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Research Paper

# 'Wild' in the city context: Do relative wild areas offer opportunities for urban biodiversity?

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ABSTRACT

Urbanization is increasing worldwide, making it essential to improve management of urban greenspaces for better provisioning of ecosystem services and greater biodiversity benefits. At the same time, societal interest in reduced intensity management regimes is growing for a range of practical and normative reasons. We assessed if relative wild urban greenspaces, under little or no management, are associated with increased levels of biodiversity. We conducted a GIS-based relative wildness mapping for the Danish city Aarhus, and compared relative wildness to field-measured perceived biodiversity at 100 randomly placed sample sites in the city centre. Perceived biodiversity was estimated using the bioscore methodology. The results show a positive relationship between mapped wildness and bioscores, notably within artificial vegetated areas such as parks and gardens, while woodland had the highest wildness and bioscore values overall. All bioscore components measuring structural diversity increased with increasing mapped wildness. The bioscore component compositional richness covered site-level species richness for birds, invertebrates and plants, with invertebrate and bird species richness increasing and plant species richness decreasing with increasing wildness. The latter reflects that woodlands had low site-level plant diversity. Overall, woodlands nevertheless harboured many unique plant species, with woodlands and ruderal areas contributing the greatest beta diversity (inter-site variability in species composition). These findings show that urban greenspace management allowing for spontaneous ecological processes (greater wildness) overall also promotes urban biodiversity, pointing to potential synergies between urban design and management goals for reduced management intensity, increased wildness experiences, and higher biodiversity in urban greenspaces.

## 1. Introduction

Given increasing urbanization worldwide (Chen, Zhang, Liu, & Zhang, 2014), it is important to understand if and how urban greenspaces can be managed for better provisioning of ecosystem services and greater biodiversity benefits. For this reason, urban ecology has gained momentum in recent decades, with the first ecosystem studies carried out in urban areas dating back to the 1970s (Sukopp, 2008). In cities, human activities are the main drivers of ecological processes and patterns (Warren et al., 2010), and urban greenspaces often do not consist of the natural habitat types, but rather of novel ecosystems, systems, that '[…] have been potentially irreversibly changed by large modifications to abiotic conditions or biotic composition' (Hobbs, Higgs, & Harris, 2009). Nevertheless, they can sustain important ecological functions such as nutrient absorption, heat reduction or erosion control and serve as wildlife habitats (Del Tredici, 2014). Urban greenspaces have also been shown to provide important ecosystem services such as the filtration of air and micro-climate regulation that increase the living quality for urban citizens (Bolund & Hunhammar, 1999). Furthermore, exposure to urban biodiversity may have positive health benefits (Cox et al., 2017).

At the same time, there is increasing societal interest in reduced-intensity management regimes for a range of practical and normative reasons (Buck, 2015). At a European level, there is increasing focus on wilderness protection and restoration, as one key approach to avoid and reverse biodiversity losses (European Parliament, 2009). Notably, the maintenance and development of wilderness in nature protection areas is advocated (European Commission, 2013). Additionally, there is strongly increasing interest among both managers and scientists worldwide and in Europe towards rewilding as a strategy for

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biodiversity conservation and natural area management (Corlett, 2016a; Jepson, 2016; Svenning et al., 2016). The concept covers a range of variants, but a common aspect is reduction of human management and restoration of self-managing ecosystems (Navarro & Pereira, 2012). One prominent version in Europe is passive rewilding, which is simply the cessation of human management (Corlett, 2016a). Even though rewilding naturally focuses on rural and natural landscapes, the applicability of the concept to urban settings calls for exploration, especially regarding increasing urbanization. There is emerging evidence that urban wastelands (defined as abandoned sites with spontaneous vegetation) can contribute importantly to urban biodiversity, generally harbouring more species than other urban greenspaces (Bonthoux, Brun, Di Pietro, Greulich, & Bouché-Pillon, 2014). More broadly, there is also increasing interest in exploring possibilities in cities for not just more unmanaged and spontaneous ecological, but also social dynamics in greenspaces to improve the liveability of cities (Jorgensen & Keenan, 2012). The diversity of urban resident groups is reflected in a diversity of recreational needs, and unmanaged urban greenspaces offer unique opportunities for nature experiences, discovery and a range of informal activities (Rupprecht & Byrne, 2014).

A key issue for studying ecological wildness and its services and disservices in an urban setting concerns its definition and measurement, given the pervasive human influence on urban landscapes. Here, the wilderness continuum concept (Carver, Comber, McMorran, & Nutter, 2012) is useful: Instead of a binary definition of 'wild' and 'not wild', it acknowledges a gradient of human modification of landscapes. It allows us to define parts of a landscape as 'wilder' and 'less wild' compared to other parts within a given geographic scope. Relative wildness mapping based on this concept and conducted in Geographic Information Systems (GIS) have been carried out ranging from worldwide assessments to national, regional and even local scales (Carver et al., 2012), enabling the examination of relative wildness in anthropogenic landscapes (Müller, Bøcher & Svenning, 2015). GIS-based relative wildness mapping should therefore also allow us to assess the relative wildness of urban greenspaces.

The overall aim of the present study was to investigate if relative wild urban areas harbour particularly high levels of biodiversity in a European city. This setting is highly relevant for investigating the wildness-biodiversity link, as 70% of the European population live in cities, predicted to further increase by 10% by 2050 (European Union, 2011). Hence, urban areas in this region will continue to grow, forming the setting where an increasing proportion of the overall population will experience ecological wildness and biodiversity on a daily basis. We first assessed the applicability of GIS-based relative wildness mapping to the urban study setting. We then tested for a positive relationship between relative wildness and biodiversity, as assessed in a field survey. Finally, we assessed how relative wildness and biodiversity varied among major urban habitat types.

## 2. Methods

### 2.1. Study area

Our study was conducted in Aarhus Municipality, situated in the Central Jutland region in Denmark (Fig. 1) at the coast of the Baltic Sea, with an area of 476.85 $km^2$ (Statistics Denmark, 2016a) and 331,332 inhabitants (Statistics Denmark, 2016b). It consists of the city of Aarhus and several rural communities. The city of Aarhus is the next-largest city in Denmark and the fastest growing in the whole country (Aarhus Kommune, n.d.). The GIS-based relative wildness mapping was conducted for the whole municipality, whereas the fieldwork to collect biodiversity data was carried out only in the city centre to focus on the most urbanized parts. The city centre was defined as the area within Ringvejen, the outer ring road of Aarhus (Fig. 1, yellow border).

### 2.2. Wildness mapping

We chose the following four indicators to represent urban wildness in this mapping based on two previous relative wildness mapping studies (Scottish Natural Heritage, 2014; Müller, Bøcher & Svenning, 2015): (1) perceived naturalness of land cover, (2) challenging terrain, (3) remoteness and (4) visibility of built modern artefacts.

For perceived naturalness of land cover, land cover data were mainly derived from Basemap 2012 (Levin, Jepsen, & Blemmer, 2012). Data on agricultural land use were updated from Markkort 2015 (Danish Agrifish Agency, 2015). Two land use classes from Basemap, 'land' and 'unclassified' were reclassified into other land use classes from Basemap by doing a spatial overlap with polygons from KORT10 (Danish Geodata Agency, 2013) and by comparison to orthophotos (COWI, 2014). All the joined land use classes (hereafter referred to as 'the land use dataset') were reclassified into 20 naturalness classes ranging from 'completely sealed areas' with the lowest naturalness value over 'permanent grassland with normal yields' (naturalness class 10) to 'land cover presumably under least human influence' (for a detailed description of the 20 classes, see Table S1, Supplementary data).

To describe challenging terrain, terrain ruggedness and occurrence of wetlands were combined as suggested in previous work (Scottish Natural Heritage, 2014). For ruggedness of terrain, the curvature of a 1.6 m resolution digital terrain model (DTM) (Danish Geodata Agency, 2007a) was calculated. Afterwards the dataset was aggregated and resampled into a 10-m resolution. At this fine scale, a DTM does not only capture the actual terrain, but also anthropogenic structures such as raised roads. When calculating the standard deviation of the curvature, these structures would also tend to show high values. Consequently, the possibly higher ruggedness in such places does not necessarily capture places that are perceived as wild, probably rather the opposite. Therefore, all pixels with construction (roads, railways, buildings) were excluded from the dataset. Afterwards, the standard deviation for each cell in a 250 m neighbourhood was calculated, reflecting the area an individual would consider his or her immediate surrounding. To fully cover challenging terrain in terms of physical properties of the ground, information on the occurrence of wetlands (layer 'vådområde' (wetlands) of KORT10 (Danish Geodata Agency, 2013) and layer 'mose' (swamps) of the protected nature types dataset (Danish Natural Environment Portal, 2007)) was added to the terrain ruggedness dataset: If a pixel cell laid within wetland, 0.3 (mean standard deviation value of terrain ruggedness calculation), was added to the pixel cell value.

The indicator remoteness was depicted by remoteness from mechanized access and noise exposure. Remoteness from mechanized access was measured by calculating the shortest walking distances from mechanized access (major roads) to any pixel on the map following Carver et al. (2012). The land use dataset was reclassified into a cost surface (Table S2, Supplementary data), estimating the seconds it takes a person to pass through each pixel based on assumed travel times for each land use class. The shortest time it would take a hiker to access any pixel in the study area from a point of mechanized access was then calculated by using the pathdistance tool of ArcGIS. Noise exposure from roads, railways and agglomerations was available for most parts of the study area (Danish Environmental Agency, 2012). The weighted means of noise values ($L_{den}$) were chosen for calculation using the highest measured decibel value. The data for roads, railways and agglomerations (areas of high population density) were then merged, always choosing the highest decibel value if datasets overlapped. All pixels not covered by the existing noise exposure data were considered rather quiet. They were assigned 30 dB, similar to a quiet garden (Cercle Bruit Schweiz, 1998). The dataset was reclassified into inverse values, so high values in the dataset would depict low decibel values and vice versa, ensuring that values for all indicators correlated positively to likely wildness experience. Afterwards, the remoteness of mechanized access dataset and the noise dataset were summed up to