Informal urban green space – A trilingual systematic review of its role for biodiversity and trends in the literature

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Abstract

Urban greenspaces harbor considerable biodiversity. Such areas include spontaneously vegetated spaces such as such as brownfields, street or railway verges and vacant lots. While these spaces may contribute to urban conservation, their informal and liminal nature poses a challenge for reviewing what we know about their value for biodiversity. The relevant literature lacks a common terminology. This paper applied a formal definition and typology of informal urban greenspace (IGS) to identify and systematically review a total of 174 peer-reviewed papers in English (152), German (14) and Japanese (8). We identified three main topics: value for conservation (94 papers), factors influencing diversity (80), and non-indigenous species (37). Additionally, we analyzed this literature for temporal trends, spatial patterns, studied IGS types, taxa, climate zones, human impact types, and key authors. Results show IGS plays an important role for biodiversity. Management practices were identified as the most common and negative impact on diversity, while vegetation, site age, distance to city center, and habitat diversity were positive-influence factors. The number and impact of non-indigenous species varied widely. The analysis of literature patterns reveals: an increase in publications over the last 15 years and a strong geographic bias in publications, as well as towards temperate and humid climate zones. Studies of gap, powerline and microsite IGS were scarce, as were studies of mammals and reptiles. Results suggest different maintenance regimes for IGS may improve its contribution to urban conservation. We therefore propose adapting management to the local context. (243/250 words)

Keywords: urban ecology; conservation; wasteland; spontaneous vegetation; cities, liminal

1. Introduction

Some of the biggest conservation challenges, and most permanent ecological changes occur in cities and towns (Goddard et al., 2010; Kowarik, 2011). Much of the research on urban forestry and urban greening is dedicated to two types of spaces: (1) naturally vegetated spaces (e.g. remnants of the pre-development vegetation), and (2) highly managed spaces with planted vegetation (e.g. formal parks and gardens). Yet many scholars have emphasized the potential of spontaneously vegetated spaces (e.g. brownfields, street or railway verges etc.) for urban conservation (Del Tredici, 2010a; Kowarik, 2011; Kühn, 2006). For example, recent reviews concluded urban wasteland can contribute to biodiversity conservation in urban regions (Bonthoux et al., 2014; Gardiner et al., 2013), and quantitative research suggests such spaces cover around five percent of surveyed cities (Rupprecht and Byrne, 2014a). However, knowledge of this topic is still quite limited. Most of what we know is derived from English language literature. In contrast to research on parks and conservation areas, research on informal green spaces also faces a conceptual challenge that complicates identifying relevant papers – namely the lack of an agreed approach about how to define these spaces.

In absence of a formal definition, researchers from urban geography and other fields have explored the characteristics of informal green spaces. They argue such spaces are ‘liminal’ (Rupprecht and Byrne, 2014b), and hard to identify and analyze because they form an ‘ambivalent landscape’ (Jorgensen and Tylecote, 2007) where land tenure, conservation, maintenance regimes, use, regulation, and legitimacy are fraught with uncertainty (McLain et al., 2014). Liminality is a term emerging from the social sciences (Rupprecht and Byrne, 2014a). It refers to a condition of becoming, a transitional state of ‘in-between-ness’ or hybridity – distinguished by temporal and spatial flux – and not easily categorized (Sweeney, 2009). As Pritchard and Morgan (2006, 764-65) note, liminal spaces: ‘are borderlands between the mundane and the extraordinary…betwixt places…[that are] mutable’. Head and Muir (2006, 506) assert that in liminal spaces can be found ‘complex entanglements of humans and nature…[where] …nature and culture are reinforced, maintained or ruptured’ and ‘belonging is highly contingent’. Instone and Sweeney (2014) astutely observe that for liminal ecologies, the culture/nature boundary is disrupted and divisions between public/private and controlled/neglected are blurred. In sum, liminal spaces are ‘interfaces’ or intersections of cooperation and competition, separation and reintegration, characterized by informality and emergence (Imai, 2013).

The liminality of IGS may explain why researchers have referred to it using a variety of different names, such as ‘urban wilderness’, ‘urban wildscapes’, ‘ambivalent landscapes’ or ‘urban wasteland’ (Rupprecht and Byrne, 2014b). Without clearly specifying the object of study, researchers risk overlooking important details about the attributes of these spaces and may remain ignorant about a body of relevant and important previous research. Moreover, without definitional certainty - that we are studying the same object, efforts to compare between different research findings and to build knowledge are severely impeded. To address this issue, Rupprecht and Byrne advanced a definition and typology of ‘informal urban green space’ (IGS) in a field survey of IGS quantity (2014a) and provided a review of IGS’ role and value for urban residents (2014b). But there is still a lack of knowledge about the biodiversity value of these spaces. This paper reviews the scholarly literature on IGS and urban biodiversity, using the analytical framework provided by Rupprecht and Byrne (2014a), offering researchers, planners, and stakeholders an integrated understanding and synthesis of research findings.

Specifically, the review aims to address two sets of questions. The first set targets the role of IGS for urban biodiversity: (1.a) how is IGS valuable to urban biodiversity conservation; (1.b) what factors influence IGS biodiversity; and (1.c) how is IGS used by indigenous and non-indigenous species? The second set of questions targets patterns and trends in the scholarly knowledge of IGS biodiversity: (2.a) how has the number of relevant publications changed over time; (2.b) what is the spatial and linguistic structure of the literature; (2.c) which IGS types have been studied most; (2.d) which species groups have been studied most; (2.e) what forms of human impact are most common; (2.f) what are the most studied climate zones; and (2.g) who are the key authors? These questions assist in identifying knowledge gaps and identifying directions for future research. To answer these questions, this paper provides a concise, tri-lingual review of 174 peer-reviewed research papers on the biodiversity of IGS. Findings have important policy implications for biodiversity conservation in urban areas.

2. Methods

We used a systematic review approach (Pickering and Byrne, 2013) that differs from a classic meta-analysis. The systematic review has recently emerged as a useful tool for scholarly literature analysis (Byrne and Portanger, 2014; Guitart et al., 2012; Roy et al., 2012). Such reviews do not analyze published data; rather they identify geographic, theoretical and methodological gaps by analyzing trends in the literature. Similar to a recent systematic review of the role of IGS for urban residents (Rupprecht and Byrne, 2014b), this review included German, Japanese and English papers to extend the scope of the review. These languages were chosen based on the multi-lingual proficiency of the review's first author. Preliminary searches revealed IGS-related research papers published in other languages, such as Spanish (Lopez-Moreno et al., 2003) and Russian (Tikhonova et al., 2002), and we recognize that we have not been able to address papers published in many other languages (e.g. Mandarin, French, Portuguese etc.) – a point we return to in the discussion.

For this review, we systematically searched five major databases (Web of Knowledge, Scopus, Google Scholar, CiNii and J-STAGE) using Boolean functions to combine search terms, for example "urban AND species AND [all biodiversity terms with OR functions] AND [IGSvariable]" (for full list of search terms in all three languages see Appendix A). Database searches were performed in early 2011 for the full time frames available, and updated in early 2013 and late 2014 with a repeated search in Web of Knowledge, Scopus, Google Scholar, and J-STAGE for papers published since the first search. We did not seek to impose a time limit on the search (e.g. 20 years) but it should be noted that not all older papers may be full-text searchable, a limitation that may cause them to be underrepresented. We selected a number of research papers specifically targeting IGS to look in their reference sections for additional potentially relevant publications not returned in the database searches.

To be included for analysis, publications had to meet three inclusion criteria: (1) the studied area comprised or included at least one type of IGS following Rupprecht and Byrne's typology (2014a, 2014b)(Table 1, Fig. 1); (2) the study reported sufficient details to identify a space as IGS (e.g. in urban area, management arrangements, official park designation, site history); (3) the data reported for an IGS was sufficient to include the study in the analysis of literature trends (e.g. target species group). All feasible effort was made to clarify whether a study area fulfilled the requirements to be included; aside from a close examination of all information provided in the publication, study areas were (if possible) also located in Google Earth. Aerial photography and photographic material in Google Earth was sighted to examine whether site conditions and site context in the urban matrix complied with the three selection criteria above (a form of "ground-truthing").

Figure 1 Photographs of informal greenspace types following the typology presented in Table 1. a) Street verge, covered in spontaneous herbal vegetation (Brisbane, Australia); b) Lot, formerly residential with perfunctory access restriction (Tōkyō, Japan), c) Gap, space between three buildings with spont. herbal vegetation used by birds (Sapporo, Japan); d) Railway, annual grass verge between rail track and street; e) Brownfield, spont. vegetated industrial space around abandoned factory (Brisbane); f) Waterside, spont. vegetation on banks and deposits in highly modified river (Nagoya, Japan); g) Structural, spont. vegetation growing out of vertical, porous retaining wall (Tōkyō); h) Microsite, grass growing spont. growing out of crack in the pavement (Nagoya); i) Powerline, vegetated right of way underneath high voltage powerline (Brisbane); (Rupprecht & Byrne, 2014a).

Table 1 Informal urban greenspace typology (modified from Rupprecht & Byrne, 2014a)

IGS	Examples	Description	Management	Common substrates
Street verges	Roadside verges, roundabouts, tree rings, informal trails and footpaths	Vegetated area within 5m from street not in another IGS category; mostly maintained to prevent high and dense vegetation growth other than street trees; public access unrestricted, use restricted.	Regular vegetation removal (>= once per month); governmental and private stewardship	Soil, gravel, stone, concrete, asphalt
Lots	Vacant lots, abandoned lots	Vegetated lot presently not used for residential or commercial purposes; if maintained, usually vegetation removed to ground cover; public access and use restricted.	Irregular veg. removal, medium to long removal intervals; private stewardship	Soil, gravel, bricks
Gap	Gap between walls or fences	Vegetated area between two walls, fences or at their base; maintenance can be absent or intense; public access and use often restricted.	Irregular veg. removal; variable removal intervals; private stewardship	Soil, gravel
Railway	Rail tracks, verges, stations	Vegetated area within 10m adjacent to railway tracks not in another IGS category; usually herbicide maintenance to prevent vegetation encroachment on tracks; public access and use mostly restricted.	Regular veg. removal (monthly to yearly); corporate or governmental stewardship	Soil, gravel, stone
Brownfields	Landfill, post-use factory grounds, industrial park	Vegetated area presently not used for industrial or commercial purposes; usually no or very infrequent vegetation removal and maintenance; public access and use mostly restricted.	Irregular veg. removal, long removal intervals; corporate and governmental stewardship	Soil, gravel, concrete, asphalt
Waterside	Rivers, canals, water reservoir edges	Vegetated area within 10m of water body not in another IGS category; occasional removal of vegetation to maintain flood protection and structural integrity; public access and use often possible with some restrictions.	Irregular veg. removal, long removal intervals; governmental stewardship	Soil, stone, concrete, bricks
Structural	Walls, fences, roofs, buildings	Overgrown human artifacts; often vertical; occasional removal of vegetation to maintain structural integrity; public access and use mostly restricted.	Irregular veg. removal, medium to long removal intervals; varying stewardship	Soil, stone, gravel, wood, metal
Microsite	Vegetation in cracks or holes	Vegetation assemblages in cracks, may develop into structural IGS; maintenance can be absent or intense	Irregular veg. removal, variable removal intervals; variable stewardship	Deposits, soil, stone, conrete
Power line	Powerline rights of way	Vegetated corridor under and within 25m of powerlines not in another IGS category; vegetation removed periodically to prevent high growth; public access and use mostly unrestricted.	Regular veg. removal (less than yearly); utility or governmental stewardship	Soil

Publications were systematically analyzed for findings on the role of IGS for urban biodiversity, characteristics of each published study (year of publication, location, Köppen-Geiger climate type, IGS description, target species group, species number or range found (where available) and human impact). We also analyzed publication patterns across all research papers, such as temporal trends, spatial patterns, studied IGS types, taxa, climate types, human impact types, and key authors. Results are presented in tables and figures to efficiently present and synthesize findings from the large number of articles, following similar presentation and analysis methods used in recent literature reviews (e.g., Garden et al., 2006). Analysis of distribution among different climate zones followed an updated version of the Köppen-Geiger system (Kottek et al., 2006) using a KMZ-file (Wilkerson and Wilkerson, 2010). Principal and co-authorship was used to identify key authors who contributed multiple articles.

3. Results

We found a total of 174 papers, consisting of 172 original journal articles widely distributed across 90 journals, one book chapter and one Masters' thesis. Journals publishing the most research papers were *Urban Ecosystems,* followed by *Landscape and Urban Planning*, *Diversity and Distributions*, *Biological Conservation*, then *Journal of the Japanese Institute of Landscape Architecture* (Table 2). This demonstrates that a variety of journals and scholars share an interest in this topic.

Table 2 Journals containing most papers on IGS biodiversity

Journals containing two or more papers	Number of papers	Percent of papers*
Urban Ecosystems	22	13%
Landscape and Urban Planning	19	11%
Diversity and Distributions	7	4%
Biological Conservation	6	3%
Journal of the Japanese Institute of Landscape Architecture	5	3%
Urban Ecology	4	2%

* Percentage does not add up to 100% as only journals with >3 papers are shown

3.1 Role of IGS for urban biodiversity

Research papers focused on three main topics: (a) value of IGS for conservation (94 papers), (b) factors influencing IGS biodiversity (80), and (c) non-indigenous species found in IGS (37). A table shows a summary of findings for the individual papers, including their publication year, location, IGS type, climate zone, a detailed IGS description, details regarding human impact, the target species group, number of species found (if available), and noteworthy comments about IGS and its value (Appendix B). We discuss the main findings and their implications after summarizing the results and examining trends in the literature.

3.1.(a) Value of IGS for conservation

The value of IGS for conservation was emphasized by just over half the papers (53%). Researchers reported high species numbers across different IGS types and taxa (e.g., Brandes, 2001; Geibert, 1980; Muratet et al., 2007; Tan, 2010). Some IGS harbors rare species (Dana, 2002; Eyre et al., 2003; Gilbert, 1990; Kadas, 2006) and was thus characterized as a wildlife refuge (Kantsa et al., 2013). The contribution of IGS to biodiversity was often assessed in comparison to other areas and habitats. Urban IGS can have higher species richness or diversity than rural areas (Mason et al., 2006; Meek et al., 2010; Ray and George, 2009), lawns and forest (Robinson and Lundholm, 2012), or ornamental plantings (Fründ et al., 1988; Vakhlamova et al., 2014), although non-indigenous species may account for the difference (Ray and George, 2009). IGS can provide valuable habitat (Brandes, 1992; Brown and Sawyer, 2012; Colla and Willis, 2009; Dallimer et al., 2012b; Rebele, 1988; Winter, 2013), and occasionally serve as a substitute for natural habitats (Joger, 1988; Kaupp et al., 2004). It also represents an opportunity for urban residents to experience nature as a 'natural-cum-cultural' heritage (Jim and Chen, 2011, 2010, 2008) or as a source of edible plants (e.g. in urban foraging) (Diaz-Betancourt et al., 1999; Rapoport et al., 1995). While IGS can have additional benefits for residents, this topic has been covered in our earlier review (Rupprecht and Byrne, 2014b). We will return to how and why IGS can provide habitat and other benefits in the discussion.

3.1.(b) Factors influencing IGS biodiversity

A wide variety of factors influencing IGS biodiversity were identified in the research papers. Scholars most commonly cited management practices and their negative impact on diversity (e.g., Helden and Leather, 2004; Jantunen et al., 2006; Jim and Chen, 2010; Vakhlamova et al., 2014), even though habitat value for some indigenous species may depend on such management (Nemec et al., 2011). Less direct disturbance may contribute to higher species numbers (Dana, 2002; Schadek et al., 2008) by preserving vegetation communities valuable for conservation (Lenzin et al., 2007). Different aspects of vegetation were regarded as important, especially vegetation structure (Fernandez-Juricic, 2000; Florencia Carballido et al., 2011; Geibert, 1980; Strauss and Biedermann, 2006), vegetation as a food source (Eremeeva and Sushchev, 2005; Kazemi et al., 2011; Small et al., 2006; Tommasi et al., 2004), and vegetation (including tree) cover (Ichinose, 2006; Itagawa et al., 2010; Luther et al., 2008; Pennington et al., 2008). Biodiversity was found to increase with site age (Crowe, 1979; Jantunen et al., 2006; Kim and Lee, 2005), distance from the city center (Vakhlamova et al., 2014; Wahlbrink and Zucchi, 1994; Zorenko, 2003), and habitat diversity (Dallimer et al., 2012b; Murgui, 2009), while it was negatively affected by sealed site surface (e.g., hard surfaces such as asphalt that can impede seedling growth) and substrate (Dallimer et al., 2012b; Francis and Hoggart, 2008; Godefroid et al., 2007).

3.1.(c) Non-indigenous species found in IGS

Many researchers reported that they found high numbers of non-indigenous species across different IGS types (Bigirimana et al., 2011; Garcillán et al., 2009; Kim et al., 2004; Ray and George, 2009), particularly in New Zealand (Asmus and Rapson, 2014; de Neef et al., 2008), China (Gong et al., 2013; Zhao et al., 2009), and the USA (Pennington et al., 2010; Stylinski and Allen, 1999). This finding contrasts with papers reporting low numbers of such species (Catterall et al., 2010), particularly in South-Africa (Cilliers and Bredenkamp, 2000, 1999) and Europe (Bornkamm, 2007; Celesti-Grapow and Blasi, 1998). While some researchers reported that non-indigenous species dominated (Asmus and Rapson, 2014; Crawford, 1979; Gantes et al., 2014; Stylinski and Allen, 1999), others found little evidence for competition (Celesti-Grapow et al., 2006). Some researchers asserted that naturalized species may enhance urban biodiversity (Zerbe et al., 2004), provide ecosystem services (Meek et al., 2010), and are of socio-cultural significance as they may possess various desirable ecological and aesthetic qualities (Chmaitelly et al., 2009). Non-indigenous species composition may also be used to trace historical patterns of introduction (Dehnen-Schmutz, 2004). While railway IGS was found to function as a corridor for grassland plants, it was not found to provide any bonus to invasive species (Penone et al., 2012).

3.2. Trends and patterns in the literature

3.2.(a) Temporal trends

The earliest study included in our review was published in the 1960s (Bornkamm, 1961). Earlier studies not appearing in our systematic search were reported in a post-war botanical study of bombed cities (Lachmund, 2003). Over the last 15 years, the number of publications on IGS and urban biodiversity has risen, with 70% of all research papers published since 2004 (Fig. 2). This increasing interest could be related to ongoing global urbanization, the rise of urban ecology (Douglas and Goode, 2011), as well as increasing recognition of the interconnections between biodiversity and the well-being of urban residents (Dallimer et al., 2012a; Dearborn and Kark, 2010; Keniger et al., 2013).

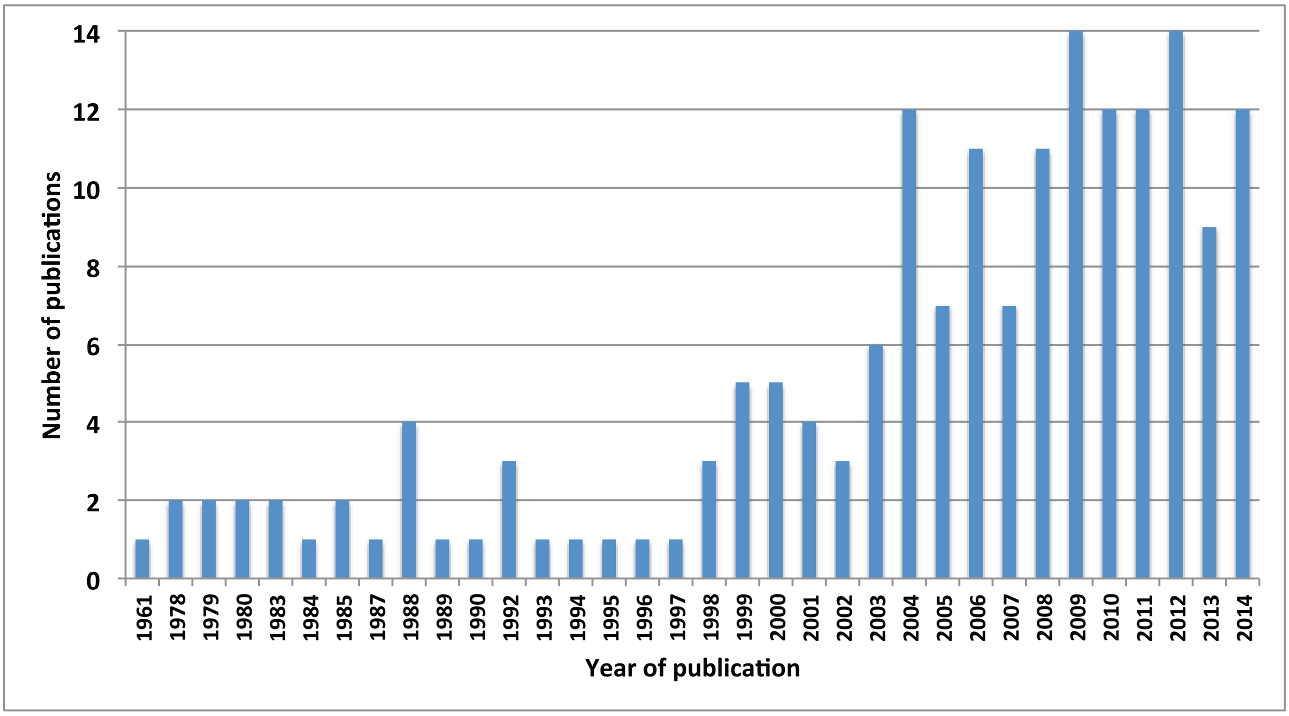

Figure 2 Publication history of papers on IGS biodiversity

3.2.(b) Spatial and linguistic patterns

The geographic distribution of study locations in single-country papers shows a heavy bias towards four countries: Germany (23 papers, 13%), the UK (22 papers, 13%), the US (18 papers, 10%), and Japan (15 papers, 9%) (Fig. 3). Few research papers compared IGS in different geographical contexts, causing a geographic concentration of knowledge about IGS especially in Europe (Fig. 4). Papers from countries with increasing research output, such as China, are rare – a result possibly caused by our limited capacity to search other languages, which we discuss in more detail later. Research papers written in German (14 papers, 8%) and Japanese (eight papers, 5%) made up 13% of all papers. Three German language papers studied IGS in Switzerland, while another one compared IGS in multiple countries.

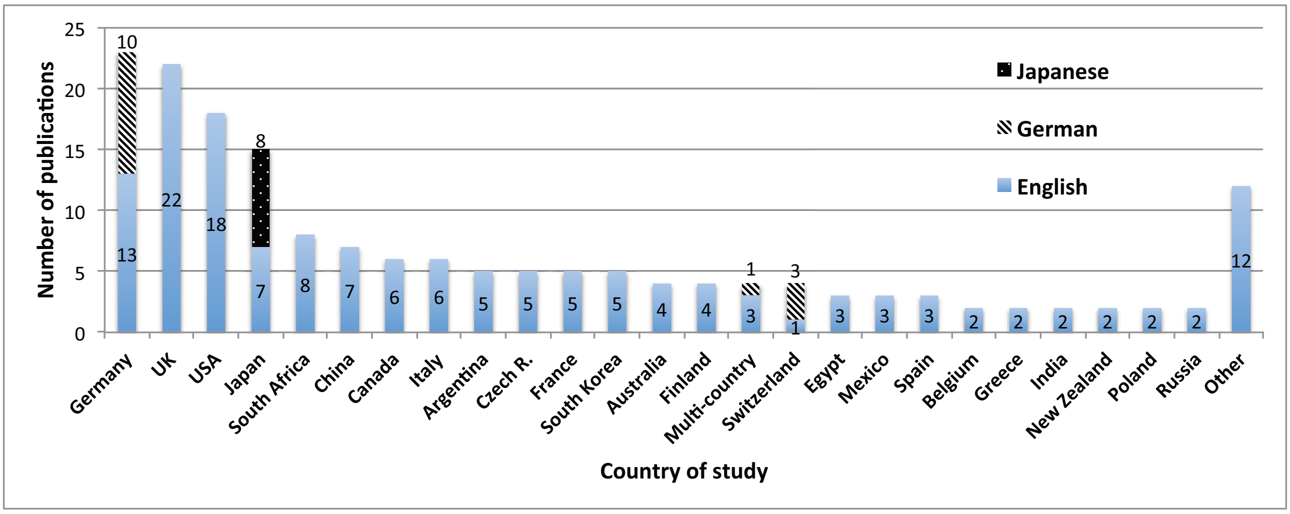

Figure 3 Geographic and linguistic distribution of papers on IGS biodiversity

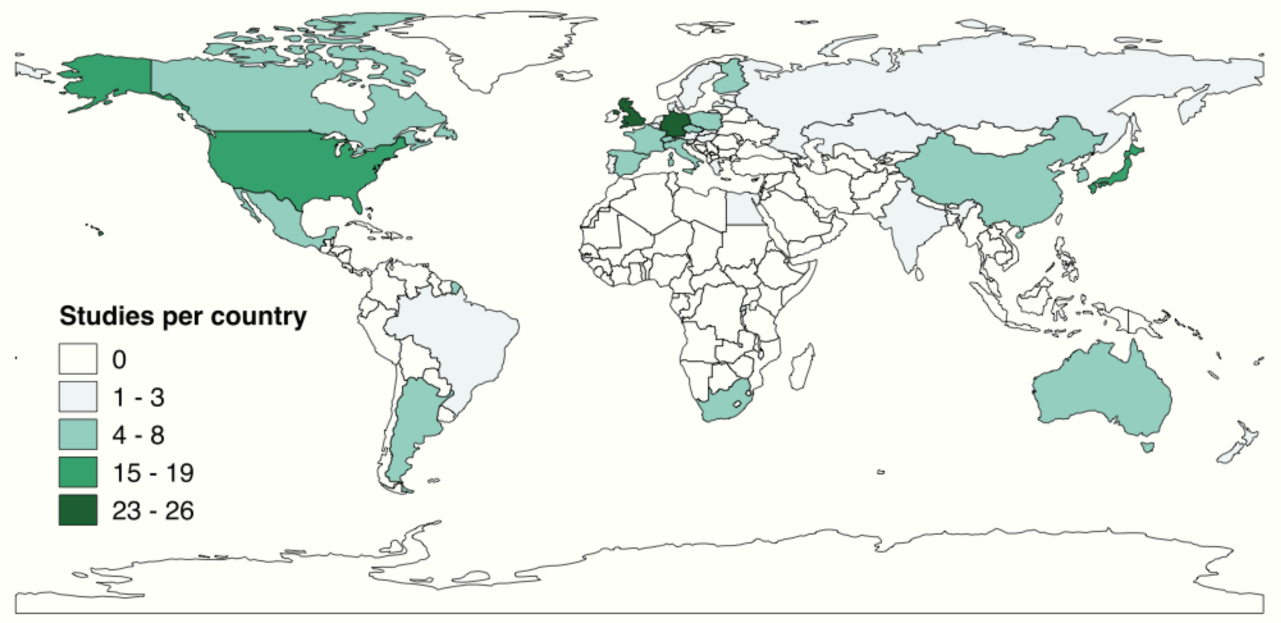

Figure 4 Map of IGS biodiversity studies per country (including multi-national studies)

3.2.(c) IGS types studied

Research papers that targeted at least two different types of IGS accounted for a third of all papers (61 papers, 35%, Fig. 5). Brownfield and waterside were the most commonly studied IGS types in single-type studies (27 papers or 16% each), followed by verges (22 papers, 13%) and structural IGS (17 papers, 10%). Gap, powerline and microsite IGS were almost completely absent from the literature. While some articles compared between types (Brandes, 2001), the number of IGS types included in most multi-IGS-type papers was limited, which in turn limited potential comparisons. As mentioned above, different authors may also refer to similar spaces by different names (e.g. wasteland, derelict land, abandoned lot, vacant lot), which may complicate drawing upon their data for potential future meta-analyses.

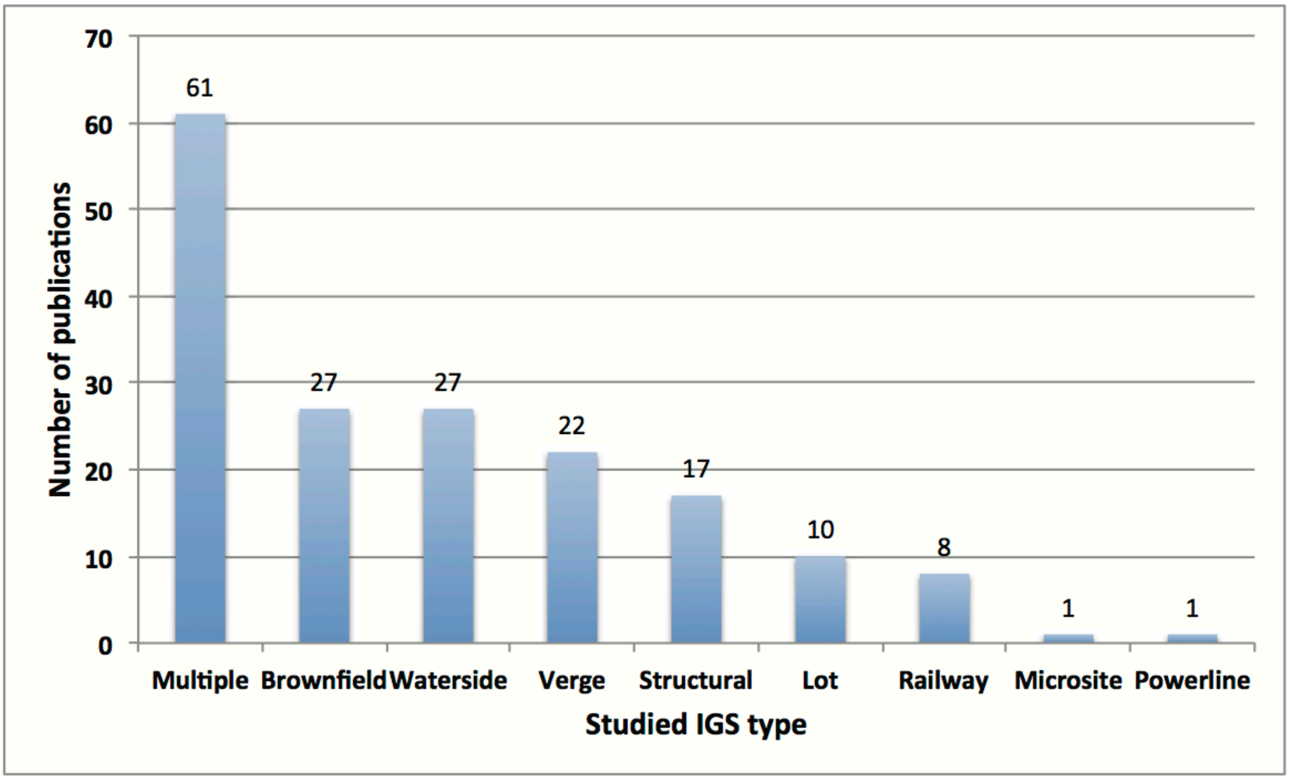

Figure 5 Distribution of papers on IGS biodiversity by studied IGS type

3.2.(d) Species groups studied

Vegetation dominated as the target of IGS biodiversity papers. Papers examining vegetation in general were most common (79 papers, 45%, Fig. 6), but researchers also studied various subsets of vegetation, such as vascular plants (5 papers, 3%), and groups of species not identical with a specific taxon, such as spontaneous or non-native vegetation (4 papers or 2% each) or edible weeds (2 papers, 1%). With regard to animals, birds (24 papers, 14%) and beetles (9 papers, 5%) were most frequently studied.

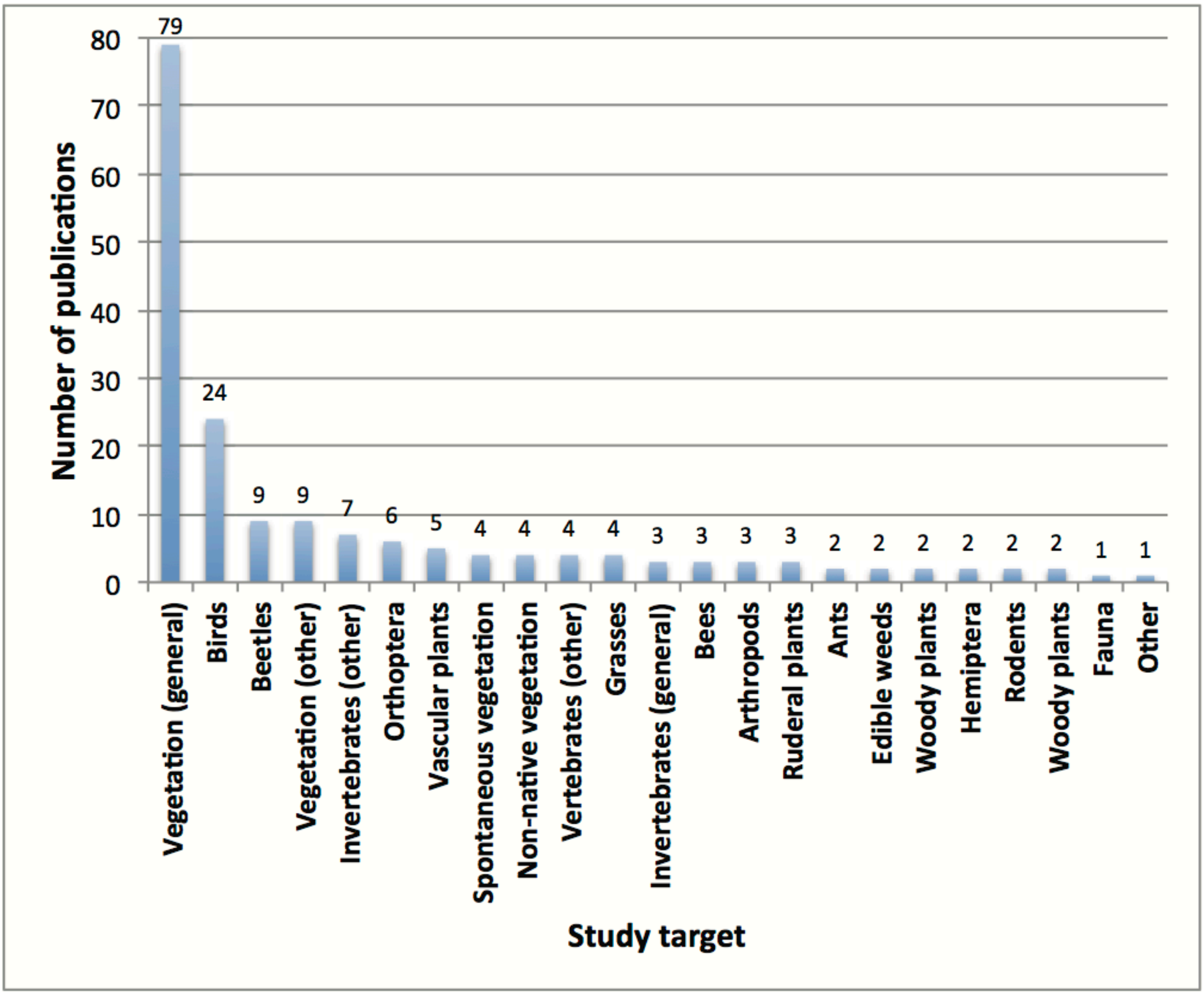

Figure 6 Distribution of papers on IGS biodiversity by studied species group

3.2.(e) Human impact

Researchers have found a variety of anthropogenic influence types affect IGS. The most commonly mentioned types were the design of the site and general maintenance/management (29 papers, 17%, Fig 7.), followed by vegetation removal in the form of mowing, cutting or weeding (26 papers, 15%) and pollution of various kinds (24 papers, 14%). Aspects of site design such as substrate type (e.g., bricks, gravel) were emphasized as particularly important for waterside (Francis and Hoggart, 2012) and structural IGS (Jim and Chen, 2011).

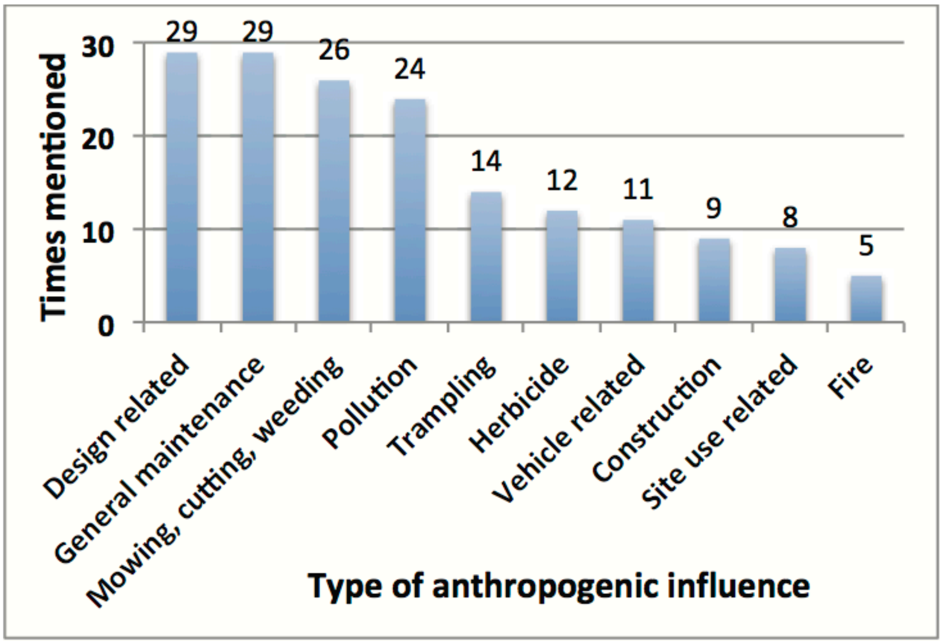

Figure 7 Most commonly mentioned types of human impact on IGS

3.2.(f) Climate zone distribution

Research papers showed a strong bias towards warm, temperate, and fully humid climate zones, particularly Köppen-Geiger climate type Cfb (79 papers, 45%, Fig. 8), followed by Cfa (29 papers, 17%) and Dfb (18 papers, 10%). This bias likely results from the biased geographic distribution of IGS biodiversity research sites and/or researchers (i.e. North America, Europe, and Japan).

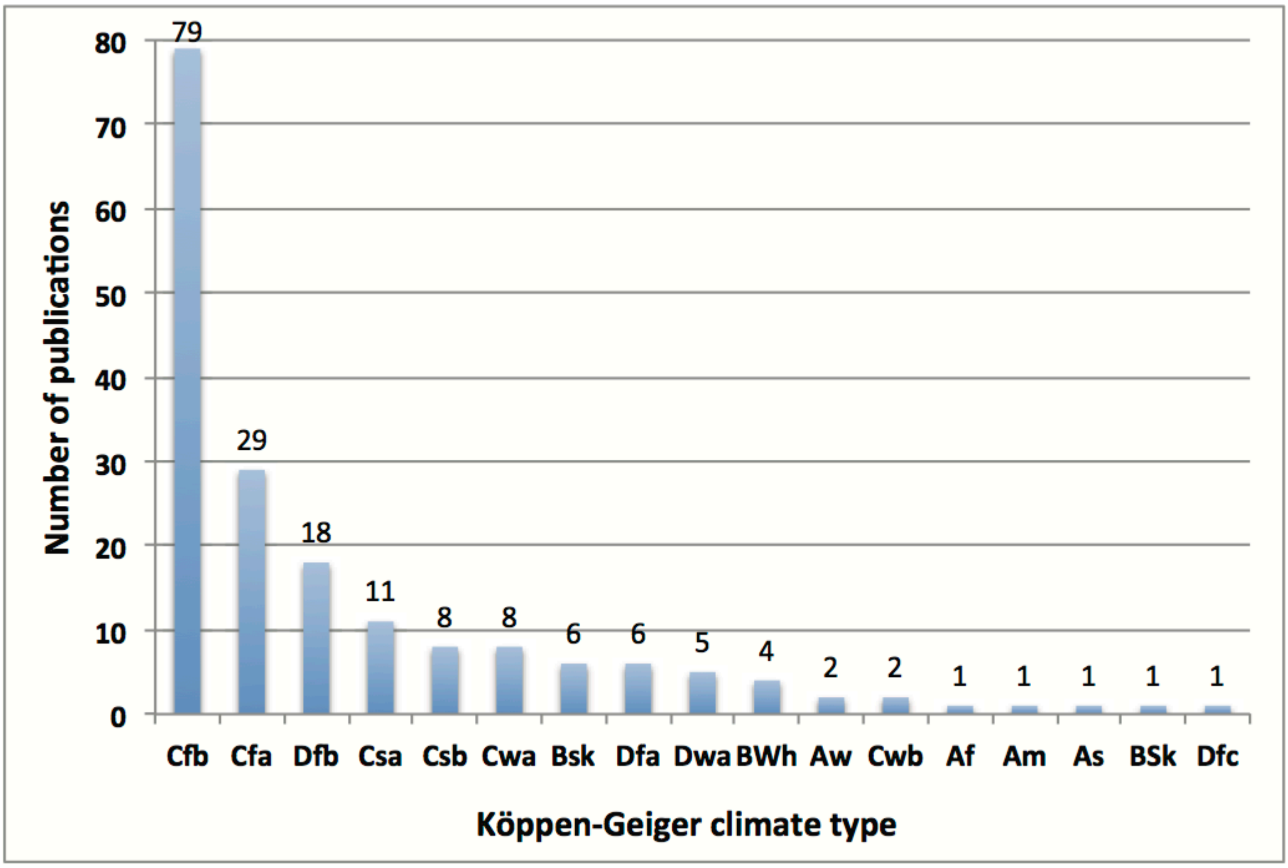

Figure 8 Distribution of papers on IGS biodiversity by Köppen-Geiger climate zone

3.2.(g) Key authors

Five scholars contributed four or more of the research papers reviewed. Petr Pyšek analyzed trends in urban vegetation diversity and composition over three decades (Pyšek et al., 2004) and co-authored several papers on European IGS vegetation (Celesti-Grapow et al., 2006; Prach et al., 2014; Prach and Pyšek, 2001; Pyšek et al., 2003). Cilliers and Bredenkamp studied the ruderal vegetation of railway reserves, vacant lots, and road verges of South Africa (Cilliers and Bredenkamp 1998, 1999a, 1999b, 2000). Brandes worked on ruderal vegetation of railway stations, walls, and that of a small town (Brandes, 2001, 1992, 1983; Oppermann and Brandes, 1993). Francis (with Hoggart) examined river walls and the influence of substrate on vegetation (Francis, 2011; Francis and Hoggart, 2009, 2008; Hoggart et al., 2012). Ten scholars contributed three research papers as authors or co-authors, including Bornkamm (Abd El-Ghani et al., 2011; Bornkamm, 2007, 1961), Jim and Chen (Jim and Chen, 2011, 2010, 2008), Kim (Kim, 2013; Kim et al., 2004; Kim and Lee, 2005), Kowarik (Weber et al., 2014; Westermann et al., 2011; Zerbe et al., 2004), Muratet (Maurel et al., 2010; Muratet et al., 2008, 2007), Pennington (Pennington et al., 2010, 2008; Pennington and Blair, 2011), and Small (Angold et al., 2006; Small et al., 2006; Small and Sadler, 2003). Twenty-six scholars contributed two research papers as authors or co-authors.

4. Discussion

4.1 Role of IGS for biodiversity

Researchers have found that IGS plays an important role for urban biodiversity because it provides a range of species with valuable habitat, as our systematic review of 174 research papers has shown. This result is consistent with an earlier review by Bonthoux and colleagues (2014), who analyzed 37 papers and reported that the diverse local features of wasteland encourage diverse communities. Our results further emphasize that the value of IGS depends on its local context.

IGS can provide habitat of a specific type otherwise scarce or absent in an urban area, for example as structural IGS in the form of vegetated brick walls (Brandes, 1992). It may also resemble ecosystems that were once dominant, but have declined as a result of landscape changes, such as verges and brownfields with characteristics similar to sand plain grassland (Brown and Sawyer, 2012). By providing stepping-stones that support dispersal in urban areas, informal greenspaces form part of a habitat network and enhance sustainability of metapopulations, as Kaupp and colleagues (2004) reported for beetles nesting on spontaneously vegetated roofs. In addition to such direct contributions to conservation, the localized socio-ecological aspects of IGS can produce indirect benefits. In Hong Kong, spontaneous strangler figs may inspire awe in the viewer (Jim and Chen, 2011), thus inspiring ecological awareness, and increasing the possibility of support for nature conservation initiatives (Dunn et al, 2006). In Bariloche (Argentina), where malnutrition poses a serious problem, 1.3 tons of edible weeds may be harvested per hectare of vacant urban and suburban lots (Diaz-Betancourt et al., 1999), thus reducing the use of protected areas for unsustainable livelihood practices. Such socio-ecological aspects can be important for biodiversity because urban residents' contact with nature likely influences conservation efforts beyond the local urban area (Dunn et al., 2006; Millard, 2010; Miller, 2005). However, the main value of IGS for conservation remains context-specific (e.g., which species benefit the most, and which likely do not? Which type of IGS may provide which kind of threatened habitat type?). As Bonthoux and colleagues (2014) argued, wastelands are not a uniform environment. The same is true for IGS, which means planners and environmental managers must depend on localized knowledge to effectively integrate IGS into urban conservation strategies – a point we return to shortly.

Factors influencing the biodiversity of IGS are characterized by two aspects, (i) the importance of local features and (ii) the strong impact of management practices. Regarding the importance of local features, our results are consistent with the findings of Bonthoux and colleagues (2014). Our results further emphasize the importance of vegetation structure, vegetation as a food source, vegetation cover, site age, and soil – in other words, characteristics that require planners to have a thorough understanding of the local conditions in order to adopt appropriate conservation strategies (as discussed above). The impact of management on IGS biodiversity was a widely reported issue in the papers we reviewed, but was in contrast not reviewed by Bonthoux and colleagues (2014).

The expanded scope of our review casts a new light on the importance of maintenance practices and their negative impact on diversity (Cilliers and Bredenkamp, 1998; Helden and Leather, 2004; Jantunen et al., 2006; Jim and Chen, 2010; Namba et al., 2010; Vakhlamova et al., 2014; Yamato et al., 2004). IGS, according to the definition used in this review (Rupprecht and Byrne, 2014a, 2014b), is neither formally recognized, nor its vegetation managed by its owner for agriculture, forestry, gardening, or recreation. Yet various forms of maintenance (e.g., mowing, herbicide spraying) are still regularly carried out (see above). Maintenance generally reduces vegetation structure and complexity, in turn limiting the amount of food and shelter IGS can provide. This may benefit pioneer and opportunistic species, but could make IGS less valuable for specialists. Some maintenance may be necessary for utilizing the space (e.g., keeping verge vegetation from blocking motorists' line of sight (Brown and Sawyer, 2012)). However, as Hard (2001) pointed out, both conservation-related and formal vegetation management in cities is ecologically and functionally flawed: spontaneous vegetation is 'managed' using high levels of money, labor and herbicides to protect abstract notions of aesthetics or risk minimization. Research by Nassauer has demonstrated how aesthetics and social norms are important drivers for vegetation management (1988; 1992; Nassauer et al., 2009), and as a result a perceived absence of management may signal a lack of care (Nassauer, 1988), with flow-on impacts for biodiversity.

Such socially constructed ideals of greenspace (Lossau and Winter, 2011) and the notion that cities are devoid of nature (long since dispelled by urban ecologists) may be reasons why IGS is often viewed negatively and associated with decline (Corbin, 2003; Rall and Haase, 2011). To unlock the potential of IGS to contribute to specific conservation goals, we may need to adapt management practices accordingly. Brown and Sawyer (2012) provide examples for such adaptations in the management of roadsides resembling sand plain grassland: changing mowing regimes to allow the grasses to flower and mature seed could enhance the presence of rare species, while adjustments to mowing height and width aid perennial species. This example demonstrates that management adaptation is an intricate process. For such adaptions to succeed, we need to understand local IGS conditions as well as the requirements of the species we aim to conserve.

Rare indigenous species have been found in IGS (Dana, 2002; Eyre et al., 2003), but so have non-indigenous and invasive species (Asmus and Rapson, 2014) – an aspect that affects IGS biodiversity management. Urban areas are characterized by challenging environmental conditions that not all species are able to tolerate. While modified maintenance regimes may increase the number of threatened species in IGS, even non-indigenous species that can adapt well to urban environments may enhance biodiversity or provide ecosystem services. For example, Zerbe and colleagues (2004) reported that non-indigenous vascular plants in industrial, road and railway sites contribute close to a third of urban plant biodiversity in Chonju, South Korea. Moreover, Meek and colleagues (2010) drew upon the concept of 'novel ecosystems' (Hobbs et al., 2006) to argue that where restoration to historic conditions is not feasible, management should make use of non-indigenous species to provide ecosystem functions. Importantly, IGS does not replace formal green space such as parks, gardens and conservation areas. Rather, IGS is a liminal, hybrid, socio-ecological entity that provides habitat for plants and animals as well as opportunities for urban residents to interact with and experience nature (Rupprecht et al., in press; Rupprecht et al., 2015; Rupprecht and Byrne, 2014b). Therefore, researchers have suggested spontaneous vegetation could be understood as the “de facto native vegetation of the city” (Del Tredici, 2010b) because it is always appropriate to site conditions (Kühn, 2006). This affects policy recommendations, discussed in more detail later.

4.2 Trends and patterns in the literature

Our results have revealed a strong bias in the reviewed IGS literature towards specific regions (Europe, the USA, and Japan) and climate zones (temperate and humid such as Cfb, Cfa, and Dfb). One limitation of our review was our capacity to search other languages besides English, German, and Japanese. This limitation likely contributed to the spatial bias we found in the literature. However, papers published in both German and Japanese only accounted for about half of the studies conducted in Germany and Japan, even though the different linguistic distance between English and the two languages (Chiswick and Miller, 2005) makes learning English easier for German researchers than for Japanese researchers. This could suggest that the comparatively low number of English publications on IGS biodiversity may not solely result from missing non-English publications, but could instead indicate an actual gap in our knowledge about IGS biodiversity in these countries. Future reviews should therefore target additional languages to clarify this issue.

If we lack local IGS knowledge, the spatial and climate zone bias is a major concern, because it would impede our ability to devise context-specific conservation measures in regions that are home to large urban populations, such as China, India, South-East Asia, Africa, and South-America. In particular, climate zones A (four studies) and B (11 studies) are severely understudied, but account for 88% of Africa, 75% of South America, and almost all of South-East Asia (Peel et al., 2007). Countries in these regions are experiencing both rapid urbanization (UN-HABITAT, 2012) and threatened biodiversity (Zhao et al., 2006). But it is possible that there is a literature on IGS in these climatic zones that has not been explicitly framed around biodiversity conservation. For example, in the megacities of Africa and Asia, there may be an emphasis on food security rather than biodiversity. Urban interstices offer the potential for growing food, especially for socio-economically marginalized and vulnerable populations, and for growing medicinal herbs. Growing plants valued for their medicinal properties or nutritional benefits does not necessarily diminish biodiversity, and recent studies of urban food gardens have shown that they can be highly biodiverse (Galuzzi et al., 2010; Weinberger, 2013). Therefore, a better knowledge of local IGS could help to devise strategies for preserving urban biodiversity in these areas, which depend on local knowledge to be effective (see above).

Studies on brownfield, waterside, verges, and structural IGS types were the most common, while gap, powerline and microsite IGS are still comparatively understudied. The area of these understudied sites is usually much smaller than that of a vacant lot or brownfield IGS, which may make such sites seem like a less rewarding object of study, and/or present significant methodological challenges. However, the fragmented nature of urban landscapes makes it likely that a high number of such spaces exist within cities. For example, a recent case study suggested that almost 20% of IGS, or one percent of the surveyed area in Sapporo (Japan) consisted of gap IGS (Rupprecht and Byrne, 2014a) – an amount particularly valuable for conservation in dense urban areas where other greenspace is scarce. These hitherto little-examined IGS types also warrant closer attention because different IGS types differ in their characteristics (Table 1), and may consequently contribute to urban conservation in different ways. A better understanding of gap and microsite IGS may also help planners to create synergies between conservation and greenspace strategies. Specifically, they may be able to act as additional stepping-stones, similar to vegetated roofs (Kaupp et al., 2004), while contributing to the prevention of urban heat-island effects.

Studies on the vegetation of IGS and its role for birds and beetles were comparatively common, but we presently know little about if and how IGS can be valuable for mammals and reptiles. Studies on ants were also scarce, despite research suggesting vacant lots can feature a distinct species composition and can be richer in species than gardens (Uno et al., 2010). While the limited size of some IGS sites suggest their value could be limited, large or linear sites such as powerline and railway verge IGS could potentially function as movement corridors for large urban wildlife (e.g., coyotes, foxes, deer, kangaroos) connecting urban and peri-urban areas (Rudd et al., 2002).

A number of authors (e.g., Cilliers and Bredenkamp in South Africa, Jim and Chen in Hong Kong, Kim in South Korea) that contributed three of more studies were based outside of Europe, the USA, and Japan. This stands in contrast with the regional bias of the literature. Knowing authors central to the field is important, because it allows us to understand how the current body of IGS literature developed. Additionally, it provides a starting point for studies on the history of IGS biodiversity science. Such authors possess valuable expertise that may help in devising locally adapted conservation strategies. They could also play a role in coordinating future research efforts in their regions, or collaborate for cross-regional and cross-cultural studies as follow-ups to emerging cross-national studies (e.g., Lososová et al., 2011).

5. Conclusions

5.1 Policy recommendations

Our review of 174 research papers on the role of IGS for biodiversity found that IGS is valuable for conservation, but appropriate management is important for maintaining IGS biodiversity (though this must be inferred because few, if any, studies have demonstrated a statistically significant correlation). We therefore propose to complement the suggestions for conservation and planning of urban wastelands by Bonthoux and colleagues (2014) with a review of maintenance practices. For example, reducing or changing mowing intervals may not only benefit site diversity (Brown and Sawyer, 2012) and save resources, but may also preserve the natural site character that residents cherish (Rupprecht and Byrne, 2014b). However, planners should avoid treating IGS like conservation areas by restricting residents' access, as the diversity of formal and informal uses produces the habitat diversity and local features that make IGS valuable for biodiversity (Bonthoux et al., 2014; Hard, 2001). A thorough understanding of these local features and the local context should inform IGS management, and facilitate integration into urban conservation strategies.

Planners and government agencies need to work with owners of IGS, such as utilities and railway operators, to phase out harmful maintenance practices (e.g., herbicide spraying). Where frequent vegetation maintenance is essential or strongly preferred as a result of residents' preferences (Nassauer et al., 2009), encouraging a conversion of IGS toward recreational green space types such as community gardens may be an option. For example, the power utility Chubu Electric Power invites local residents in Nagoya (Japan) to use land under urban power transmission lines for gardening free of charge, if they in return keep vegetation under a specified height (Rupprecht and Byrne, 2015). The utility profits financially from reduced maintenance expenses, the community enjoys additional recreational opportunities, and birds as well as insects gain a source of food. As such arrangements in particular and the conservation value of IGS in general are determined by its local context, we propose directions for future research to fill the gaps in our local knowledge of IGS biodiversity.

5.2 Directions for future research

This review has identified three major gaps in our knowledge of IGS, our localized knowledge of IGS around the world, our knowledge of understudied IGS types, and our knowledge of understudied species groups. First, we know little about IGS biodiversity outside of the temperate and humid Cfb, Cfa and Dfb climate zones of Germany, the UK, the USA, and Japan. Future research should target IGS biodiversity in South-East Asia, Africa, South America, the Middle East, India, China, and Australia, as well as IGS in the climate zones A and B. Moreover, international comparisons of IGS are rare, and the lack of studies in many regions limits potential meta-analyses and cross-cultural studies. How do different cultural contexts influence the value of IGS for biodiversity, the possibilities for management adaptions, or the potential for hybrid conservation-recreational use? However, it is important to note that this review only examined the available literature in English, German and Japanese. As discussed above, our search also found Spanish and Russian research papers on IGS. A review of literature on IGS in these languages, Chinese, French, Indonesian, Polish and other languages would likely advance our understanding of IGS and help local planners and IGS owners to adapt policies and management.

Second, we lack studies on gap, powerline and microsite IGS as well as comprehensive comparative studies. Future research should address this lack of knowledge by examining some of the following questions. How do gap, powerline or microsite IGS contribute to urban biodiversity? How does their potential contribution compare to other IGS types? How can management practices for these sites be adapted to benefit conservation? Moving to study designs based on a common IGS typology may help us to identify urban habitats important to biodiversity that researchers might have previously overlooked, and could facilitate studies comparing between different IGS types. Research on smaller sites could also redress the paucity of knowledge about IGS in the megacities of Africa and Asia. For instance, it might help to answer questions about whether IGS is meeting food-security needs, such as the harvesting of spontaneous vegetation or the growing of ‘bush foods’ in the urban interstices, and how in turn this might impact biodiversity.

Third, future studies should investigate the role IGS may play for hitherto scarcely studied species groups. Can IGS benefit mammals, reptiles, or marsupials? Do limited size and human disturbance prevent large animals from using IGS? How does the presence of animals in IGS affect resident perception (e.g., opportunities for nature contact, potential for wildlife conflict)? We need to address these three main gaps in our knowledge. Closing these gaps would be a first step to better understanding the local features of IGS – local features that are key to how IGS contributes to biodiversity, how we should adapt our management of IGS, and how we can integrate IGS into urban conservation strategies. Better knowledge of IGS is crucial for future conservation efforts in urban areas.

Finally, the increasing number of studies on IGS biodiversity provides a growing source of data that future studies could draw upon for meta-analyses. For example, IGS size did not feature prominently as a driving factor for species diversity in the papers we examined in our study – despite the important role of this factor in ecological theory (e.g., island biogeography). Future research could analyze a set of IGS studies to explore what role IGS size and related factors such as fragmentation play for the biodiversity of these urban spaces. Another potential target for a meta-analysis would be to quantify (using statistical analysis) the apparent negative relationship between the degree of IGS management and IGS biodiversity – as suggested in some of the literature addressed by this paper. We recognize that this is just one step in a much larger research agenda on IGS. Future studies could address diverse aspects of this understudied component of urban forestry and urban greening.

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Appendix A – Search terms used in English, Japanese, and German

English	Japanese	German
IGSVariable		
ruderal	荒地 (arechi)	ruderal
railway	鉄道 (tetsudō)	Eisenbahn
vacant lot	空き地 (akichi)	leeres Grundstück
abandoned lot	空き地 (akichi)	verlassenes Grundstück
walls	壁 (kabe)	Mauer, Wall
street/ road verges	道の端 (michi no hashi)	Straßenrand, Straßengraben
curbside	舗道の縁石 (hodō no enseki)	Straßenrand
wasteland	荒地、荒野 (kōya)	Ödland, Brache
brownfield	工場跡地 (kōjōatochi), ブラウンフィールド	Industriebrache, Brache, Braunfeld
landfill	埋立地 (umetatechi)	Deponie, Müllhalde
industrial park	工業団地 (kōgyōdanchi)	Industriepark
corridor	回廊 (kairō)	Korridor, Schneise
powerline	電線 (densen)	Hochspannungsleitung, Stromleitung
riverbank	川岸 (kawagishi)	Flussufer
buildings	建物 (tatemono)	Gebäude
road swales	ー	Straßengraben
trails, foot paths	路 (michi)	Weg, Pfad, Fusspfad, Trampelpfad
wilderness	荒野, 自然 (shizen)	Wildniss
spontaneous vegetation	自然発生植生 (jihatsutekishokusei)	Spontane vegetation
novel ecosystem	新興生態系 (shinkōseitaikei)	Neue Ökosysteme
riparian	河岸 (kawagishi), 川岸、水辺 (suihen)	Ufer...
Biodiversity aspects		
biodiversity	生物多様性 (seibutsutayōsei)	Biodiversität, Artenvielfalt
richness	種豊富さ (shuhōfusa)	Reichtum
composition	種組成 (shusosei)	Zusammensetzung
diversity	種多様性 (shutayōsei)	Diversität, Vielfalt
species	種類 (shurui)	Spezies
urban	都市 (toshi)	urban, städtisch

Appendix B (online suppl. info?) – Author, year, location, IGS type, species group, study area, climate zone, IGS description, species number, human impact, and comments on IGS of all 174 individual research papers

First author	Year	Country	IGS type	Species group	Study area	Climate	IGS description	Species number	Human impact on IGS	Value and comments regarding IGS
Abd El-Ghani	2011	Egypt	multi	Vegetation	multi	BWh	Wasteland	172		Flora distinct from other urban habitats
Abd El-Ghani	2012	Egypt	multi	Vegetation	multi	BWh	Wasteland, abandoned fields, railways, highways, canals	na	Pollution, weeding, canal design	Species diversity increases with aridity, soil character changed by anthropogenic activities
Angold	2006	UK	Brownfield	Vegetation	Birmingham	Cfb	Derelict sites	378		Dispersal between sites important for flora, chain of habitats, recommend delaying redevelopment
Asami	1999	Japan	multi	Imperata cylindrica	Okinawa	Cfa	Expressway slope, airfield	8-24	cutting	Separate seed pool from urban ecosystem, easily invaded
Asmus	2014	New Zealand	multi	Vegetation	multi	Cfb	Ruderal & waste areas, railways, paving, walkways, walls, lawns (var. management levels)	483	Management, trampling	89% exotic species, town flora very homogenous, environmental influence factors include distance from coast & size of central business district
Bacaro	2012	Germany	Brownfield	Vegetation	Bremen	Cfb	Brownfields on university campus	60	Trampling, grazing	No decay of compositional similarity with increasing spatial or environmental distance was found
Banville	2012	USA	Waterside	Herpetofauna	Tempe	BWh	Riparian reach	2	Vegetation removal, water diversion	Disturbed reach had lowest herpetofauna abundance and species richness, increased vegetation structural complexity recommended
Bigirimana	2011	Burundi	multi	Urban vegetation	Bujumbura	Aw	Ruderal grasslands, verges, abandoned ditches	176-337	trampling, grazing, fire	High abundance of introduced species
Bornkamm	1961	Germany	Structural	Spont. vegetation	Göttingen	Cfb	Gravel-based unplanted roofs	2-20	construction	Variety of plant communities, extreme wet and dry conditions
Bornkamm	2007	Germany	Microsite	Spon. woody vegetation	Berlin	Cfb	Bare experimental plots over 38 years	17-28, 33	none	Alien species rare, results support spontaneous succession as cheap way to develop near-natural plant communities rich in species

First author	Year	Country	IGS type	Species group	Study area	Climate	IGS description	Species number	Human impact on IGS	Value and comments regarding IGS
Brandes	1983	Germany	Railway	Vegetation	multi	Cfb	Active and abandoned core rail yard areas	385	Intense herbicide spraying	Abandoned rail yards of special importance, valuable for biodiversity
Brandes	1992	multi	Structural	Vegetation	multi		City walls	221	Wall restoration	Important as habitat and for biodiversity, recommendations for plant-friendly restoration work
Brandes	2001	Germany	multi	Ruderal plants	Lüchow	Cfb	Stone and walls, verges, riverbanks, rail tracks, rail yard, wasteland	ca. 300	varying	Highest diversity in wasteland and rail yard
Brown	2012	USA	Verge	Vegetation	multi	Cfa, Cfb	Limited-access highway roadsides	80	Mowing, salt	Complex upland grassland habitat reminiscent of agricultural grasslands in 19th century; not ecological wasteland
Campbell	2008	UK	Waterside	Waterbirds	Glasgow	Cfb	Riverbank (0-20m from bank)	15	Presence, food waste, feeding	Vegetation and veg. Diversity important for birds
Carbo-Ramirez	2011	Mexico	Verge	Birds	Pachuca	Cwb	Road strip corridors	9	Pedestrians, vehicles, noise, vegetation cutting	Can function as corridors, can contribute to gamma diversity, potential not recognized by authorities
Castillo	2003	Argentina	multi	Rodents	Rio Cuarto	Cwa	Vacant lots, rubbish dumps, stream banks, railway banks, vacant areas	7	Food waste, shelter, control efforts	Health risk, examined spaces provide habitat
Catterall	2010	Australia	Verge	Birds	Brisbane	Cfa	Suburban road verges	69	Vegetation cutting, planting, presence	Relatively high diversity and thus valuable, may increase diversity if replacing agriculture, homogenization not supported, low replacement of natives by non-natives
Celesti-Grapow	1998	Italy	multi	Spont. vegetation	multi	Cfa, Csa	Ruins, dumping sites, industrial sites, road ides	ca. 50-160	Intense human use	Flora not uniform between cities, high diversity, low alien diversity and influence
Celesti-Grapow	2006	Italy	multi	Vegetation	Rome	Csa	Archeological sites, new development with wasteland and vacant lots, historical center with spon veg, roadsides, walls	179-324	Intense human use	No competition between natives and aliens, high diversity, diversity dependent on habitat and disturbance

First author	Year	Country	IGS type	Species group	Study area	Climate	IGS description	Species number	Human impact on IGS	Value and comments regarding IGS
Cervelli	2013	China	multi	Vegetation	Xi'an	Cwa	Permeable pavement, unmanaged soil, walls, sidewalk, planted beds	95	Trampling, distance to city center	Microhabitats similar in species composition, could be used to enhance species diversity in city center
Ceschin	2010	Italy	Waterside	Vegetation	Rome	Csa	Riverbank	555)	Pollution, maintenance work	Diversity may have been decreased by more frequent maintenance, increase of ruderals and aliens due to increased human activity
Chen	2014	China	multi	Vegetation	Harbin	Dwa	Road gap, abandoned land (soil or gravel)	na	Temperature increase, land use change, construction, trampling	Species diversity much lower than in former non-IGS land use, increase in xeric and mesic species
Chiquet	2013	UK	Structural	Vegetation, birds	multi	Cfb	Vegetated walls	na	Human presence	Birds exploited green walls but were never found on bare walls, veg. walls can provide resources for birds without requiring land
Chmaitelly	2009	Lebanon	multi	Vegetation	Beirut	Csa	Vacant lots, coastal cliffs	34-47	limited	High floral diversity, recognize that naturalized flora have various ecological as well as aesthetic qualities and socio-cultural significance
Christian	2004	Austria	multi	Protura	Vienna	Cfb	Roadside green, bridge, ruderal sites, waste disposal site	0-3, 5	Human-deposited soil	Anthropogenic habitats bear a poor and apparently random proturan fauna - yet contribute one sixth to the overall species number
Cilliers	1998	South Africa	Railway	Vegetation	Potchefstroom	Bsk	Railway reserves	169	Soil compaction, herbicide	Low species number per sample plot in comparison with natural areas, management should encourage successional changes
Cilliers	1999 a	South Africa	multi	Vegetation	Potchefstroom	Bsk	Pavements, parking areas	na	Herbicide, weeding, mowing	Previously undescribed communities, conservation not necessarily means changes in maintenance practices
Cilliers	1999 b	South Africa	Lot	Ruderal plant	Potchefstroom	Bsk	Vacant lots	172	Disturbed soil (post-building) lots	Relatively low percentage of introduced species (35%), no similarities with ruderal communities in other continents
Cilliers	2000	South Africa	Verge	Vegetation	Potchefstroom	Bsk	Road verges	253	Construction, maintenance	Well-established vegetation, low percentage of introduced species (26%), higher than similar ruderal sites in the city (see Cilliers 1998, 1999a, 1999b)

First author	Year	Country	IGS type	Species group	Study area	Climate	IGS description	Species number	Human impact on IGS	Value and comments regarding IGS
Clemens	1984	UK	Brownfield	Vegetation	Sheffield	Cfb	Derelict demolition sites	83-93, 152	Disturbed soil, brick rubble	Cheap landscaping could increase potential use, diversity and attractiveness could be increased by sowing seed collections from other wasteland sites
Colla	2009	Canada	Structural	Apidae	Toronto	Dfb	Spontaneously vegetated green roof	54	None after construction	Green roofs can offer habitat for a variety of bee species
Crawford	1979	USA	Brownfield	Spiders, arthropods	Seattle	Csb	Former dumping site with surface earth fill	na	Construction, limited afterwards	Low arthropod diversity, absence of low dispersal ability taxa, spider fauna dominated by an introduced species
Crowe	1979	USA	Lot	Flowering plants	Chicago	Dfa	Vacant lots	128	Mowing	Diversity increases with age and lot size, decrease with isolation
Dallimer	2012	UK	Waterside	Vegetation, birds, butterflies	Sheffield	Cfb	Heavily modified riparian corridors	363, 74, 21	Pollution, canalization	Important part of urban habitat mosaic, influence of habitat diversity (positive) and sealed surface (negative) on species richness
Dana	2002	Spain	multi	Urban vegetation	Almeria	Csa	Vacant lots, walls, dumps	na	Complete destruction of vegetation possible several times a year	Should be considered for conservation, contain rare species, balance between protection and needed disturbance difficult
De Neef	2008	New Zealand	Structural	Vegetation	multi	Cfb	Walls	117	Frequent spraying and cleansing	High number of exotic species, numerous benefits of wall vegetation, great potential (large area, additional vertical space for densely developed districts)
Dehnen-Schmutz	2004	Germany	Structural	Alien plant species	multi	Cfb	Castle rocks and walls	na	limited	Number of usable exotic plants show historical reasons for introduction
Desjardins	2014	Canada	Brownfield	Vegetation	Varennes	Dfb	Former decantation basin	23	Pollution	Rare species excluded, up to 60% of variance in spont. Plant distribution was explained by pollutant dispersion pattern
Diaz-Betancourt	1999	multi	multi	Edible weeds	multi	Csb, Aw	Verges, pathways, vacant lots	43 (Coatepec), 32 (Bariloche)		Significant potential as food source providing more than 1 ton per ha of edible fresh biomass
Dickman	1987	UK	multi	Small mammals and plant	Oxford	Cfb	Minimally managed long grass fields	47-58	Minimal	Vegetation more important for small mammals than urban environment factors

First author	Year	Country	IGS type	Species group	Study area	Climate	IGS description	Species number	Human impact on IGS	Value and comments regarding IGS
Dingaan	2013	South Africa	multi	Vegetation	Bloemfontain	BSk	Drainage line surroundings, fallows, vacant lots, railway and road verges	na	Grazing, burning, mowing	Preservation important because vegetation could form dispersal corridors
Do	2014	South Korea	Brownfield	Carabid beetles	Busan	Cfa	Covered-up former landfill	15	Artificial drainage facilities	Landfill provides stable habitat, but drainage facilities critically affect beetles (fall into drainage)
Eremeeva	2005	Russia	multi	Pollinating insects	Kemerovo	Dfb	Industrial zone	36, 7	Litter, pollution	Large areas of urban plots with partly restored vegetation provide sufficient food supply for butterflied and bumblebees, pollution important for bumblebees
Eyre	2003	UK	Brownfield	Coleoptera	multi	Cfb	Various brownfield sites (railway, factory, canals)	473	Pollution, rubble	Large number of rare species, high conservation value
Fernandez-Juricic	2000	Spain	Verge	Birds	Madrid	Csa	Wooded streets	14	Pedestrians, vehicles	Vegetation structure and park connection have positive influence
Florencia Carballido	2011	Argentina	Brownfield	Rodents, plants	Buenos Aires	Cfa	Closed landfill	6, 70	Reduced vegetation due to landfill legacy	Mostly indigenous species, can play role in conservation, vegetation structure factors explain most abundance data
Franceschi	1996	Argentina	Lot	Ruderal vegetation	Rosario	Cfa	Vegetated vacant lots	172	Mowing, burning, weeding, rubble, rubbish	No similarity to other vacant lot studies, many therophytes, usually one dominating species per community
Francis	2008	UK	Waterside	Vegetation	London	Cfb	River walls	35	Maintenance, choice of substrate	Strong influence of substrate material on habitat potential, brick and boulders preferred to concrete, conservation potential
Francis	2009	UK	Waterside	Vegetation	London	Cfb	River walls	20	Maintenance, pollution, choice of substrate	Mix of terrestrial and riparian species, surface fractures increase plant diversity, habitat improvement potential
Francis	2011	UK	Waterside	Vegetation	London	Cfb	River walls	90	Limited, maintenance, pollution, substrate choice	"Mass effect" - flora maintained by propagule pressure, significantly more diversity on bricks than sheet metal, potential for habitat improvement
Fründ	1988	Germany	multi	Soil biota and vegetation	Berlin	Cfb	Wasteland, parking space, verges, street tree rings	na	Trampling (including vehicles)	High diversity, wasteland and verges more diverse than flower plantings

First author	Year	Country	IGS type	Species group	Study area	Climate	IGS description	Species number	Human impact on IGS	Value and comments regarding IGS
Gantes	2014	Argentina	Brownfield	Vegetation	Buenos Aires	Cfa	Partly active landfills	48	Machinery movement, maintenance, mowing, cover material	Exotic species are dominant, natives gain with age of cells, in oldest cells some species belong to local climax community
Garcillán	2009	Mexico	Lot	Non-native vegetation	Ensenada	Bsk	Vacant lots	97		High percentage (61%) of non-natives in comparison to other vacant lot studies
Gatesire	2014	Rwanda	multi	Birds	Musanze	Cfb	Riversides, streamsides, wasteland	35, 24, 16	Human presence, vehicle noise	Lower diversity than other urban landscapes, but different microlandscape types harbor different species
Geibert	1980	USA	Powerline	Songbirds	South Kingstown	Cfb	Powerline right-of-way	52	Infrequent cutting	High diversity, higher than in neighboring residential area, vegetation structure complexity and cover over 60cm correlated with bird diversity
Gilbert	1990	UK	multi	Lichen	multi	Cfb	Highly urban, recently disturbed wasteland	100	Rubble, rubbish dumping, maintenance, vehicle encroachment, contractors' camps, bonfires and children's play	Higher than expected diversity, rare and newly discovered species, threatened by development and economic growth
Godefroid	2007	Belgium	multi	Vegetation	Brussels	Cfb	Derelict and despoiled land	na	Former land use, pollution	Probability of species occurrence related to land use
Godefroid	2007	Belgium	multi	Vegetation	Brussels	Cfb	Former industrial area, demolished house lots	74	Trampling	Concrete substrate and walls around a site lowered diversity, different anthropogenic substrates have different flora
Gong	2013	China	Verge	Vegetation	Shenzhen	Cwa	Linear corridors along roads and sidewalks or island patches	205		Verges similar to residential and industrial vegetation in native-alien ratio, alien species widespread
Gruttke	1988	Germany	Lot	Carabids	Berlin	Cfb	Abandoned ruderal area	68		Building density and use intensity influence carabid distribution
Guggenheim	1992	Switzerland	Structural	multi	Zurich	Cfb	Vegetated walls	199, 51 (moss)	Maintenance, substrate choice, herbicides	Wall vegetation contributes to urban diversity and to the visual character of the city center and thus deserves protection, human beauty perception plays a role in conservation
Gupta	2010	India	Brownfield	Vegetation	Bulandshahr	Cwa	Brick kiln brownfield	25	Brick and ash rubble	Varying diversity in different seasons, less diversity due to brick dust stress

First author	Year	Country	IGS type	Species group	Study area	Climate	IGS description	Species number	Human impact on IGS	Value and comments regarding IGS
Haigh	1980	UK	Lot	Spont. vegetation	Birmingham	Cfb	Weed patches	61		Urban ruderal communities may comprise consistent and separate plant associations
Hanba	2009	Japan	multi	Poaceae	multi		Open wasteland, roadside, empty lots	76	Gas exhaust	C3 and C4 alien species prefer ruderal habitat compared to the native species
Hashimoto	2010	Japan	Waterside	Vegetation	Osaka	Cfa	Riverbanks and islands	39	Cutting	Elimination of dominant alien plant has temporary positive effect on native plant richness but causes other alien plant to dominate
Hayasaka	2012	Japan	Verge	Vegetation	multi	Cfa	Curbside cracks	na	Mowing, traffic	Road management practices favor ephemeral annuals and short-lived taxa, arable land weeds dominant
Helden	2004	UK	Verge	Hemiptera, grassland plants	Bracknell	Cfb	Roundabouts and other road-enclosed sites	1-17	Cutting, herbicide	Grassland Hemiptera diversity would be increased with a reduction in the intensity of management, such a reduction in the frequency of mowing
Hoggart	2012	UK	Waterside	Macroinvertebrates	London	Cfb	Flood defense walls	37	Wall design choice	Highest richness on brick walls, lowest richness on concrete walls, influence of algal cover and river flows
Hruska	2008	Italy	Waterside	Vegetation, algae	Ascoli Piceno	Cfb	Riparian areas	53	Strong human influence	Different levels of anthropogenic disturbance are reflected in the two rivers' ecosystem health
Ichinose	2006	Japan	Verge	Birds	Osaka	Cfa	Wooded streets	8	Urban matrix (perching etc.)	Strong relationship with vegetation cover and >2ha woodlot vicinity
Isermann	2007	Germany	multi	Bryophytes	Bremen	Cfb	University grounds (grassland and stonework)	40		High diversity compared to other urban areas
Itagawa	2010	Japan	multi	Orthoptera	Yokohama	Cfa	Wooded streets on reclaimed land	na		Vegetation height, tree cover and distance to original land are related to inhabitation
Jantunen	2006	Finland	Verge	Vegetation	multi	Dfb	Intersections, verges	na	Road-related effects (drastic chemical and physical changes)	Verges are distinct from semi-natural grasslands, are species-poor due to young age, over-management and disturbance but show potential if these conditions change (old, unmanaged verges)
Jim	2008	China	Structural	Trees	Hong Kong	Cwa	Stone retaining walls	30	Wall characteristics, maintenance	Precious ecological asset, natural-cum-cultural heritage, threatened by misguided maintenance practice

First author	Year	Country	IGS type	Species group	Study area	Climate	IGS description	Species number	Human impact on IGS	Value and comments regarding IGS
Jim	2010	China	Structural	Vegetation	Hong Kong	Cwa	Masonry walls	162	Land use, wall characteristics, management	Ecological heritage, environmental and visual amenities, need to be protected from management
Jim	2011	China	Structural	Spont. arboreal flora	Hong Kong	Cwa	Buildings	11	Building materials, maintenance	Conservation and biodiversity value, places of nature-in-city, beneficial win-win situations possible
Joger	1988	Germany	Structural	Fauna	Göttingen	Cfb	Town wall	237	Wall characteristics, maintenance	High diversity, may act as substitute for disappearing natural habitats (cliffs)
Junghans	2008	Germany	Railway	Vegetation	multi	Cfb	Railway stations	170	Maintenance, ongoing use	High diversity of species, substrate, structure and processes
Kadas	2006	UK	multi	Invertebrates	London	Cfb	Roofs, brownfields	ca. 210	Substrate choice	High diversity and large future potential, rare species
Kantsa	2013	Greece	multi	Vegetation	Ioannina	Csa	Old stonewall, rubble, vacant lots, building walls, fortress wall. Microsites	278		Plants of conservation interest present, wildlife refuge character
Kaupp	2004	Switzerland	Structural	Beetles	Basel	Cfb	Vegetated roofs	183	Design choices	High diversity, function as stepping stone and natural habitat substitute
Kazemi	2009	Australia	Verge	Terrestrial invertebrates	Melbourne	Cfb	Lawn-type street verges	na	Mowing	Monoculture lawn with intense management and low biodiversity
Kazemi	2011	Australia	Verge	Invertebrates	Melbourne	Cfb	Lawn-type street verges	na	Mowing	Comparatively low diversity, negative impact of missing flowering plants
Kim	2004	South Korea	Brownfield	Vegetation	Seoul	Dwa	Closed nonsanitary landfill	255	Very limited	Possible to support succession to typical forests, comparatively high number of exotics
Kim	2005	South Korea	Brownfield	Vegetation	Seoul	Dwa	Closed landfills	41-141	Management	Soil seed bank important, age related to diversity
Kim	2013	South Korea	Brownfield	Vascular plants	multi	Cwa, Dwa	Waste landfill with natural vegetation recovery	275	Fill materials, soil compaction, pollution	Succession is a viable option for restoration unless no nearby propagule source is present
Koide	2004	Japan	Waterside	Birds	multi	Cfa	Riparian areas	42	River modifications	Areas serve variety of bird species groups; influence of slope, artificial structures and vegetation
Kondo	1983	Japan	Waterside	Chironomids	Nagoya	Cfa	Water reservoirs	34	Reservoir design, maintenance	Difference in urban and suburban sites, influence of water quality, vegetation, reservoir structure

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Koyanagi	2012	Japan	Verge	Vegetation	Tsukuba	Cfa	Linear roadside vegetation	285	Mowing	May have functioned as habitats under regular mowing, can serve as key reservoirs for recovery
Krigas	2004	Greece	multi	Alien vascular plants	Thessaloniki	Cfa	Archaeological sites, microsites, walls, fallows	na		Non-native species not discovered before found
Lanikova	2009	Czech R.	Structural	Vegetation	multi	Cfb, Dfb	Wall tops, verticals	358, 323	Substrate choice, air pollution	High diversity, nutrient and moisture-rich, mostly common species
Lenzin	2001	Switzerland	multi	Neophytes	Basel	Cfb	Verges, roofs, cracks	na	Urban structure, maintenance, pollution	Some neophytes resistant to urban disturbance, but outcompeted by natives in other places
Lenzin	2007	Switzerland	Brownfield	Vegetation	Birsfelden	Cfb	Industrial area, harbor	230	Maintenance, former use, (absent) disturbance	High conservation value, absence of anthropogenic disturbance causes problems
Lososova	2011	multi	multi	Vegetation and snails	multi	multi	Successional sites (construction, abandoned)	632, 675 (plants), 40, 73 (snails)		High diversity esp. in mid-successional sites, high conservation value, endangered by urbanization
Lussier	2006	USA	Waterside	Birds	multi	Cfa, Cfb	Riparian surrounded by industrial, infrastructure	na	Infrastructure, land use	Infrastructure and residential areas have most influence, benefit tolerant species
Luther	2008	USA	Waterside	Birds	multi	Csb	Urban riparian areas	na	Development, management	Main factors influencing diversity are tree cover percent and shrub species richness
MacGregor-Fors	2012	Mexico	multi	Anurans	Morelia	Cwb	Abandoned lots, small urban waterway	1	Pollution	Abandoned lots have highest abundance, offer better breeding conditions than polluted waterways
Madre	2014	France	Structural	Wild plants	multi	Cfb	Green roofs spontaneously colonized	176	Maintenance, substrate depth	Provide habitat for high number of native plants, "wild roof" as potential rooftop model
Maskell	2006	UK	Waterside	Vegetation	West Midlands	Cfb	Urban riparian areas	249	Channelization, pollution	Diversity key influence is dominance by invasive species (regardless of nativeness)
Mason	2006	UK	Waterside	Birds	multi	Cfb	Urban riparian areas	na	Habitat modification	Urban areas have higher species richness than rural areas
Maurel	2010	France	multi	Vegetation	Paris	Cfb	Vacant urban land, unused spaces, transportation-related	84		R. japonica negatively influences other species, but covers not more than 4% per site
Maurer	2000	Germany	multi	Vascular plants	Berlin	Cfb	Former inner-German border area	249	Intense herbicide spraying	Area provides rare open space habitat for wild plants within Berlin

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Meek	2010	South Africa	Waterside	Vegetation	multi	Csa, Csb	Urban riparian areas	na	Land use regime	Urban areas have higher species richness, alien species can provide ecosystem services
Meffert	2012	Germany	multi	Birds	Berlin	Cfb	Brownfields, switching yard, other	50		Value for endangered species, no impact of human and dogs, greenspace design implications
Melander	2009	Denmark	Verge	Weeds	multi	Cfb	Edges and center of pavement	86	Use/non-use of glyphosate	Increase of weeds without herbicide, but not very pronounced
Menke	2011	USA	multi	Ants	Raleigh	Cfa	Industrial areas	21	Disturbance, impervious surface	Lower species richness than any other land use type
Morin	1989	Canada	Waterside	Vegetation	Montreal	Dfb	Disturbed river banks	156	Disturbance, substrate choice	Large number of ruderal species, soil texture and topography strongest influence
Motegi	2005	Japan	Structural	Birds	Tokyo	Cfa	Roof tops	12	Vegetation choice	Relatively high diversity, tall trees recommended to attract tree-reliant species
Muratet	2007	France	multi	Vegetation	Hauts-de-Seine	Cfb	Areas with abandoned vegetation management	365	Management	Wasteland has highest species richness of all habitat types, 20% naturalized species
Muratet	2008	France	multi	Vegetation	Hauts-de-Seine	Cfb	Wasteland, walls, verges, railway	na	Management, substrate, buildings	Highest floristic interest index habitats semi-natural, dwellings exhibits neg. influence
Murgui	2009	Spain	Brownfield	Birds	Valencia	Csa	Derelict land	na	Built-up land cover	Positive influence of habitat diversity, negative influence of built-up habitat
Namba	2010	Japan	multi	Birds	Sapporo	Dfb	Verges, vacant areas	na	Feeding, vegetation management	Population decline due to intensified vegetation management
Nemec	2011	USA	Railway	Woody plants	Lincoln	Dfa	Urban trails along (e.g.) abandoned railway	19	Mowing	Habitat value for native species may depend on intensive management
Noordijk	2009	Netherlands	Verge	Arthropods	multi	Cfb	Road verges	638	Maintenance	High number of indigenous species, high overall species number, important for conservation
Nowak	2006	Poland	multi	Sozophytes	multi	Cfb	Brownfields, rail and road verges, walls, industrial areas	na	Disturbance, soil transformation	Conservation value of strongly transformed habitats pose conservation attitude challenge
Öckinger	2009	Sweden	multi	Butterflies	Malmö	Cfb	Ruderal, industrial or built-up areas	na		Ruderal area has highest species richness and density, high conservation value

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Oppermann	1993	Germany	Waterside	Vascular plants	multi	Cfb	Urban riparian areas	na	Canalization	Canalized areas less diverse than un-built ones, many neophytes but little use of river as vector
Pavlik	2000	Slovakia	multi	Woody plants, birds	Zvolen	Dfb	Spontaneous woody vegetation areas	37 (wp), 50 (birds)	Disturbance, pedestrians, noise	Spontaneous woody vegetation plots had higher bird diversity, plot size important for plants and birds
Payne	1978	UK	Structural	Vegetation	multi	Cfb	Garden, churchyard, railway, building, retaining walls	286	Disturbance, pollution	29% of probable horticultural origin, derelict railway walls have higher variety
Pennington	2008	USA	Waterside	Birds	Cincinnati	Cfa	Riparian edges in urbanizing area	102	Built-up area	Tree cover, native vegetation and building area influence opposite for native and non-native species
Pennington	2010	USA	Waterside	Woody plants	Cincinnati	Cfa	Riparian edges in urbanizing area	103	Development, altered hydrology	Native species decrease, non-native increase with urbanization, some natives tolerant
Pennington	2011	USA	Waterside	Breeding birds	Cincinnati	Cfa	Riparian edges in urbanizing area	68		Habitat selection factors operate on both proximate and broader spatial scales
Penone	2012	France	Railway	Vegetation	Paris	Cfb	Railway verges	186	Herbicide, mowing	Railway edges function as corridors for common grassland plants but provide no bonus to invasive species
Poague	2000	USA	Railway	Birds	Lincoln	Dfa	Abandoned railroad	na		Seasonal fluctuations of species richness between urban/rural areas
Prach	2001	Czech R.	multi	Vegetation	Plzen	Cfb	Ruderal urban sites	na		Spontaneous succession can be relied upon for restoration projects, cheap
Prach	2014	Czech R.	multi	Vegetation	multi	Cfb, Dfb	Road verges, ruderal urban sites, abandoned fields	na	Construction	Sere identify was not sign., sere vegetation formed continuum along moisture gradient and by successional age, spontaneous succession mostly results in woodland and is ecologically suitable restoration option
Pysek	2003	Czech R.	Brownfield	Vegetation	multi	Cfb, Dfb	Rubbish dumps	588	Disturbance, toxic waste	Dump area, human density in region and altitude positively influence species numbers
Pysek	2004	Czech R.	multi	Synanthropic vegetation	Plzen	Cfb	Ruderal urban habitats	na	Change in construction practice, winter salt use	Decrease in archaeophyte species richness and diversity from 1960s to 1990s,

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Ranta	2014	Finland	multi	Vegetation	Vantaa	Dfb	Road and railway corridors	484	Maintenance	Corridors cover only 2.7% of city but hold 76.3% of flora, CR-strategists prevail, corridors resilient to disturbance
Rapoport	1995	Argentina	Lot	Edible weeds	Bariloche	Csb	Disturbed suburban lots	24	Cultural preferences for food	Edible weeds can provide considerable food source, should be used to complement agriculture
Ray	2009	India	Verge	Vegetation	multi	Am, As	Roadside areas	73	Pollution, trampling, vehicle crushing	Urban areas have higher species richness than rural areas, more exotics
Rebele	1988	Germany	Brownfield	Vegetation	Berlin	Cfb	Brownfields and industrial areas	596	Use (industrial, kids), pollution	Decrease of derelict areas leads to dwindling wild flora habitats
Reis	2006	Brazil	Structural	Vascular plants	Jundiai	Cfa	Urban walls	28		Most species grow better on base of wall, less diversity than in Europe
Robinson	2012	Canada	Brownfield	Vegetation, invertebrates	Halifax	Dfb	Urban spontaneous vegetation sites	na		Higher plant species diversity, invertebrate abundance and taxonomic diversity than lawns and forest
Rouquette	2013	UK	Waterside	multi	Sheffield	Cfb	Don river banks	na	Legacy of industrialization, urbanization, mining, modification	River banks provide habitat to bird, plant, butterfly and macroinvertebrate species, benefit from river connectivity
Saarinen	2005	Finland	Verge	Butterflies and moths	multi	Dfb	Urban roadsides	75	Road kill, pollution, mowing	Important reserve for some species, diversity similar in different road verge types
Salvati	2003	Italy	multi	Birds	Rome	Csa	Ruderal areas, verges, factories	na	Development	Relict areas form basis of rich species composition, but threatened by development
Sanderson	1992	UK	Brownfield	Hemiptera, Vegetation	multi	Cfb	Derelict sites	149, 153		Rare plant species important in determining rare Hemiptera species presence
Sasaki	2006	Japan	Waterside	Vegetation	multi	Cfa	Artificial coast	na		Artificial coasts are colonized by plants with floating seeds but not by those without
Schadek	2008	Germany	Brownfield	Vegetation	multi	Cfb	Derelict industrial, abandoned railroad, new land fills	213	Soil alteration (rubble, dog droppings)	High plant species richness possibly achieved by strong disturbances every 5 years
Schmidt	2014	Germany	multi	Vascular plants	Hamburg	Cfb	Port, industrial sites, railway system, traffic	na	Urban redevelopment	Diversity similar between urbanization zones, high number of species

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Schmitz	1998	Germany	Brownfield	Vegetation	Berlin	Cfb	Former inner-German border area	na	Past herbicide use	Influence of surrounding gardens, areas contribute to urban biodiversity
Shaltout	2002	Egypt	multi	Vegetation	multi	BWh	Demolished houses, abandoned fields, refuse areas, railway, roads	na	Fire, cutting, digging, trampling, waste dump, maintenance, pollution	Urban vegetation favored disturbance, nutrient and water resources are abundant
Shushpannikova	2001	Russia	multi	Vegetation	Syktyvkar	Dfc	Verges, embankments	na	Disturbance by motor vehicles	Enrichment from adventitious species, but species composition loss in technogenic sites
Small	2003	UK	Brownfield	Carabid beetles	Birmingham	Cfb	Former factory, housing an railway ground	63		Most species rich assemblages found on early successional sites
Small	2006	UK	Brownfield	Carabids	West Midlands	Cfb	Derelict land	32		Habitat quality (early successional sites with diversity of seed producing plants) important
Smith-Adao	2007	South Africa	Waterside	Vegetation	Somerset West	Csb	Riverbank (partly modified)	na	Degradation	Channel discharge changes and riparian vegetation changes controlled channel instability
Strauss	2006	Germany	Brownfield	Leafhoppers, grasshoppers	Bremen, Berlin	Cfb	Derelict sites	146/130 (LH), 11/15 (GH)		Vegetation structure most important, species prefer certain succession stages
Stylinski	1999	USA	Brownfield	Vegetation	San Diego	Bsk	Formerly severely disturbed sites (e.g. military training ground)	140		Exotic species dominate, native species cover low even after 70 years
Sudnik-Wojcikowska	2005	Poland	multi	Vegetation	Warsaw	Cfb	Tramlines and building surface	213, 111	Maintenance, herbicide	Higher number of therophytes, many (light) tree seedlings on building surface
Tabata	1978	Japan	Waterside	Birds, ground-beetles	Tokyo	Cfa	Highly modified river bed and banks	23, 32	River modifications, land use, water quality	Complexity of land use and environmental quality affects birds, ground beetles and plants
Tan	2010	Singapore	Lot	Orthoptera	Singapore	Af	Vacant lot vegetated wasteland	18	Disturbance, development	High diversity despite small area and high disturbance
Tommasi	2004	Canada	multi	Bees	Vancouver	Cfb	Powerline corridors, road edges	na		Bloom and habitat heterogeneity are key to urban area potential for bees
Trammell	2012	USA	Waterside	Birds	multi	Csb	Riparian patches	59		Urban structure (both land use and vegetation) best described potential habitat
Uno	2010	USA	Lot	Ants	multi	Dfa, Dfb	Former residential use vacant lots	20		Exotic species abundance correlates with ant species richness

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Vakhlamova	2014	Kazakhstan	multi	Vegetation	Pavlodar	Dfb	Unmanaged land, wasteland, industrial land, landfills, eroded patches	na	Grazing, mowing, trampling, waste deposit, fire, industrial contamination, traffic,	Species diversity increased with distance to city center, species richness at unmanaged sites higher than at ornamental sites, alien species lowest
Venn	2013	Finland	Brownfield	Carabid beetles	multi	Dfb	Matrix grassland on former military fortifications	34	Human population density	Urban dry meadows important habitats, but matrix grassland least diverse, important to avoid replacement with asphalt
Vincent	1985	Canada	Lot	Vegetation	Montreal	Dfb	Vacant lots	136		Low diversity per site but high discrimination among lots
Wahlbrink	1994	Germany	Railway	Carabid beetle	Osnabrück	Cfb	Railway embankments	52	Herbicide	Towards city center shannon diversity, evenness and carabid body size decrease
Weber	2014	Germany	Verge	Herbaceous plants	Berlin	Cfb	Roadside verges		Air pollution (particulate matter)	Not dedicated diversity survey, roadside spont. Vegetation immobilizes significant amount of air pollutants, increasing biodiversity supports air filtration
Westermann	2011	Germany	Railway	Vegetation	Berlin	Cfb	Abandoned railway areas	210		Environmental and landscape predictors important, persistent seed bank advantageous
White	2005	Australia	Verge	Birds	Melbourne	Cfb	Native, exotic and recently developed streetscapes	44	Planting choice	Parks and native streetscapes have higher species richness and abundance
Whitmore	2002	South Africa	Verge	Invertebrates	Durban	Cfa	Traffic islands	232	Design, management	Enhanced islands (shrubs, herbs, trees) support more species than mown islands
Whitney	1985	USA	multi	Vegetation	Wooster	Dfa	Powerline, vacant lots, walls, railway, land fills	na	Trampling, weeding, herbicide	Ruderal communities are American analogues of common European urban communities
Winter	2013	Germany	multi	Vegetation	Bremen	Cfb	Pavements, streets, brownfields, railroad tracks & surroundings, verges, construction sites, vacant lots	na	Development, mowing, driving, walking, dredging	Harbor area is species-rich habitat, but diversity is decreasing as result of restructuring and restricted seed dispersal
Wittig	2010	multi	Verge	Spont. vegetation	multi	Cfa, Cfb	Area around street trees	194	Trampling, vegetation clearing	High similarity between sites in different cities in Europe as well as the city in USA

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Wojcik	2012	USA	Verge	Bees	multi	Csb	Spontaneous vegetation verges	na		Magnitude of floral resource and foraging energetics factors important irrespective of location
Yamano	2004	Japan	multi	Vegetation	Tsukuba	Cfa	Vacant land, former parking lot	na		Vacant lands contain more hybrid (tetraploid) dandelions than natives
Yamato	2004	Japan	multi	Grass	multi	Cfa	Construction sites, expressway slopes, airfields		Weeding, management, cutting	Management changes are leading to change in plant associations
Zapparoli	1997	Italy	Brownfield	Centipedes	Rome	Csa	Urban wasteland	20	Fire, former land use	Relatively high number of species, about 57% of whole Rome centipede fauna
Zerbe	2004	South Korea	multi	Non-native plants	Chonju	Dfa	Railway, roadway, fallow land	na	Disturbance	Non-native species play a significant role in enhancing urban area biodiversity
Zhao	2009	China	multi	Vegetation	Beijing	Dwa	Greenspace in vacant land without definite land use	na	Land use	Changes in plant species composition in built-up areas, more than half non-native
Zorenko	2003	Latvia	multi	Mammal	Riga	Dfb	Weeds/ruderal, highway edges, river/lake banks	na	Anthropogenic load	Species diversity increases towards city periphery