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After "the call": a review of urban insect ecology trends from 2000–2017

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Abstract

A sample of the 100 most cited papers on urban insect ecology from 2000-2017 is reviewed. This period represents the time since a call for more research on urban arthropods was raised by McIntyre (2000). Only literature on urbanization and its effects on insects were examined. Most studies concentrated on habitat suitability, beetles, butterflies, and bees.

An increasing number of people worldwide are living in cities. Regardless of whether this is a good or bad development, a majority of humanity, having evolved in natural surroundings, now lives in heavily modified, highly artificial spaces with tremendously reduced ecosystem complexity and depauperate wildlife. Most human food is farmed, and food is processed to obtain longer preservation times, much of the day is spent indoors, away from sunlight, and physical activity levels are a small fraction of what they once were. These modified conditions probably cause most of the epidemic diseases of affluence, but there is also a suspicion that separation of humans from other biodiversity also takes a toll on emotional/mental well-being. For this reason, as well as for the ecosystem goods and services that they provide, there is a renewed interest in promoting increasing levels of urban biodiversity.

Some animals and plants are already firmly rooted in cities, and have become cosmopolitan in their distributions. These synanthropic species are the weeds, house flies, cockroaches, rats, house sparrows, and rock doves of the world, commonly considered to be undesirable pests. Additionally, there are numerous less-conspicuous species that have co-dispersed with humans (Lindroth 1957), often unnoticed as they go about their lives without interacting significantly with people. Lastly, there are the native species that can co-exist, or even thrive in cities. They are derived from the less urbanized spaces surrounding urban areas, and may be highly valued and desirable to lure into more developed areas, either to help support their populations, or to bring pleasure to city dwellers.

Insects are the most diverse group of animals in the world, and given their small body size and ubiquity, are the most commonly encountered wildlife for city dwellers. Recently, there has been a resurgence of interest in the entomofauna of cities (Appendix 1), not from the pest control arena, but from researchers interested in the urban backyards, houses, and natural habitat remnants in the developed areas as habitat.

Recognizing the importance of this trend, McIntyre (2000) put out a call for action on urban ecology, challenging researchers to study the effects of urbanization on insects. In this paper, I briefly review the results of this call to action, and the most influential papers that arose after it.

Methods

The Google Scholar database was queried using Harzing's Publish or Perish, version 5.27.2.6281, with the keywords "urban", "insect", and "-pest" (to exclude all pest references), and the date range set from 2000-2017. The resulting set of references was downloaded as a CSV file, and opened in Microsoft EXCEL. The dataset was then sorted in descending order based on number of citations. Irrelevant references were removed (such as those documenting insects only as food for other animals, as were general articles on urban biodiversity not having insects as the primary reference group, insects as disease vectors, or those in which

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urbanization was not integral to the study), and the top 100 most cited articles retained. This produced an idiosyncratic, but generally representative sample of trends in the most influential urban insect ecology and biodiversity studies. It also eliminated some extremely important general references (Grimm et al. 2000, McKinney 2006, 2008) that should be read by all urban insect researchers.

References were sorted first by number of citations, then by research theme (Fig. 1), and finally by taxonomic groups (Fig. 2). "Research theme" is a subjective quality as classified in this review, and was qualified by the following criteria (others could equally be applied):

1. Habitat suitability, or the ability of organisms to live under various conditions. These papers include most of those identifying the effects of rural to urban gradients, and how species react to urbanization.
2. Biology. The function of the species within an environment, rather than how they are distributed across environments, is the subject of this category.
3. Restoration. Applied aspects of biodiversity work.
4. Faunistics. Inventory of the species present.
5. Theory. One paper (Fattorini 2016) was written on island biogeography theory as applied to urban insects.

Results

The most cited

Few of the papers were highly cited (over 250 citations), but three fit into this category: Bolger et al. (2000), Gibb and Hochuli (2001) , and Moore and Palmer (2005). As expected, these papers were broad, general analyses of urbanization and its effects on the insect fauna; thus, they deservedly are widely cited. Bolger et al. (2000) looked at the effects of natural habitat fragmentation on the success of the invasive Argentine ant (*Linepithema humile*) in Southern California. They found that increasing fragmentation increased the success of these highly dominant ants, especially with respect to the native ants. Concurrently, fragmentation decreased the ability of native ants to persist in habitat fragments, which is problematic for the many species that depend on native ants (horned lizards, for example). Gibb and Hochuli (2001), also working on fragmentation, found that species numbers of four groups of insects, plus spiders, did not differ significantly between large and small fragments. Instead, they found that the community makeup changed, with smaller fragments having fewer parasitoids and predators. Finally, Moore and Palmer (2005) found that biodiversity of stream macroinvertebrates was highly negatively correlated with an increase in impermeable surface (pavement, roads, etc.), but that having some riparian vegetation along the waterway decreased the negative effects of high impermeable surface. This study gives a clear guideline to those wishing to effect positive change on stream biodiversity, even in places where it seems impossible because the surrounding urbanization.

The most frequent research theme

By a fairly large margin, the topic of habitat suitability was most represented in these papers, with seventy-three percent classified in this research theme. In addition to the top three most cited papers mentioned above (all of which fit in the habitat suitability category) was an important paper by Niemelä et al. (2000), who organized a worldwide network for study of urbanization and carabid beetles. As a graduate student, I overlapped with Niemelä when I was a PHD student (and he was a postdoctoral fellow) in the early 1980s at the University of Alberta, and I was puzzled by his interest in insects associated with disturbed environments; clearly, however, he was ahead of his time, and my attitude reflected the prevailing bias against urban entomology. Niemelä and colleagues have published an impressive array of work on urbanization and carabids (e.g., Ishitani et al. 2003, Niemelä et al. 2010), which they argue are useful taxa for such studies, but must be used with caution as representatives for other species (Rainio and Niemelä 2003).

One of the main conclusions found by Niemelä and co-authors is that, besides a reduction in species richness as urbanization intensifies, there is a loss of larger and more specialized species. It is not discussed whether the same forces that exclude the largest mammals from urban areas also affect the "charismatic megafauna" of carabids.

An important paper discussing habitats at the micro-scale (probably the scale most relevant to individual species of insects) is part of the comprehensive series from Britain on "Urban domestic gardens"- what we call backyards in North America. In a broad study of several sampling methods and taxonomic groups, the authors (Smith et al. 2006) found that there were weak effects of their 22 variables, and that they varied widely according to taxonomic groups under study. Although this is disappointing, in that just doing "one thing" cannot restore an entire fauna, it is still interesting that they came out with a single recommendation: "If specific garden features are to be encouraged for invertebrates, then vegetation – especially tree cover – is likely to provide benefits for the widest range of taxa." Not known is how relevant, or how similar, these results are to other parts of the world, since so few comparable studies have been done elsewhere, especially in different climates where planting trees might not be as desirable from a wildlife habitat perspective (for instance, in desert cities like Tucson, Arizona). Also, the types of trees planted must make some difference, although the effects of alien versus native vegetation were not strong factors in their analysis.

Indeed, some papers from have shown that increasing native vegetation is not necessarily sufficient, especially at smaller scales (Gaston et al. 2005, Matteson and Langellotto 2010) to boost insect life, and that many insects are able to make good use of non-natives as food (Owen 1991, Shapiro 2002, Helden et al. 2012). This contrasts with situations where native plantings are highly correlated with greater density and diversity of caterpillars (Burghardt et al. 2009), some bees (Pardee and Philpott 2014), and biodiversity in general (Threlfall et al. 2017). Studies have again shown highly species-specific responses, however, to different types of vegetation structure and diversity. For instance, Mata et al. (2017) showed that "golf courses sustain higher species richness of [hemipteran] herbivores and predators than parks and gardens". Thus, studies based on single taxonomic groups must be interpreted in a larger context.

The most frequently studied taxonomic groups

As expected, the most cited papers were general ones that dealt with an insect fauna (terrestrial or stream), rather than a particular taxonomic group. Those that did specialize, however, were skewed towards beetles (especially the carabids mentioned above), butterflies, and bees. It is understandable that butterflies and bees are heavily researched, being highly visible and popular organisms, and certainly we need to know more about them. These groups are "front-line" taxa in the conservation literature, like birds, yet I hope that not too many conservation decisions are made based on their distribution. As Hartop et al. (this volume) show, it is relatively easy to manipulate a landscape to attract more bees and butterflies, but it can be questioned whether such a "restoration", effected by planting strategic host plants, is comprehensive enough. Planting butterfly gardens and providing bee hotels is one step in habitat improvement (but see below for bee hotels); hopefully we will take many more steps to provide more vibrant urban ecosystems.

The public perception of urban bee conservation also requires comment. Often, laypeople do not know that the western honey bee (*Apis mellifera* L.) is an introduced species suspected of having at least some detrimental effects on native bees. While honey bees are vital tools in agriculture, the promotion of urban bee-keeping increases the likelihood of stings, has a financial impact through the need for removal of pest feral colonies from houses and other structures, and usually is not necessary (at least not in our city, Los Angeles). No significant agriculture takes place in our urban areas, and the abundant feral colonies are more than sufficient to pollinate food plants in backyard and community gardens. Keeping bees for their honey production is another motivation, but honey from cities must be the most contaminated imaginable (even if it has not been studied in detail). Nevertheless, urban beekeeping is heavily promoted in literature rife with misconceptions and irrelevant facts (Colla and MacIvor 2017). Many people have the misconception that we need to be "helping" honey bees rather than the native bees that really could use their assistance.

What can one do?

All of these studies hopefully will allow us, in the near future, to increase desirable insect biodiversity in urban areas. Aside from perception difficulties that must be overcome in people who consider increased insect populations and diversity undesirable, what actually works? The authors of the "Urban domestic gardens" series have attempted to answer this question, but the answer is "it is complicated". Their study (Gaston et al. 2005) tried a number of methods to increase biodiversity, some of which were successful, others of which were complete failures. Particularly stunning failures were planting host plants for butterflies that were present in the gardens but that did not use the plants and bumble bee houses that housed not a single colony. Providing artificial ponds had some positive effects, whereas dead wood left out to attract saproxylic organisms probably needed more time (decades) to work. In contrast, providing artificial nests for cavity-nesting solitary bees was successful.

In spite of some successes, the betterment of backyard habitat for individual taxa (such as Monarch butterflies) or small groups of organisms (bumble bees), begs the question of "what about all the other species". Single species (or small taxon) approaches are suspected to cause further problems and imbalances. For instance, planting tropical milkweed for Monarch butterflies may disrupt their migratory behavior (Satterfield et al. 2015). Provision of nesting habitat ("bee hotels") for solitary bees can work quite well, even in highly urbanized areas (personal observation), but are not without possible negative effects of their own (MacIvor and Packer 2017). A better approach at the landscape level would be to make each backyard more like the surrounding natural habitat, encouraging greater use by the native fauna, rather than enhancing conditions for only a small group.

Summary

The field of urban entomology is active and vital, with many centers of research working on a variety of tasks. There is still relatively little known about urban biodiversity outside of a few groups of popular insects, however, as attested by our discovery of 43 new species of phorid flies in Los Angeles (Hartop et al. 2015, 2016), and the impact of molecular studies are still yet to come. This brief review has concentrated on the most influential papers and themes in urban insect biodiversity, but these will doubtlessly evolve as the field matures.

Acknowledgements

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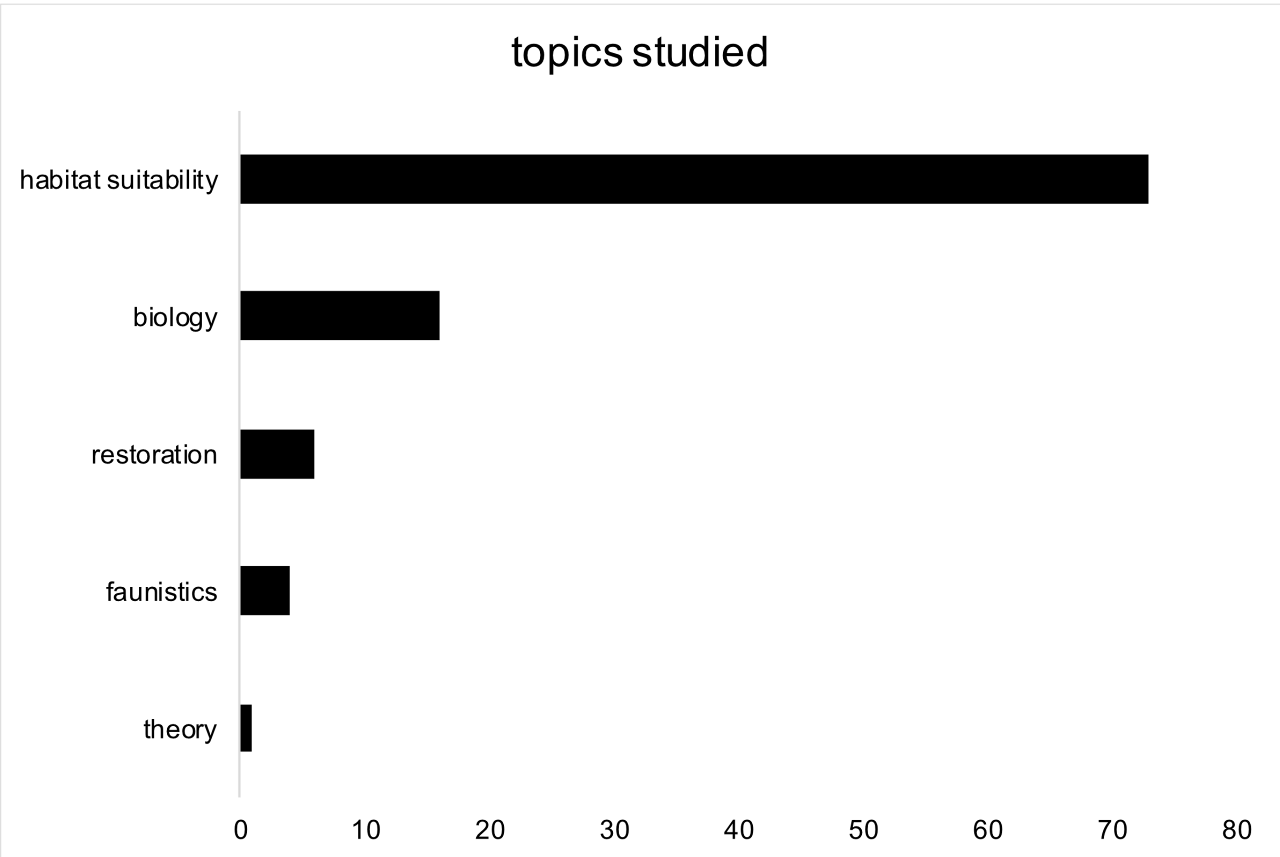

FIGURE 1. Bar chart of topic frequency in 100 studies selected for this review.

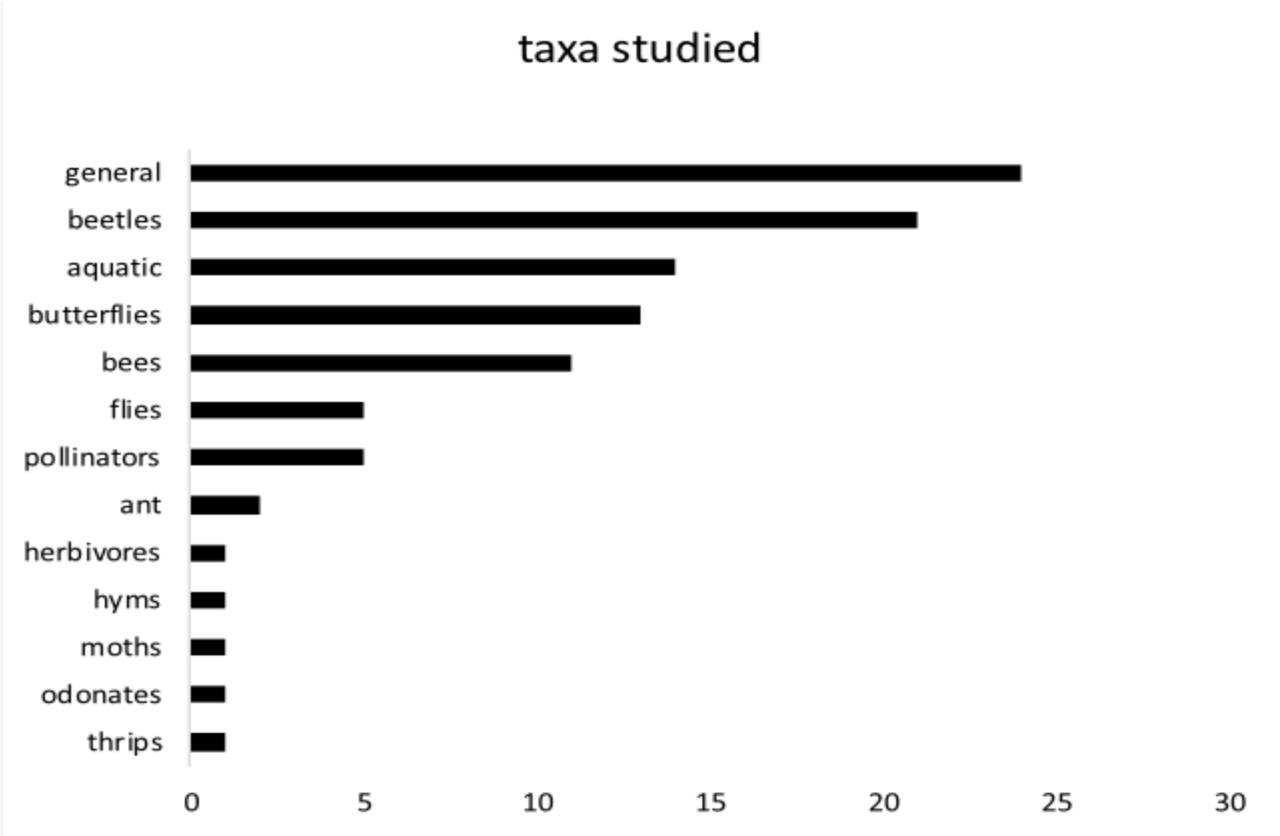

FIGURE 2. Bar chart of taxa of focus frequency in 100 studies selected for this review.

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APPENDIX 1. The 100 papers referred to in this study.

subject	taxon	Cites	Year	Authors	Title
habitat suitability	general	347	2000	DT Bolger, AV Suarez, KR Crooks…	Arthropods in urban habitat fragments in southern California: area, age, and edge effects
habitat suitability	general	315	2002	H Gibb, DF Hochuli	Habitat fragmentation in an urban environment: large and small fragments support different arthropod assemblages
habitat suitability	aquatic	263	2005	AA Moore, MA Palmer	Invertebrate biodiversity in agricultural and urban headwater streams: implications for conservation and management
faunistics	bees	237	2008	KC Matteson, JS Ascher, GA Langellotto	Bee richness and abundance in New York City urban gardens
habitat suitability	general	204	2000	J Niemelä, J Kotze, A Ashworth, P Brandmayr…	The search for common anthropogenic impacts on biodiversity: a global network
habitat suitability	bees	202	2006	QS McFrederick, G LeBuhn	Are urban parks refuges for bumble bees Bombus spp.(Hymenoptera: Apidae)?
habitat suitability	general	185	2009	KT Burghardt, DW Tallamy…	Impact of native plants on bird and butterfly biodiversity in suburban landscapes
habitat suitability	general	178	2006	RM Smith, PH Warren, K Thompson…	Urban domestic gardens (VI): environmental correlates of invertebrate species richness
restoration	aquatic	165	2001	MG Larson, DB Booth, SA Morley	Effectiveness of large woody debris in stream rehabilitation projects in urban basins
habitat suitability	butterflies	163	2004	LP Koh, NS Sodhi	Importance of reserves, fragments, and parks for butterfly conservation in a tropical urban landscape
habitat suitability	aquatic	156	2003	CC Morse, AD Huryn, C Cronan	Impervious surface area as a predictor of the effects of urbanization on stream insect communities in Maine, USA
habitat suitability	general	153	2001	JP Gibbs, EJ Stanton	Habitat fragmentation and arthropod community change: carrion beetles, phoretic mites, and flies
biology	butterflies	150	2002	AM Shapiro	The Californian urban butterfly fauna is dependent on alien plants

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APPENDIX 1. (Continued)

subject	taxon	Cites	Year	Authors	Title
habitat suitability	pollinators	145	2001	NE Hostetler, ME McIntyre	Effects of urban land use on pollinator (Hymenoptera: Apoidea) communities in a desert metropolis
biology	general	134	2004	LML Carvalho, PJ Thyssen, ML Goff…	Observations on the succession patterns of necrophagous insects on a pig carcass in an urban area of Southeastern Brazil
habitat suitability	beetles	134	2006	JP Sadler, EC Small, H Fiszpan…	Investigating environmental variation and landscape characteristics of an urban–rural gradient using woodland carabid assemblages
habitat suitability	general	134	2010	KC Matteson, GA Langellotto	Determinates of inner city butterfly and bee species richness
habitat suitability	beetles	133	2003	M Ishitani, DJ Kotze, J Niemelä	Changes in carabid beetle assemblages across an urban?rural gradient in Japan
habitat suitability	bees	131	2004	D Tommasi, A Miro, HA Higo…	Bee diversity and abundance in an urban setting
habitat suitability	butterflies	128	2002	KS Brown, AVL Freitas	Butterfly communities of urban forest fragments in Campinas, São Paulo, Brazil: structure, instability, environmental correlates, and conservation
habitat suitability	butterflies	124	2002	BC Wood, AS Pullin	Persistence of species in a fragmented urban landscape: the importance of dispersal ability and habitat availability for grassland butterflies
habitat suitability	aquatic	118	2002	KF Stepenuck, RL Crunkilton…	Impacts of urban landuse on macroinvertebrate communities in southeastern Wisconsin streams
habitat suitability	beetles	118	2009	J Niemelä, DJ Kotze	Carabid beetle assemblages along urban to rural gradients: a review
habitat suitability	aquatic	116	2006	TJ Blakely, JS Harding, AR Mcintosh…	Barriers to the recovery of aquatic insect communities in urban streams
habitat suitability	beetles	114	2002	D Alaruikka, DJ Kotze, K Matveinen…	Carabid beetle and spider assemblages along a forested urban–rural gradient in southern Finland
habitat suitability	flies	112	2005	C Hwang, BD Turner	Spatial and temporal variability of necrophagous Diptera from urban to rural areas

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APPENDIX 1. (Continued)

subject	taxon	Cites	Year	Authors	Title
habitat suitability	beetles	108	2004	B Weller, JU Ganzhorn	Carabid beetle community composition, body size, and fluctuating asymmetry along an urban-rural gradient
habitat suitability	aquatic	108	2007	SRM Couceiro, N Hamada, SLB Luz, BR Forsberg…	Deforestation and sewage effects on aquatic macroinvertebrates in urban streams in Manaus, Amazonas, Brazil
biology	bees	102	2005	GW Frankie, RW Thorp, M Schindler…	Ecological patterns of bees and their host ornamental flowers in two northern California cities
habitat suitability	flies	102	2011	AJ Bates, JP Sadler, AJ Fairbrass, SJ Falk, JD Hale…	Changing bee and hoverfly pollinator assemblages along an urban-rural gradient
habitat suitability	bees	98	2008	ED Fetridge, JS Ascher, GA Langellotto	The bee fauna of residential gardens in a suburb of New York City (Hymenoptera: Apoidea)
habitat suitability	general	93	2002	EF Connor, J Hafernik, J Levy, VL Moore…	Insect conservation in an urban biodiversity hotspot: the San Francisco Bay Area
biology	bees	87	2009	JL Hernandez, GW Frankie…	Ecology of urban bees: a review of current knowledge and directions for future study
habitat suitability	general	87	2010	T Sattler, P Duelli, MK Obrist, R Arlettaz, M Moretti	Response of arthropod species richness and functional groups to urban habitat structure and management
biology	flies	87	2011	W Coura-Vital, MJ Marques, VM Veloso…	Prevalence and factors associated with Leishmania infantum infection of dogs from an urban area of Brazil as identified by molecular methods
habitat suitability	general	87	2012	L Santorufo, CAM Van Gestel, A Rocco, G Maisto	Soil invertebrates as bioindicators of urban soil quality
habitat suitability	bees	85	2012	W Banaszak-Cibicka, M Żmihorski	Wild bees along an urban gradient: winners and losers
faunistics	aquatic	80	2006	P Moreno, M Callisto	Benthic macroinvertebrates in the watershed of an urban reservoir in southeastern Brazil
habitat suitability	butterflies	76	2009	E Öckinger, Å Dannestam, HG Smith	The importance of fragmentation and habitat quality of urban grasslands for butterfly diversity

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APPENDIX 1. (Continued)

subject	taxon	Cites	Year	Authors	Title
habitat suitability	pollinators	76	2015	KCR Baldock, MA Goddard, DM Hicks…	Where is the UK's pollinator biodiversity? The importance of urban areas for flower-visiting insects
habitat suitability	beetles	72	2002	EC Small, JP Sadler, MG Telfer	Carabid beetle assemblages on urban derelict sites in Birmingham, UK
biology	butterflies	72	2004	Y Takami, C Koshio, M Ishii, H Fujii, T Hidaka…	Genetic diversity and structure of urban populations of Pieris butterflies assessed using amplified fragment length polymorphism
habitat suitability	ant	71	2007	MJ Angilletta Jr, RS Wilson, AC Niehaus, MW Sears…	Urban physiology: city ants possess high heat tolerance
habitat suitability	general	70	2014	S Braaker, J Ghazoul, MK Obrist, M Moretti	Habitat connectivity shapes urban arthropod communities: the key role of green roofs
restoration	aquatic	68	2005	AM Suren, S McMurtrie	Assessing the effectiveness of enhancement activities in urban streams: II. Responses of invertebrate communities
biology	aquatic	66	2009	RF Smith, LC Alexander, WO Lamp	Dispersal by terrestrial stages of stream insects in urban watersheds: a synthesis of current knowledge
habitat suitability	moths	65	2003	JK Rickman, EF Connor	The effect of urbanization on the quality of remnant habitats for leaf?mining Lepidoptera on Quercus agrifolia
habitat suitability	aquatic	65	2006	CJ Walsh	Biological indicators of stream health using macroinvertebrate assemblage composition: a comparison of sensitivity to an urban gradient
habitat suitability	beetles	63	2008	A Fujita, K Maeto, Y Kagawa, N Ito	Effects of forest fragmentation on species richness and composition of ground beetles (Coleoptera: Carabidae and Brachinidae) in urban landscapes
habitat suitability	general	59	2011	S Fattorini	Insect extinction by urbanization: a long term study in Rome
habitat suitability	beetles	58	2000	AC Grandchamp, J Niemelä, J Kotze	The effects of trampling on assemblages of ground beetles (Coleoptera, Carabidae) in urban forests in Helsinki, Finland

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APPENDIX 1. (Continued)

subject	taxon	Cites	Year	Authors	Title
habitat suitability	general	58	2008	S Knapp, I Kühn, V Mosbrugger, S Klotz	Do protected areas in urban and rural landscapes differ in species diversity?
habitat suitability	aquatic	57	2007	SE Gresens, KT Belt, JA Tang, DC Gwinn, PA Banks	Temporal and spatial responses of Chironomidae (Diptera) and other benthic invertebrates to urban stormwater runoff
habitat suitability	butterflies	57	2008	T Kadlec, J Benes, V Jarosik, M Konvicka	Revisiting urban refuges: changes of butterfly and burnet fauna in Prague reserves over three decades
habitat suitability	ant	57	2009	MP Sanford, PN Manley, DD Murphy	Effects of urban development on ant communities: implications for ecosystem services and management
restoration	odonates	56	2000	R Primack, H Kobori, S Mori	Dragonfly pond restoration promotes conservation awareness in Japan
habitat suitability	butterflies	56	2012	M Dallimer, JR Rouquette, AMJ Skinner…	Contrasting patterns in species richness of birds, butterflies and plants along riparian corridors in an urban landscape
habitat suitability	bees	55	2009	G Frankie, R Thorp, J Hernandez, M Rizzardi…	Native bees are a rich natural resource in urban California gardens
biology	beetles	52	2002	E Lundkvist, J Landin, F Karlsson	Dispersing diving beetles (Dytiscidae) in agricultural and urban landscapes in south-eastern Sweden
habitat suitability	aquatic	52	2008	RF Smith, WO Lamp	Comparison of insect communities between adjacent headwater and main-stem streams in urban and rural watersheds
biology	beetles	51	2010	GM Carpaneto, A Mazziotta, G Coletti, L Luiselli…	Conflict between insect conservation and public safety: the case study of a saproxylic beetle (Osmoderma eremita) in urban parks
habitat suitability	beetles	50	2006	R Deichsel	Species change in an urban setting—ground and rove beetles (Coleoptera: Carabidae and Staphylinidae) in Berlin
restoration	aquatic	49	2005	W Miller, AJ Boulton	Managing and rehabilitating ecosystem processes in regional urban streams in Australia

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subject	taxon	Cites	Year	Authors	Title
habitat suitability	flies	49	2007	MS Gottschalk, DC De Toni, VLS Valente…	Changes in Brazilian Drosophilidae (Diptera) assemblages across an urbanisation gradient
habitat suitability	general	49	2011	F Kazemi, S Beecham, J Gibbs	Streetscape biodiversity and the role of bioretention swales in an Australian urban environment
habitat suitability	pollinators	47	2013	KC Matteson, JB Grace, ES Minor	Direct and indirect effects of land use on floral resources and flower?visiting insects across an urban landscape
habitat suitability	aquatic	46	2012	KB Lunde, VH Resh	Development and validation of a macroinvertebrate index of biotic integrity (IBI) for assessing urban impacts to Northern California freshwater wetlands
biology	bees	46	2013	S Jha, C Kremen	Urban land use limits regional bumble bee gene flow
biology	hyms	45	2006	RD Loyola, RP Martins	Trap-nest occupation by solitary wasps and bees (Hymenoptera: Aculeata) in a forest urban remanent
habitat suitability	general	44	2009	TB Francis, DE Schindler	Shoreline urbanization reduces terrestrial insect subsidies to fishes in North American lakes
biology	bees	43	2008	VA Wojcik, GW Frankie, RW Thorp…	Seasonality in bees and their floral resource plants at a constructed urban bee habitat in Berkeley, California
habitat suitability	bees	43	2014	GL Pardee, SM Philpott	Native plants are the bee's knees: local and landscape predictors of bee richness and abundance in backyard gardens
habitat suitability	general	40	2012	MK Widerberg, T Ranius, I Drobyshev…	Increased openness around retained oaks increases species richness of saproxylic beetles
biology	beetles	39	2004	JM Wolf, JP Gibbs	Silphids in urban forests: diversity and function
habitat suitability	butterflies	38	2012	MH Lizée, S Manel, JF Mauffrey, T Tatoni…	Matrix configuration and patch isolation influences override the species–area relationship for urban butterfly communities
faunistics	general	35	2011	T Sattler, MK Obrist, P Duelli, M Moretti	Urban arthropod communities: Added value or just a blend of surrounding biodiversity?

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subject	taxon	Cites	Year	Authors	Title
habitat suitability	beetles	23	2013	M Soga, N Kanno, Y Yamaura, S Koike	Patch size determines the strength of edge effects on carabid beetle assemblages in urban remnant forests
habitat suitability	general	22	2012	AJ Helden, GC Stamp, SR Leather	Urban biodiversity: comparison of insect assemblages on native and non-native trees
habitat suitability	beetles	21	2012	DJ Kotze, S Lehvävirta, M Koivula, RB O'Hara…	Effects of habitat edges and trampling on the distribution of ground beetles (Coleoptera, Carabidae) in urban forests
habitat suitability	butterflies	19	2012	M Strausz, K Fiedler, M Franzén, M Wiemers	Habitat and host plant use of the Large Copper Butterfly Lycaena dispar in an urban environment
habitat suitability	beetles	19	2013	T Magura, D Nagy, B Tóthmérész	Rove beetles respond heterogeneously to urbanization
habitat suitability	pollinators	17	2014	LM Blackmore, D Goulson	Evaluating the effectiveness of wildflower seed mixes for boosting floral diversity and bumblebee and hoverfly abundance in urban areas
habitat suitability	beetles	16	2009	S Pinna, H Varady-Szabo, P Boivin, E Lucas	Relevance of using a vegetation-based method to conserve urban carabid diversity
habitat suitability	butterflies	16	2011	AD Tiple, AM Khurad, RLH Dennis	Butterfly larval host plant use in a tropical urban context: Life history associations, herbivory, and landscape factors
habitat suitability	beetles	14	2013	MS Picchi, L Avolio, L Azzani, O Brombin…	Fireflies and land use in an urban landscape: the case of Luciola italica L.(Coleoptera: Lampyridae) in the city of Turin
habitat suitability	beetles	13	2009	AM Cárdenas, CM Buddle	Introduced and native ground beetle assemblages (Coleoptera: Carabidae) along a successional gradient in an urban landscape
biology	herbivores	11	2004	DF Hochuli, H Gibb, SE Burrows, FJ Christie	Ecology of Sydney's urban fragments: Has fragmentation taken the sting out of insect herbivory
habitat suitability	pollinators	9	2017	DM Hall, GR Camilo, RK Tonietto, J Ollerton…	The city as a refuge for insect pollinators

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subject	taxon	Cites	Year	Authors	Title
habitat suitability	beetles	8	2014	S Fattorini	Island biogeography of urban insects: tenebrionid beetles from Rome tell a different story
habitat suitability	beetles	7	2013	A Vergnes, S Chantepie, A Robert…	Are urban green spaces suitable for woodland carabids? First insights from a short-term experiment
biology	butterflies	6	2009	JW Dover, RLH Dennis, L Atkins	The western jewel butterfly (Hypochrysops halyaetus: Lycaenidae) II: factors affecting oviposition within native Banksia bushland in an urban setting
restoration	bees	6	2016	L Fortel, M Henry, L Guilbaud, H Mouret…	Use of human-made nesting structures by wild bees in an urban environment
habitat suitability	general	5	2004	TJ Emery, DL Emery	Insect biodiversity in three Sydney urban parklands with differing levels of human usage
habitat suitability	flies	4	2005	ACG Heath, JGB Derraik	Adult Diptera trapped at two heights in two native forests and an urban environment in New Zealand
biology	flies	4	2014	MV Cardo, D Vezzani, A Rubio, AE Carbajo	Integrating demographic and meteorological data in urban ecology: a case study of container?breeding mosquitoes in temperate Argentina
restoration	general	3	2004	RJ Toft, C Meurk, RJ Harris, JS Dugdale	Restoration of Insect Communities in an Urban Landscape: Criteria for Success
habitat suitability	thrips	3	2012	J Wang, X Tong	Species diversity, seasonal dynamics, and vertical distribution of litter–dwelling thrips in an urban forest remnant of South China
habitat suitability	beetles	3	2013	S Fattorini	Faunistic knowledge and insect species loss in an urban area: the tenebrionid beetles of Rome
theory	general	2	2016	S Fattorini	Insects and the city: what island biogeography tells us about insect conservation in urban areas
faunistics	general	2	2001	Y Mori	Urban insect assemblages from the pre-historical and historical sediments