and the 1966 Stockholm plan (which addressed 17 and 19 ES respectively) did the next plans for both cities pay attention to so few ES? Do the plans that address less ES correspond to particular economic or political climates? It lies outside the purpose of this study to explore these types of questions. However, given that the ES framework can reveal such questions shows that it can usefully inform future research agendas. Future research could extend both the breadth and depth of this research. It could be broadened to discover if the patterns we discovered are similar to those found in other cities, and in any particular city the historical processes that lead to the variation in ecosystem services across plans could be explored in depth.

Framing human–nature relationships

Our analysis shows that strategic spatial plans generally demonstrate awareness that urban populations are dependent on ecosystems. Indeed framing this relationship has been an important discourse in many of the plans examined, and the plans appear to be responding to increasing ecological concerns (Rockström et al. 2009, Folke et al. 2011), because over time the plans refer to an increasing number of ES. This awareness is not surprising for four reasons. First, strategic spatial plans are an established urban governance mechanism concerned primarily with establishing policy for integrated land use and transport issues (Wilkinson 2011). Second, the general shift in framing of environmental issues reflects known transitions in urban environmental history. For example, there has been a general shift from local to catchment-based awareness and then onward to global scale awareness. Third, there has also been a shift from instrumental and aesthetic concerns to awareness of the importance of ecosystems as humanity's life support system and recognition of local responsibility for global outcomes, through processes such as carbon emissions and biodiversity loss. Fourth, there is an increased awareness of the economic value of a high quality urban environment. Taken together these reasons suggest that at least for the field of strategic spatial planning, an ES approach per se does not bring novel insights with respect to the framing of human–nature relations. However, as has been already discussed, within the general trajectory of increasing awareness of human dependence on ecosystems there exist significant variations over time between the plans within each city, between Melbourne and Stockholm, and with respect to the gap between awareness as expressed in the plans and on-ground action and results. This suggests that the use of a more explicit ecosystem services approach has the potential to improve the quality of strategic spatial plans by better understanding how ecological dynamics and human action can shape the dynamics and interactions of multiple ecosystem services, as well as improve the ability of cities to learn from one another and from nonurban work on ecosystem services.

Valuation of ecosystem services to inform decision making

Our analysis shows that strategic spatial plans are a significant means to articulate policy positions regarding trade-offs between ES with respect to land use conflicts. These policy positions are political decisions, usually informed by scientific and technical information and varying degrees of community engagement and expression of value with respect to ES through the plan formation process. The policy positions can often be the catalyst for subsequent institutional changes regarding governance of ES, such as stricter control over uses permitted in green wedges. So when Daily et al. (2009:23) pose the challenge to "integrate ecosystem services into everyday decisions", a pertinent question is to what extent strategic spatial planning already meets this challenge. Our analysis shows that strategic spatial planning only partially meets this challenge, because while ES are often part of the discourse in the strategic spatial plans for Melbourne and Stockholm, their consideration is not systematic or consistent.

Spatial planning could benefit from adopting or adapting new tools and methods being developed by scientists to improve the systematic evaluation of ES to inform decision making

processes. Such approaches include the consideration of bundles of ecosystem services based on social-ecological factors (Raudsepp-Hearne et al. 2010) and tools such as InVEST (A tool for Integrated Valuation of Ecosystem Services and Tradeoffs) which allow users to fairly easily compare the ES produced in different landscapes (Nelson et al. 2009). Further development of systematic tools by ecologists would benefit from more detailed, ethnographic understanding of how ES trade-offs are currently made through decision processes. Where trade-off discussions are included in the plans they are usually specific to the focal policy problem, informed by detailed knowledge of the institutional context, and reflect the political climate in which the plan is positioned. Developing tools that take into account such contexts would improve their capacity to inform decision making about ES trade-offs through spatial planning processes.

CONCLUDING DISCUSSION - BROADER IMPLICATIONS OF THE ECOSYSTEM SERVICES APPROACH

While ES continue to decline globally (MA 2005), operationalizing an ES approach has been promoted as a tool for better fitting human society with the biosphere (Folke at al. 2011) and described as the "last best hope" (Daily et al. 2009:21) for mainstreaming biodiversity. There is an expectation that this operationalization will lead to "ecologically sustainable urban regions" (Niemelä et al. 2010:3238). At the same time it is acknowledged that these ambitions remain to be empirically demonstrated (Daily et al. 2009). The need for more scientific research on the social-ecological underpinning of ES (Kremen and Ostfeld 2005, Bennett at al. 2010, Raudsepp-Hearne at al. 2010*b*), how human actions affect ecosystems and how this understanding can be incorporated into decision making (Daily et al. 2009) has been identified.

Our historical analysis contributes to a better understanding of the diverse institutional decision making contexts that shape the use of ES concepts. Understanding this context is likely to improve the operationalization of an urban ES approach. For the case of strategic spatial planning, we have shown that while human–nature relations are central to most of the plans and the number of ES referred to in the plans has generally increased, attention to ES over time has been variable and inconsistent. This inconsistency demonstrates the need for research to address matters of "time scale mismatch". The importance of geographic and institutional scale mismatch has already been recognized (Folke at al. 1998, Ernstson at al. 2010), as well as possible mismatches between the temporal scale of planning and the temporal scale of the environmental implications of decisions (Bai et al. 2010). We identify the related but separate need to understand the implications of variable and inconsistent attention to environmental considerations over time even when these two temporal scales nominally align. The lack of continuity of attention over time to ES in strategic spatial plans revealed by this analysis (see Figure 2f) emphasizes the importance of longitudinal studies of the kind reported here. It also demonstrates the potential utility of the ES framework as a policy analysis tool.

Our analysis also identifies research questions that could usefully inform attempts to operationalize an ES approach. For example, how can the timing of the first consideration of an ES to appear in a plan be explained? Does it relate at all to the extent of science–policy interaction in a city or the manifestation of local on-ground problems, or the role of policy entrepreneurs? In the case of Melbourne, how did "nutrient cycling (carbon)" (A3a) come to be referenced in the 1992 Melbourne plan almost two decades before Australia signed the Kyoto protocol? Furthermore, while our research assesses what ecosystem services were planned for, a vital unanswered question is the impact of these plans on ecosystem services, and creating a comparative understanding of the longer term successes, failures and surprises produced by strategic spatial planning.

This sort of historical analysis can also potentially inform better understanding of the link between policy frameworks and on-ground outcomes. For example, have multiple gaps of attention in the plans to "food - commercial fishing" (B2) in both Melbourne (only mentioned in 1987 and 1992) and Stockholm (not mentioned in 1936, 1973-2001) contributed to declining fish stocks and marine health? In this respect it must be remembered that strategic spatial plans are only one of many urban governance tools, alongside legislative and regulatory frameworks and other fiscal and financial mechanisms. The type of longitudinal document analysis undertaken here could however be extended to these other domains to trace a more comprehensive understanding of how ES are governed in practice, as well as linked to long-term changes in ecological dynamics.

Finally, this type of analysis can also inform various broader debates regarding ES as an approach. The ES approach has been accused of oversimplifying human–nature relations, "blinding us to the ecological, economic, and political complexities of the challenges we actually face" (Norgaard 2010:1) and of contributing to the commodification of nature (Kosoy and Corbera 2009, Robertson 2004 and 2006). However, our historical analysis shows that, even in the absence of a formalized ES approach, both these tendencies are evident in the way human–nature relations have been framed in strategic spatial plans. Our argument is that further development of and debate about an ES approach should be critically informed by more detailed historical analysis of how different decision making contexts are already informed by an ES approach in practice, if not by name, and what can be learned for management and ecosystem services research from analyzing the lessons of these long-term histories of ES management.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/5368

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ES CODING PROTOCOL

Supporting services (A)

ID	ECOSYSTEM SERVICE	DESCRIPTOR (MILLENIUM ASSESSMENT)	DESCRIPTOR (OTHER)	CODING FORMULATIONS
1	*Water cycling* (MA 2005)	'Water cycling. Water cycles through ecosystems and is essential for living organisms.' (MA 2005, p. 40)		The hydrological cycle, precipitation patterns, protection of precipitation area
2	*Soil Formation* (MA 2005)	'Soil Formation. Because many provisioning services depend on soil fertility, the rate of soil formation influences human well-being in many ways.' (MA 2005, p. 40)		Soil formation, soil quality, high quality agricultural land (underlying quality of soil context)
3A	*Nutrient cycling – carbon cycle* (Daily 1997)	'Nutrient cycling. Approximately 20 nutrients essential for life, including nitrogen and phosphorus, cycle through ecosystems and are maintained at different concentrations in different parts of ecosystems.' (MA 2005, p. 40) Due to contextual difference, the carbon cycle (3A), the nitrogen cycle (3B), the sulfur cycle (3C) and the phosphorus cycle (3D) are separated from each other.	A) Carbon is the key element of all life. It is stored in the atmosphere, is used in the photosynthesis by plants, which are consumed by animals that use the carbon from the plants in their metabolism, and dead organic material is deformed to CO_2 or redeposited as sediment. (Daily 1997)	The carbon cycle, , emissions of greenhouse gases, emissions (general context), emissions of CO2, greenhouse gas strategies, international climate obligations
3B	*Nutrient cycling – nitrogen cycle* (Daily 1997)		B) Nitrogen, in its different forms, is involved in several biological and abiotic processes, e.g. as a compound in the atmosphere and in nitrogen fixation, which is the primary source of nitrogen for living organisms. (Daily 1997)	The nitrogen cycle, eutrophication, emissions (eutrophication context), nutrient cycle (agricultural or eutrophication context)
3C	*Nutrient cycling – sulfur cycle* (Daily 1997)		C) Required by living organisms. Sulfur is an important compound of plant tissue and is also consumed by animals and eventually returned to the soil. In its acid form, sulfur has a significant role in different processes, such as natural weathering of rocks acid rain. (Daily 1997)	The sulfur cycle
3D	*Nutrient cycling – phosphorus cycle* (Daily 1997)		D) As nitrogen and sulfur, phosphorus is an essential nutrient to plants and animals. (Daily 1997)	The phosphorus cycle, eutrophication, emissions (eutrophication context), nutrient cycle (agricultural or eutrophication context)
4	*Primary production (of the biosphere)* (MA 2005)	'Primary production. The assimilation or accumulation of energy and nutrients by organisms.' (MA 2005, p. 40)		
5	*Photosynthesis* (MA 2005)	'Photosynthesis. Photosynthesis produces oxygen necessary for most living organisms.' (MA 2005, p. 40)		Photosynthesis, oxygenation of the air by green areas
6	*Biodiversity* (Daily 1997, Forest et al. 2011)		Increases ecosystem productivity and stability, essential for all other categories of ESS. Interacts with the atmosphere, geosphere and hydrosphere to make services available (Daily 1997; Forest et al. 2011). Connectivity between different green areas make it possible for animal species to move from one area to another, which is positive for biological diversity (Daily 1997).	Biodiversity, conservation of species, ecologically vulnerable area, ecological linkage, linkage (ecosystem context), natural values, unique species/natural types, nature care (ecosystem context), valuable green area, habitat connectivity, seed dispersal, pollination, linked green areas, barrier (ecosystem context), corridors, ecology (conservation context), systems of green areas, allotment gardening, cultural landscapes (ecosystem context)

Provisioning services (B)

SD	ECOSYSTEM SERVICE	DESCRIPTOR (MILLENIUM ASSESSMENT)	ADDITIONAL INFORMATION	CODING FORMULATIONS
1	*Food - agriculture* (MA 2005)	'Food. This includes the vast range of food products derived from plants, animals, and microbes.' (MA 2005, p. 40)		Agriculture (ecosystem context), agricultural landscape (ecosystem context), food production, food security
2	*Food – capture fisheries* (MA 2005)	'Food. This includes the vast range of food products derived from plants, animals, and microbes.' (MA 2005, p. 40)		Fishery, fishing (commercial context)
3	*Food - wild* (Daily 1997)	'Food. This includes the vast range of food products derived from plants, animals, and microbes.' (MA 2005, p. 40)	Harvesting of wild plants, recreational fishing and hunting of wild animals for meat. (Daily 1997)	Berries, mushrooms, fishing (recreation context), hunting
4a	*Fresh water* (MA 2005)	'Fresh water. People obtain fresh water from ecosystems and thus the supply of fresh water can be considered a provisioning service.' (MA 2005, p. 40)		Access to water, drinking water, fresh water resources
4b	*Water - energy*		Hydroelectric generation (Postel and Carpenter 1997, p.196, in Daily 1997)	Hydro-electric power
4c	*Water - transportation*		'In many parts of the world, inland waterways offer convenient and relatively inexpensive pathways for the transport of goods from one place to another.' (Postel and Carpenter 1997, p.201, in Daily 1997)	Use of water body (sea, river or lake) for transportation purposes
5	*Biochemicals and genetic resource* (MA 2005)	'Genetic resources. This includes the genes and genetic information used for animal and plant breeding and biotechnology. Biochemicals, natural medicines, and pharmaceuticals. Many medicines, biocides, food additives such as alginates, and biological materials are derived from ecosystems.' (MA 2005, p. 40)		Biotechnology, genetic diversity
6	Fiber (MA 2005)	'Fiber. Materials included here are wood, jute, cotton, hemp, silk, and wool.' (MA 2005, p. 40)		Forestry, timber, wood, cotton
7	Fuel (MA 2005)	'Fuel. Wood, dung, and other biological materials serve as sources of energy.' (MA 2005, p. 40)		Bio-fuel supply, bio gas, methane (bio gas and energy context), energy crop

Regulating services (C)

SD	ECOSYSTEM SERVICE	DESCRIPTOR (MILLENIUM ASSESSMENT)	ADDITIONAL INFORMATION	CODING FORMULATIONS
1A	*Climate regulation – local* (MA 2005)	'Climate change. Ecosystems influence climate […] At a local scale, for example, changes in land cover can affect both temperature and precipitation. Climate regulation.' (MA 2005, p. 40)		Evapotranspiration, green area (local climate context), climate regulation (local context), temperature regulation, albedo (local context), shade
1B	*Climate regulation – global* (MA 2005)	'Climate change. Ecosystems influence climate […] At the global scale, ecosystems play an important role in climate by either sequestering or emitting greenhouse gases.' (MA 2005, p. 40)		Greenhouse gas sink, green area (global climate context), climate regulation (global context), albedo (global context)
2	*Air quality regulation* (MA 2005)	'Air quality regulation. Ecosystems both contribute chemicals to and extract chemicals from the atmosphere, influencing many aspects of air quality.' (MA 2005, p. 40)		Green areas (in a cleaning context), air cleaning, air pollution (general), air quality (general), "natural sewage plant" (air quality context)
3	*Water purification and Waste Treatment* (MA 2005)	'Water purification and waste treatment. Ecosystems can be a source of impurities (for instance, in fresh water) but also can		Water cleaning, sewage treatment, water quality, water pollution (general), "natural

		help filter out and decompose organic wastes introduced into inland waters and coastal and marine ecosystems and can assimilate and detoxify compounds through soil and subsoil processes.' (MA 2005, p. 40)		sewage plant" (water quality context)
4	Water regulation (MA 2005)	'Water regulation. The timing and magnitude of runoff, flooding, and aquifer recharge can be strongly influenced by changes in land cover, including, in particular, alterations that change the water storage potential of the system, such as the conversion of wetlands or the replacement of forests with croplands or croplands with urban areas.' (MA 2005, p. 40)	Forests preserve watersheds, which are necessary to regulate water flows in quality and quantity. (Daily 1997)	Regulation of water flows, water flows, storm water run off (reliability context)
5	*Disease regulation* (MA 2005)	'Disease regulation. Changes in ecosystems can directly change the abundance of human pathogens, such as cholera, and can alter the abundance of disease vectors, such as mosquitoes.' (MA 2005, p. 40)		
6	*Pest regulation* (MA 2005)	'Pest regulation. Ecosystem changes affect the prevalence of crop and livestock pests and diseases.' (MA 2005, p. 40)		Noxious weed infestation, exotic marine pests, introduction of invasive pathogens (resistance context)
7	*Natural hazard regulation* (MA 2005)	'Natural hazard regulation. Wetlands and barrier beaches have a flood storage capacity. Urban ecosystems are especially sensitive due to constrained water flows, which can increase the risk of floods in urban areas. Natural forests are effective protectors of crops and humans from high winds. Some ecosystems have the ability to prevent major fire disasters, which can be futile for plants, animals and the human society'. The presence of coastal ecosystems such as mangroves and coral reefs can reduce the damage caused by hurricanes or large waves.' (MA 2005, p. 40)		Water flows (extreme events context), bush fire, shade (context), flooding (flood plains, flood mitigation, flood control)
8	*Erosion regulation – soil retention* (MA 2005)	'Vegetable cover plays an important role in soil retention and the prevention of landslides.' (MA 2005, p. 40)		Landslides (context), erosion regulation (e.g. river bank protection, coastal protection, soil erosion)
9	*Pollination* (MA 2005)	'Pollination. Ecosystem changes affect the distribution, abundance, and effectiveness of pollinators' (MA 2005, p. 40)	Pollination of flowers by insects, wind, birds and water is necessary for sexual reproduction in flowering plant species. Functional composition of pollinator assemblage and connectivity of landscapes are necessary for maintenance of plant genetic pool and quality as well as quantity of fruits (Nabhan and Buchmann 1997, pp.133-150, in Daily 1997).	Pollination, ecological linkage, linked green areas (ecosystem context), barrier (ecosystem context), corridors, linkage (ecosystem context), allotment gardening
10	*Seed dispersal* (Daily 1997)		Seeds are dispersed by wind, water or by animals in various ways (Daily 1997).	Seed dispersal, ecological linkage, linked green areas (ecosystem context), barrier (ecosystem context), green corridors, linkage (ecosystem context), allotment gardening
11	*Noise regulation* (Bolund and Hunhammar 1999)		A soft lawn reduces noise from e.g. traffic better than concrete ground and vegetation, i.e. shrubbery and dense plantation, also reduces noise at some level. (Bolund and Hunhammar 1999)	Green areas (in a noise context)

Cultural services (D)

SD	ECOSYSTEM SERVICE	DESCRIPTOR (MILLENIUM ASSESSMENT)	ADDITIONAL INFORMATION	CODING FORMULATIONS
1	*Social relations* (MA 2005)	'Social relations. Ecosystems influence the types of social relations that are established in particular cultures. Fishing societies, for example, differ in many respects in their social relations from nomadic herding or agricultural societies' (MA 2005, p. 40)		
2	*Cultural heritage values* (MA 2005)	Cultural heritage values. Many societies place high value on the maintenance of either historically important landscapes ("cultural landscapes") or culturally significant species.' (MA 2005, p. 40)		Cultural values, of cultural history interest, of cultural interest, cultural landscapes, heritage values, ancient remains (conservation context)
3	*Sense of place* (MA 2005)	'Sense of place. Many people value the "sense of place" that is associated with recognized features of their environment, including aspects of the ecosystem.' (MA 2005, p. 40)	Emotional impact tied to place identity rather than cultural or aesthetic value. Note that this often overlaps with D2 or D4.	
4	*Aesthetic* (MA 2005)	'Aesthetic values. Many people find beauty or aesthetic value in various aspects of ecosystems, as reflected in the support for parks, scenic drives, and the selection of housing locations.' (MA 2005, p. 40)		Scenic views, beautiful nature.
5	*Inspirational* (MA 2005)	'Inspiration. Ecosystems provide a rich source of inspiration for art, folklore, national symbols, architecture, and advertising.' (MA 2005, p. 40)		
6	*Recreation and ecotourism* (MA 2005)	'Recreation and ecotourism. People often choose where to spend their leisure time based in part on the characteristics of the natural or cultivated landscapes in a particular area.' (MA 2005, p. 40)		Recreation, tourism (nature context), closeness to/access to nature/recreation, strolling area (nature context), walking area (nature context), active outdoor life, golf course, nature silence, park, fishing (recreation context), silence (nature context), good living environment (nature context), tourism (nature context)
7	*Educational and knowledge* (MA 2005)	'Knowledge systems (traditional and formal). Ecosystems influence the types of knowledge systems developed by different cultures. Educational values. Ecosystems and their components and processes provide the basis for both formal and informal education in many societies.' (MA 2005, p. 40)		Botanical garden, informational plaque (ecosystem context), learning about nature, experiencing nature
8	*Health* (Maas et al. 2006)		Closeness to green areas generates positive health effects to humans. (Mass et al. 2006)	Health related (outdoor recreation and appreciation context including green areas and beaches)
9	*Spiritual and religious values* (MA 2005)	'Spiritual and religious values. Many religions attach spiritual and religious values to ecosystems or their components.' (MA 2005, p. 40)		Ancient remains (nature context),, spiritual/religious connection to the land, religious heritage