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Urbanization drivers differentially affect ground arthropod assemblages in the city of Turin (NW-Italy)

This is the author's manuscript

Original Citation:

Availability:

This version is available <http://hdl.handle.net/2318/1727361> since 2021-12-23T12:46:47Z

Published version:

DOI:10.1007/s11252-020-00937-z

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(Article begins on next page)

Urban Ecosystems

Urbanization drivers differentially affect ground arthropod assemblages in the city of Turin (NW-Italy) --Manuscript Draft--

Manuscript Number:	UECO-D-19-00020R3	
Full Title:	Urbanization drivers differentially affect ground arthropod assemblages in the city of Turin (NW-Italy)	
Article Type:	Manuscript	
Keywords:	UHI-effect, fragmentation, activity density, multitaxonomic approach	
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Funding Information:	Fondazione Giovanni Gorla (Bando dei Talenti della Società Civile 2016)	Dr Elena Piano
Abstract:	<p>Urbanization is a complex process associated with environmental changes affecting many biotic and abiotic ecosystem components, which cause the alteration of biological communities, habitat features, connectivity and stability. In particular, the urbanization process is usually associated with a decrease in species richness that parallels a general increase in the overall abundance of individuals, mostly due to generalist and tolerant species taking advantage of the altered environmental conditions and outcompeting and excluding native species. We here adopted a hierarchically nested sampling design to investigate the response of ground arthropods to the combined effects of multiple facets of urbanization, namely increased impervious surface cover, temperature and patch isolation, measured at small, intermediate and large spatial scale. We studied 15 plots of 150 m in diameter located in the city of Turin (NW-Italy), along an urbanization-cover gradient ranging from suburbia to the city center. For each plot we considered the level of urbanization at three different scales (circular buffers with a 100, 400 and 1600 m radius). Within each plot, we identified a control and an isolated subplot, and in each subplot, we measured ground temperature using dataloggers and we sampled ground arthropods with pitfall traps. Firstly, by relating ground temperature and urbanization cover, we showed that temperature values reflected an Urban Heat Island (UHI) effect, which indicates increasing values of temperature along the urbanization gradient. This trend was particularly evident at large scale regarding daily and diurnal temperature, and at small scale regarding nocturnal temperature. Secondly, we demonstrated that different groups of ground arthropods respond differently to urbanization cover, with major effects at the largest spatial scale. Finally, we extrapolated the differential contribution of urbanization cover, UHI-effect and patch isolation to the observed activity density of the investigated taxonomic groups: Coleoptera and Hemiptera were influenced by temperature, whereas Hymenoptera, Collembola, Acari and Araneae were mainly influenced by</p>	

urbanization, especially in control subplots. Our results emphasize how a multitaxonomic approach can help unravel patterns of community assembly in urban areas.

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Urbanization drivers differentially affect ground arthropod assemblages in the city of Turin (NW-Italy)

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ABSTRACT

Urbanization is a complex process associated with environmental changes affecting many biotic and abiotic ecosystem components, which cause the alteration of biological communities, habitat features, connectivity and stability. In particular, the urbanization process is usually associated with a decrease in species richness that parallels a general increase in the overall abundance of individuals, mostly due to generalist and tolerant species taking advantage of the altered environmental conditions and outcompeting and excluding native species. We here adopted a hierarchically nested sampling design to investigate the response of ground arthropods to the combined effects of multiple facets of urbanization, namely increased impervious surface cover, temperature and patch isolation, measured at small, intermediate and large spatial scale. We studied 15 plots of 150 m in diameter located in the city of Turin (NW-Italy), along an urbanization-cover gradient ranging from suburbia to the city center. For each plot we considered the level of urbanization at three different scales (circular buffers with a 100, 400 and 1600 m radius). Within each plot, we identified a control and an isolated subplot, and in each subplot, we measured ground temperature using dataloggers and we sampled ground arthropods with pitfall traps. Firstly, by relating ground temperature and urbanization cover, we showed that temperature values reflected an Urban Heat Island (UHI) effect, which indicates increasing values of temperature along the urbanization gradient. This trend was particularly evident at large scale regarding daily and diurnal temperature, and at small scale regarding nocturnal temperature. Secondly, we demonstrated that different groups of ground arthropods respond differently to urbanization cover, with major effects at the largest spatial scale. Finally, we extrapolated the differential contribution of urbanization cover, UHI-effect and patch isolation to the observed activity density of the investigated taxonomic groups:

1 Coleoptera and Hemiptera were influenced by temperature, whereas Hymenoptera, Collembola, Acari and
2 Araneae were mainly influenced by urbanization, especially in control subplots. Our results emphasize how a
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4 multitaxonomic approach can help unravel patterns of community assembly in urban areas.
5

6 **Keywords:** UHI-effect, fragmentation, activity density, multitaxonomic approach
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10 11 12 **INTRODUCTION** 13

14
15 Land-use change has been recognized as one of the major drivers affecting biodiversity (Sala et al. 2000)
16 and, over the recent decades, the conversion of natural lands into urban areas has been greatly increasing
17 worldwide (Seto et al. 2011). From an ecological standpoint, urban ecosystems are associated with
18 substantial changes in the physical environment, among which the increasing nutrient and pollution levels
19 are the most evident (Parris 2016). However, other physical alterations may affect urban areas too. For
20 instance, due to the amount of area characterized by a high built-up cover, ambient temperature in city cores
21 is typically 1.5-2°C higher than in the rural surroundings, i.e. the Urban Heat Island (UHI) effect (Oke 1982;
22 Arnfield 2003). Higher urban temperatures mainly stem from an anthropogenic release of heat, combined
23 with the heat stored and re-radiated by massive and complex urban structures (Rizwan et al. 2008).
24 Urbanization effects are apparent also at a landscape scale, as the continuous growth of built-up areas
25 interrupts the semi-natural habitats surrounding cities, creating partially or completely small isolated patches
26 (Parris and Schneider 2009; Rotholz and Mandelik 2013). In addition, the residual natural habitat is often
27 converted into highly impermanent and disturbed habitats, mainly derelict sites — such as brownfields,
28 landfills, gravel and sand pits, industrial dumps and railway lands — characterized by altered soil physical
29 and chemical properties (Small et al. 2003; Tóthmérész et al. 2011).
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50 Such biophysical processes linked to urbanization can have wide-ranging effects on populations and species
51 by altering the quantity, quality, temporal and spatial arrangement of resources (Parris 2016). For instance,
52 the Urban Heat Island (UHI) effect may alter the composition of biological communities due to differences
53 in the thermal tolerance of species, causing a shift in community composition towards species with
54 preferences for higher temperatures (Merckx and Van Dyck, 2019). In addition, as suitable habitat patches in
55 urban environments are often isolated, they are more likely to be colonized by good rather than poor
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1 dispersers (see Piano et al. 2017a for an example on ground beetles and Merckx and Van Dyck 2019 for
2 lepidopterans). As a consequence, the number of species is expected to decrease in residual habitat patches
3 (McKinney 2008).
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7 Nonetheless, urban fragments can be characterized by abundant populations of some taxa, since synanthropic
8 urban species may outcompete and exclude native species (Shochat et al. 2010; Mammola et al. 2018),
9 leading to contradictory results (e.g. Christie et al. 2010; Faeth et al. 2011; Fortel et al. 2014; Saari et al.
10 2016; Banaszak-Cibicka et al. 2018; Alvarez Guevara and Ball 2018). In fact, not only do organisms react
11 differently to environmental changes in urban areas, but they also differ in their response to the scales at
12 which urbanization takes place, as a result of their combination of traits, e.g. dispersal capacity or foraging
13 range (see Egerer et al. 2017, Merckx and Van Dyck 2019, Merckx et al., 2018b). These changes in
14 biodiversity may, in turn, affect key ecosystem processes, like nutrient cycling, decomposition and pest
15 control (McIntyre et al., 2001). Thus, the understanding of the ecological implications of the urbanization
16 process is gaining more and more importance in the scientific debate.
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30 Since ground arthropods cover all of the consumers' trophic roles — i.e. herbivores, predators and
31 decomposers — they are abundant, diverse and responsible for numerous ecosystem functions. They exhibit
32 a variety of dispersal capacities and foraging ranges, likely being affected by urbanization at different spatial
33 scales (Egerer et al. 2017, Eggenberger et al. 2019). Many studies have shown how local factors and habitat
34 types in urban patches may negatively affect the abundance of different arthropod groups (Christie et al.
35 2010; Norton et al. 2014; Philpott et al. 2014; Otsu et al. 2015; Laguki et al. 2017; Kyrö et al. 2018), but
36 little is known about their scale of response (see Egerer et al. 2017, Merckx et al. 2018a and Merckx and Van
37 Dyck 2019 for some evidences). In addition, the Urban Heat Island (UHI) effect and patch isolation have
38 been shown to seriously affect single species dynamics (Meineke et al. 2013; Youngsteadt et al. 2015; Kaiser
39 et al. 2016) and community composition in urban environments (Clavero et al. 2011; Menke et al. 2011;
40 Piano et al. 2017a; Meineke et al. 2017; Merckx et al. 2018a; Merckx et al. 2018b). However, to date, the
41 extent to which the combined effect of these phenomena affects ground arthropod abundance has never been
42 addressed by simultaneously examining multiple taxonomic groups. Given their pivotal role in ecosystem
43 functionality — e.g. litter decomposition and pest control —, understanding how urbanization impacts
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1 multiple groups of ground arthropods is necessary to predict alterations in the provision of ecosystem
2 services, which has proved to be strictly dependent on biodiversity in urban areas (Ziter 2016).
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5 Here we performed a field study to investigate the combined effect of increasing urbanization cover (i.e.
6 increasing impervious surfaces, Elvidge et al. 2007), urban heat-island effect and isolation within an urban
7 area on six orders of ground arthropods, differing in their dispersal capacity and foraging behaviour. We
8 selected 15 sampling sites along an urbanization gradient in the city of Turin (Italy), and in each site we
9 sampled arthropods in an isolated green patch (traffic roundabouts) and in the closer wider green area. In
10 addition, within each sampling patch, we measured temperature values during the entire sampling period. We
11 aimed at: i) checking the presence of the UHI-effect in the study area and the scale of temperature response
12 to urbanization, and whether it is influenced by patch isolation; ii) examining at which scale urbanization
13 mostly affects ground arthropod assemblages, by considering the percentage of impervious surfaces at
14 different scales; and iii) evaluating the differential effect of urbanization, UHI-effect and isolation on the
15 activity density of different groups of ground arthropods and whether these groups show different responses
16 to these parameters. We hypothesized that: i) temperature would increase along the urbanization gradient as
17 a consequence of the UHI-effect; ii) the scale of response would differ depending on the examined arthropod
18 group; and iii) arthropod groups would be differentially affected by urbanization, temperature and isolation,
19 showing distinctive responses.
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42 MATERIALS AND METHODS

43 Sampling design

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45 This study was conducted in the metropolitan area of Turin (NW-Italy, approximately 900,000 inhabitants),
46 within 15 km of the city center. The city of Turin was founded by the Romans around the year 50 B.C. and it
47 is located between the Western Alps and the beginning of the Po plain in the region of Piedmont. The
48 altitude ranges between 220 and 280 m a.s.l. and the climate is continental.
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58 In order to test the effect of patch isolation independently from urbanization level, we adopted a specific
59 sampling design consisting of a random selection of a total of 15 sites (plots) with open vegetation along an
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1 urbanization gradient: from less urbanized areas in the suburbia to the city center (Fig. 1). In order to
2 examine how patch isolation affects the community of ground arthropods, in each plot we identified two
3 sampling subplots: i) an isolated subplot, located in a roundabout with open vegetation, maintained by
4 regular mowing, and ii) a control subplot, located in the nearest green area with the same type of vegetation,
5 being represented by small green urban patches (1,000 m²), urban parks or semi-natural areas at the city
6 borders (up to a few hundreds of hectares). The whole sampling plot –including the two subplots – was a
7 circular area with a diameter of 150 m (approximately 18,000 m²). We chose roundabouts as appropriate
8 proxies for isolated patches because they are completely surrounded by roads, which constitute a partial - or
9 even a complete - barrier for many organisms (Jaeger and Fahrig 2004). Both control and isolated subplots
10 were, and still are, managed by the public green authority of Turin, which mowed the grass once during the
11 study period in all subplots, thus guaranteeing the same degree of disturbance in both subplot categories.
12 Roundabouts ranged from 6 to 30 m radius (i.e. approximately from 150 to 2,500 m² in surface area), and
13 were equally distributed among three age classes (1 = less than 10 years of age ; 2 = 10 years of age; 3 =
14 more than 10 years of age), which were estimated from historical aerial maps using Google Earth
15 (https://www.google.com/earth/download/ge) (Tab. 1). The average distance between sampling plots was of
16 8,878 m (±1,705.6), ranging from 1,408 to 18,512 m.

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36 In order to investigate the scale of response of ground arthropod groups to urbanization cover, we calculated
37 the degree of urbanization for each plot in three progressive larger buffers, defined as circles with a 100 m
38 (small scale), 400 m (medium scale) and 1,600 m (large scale) radius - with the roundabout as the center. By
39 using digital maps updated to 2017
40 (http://geomap.reteunitaria.piemonte.it/WEBCAT/CAPABILITIES/wms_regp_basecarto10bn_2017.xml) in
41 QGis (Quantum Gis Development 2018) with a resolution of 5 m, we delimited impervious surfaces, namely
42 buildings, roads and parking areas, within each buffer. We then calculated the urbanization cover as the ratio
43 between the area covered by impervious surfaces within the buffer and the total area of the buffer. To
44 explore the UHI effect, we monitored temperature at a ground level in both the isolated and the control
45 subplot of each sampling plot, using 30 HOBO® Pendant® Temperature Data Loggers (Onset Computer
46 Corporation), which were set to record temperature every hour. Data loggers were installed and shielded with
47 an ad-hoc, custom fabricated shield consisting of a shade cloth at the beginning of the experiment, and were
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downloaded **after** each sampling occasion. For each subplot we calculated the average daily (0 a.m. – 12 p.m.), diurnal (7 a.m. – 6 p.m.) and nocturnal (7 p.m. – 6 a.m.) temperatures **for** every sampling session.

Data collection

Within each subplot, ground-active arthropods were captured using a triplet of pitfall traps (5-10 m apart), placed at least 20 cm from the subplot border (i.e. the road) and at least 5 m apart to increase catching efficiency (Ward et al. 2001). Pitfall traps consisted of plastic jars (diameter 90 mm, length 110 mm) dug into the ground, ensuring the upper edge of the glass **was flush** with the soil surface. Pitfall traps were filled with 20 ml of 50% propylene glycol, which is a neutral field sampling preservative, with no attractive or repulsive characteristics for most arthropod groups. The pitfall traps were placed on the same day (May 16th, 2017) and were emptied every three weeks for a total of three sampling sessions (June 6th, June 27th **and** July 18th 2017).

Collected material was placed into vials containing **70%** ethanol to preserve specimens. The specimens were sorted, identified following Angelini et al. (2002) and counted. All arthropods were sorted by order or class and by superorder in the case of the Acari. Non-arthropod organisms (e.g. Gasteropoda, Oligochaeta) and larvae were discarded. Arthropod taxa that **had** been found in less than 50% of the total sampling sites (i.e. Orthoptera, Diptera, Dermaptera, Thysanoptera, Lepidoptera, Opiliones, Pseudoscorpionida, Chilopoda, Diplopoda and Isopoda) were also excluded from further analysis to avoid zero inflation. Finally, we retained only 6 out of 16 arthropod orders (Coleoptera, Hymenoptera, Hemiptera, Collembola, Acari and Araneae), which represented the dominant groups. Data from the triplets collected in the same subplot were pooled together and, prior to data analysis, abundance data **was** transformed into **a daily activity density** (D.A.; Brandmayr et al. 2005) following the formula:

$$D.A. = N/ndays * ntraps$$

where N is the abundance of each taxonomic group divided by the sampling effort, expressed as the product **of** the number of days in which traps were active and the number of retrieved traps. This data transformation **has** allowed us to standardize abundance values based on the number of effectively retrieved traps, given that some pitfall traps were lost during the sampling season.

Data analysis

All statistical analyses were performed with the R 3.5.3 (R Development Core Team, 2019) software.

UHI-effect

In order to investigate, the presence of the UHI-effect, we modelled the response of average daily, diurnal and nocturnal temperatures against urbanization cover, measured as the coverage of impervious surfaces at a small, medium and large scale. Since the levels of urbanization cover (i.e. percentage of the urbanization surface) recorded at the three scales correlated with each other, we performed three different models for each temperature variable via linear mixed models (LMMs, in accordance with Zuur et al. 2009), assuming a normal distribution for dependent variables. We compared the performance of models fitted with an urbanization level in different buffers (%Urb) and selected the model with the lowest AICc value. We preferred the AICc over the AIC because of small dimensions of the datasets (Hurvich and Tsai 1989). In addition, the model with the lowest AICc was kept as a reference point to calculate the AICc differences ($\Delta AICc$) between the models, given that models with values of $\Delta AICc < 2$ are judged to have substantial support and should be considered viable alternatives to the model with the lowest AICc (Burnham and Anderson 2002). In order to further scrutinize whether isolated subplots were characterized with a different microclimate compared to control ones, we also included a categorical variable, distinguishing control and isolated subplots. The models had the following structure:

$$y \sim \%Urb + Isolation + (1+PlotID) + (1|Session)$$

where y indicates average daily, diurnal or nocturnal temperature, %Urb represents the percentage of impervious surface in the buffer (i.e. the level of urbanization) and Isolation represents a categorical variable which distinguishes the control and isolated subplots. Given the spatial (two subplots within each plot) and temporal dependence of the data (three sampling sessions), we applied the mixed procedure to include the plot (PlotID) and the sampling session (Session) as a random factor to account for the variations they introduced in our samples, rather than testing for their direct effects on the dependent variables.

Response to urbanization

1 In order to disentangle the relative contribution of urbanization cover, UHI-effect and isolation on the
2 activity density of ground arthropods and to check whether the examined groups responded to the
3 environmental parameters differently, we tested the predictor variables and potential interactions against the
4 activity density of ground arthropods via linear mixed models (LMMs, in accordance with Zuur et al. 2009).
5 We assumed a normal distribution for dependent variables and we used the plot (PlotID) and the sampling
6 session (Session) as random variables. Firstly, we explored the dataset following the standard protocol for
7 data exploration proposed by Zuur et al. (2010). According to Zuur et al. (2009, 2010), the inclusion of
8 outliers and highly correlated predictors in the regression analysis leads to misleading results – type I and II
9 statistical errors. Successively, we used Cleveland's dotplots to assess the presence of outliers in dependent
10 and independent variables, and we investigated multi-collinearity among covariates. The percentages of
11 urbanization measured in different buffers were highly correlated, as well as average, diurnal and nocturnal
12 temperatures (Pearson's $r > 0.7$). On the other hand, temperature and urbanization were not collinear
13 (Pearson's $r < 0.5$) according to the indications provided by Zuur et al. (2009, 2010) and therefore could be
14 retained within the same models. Given that predictor variables were expressed in different measurement
15 units, we standardized them to achieve variance homogenization prior to model fitting, as suggested in Zuur
16 et al. (2009).

17 The response of arthropod groups to environmental parameters was tested with a two-step approach. First,
18 for each taxonomic group, we proceeded with fitting three separated full models, one for each scale of
19 urbanization cover, and we selected the one with the lowest AICc. This procedure was implemented to check
20 at which scale the response of each group was more evident. We also calculated the $\Delta AICc$ for all the other
21 models as the difference between the AICc of the considered model and the AICc of the best model, i.e. with
22 the lowest AICc. Models with $\Delta AICc < 2$ are considered equivalent to the best model (Burnham and
23 Anderson 2002). The full models had the following structure:

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$$y \sim \%Urb + \%Urb^2 + Temp + Temp^2 + Isolation + \%Urb*Temp + \%Urb*Isolation + Temp*Isolation +$$

25
$$(1|Session) + (1|PlotID)$$

26 where y refers to the activity density of each arthropod group, %Urb represents the percentage of urbanized
27 surface in the buffer, Temp represents the average daily temperature, and Isolation represents a categorical

1 variable between the control and isolated subplots. The quadratic terms of predictor variables were included
2 to investigate the occurrence of parabolic responses. Given the spatial and temporal dependence of the data,
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4 we applied a mixed procedure to include two grouping variables (PlotID and Session) as random factors, to
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6 account for the variation they introduced in our samples, rather than to test for their direct effects on the
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8 dependent variables. We adopted a gamma error distribution to keep into account the strictly positive values
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10 of activity density data.

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13 **Secondly**, for each taxonomic group, we performed a backward elimination on the selected model to obtain
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15 the minimum adequate model, i.e. the model including only variables that influence the activity density of
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17 the examined group.
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21 **RESULTS**

22 UHI-effect

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27 The level of urbanization (%Urb) ranged from 12.9% to 95.0%, with an average value of 54.8% at a small
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29 scale (100 m), from 11.1% to 99.6% with an average value of 56.2% at a medium scale (400 m) and from
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31 18.7% to 94.8% with an average value of 58.8% at a large scale (1,600 m), therefore covering a wide
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33 gradient of urbanization. Mean daily temperature values recorded during the sampling period ranged
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35 between 19.98°C and 31.85°C, with an average value of 26.14°C. Mean diurnal temperatures ranged from
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37 21.27 °C to 40.58°C, with an average value of 30.12°C, whereas mean nocturnal temperatures ranged
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39 between 18.29°C and 26.45°C, with an average value of 22.16°C.
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44 Results of the statistical models showed how both daily and nocturnal temperature values significantly
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46 increased with increasing urbanization level in every buffer, whereas diurnal temperature values showed a
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48 significant positive relationship only with the urbanization measured in 400 m and 1,600 m buffers (Tab. 1).
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51 In addition, according to the AICc values, the best models for daily and diurnal temperature included
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53 urbanization cover at a large scale (1,600 m buffer), whereas the best model for nocturnal temperature
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55 included urbanization cover at a small scale (100 m) (Tab. 1 and Fig. 2). These trends were particularly
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57 evident in the control subplots, whereas temperature growth was much less pronounced in isolated subplots,
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59 even if values were generally higher.
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Scale of response to urbanization

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3 A total of 215 out of 270 pitfall traps were retrieved during the whole sampling season. We collected a total
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5 of 99,897 individuals with a mean of 464.3 individuals per pitfall trap (see Fig. 3 for abundances of each
6
7 group). The best models (i.e. lowest AICc) included urbanization measured in the larger buffer (1,600 m
8
9 radius) for most groups, except Coleoptera and Acari, whose best models included urbanization at a small
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11 (buffer of 100 m of radius) and intermediate (buffer at 400 m of radius) scale, respectively (Tab. 2).
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13 However, given that the $\Delta AICc$ values are < 2 , the response of Coleoptera could be considered equivalent at
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15 a large scale, while for Hemiptera the response is equivalent at an intermediate scale.
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Response to environmental parameters

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22 The results of the models show a differential response to urbanization for the different taxonomic groups
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24 (Tab. 3 and Fig. 4). The level of urbanization (%Urb) was included in the final models of all groups, except
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26 for Coleoptera and Hemiptera, but it proved to have significant positive effect only on Acari. Temperature
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28 was included in 4 out of 6 final models, with significant responses for three groups (Tab. 3 and Fig. 5).
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30 While Coleoptera and Acari proved to be negatively affected by temperature, Araneae showed a significant
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32 positive trend. The quadratic term was included in the final model of Acari with a significant negative effect.
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34 Isolation was included in 5 out of 6 groups and we observed significantly higher values of activity density in
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36 control subplots than in isolated subplots in 3 out of 5 groups, namely Hymenoptera, Acari and Araneae
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38 (Tab. 3 and Fig. 6). The interaction between urbanization level (%Urb) and isolation was included in 4 out of
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40 6 final models, with significant lower values of activity density in isolated subplots compared to the control
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42 subplots, with increasing urbanization for Hymenoptera, Acari and Collembola, whereas Araneae showed the
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44 opposite trend (Tab. 3 and Fig. 4). The interaction between isolation and temperature was included in the
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46 final model of Hemiptera and Acari, but only the former showed a significant effect (Tab. 3 and Fig. 5), with
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48 temperature negatively affecting this group in isolated subplots more than in control subplots. The interaction
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50 between urbanization levels and temperature was included in the final model of Acari with a significant
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52 positive effect, thus underling how temperature positively affects this group in highly urbanized areas (Tab. 3
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54 and Fig. 7).
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DISCUSSION

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3 Urbanization is expected to impact biodiversity and, consequently, ecosystem functioning due to the
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5 combined effect of multiple interacting pressures – increasing impervious surfaces, increasing temperature
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7 and habitat fragmentation. Thanks to a hierarchical, nested sampling design we were able to evaluate the
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9 differential role of impervious surfaces and isolation on the UHI-effect, and tested the combined effect of
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11 these pressures on the activity density of six ground arthropod groups.
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15 Our first aim was to check whether the UHI-effect was actually ongoing by relating recorded temperature
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17 values with urbanization at a small, medium and large scale, and whether isolation could affect this
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19 parameter. We hypothesized that temperature would increase along the urbanization gradient as a
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21 consequence of the UHI-effect and our results confirmed our hypothesis. We revealed that temperature
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23 values observed during the sampling period significantly increased along the urbanization gradient,
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25 confirming the presence of a UHI-effect in the city of Turin, especially at night. Similar trends were
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27 observed by Diamond et al. (2014) and Merckx et al. (2018a) in Ohio (USA) and Belgium (Europe)
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29 respectively. However, only nocturnal temperature was mainly influenced by urbanization at a local scale —
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31 possibly because of the buildings releasing heat stored during the day — while daily and diurnal
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33 temperatures better reflect urbanization on a larger scale. As the scale increases, the influence of the
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35 adjoining land-uses decreases (Ziter et al. 2019). Thus, we can suppose that night temperatures can be
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37 mitigated by the surrounding land cover and the UHI-effect is mainly reflected on a local scale. In addition,
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39 nocturnal temperature measured at ground level, like as in this study, seems to be more influenced by
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41 microscale site characteristics than air temperature as reviewed by Arnfield et al. (2003). Conversely, during
42
43 the day, the heat absorbed by impervious surfaces probably creates extremely isolated temperature islands,
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45 limiting the possible mitigating effects of surrounding land use. These results point out how urbanization
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47 may have climatic repercussions even at a very local scale, exacerbating the UHI-effect and transforming
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49 cities into climatic mosaics. This phenomenon has been observed in the city of Baltimore (USA), where the
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51 center is 5-10°C warmer than the surrounding area (Brazel et al. 2000; George et al. 2007). In addition, our
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53 results demonstrated that isolated patches, such as roundabouts, have significantly higher temperature values
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55 compared to control ones and their temperature values appear to be less influenced by urbanization compared
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1 to the control sites. This is in accordance with the literature, since altered physical and chemical conditions,
2 such as microclimate alteration, have been documented in ruderal habitats, like road edges, as a result of road
3 operation and traffic (Parris and Schneider 2008), further contributing to the creation of a climatic mosaic in
4 cities. Moreover, control patches can be influenced by surrounding land use, e.g. tree canopy cover of
5 adjacent forested areas may mitigate the UHI-effect (Ziter et al. 2019), while this is not possible in isolated
6 patches.
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14 Our second aim was to examine to what scale urbanization could affect ground arthropods, by considering
15 the percentage of impervious surfaces at a small, medium and large scale. We showed that responses of
16 ground arthropods were better explained by large scale urbanization, contradicting our hypothesis. These
17 outcomes apparently contradict literature, since several works highlight how local factors usually have a
18 stronger effect than landscape factors (Angold et al. 2006; Small et al. 2006; Shwartz et al. 2013; Bennett
19 and Lovell 2014; Do et al. 2014; Philpott et al. 2014; Otoshi et al. 2015; Kyrö et al. 2018), even if Delgado
20 de la Flor et al. (2017) and McCary et al. (2018) observed how covariation between local and landscape
21 factors affect ground-active arthropods. In particular, McCary et al. (2018) highlighted how the shared
22 variance between local, i.e. habitat type, landscape and landscape fragmentation variables explained half of
23 the variation in several ground-active arthropods, whereas Delgado de la Flor (2017) evidenced a combined
24 effect of local habitat type and buildings in the landscape on ground beetle community composition.
25 However, as habitat types differed profoundly in these studies, it remained less clear to what extent the
26 measured response was a consequence of habitat type or urbanization *per se*. Since we consistently sampled
27 the same habitat type along the urbanization gradient, we were able to disentangle the scale of response
28 without confounding factors, underpinning how urbanization affects ground arthropods at a large scale. The
29 only exception is represented by Acari, which demonstrated a medium scale response, whereas, according to
30 the minimum adequate model, Coleoptera were not affected by urbanization.
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53 Our third aim was to evaluate the differential effect of urbanization, the UHI-effect and isolation on the
54 activity density of different taxonomic groups and whether the examined groups showed different responses
55 to these environmental parameters. We hypothesized arthropod groups would be differentially affected by
56 urbanization, temperature and isolation, showing idiosyncratic responses, and our results confirmed our
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1 hypothesis. In respect to this, our sampling design was particularly suitable in disentangling the effect of
2 patch isolation and urbanization on the different taxonomic groups here investigated.
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5 Our results showed that Acari and Araneae were mostly affected by urbanization, as their final models
6 included all the three examined environmental parameters, namely urbanization cover, temperature and patch
7 isolation. These results are in accordance with the review provided by El-Sabawii (2018), who highlighted
8 how predator groups, such as Acari and Araneae, are more affected **by urbanization than others**. A weaker
9 response was observed for Hymenoptera, here mainly represented by ants, Collembola and Hemiptera,
10 mainly represented by aphids, whose final models included two parameters. In particular, patch isolation
11 showed a **significantly** negative effect for all groups, suggesting how their fitness in urban environments may
12 be negatively affected by their low dispersal. Coleoptera showed the weakest response, as they were **only**
13 **affected** by one parameter, namely temperature. This result may be due to the heterogeneous composition of
14 Coleoptera in terms of feeding guilds, with the response of each guild being masked **by** the others.
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18 By using the percentage of impervious surfaces as a proxy of urbanization, we **have** highlighted how this
19 parameter alone does not affect examined taxonomic groups, except for Acari that showed a significant
20 positive trend with increasing urbanization. However, if we consider the interaction between urbanization
21 cover and patch isolation, we could highlight extremely variable responses among taxonomic groups: in
22 particular, Collembola and Hymenoptera showed a positive and negative trend in control and isolated
23 patches respectively with increasing urbanization, whereas Araneae showed the opposite trend. Although
24 species richness positively responds to increasing availability of natural habitats even in anthropogenic
25 environments (e.g. Piano et al. 2017b), contradictory results are common when analysing individual
26 densities. For instance, Kotze et al. (2011) highlighted how in certain cities the abundance of beetles
27 decreased with increasing urbanization, while in others this pattern was less consistent, or even opposite, in
28 the case of communities dominated by introduced species (Niemelä and Kotze 2009). Such inconsistent
29 responses reflect the complex nature of urban habitats and urban arthropod communities. On **the** one hand,
30 pollution - as well as the high level of impermanence in urban habitats - may lead to an increased
31 stochasticity in environmental conditions (Parris 2016), which may negatively affect particular groups. For
32 instance, predators, like spiders, are expected to be sensitive to pollution because they feed at higher trophic
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1 levels, where toxins and pollutants tend to accumulate (see El-Sabawii 2018 for a review on this topic). On
2 the other hand, urban patches provide a high availability of trophic resources (Parris 2016), which might
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4 favour generalist and alien species. For instance, pest arthropods, like some mites, are expected to increase in
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6 urban areas, due to human activity that eradicate native predators (Shocat et al. 2010). Similarly, omnivores,
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8 such as ants, which here represent 95% of Hymenoperans, are probably favoured in urban areas by the
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10 increase of anthropogenic food resources (El-Sabawii 2018). These changes at different trophic levels may
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12 have repercussions on the entire trophic food web, compromising the ecosystem services provided by the
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14 ground arthropod fauna, such as litter decomposition or pest control. Model outcomes displayed opposite
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16 trends of arthropod groups against temperature, which show a negative effect on Coleoptera and Acari and a
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18 positive effect on Araneae; whereas Hemiptera are favoured by temperature in control patches and
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20 disfavoured in isolated ones. Overall, the response to temperature increase has been shown to be extremely
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22 variable across arthropod groups as a consequence of variable physiological heat tolerance in ectotherms
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24 (Youngsteadt et al. 2017). Increasing temperature may, in fact, favour the fitness of those organisms with a
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26 wide thermal tolerance breadth, whereas species with a narrow thermal tolerance breath will be negatively
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28 affected (Sunday et al. 2012). This is especially true at mid-latitudes, as demonstrated by physiological tests,
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30 which showed that the lowest thermal tolerance to the UHI effect is observed between 30° and 35°N or S
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32 (Chown and Duffy 2015), whereas response patterns within the temperate zone showed contradictory results
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34 (Pelini et al. 2014). On the basis of measured physiological tolerances, two recent studies have predicted that
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36 mid-latitudes (between 20° and 40°) will encompass strong variability among taxa regarding the effects of
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38 urban warming and climate change on their fitness (Kingsolver et al. 2013; Chown and Duffy 2015).
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40 Moreover, the response of arthropod groups to environmental temperature may also be mediated by other
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42 environmental parameters, as demonstrated by the final model of Acari, which included the interaction
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44 between the urbanization cover and temperature. In respect to this group, higher temperatures have a
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46 negative effect on activity density, but this effect decreases and disappears with increasing urbanization
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48 cover, suggesting how the effect of urbanization *sensu stricto* may override the UHI-effect. In addition, the
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50 response to the UHI-effect may be even more complex since it seems to be mediated by life-history traits,
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52 such as dispersal capacity (Merckx et al. 2018a). Our results confirm such a response to temperature
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2 increase, pointing out how the repercussions of the UHI effect are extremely hard to predict and therefore
3 mitigate.

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5 It should be noted that temperature data recorded in the field with dataloggers is highly influenced by shield
6 methods and ad-hoc, custom-fabricated shields, such as those used in this work, and may produce bias in
7 temperature measures, especially in urban areas (Terando et al. 2017). Therefore, these results should be
8 interpreted with caution.
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15 Finally, we observed a consistent negative effect of isolation on 5 out of 6 taxonomic groups with significant
16 results for Hymenoptera, Acari and Araneae. Moreover, we proved that this effect is even stronger at
17 increasing levels of urbanization. Despite always showing higher values in control vs isolated patches,
18 spiders represent an exception to this pattern since their abundance in isolated patches increases with the
19 rising level of urbanization. This result contradicts literature, since Braaker et al. (2014) demonstrated how
20 isolated surrogates of natural habitats in urban areas, such as green roofs, might sustain populations of highly
21 dispersive arthropods, e.g. bees and weevils, but limit poor dispersers, e.g. carabids and spiders. However, in
22 some cases (e.g. small Linyphiids or young instars of Lycosids) spiders may show high dispersal capacity via
23 ballooning, therefore overcoming the limits imposed by isolation. Therefore, according to our results,
24 isolated patches in urban areas might be considered as islands surrounded by an inhospitable matrix that
25 limits the dispersion of organisms. While habitat connectivity between isolated patches does not represent a
26 limit for highly dispersive groups, it might severely limit poor dispersers, with serious repercussions on
27 biodiversity.
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45 Our results emphasize how a multitaxonomic approach may help in unravelling apparently contradictory
46 patterns in urban areas. Indeed, we isolated the response of taxonomic groups on an urbanization level, UHI-
47 effect and patch isolation, which may act in opposite directions depending on the sensitivity of each group.
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51 In addition, we highlighted how ground arthropod responses mainly occur on a large scale. In conclusion,
52 urbanization has negative ecological repercussions by diversely affecting the abundance of several
53 taxonomic groups of ground arthropods, which play a central role in a variety of processes, or represent a
54 food source for higher trophic levels, thus suggesting potential negative effects on ecosystem functionality
55 and services.
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Acknowledgements

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3 This work is part of the research fellowship grant “Bando dei Talenti della Società Civile 2016” won by EP
4
5 and funded by the Fondazione Gorla, the University of Turin and the Royal Belgian Institute of Natural
6
7 Sciences. The authors wish to thank the three anonymous referees, who contributed to the significant
8
9 improvement of the manuscript with their constructive comments and suggestions. We thank Giulia
10
11 Chiampo and Simone Savio for their help in the field work and sample sorting. Many thanks also to
12
13 Alexandra Jones for linguistic revision of the text. The authors declare no conflicts of interest.
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55
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57
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59
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62
63
64
65

BIBLIOGRAPHY

1
2
3 Alvarez Guevara JN, Ball BA (2018) Urbanization alters small rodent community composition but
4
5 not abundance. PeerJ 6: e4885.
6

7
8 Angold PG et al. (2006) Biodiversity in urban habitat patches. Sci Tot Env 360: 196–204.
9

10
11 Arnfield AJ (2003) Two decades of urban climate research: a review of turbulence, exchanges of
12
13 energy and water, and the urban heat island. Int J Climatol 23: 1-26.
14

15
16 Banaszak-Cibicka W, Twerd L, Fliszkiewicz M, Giejdasz K, Langowska A (2018) City parks vs.
17
18 natural areas - is it possible to preserve a natural level of bee richness and abundance in a city park? Urban
19
20 Ecosyst 21: 599–613.
21

22
23
24 Bates D, Maechler M, Bolker B, Walker S (2015) Fitting Linear Mixed-Effects Models Using lme4.
25
26 J Stat Softw 67(1): 1-48.
27

28
29 Bennett AB, Lovell ST (2014) A comparison of arthropod abundance and arthropod mediated
30
31 predation services in urban green spaces. Insect Conserv Divers 7: 405–412.
32

33
34
35 Bishop L (1990) Meteorological aspects of spider ballooning. Environ Entomol 19(5): 1381-1387.
36

37
38 Brandmayr P (2005) I coleotteri carabidi per la valutazione ambientale e la conservazione della
39
40 biodiversità: manuale operativo. APAT. Manuali e linee guida. 34/2005.
41

42
43 Braaker S, Ghazoul J, Obrist MK, Moretti M (2014) Habitat connectivity shapes urban arthropod
44
45 communities: the key role of green roofs. Ecology, 95(4): 1010-1021.
46

47
48 Brazel A, Selover N, Vose R, Heisler G. (2000) The tale of two climates Baltimore and Phoenix
49
50 urban LTER sites. Clim Res 15(2): 123-135.
51

52
53
54 Burnham KP, Anderson DR (2002) Model selection and multimodel inference New York. NY:
55
56 Springer.
57

1 Chown SL, Duffy GA (2015) Thermal physiology and urbanization: perspectives on exit, entry and
2 transformation rules. *Funct Ecol* 29(7): 902-912.
3

4
5 Christie FJ, Cassis G, Hochuli DF (2010) Urbanization affects the trophic structure of arboreal
6
7 arthropod communities. *Urban Ecosyst* 13: 169–180.
8
9

10 Clavero M, Villero D, Brotons L (2011) Climate change or land use dynamics: do we know what
11
12 climate change indicators indicate? *Plosone* 6(4): 1-8.
13
14

15 Delgado de la Flor YA, Burkman CE, Eldredge TK, Gardiner MM (2017) Patch and landscape-
16
17 scale variables influence the taxonomic and functional composition of beetles in urban greenspaces.
18
19 *Ecosphere* 8(11).
20
21

22
23 Diamond SE, Cayton H, Wepprich T, Jenkins CN, Dunn RR, Haddad NM, Ries L (2014)
24
25 Unexpected phenological responses of butterflies to the interaction of urbanization and geographic
26
27 temperature. *Ecology* 95(9): 2613-2621.
28
29

30 Do Y, Lineman M, Joo G-J (2014) Carabid beetles in green infrastructures: the importance of
31
32 management practices for improving the biodiversity in a metropolitan city. *Urban Ecosyst* 17: 661–673.
33
34

35
36 Egerer MH, Arel C, Otoshi MD, Quistberg RD, Bichier P, Philpott SM (2017) Urban arthropods
37
38 respond variably to changes in landscape context and spatial scale. *J Urb Ecol* 3.
39
40

41
42 Eggenberger H, Frey D, Pellissier L, Ghazoul J, Fontana S, & Moretti M (2019). Urban bumblebees
43
44 are smaller and more phenotypically diverse than their rural counterparts. *Journal of Animal Ecology*, doi
45
46 10.1111/1365-2656.13051
47
48

49 El-Sabaawi R (2018) Trophic structure in a rapidly urbanizing planet. *Funct Ecol* 32: 1718–1728.
50
51

52 Elvidge CD, Tuttle BT, Sutton PC, Baugh KE, Howard AT, Milesi C, Bhadura BL, Nemani R
53
54 (2007) Global distribution and density of constructed impervious surfaces. *Sensors* 7: 1962e1979.
55
56

57
58 Faeth SH, Bang C, Saari S (2011) Urban biodiversity: patterns and mechanisms *Ann NY Acad Sci*
59
60 1223: 69–81.
61
62
63
64
65

1 Fortel L, Henry M Guilbaud, L, Guirao AL, Kuhlmann M, Mouret H, Rollin O, Vaissière BE (2014)
2 Decreasing Abundance, Increasing Diversity and Changing Structure of the Wild Bee Community
3 (Hymenoptera: Anthophila) along an Urbanization Gradient. Plosone 9: e104679.
4
5

6
7 George K, Ziska LH, Bunce JA, Quebedeaux B (2007) Elevated atmospheric CO2 concentration and
8 temperature across an urban–rural transect. Atmos Environ 41(35): 7654-7665.
9

10
11
12 Hurvich CM, Tsai CL (1989) Regression and time series model selection in small samples.
13 Biometrika 76: 297–307.
14

15
16
17
18 Kaiser A, Merckx T & Van Dyck H (2016) The Urban Heat Island and its spatial scale dependent
19 impact on survival and development in butterflies of different thermal sensitivity. Ecol Evol 6(12): 4129-
20 4140.
21
22

23
24
25 Kingsolver JG, Diamond SE, Buckley LB (2013) Heat stress and the fitness consequences of climate
26 change for terrestrial ectotherms. Funct Ecol 27: 1415–1423.
27

28
29
30
31 Kotze DJ, Brandmayr P, Casale A et al. (2011) Forty years of carabid beetle research in Europe -
32 from taxonomy, biology, ecology and population studies to bioindication, habitat assessment and
33 conservation. Zookeys 100: 55-148.
34
35

36
37
38 Kyrö K, Brenneisen S, Kotze DJ, Szallies A, Gerner M, Lehvävirta S (2018) Local habitat
39 characteristics have a stronger effect than the surrounding urban landscape on beetle communities on green
40 roofs. Urban For Urban Green 29: 122–130.
41
42

43
44
45 Lagucki E, Burdine JD, McCluney KE (2017) Urbanization alters communities of flying arthropods
46 in parks and gardens of a medium-sized city. PeerJ 5: e3620.
47
48

49
50
51 Mammola S, Isaia M, Demonte D, Triolo P, Nervo M (2018) Artificial lighting triggers the presence
52 of urban spiders and their webs on historical buildings. Landscape Urban Plan 180: 187-194.
53
54

55
56
57 Mazerolle MJ (2017) AICcmodavg: Model selection and multimodel inference based on (Q)AIC(c).
58 R package version 2.1-1. <https://cran.r-project.org/package=AICcmodavg>.
59
60
61
62
63
64
65

1 McCary MA, Minor E, Wise DH (2018) Covariation between local and landscape factors influences
2 the structure of ground-active arthropod communities in fragmented metropolitan woodlands. *Landscape*
3
4 *Ecol* 33(2): 225-239.
5

6
7 McDonald RI, Kareiva P, Forman RT (2008) The implications of current and future urbanization for
8
9 global protected areas and biodiversity conservation. *Biol Cons* 141(6): 1695-1703.
10

11
12 McIntyre NE, Rango J, Fagan WF, Faeth SH (2001) Ground arthropod community structure in a
13
14 heterogeneous urban environment. *Landscape Urban Plan* 52: 257–274.
15

16
17 McKinney ML (2008) Effects of urbanization of species richness: a review of plants and animals.
18
19 *Urban Ecosyst* 11: 161-176.
20

21
22
23 Oke TR (1982) The energetic basis of the urban heat island. *Q J Roy Meteor* 108: 1-24.
24

25
26 Meineke EK, Dunn RR, Sexton JO Frank SD (2013) Urban Warming Drives Insect Pest Abundance
27
28 on Street Trees. *Plosone* 8: e59687.
29

30
31 Meineke EK, Holmquist AJ, Wimp GM, Frank SD (2017) Changes in spider community
32
33 composition are associated with urban temperature, not herbivore abundance. *J Urban Ecol* 3: juw010.
34
35

36
37 Menke SB, Guénard B, Sexton JO, Weiser MD, Dunn RR, Silverman J (2011) Urban areas may
38
39 serve as habitat and corridors for dry-adapted, heat tolerant species: an example from ants. *Urban Ecosyst*
40
41 14(2): 135-163.
42

43
44 Merckx T et al. (2018a). Body-size shifts in aquatic and terrestrial urban communities. *Nature* 558:
45
46 113–116.
47

48
49 Merckx T, Kaiser A, Van Dyck H (2018b) Increased body size along urbanization gradients at both
50
51 community and intraspecific level in macro- moths. *Global Change Biol* 24(8): 3837-3848.
52
53

54
55 Merckx T., Van Dyck H. (2019) Urbanization-driven homogenization is more pronounced and
56
57 happens at wider spatial scales in nocturnal and mobile flying insects. *Glob Ecol Biogeog* 28(10) doi:
58
59 10.1111/geb.12969
60
61
62
63
64
65

1 Niemelä J, Kotze DJ (2009) Carabid beetle assemblages along urban to rural gradients: A review.
2 Landscape Urban Plan 92: 65-71.
3

4
5 Norton BA, Thomson LJ, Williams NSG, McDonnell MJ (2014) The effect of urban ground covers
6 on arthropods: An experiment. Urban Ecosyst 17: 77–99.
7

8
9
10 Otoshi MD, Bichier P, Philpott SM (2015) Local and Landscape Correlates of Spider Activity
11 Density and Species Richness in Urban Gardens. Environ Entomol 44: 1043–1051.
12

13
14
15 Parris KM (2016) Ecology of Urban Environments. Wiley-Blackwell, Chichester, West Sussex, UK.
16

17
18
19 Parris KM, Schneider A (2009) Impacts of traffic noise and traffic volume on birds of roadside
20 habitats. Ecol Soc 14(1): 29.
21

22
23
24 Pelini SL et al. (2014) Geographic differences in effects of experimental warming on ant species
25 diversity and community composition. Ecosphere 5: 1–12.
26

27
28
29 Philpott SM, Cotton J, Bichier P, Friedrich RL, Moorhead LC, Uno S, Valdez M (2014) Local and
30 landscape drivers of arthropod abundance, richness, and trophic composition in urban habitats. Urban
31 Ecosyst 17: 513–532.
32

33
34
35 Piano E et al. (2017a) Urbanization drives community shifts towards thermophilic and dispersive
36 species at local and landscape scales. Global Change Biol 23(7): 2554-2564.
37

38
39
40 Piano E, Isaia M, Falasco E, La Morgia V, Soldato G, Bona F (2017b) Local versus landscape spatial
41 influence on biodiversity: a case study across five European industrialized areas. Environ Mon Ass 189(3):
42 126.
43

44
45
46 QGIS Development Team (2018) QGIS Geographic Information System. Open Source Geospatial
47 Foundation Project. <http://qgis.osgeo.org>
48

49
50
51 R Development Core Team (2019) R: A language and environment for statistical computing. R
52 Foundation for Statistical Computing, Vienna, Austria. <http://www.R-project.org>
53
54
55
56
57
58
59
60
61
62
63
64
65

1 Rizwan AM, Dennis LY, Chunho LIU (2008) A review on the generation, determination and
2 mitigation of Urban Heat Island. *J Environ Sci* 20(1): 120-128.
3

4
5 Rotholz E, Mandelik Y (2013) Roadside habitats: effects on diversity and composition of plant,
6 arthropod, and small mammal communities. *Biod Cons* 22(4): 1017-1031.
7

8
9
10 Saari S, Richter S, Higgins M, Oberhofer M, Jennings A, Faeth SH (2016) Urbanization is not
11 associated with increased abundance or decreased richness of terrestrial animals - dissecting the literature
12 through meta-analysis. *Urban Ecosyst* 19: 1251–1264.
13
14

15
16
17
18 Sala OE et al. (2000) Global biodiversity scenarios for the year 2100. *Science* 287(5459): 1770-
19 1774.
20

21
22
23 Seto KC, Gueneralp B, Hutyrá LR (2012) Global forecasts of urban expansion to 2030 and direct
24 impacts on biodiversity and carbon pools. *Proce Natl Acad Sci USA* 109: 16083-16088.
25

26
27
28 Shochat E, Warren PS, Faeth SH, McIntyre NE, Hope D (2006) From patterns to emerging processes
29 in mechanistic urban ecology. *TREE* 21(4): 186-191.
30

31
32
33
34 Shochat E, Lerman SB, Anderies JM, Warren PS, Faeth SH, Nilon CH (2010) Invasion, competition,
35 and biodiversity loss in urban ecosystems. *BioScience* 60(3): 199-208.
36

37
38
39 Shwartz A, Muratet A, Simon L, Julliard R (2013) Local and management variables outweigh
40 landscape effects in enhancing the diversity of different taxa in a big metropolis. *Biol Cons* 157: 285–292.
41

42
43
44 Simonneau M, Courtial C, Pétilion J (2016) Phenological and meteorological determinants of spider
45 ballooning in an agricultural landscape. *C R Biol* 339(9-10): 408-416.
46

47
48
49 Small EC, Sadler JP, Telfer MG (2003) Carabid beetle assemblages on urban derelict sites in
50 Birmingham, UK. *J Insect Cons* 6(4): 233-246.
51

52
53
54
55 Small E, Sadler JP, Telfer M (2006) Do landscape factors affect brownfield carabid assemblages?
56 *Sci Tot Environ* 360: 205–222.
57
58
59
60
61
62
63
64
65

1 Sunday JM, Bates AE, Dulvy NK (2012) Thermal tolerance and the global redistribution of animals.
2 Nature Climate Change 2(9): 686.
3

4 Terando AJ, Youngsteadt E, Meineke EK, Prado SG (2017) Ad hoc instrumentation methods in
5 ecological studies produce highly biased temperature measurements. Ecol Evol 7(23): 9890-9904.
6
7

8 Tóthmérész B, Máthé I, Balázs E, Magura T (2011) Responses of carabid beetles to urbanization in
9 Transylvania (Romania). Landscape and Urban Plan 101(4): 330-337.
10
11

12 Ward DF, New TR, Yen AL (2001) Effects of pitfall trap spacing on the abundance, richness and
13 composition of invertebrate catches. J Insect Cons 5(1): 47-53.
14
15

16 Weyman GS (1993) A review of the possible causative factors and significance of ballooning in
17 spiders. Ethol Ecol Evol 5(3): 279-291.
18
19

20 Youngsteadt E, Dale AG, Terando AJ, Dunn RR, Frank SD (2015) Do cities simulate climate
21 change? A comparison of herbivore response to urban and global warming. Global Change Biol 21: 97–105.
22
23

24 Youngsteadt E, Ernst AF, Dunn RR, Frank SD (2017) Responses of arthropod populations to
25 warming depend on latitude: evidence from urban heat islands. Global Change Biol 23: 1436–1447.
26
27

28 Ziter C (2016) The biodiversity–ecosystem service relationship in urban areas: a quantitative review.
29 Oikos 125(6): 761-768.
30
31

32 Ziter CD, Pedersen EJ, Kucharik CJ, Turner MG (2019) Scale-dependent interactions between tree
33 canopy cover and impervious surfaces reduce daytime urban heat during summer. PONAS 116(15): 7575-
34 7580.
35
36

37 Zuur AF, Ieno EN, Walker NJ, Saveliev AA, Smith GM (2009) Mixed effect models and extensions
38 in ecology with R. Berlin: Springer; 574 pp.
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41 Zuur AF, Ieno EN, Elphick SC (2010) A protocol for data exploration to avoid common statistical
42 problem. Methods Ecol Evol 1(1): 3-14.
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Tables

Table 1 AICc and Δ AICc values for models performed with urbanization at small, medium and large scale and estimated parameters and p-values (in brackets) for models performed on temperature variables against urbanization (%Urb) and patch isolation (Isolation) in each buffer. The best models and significant results are reported in bold.

	DAILY TEMPERATURE (°C)			DIURNAL TEMPERATURE (°C)			NOCTURNAL TEMPERATURE (°C)		
	100 m	400 m	1600 m	100 m	400 m	1600 m	100 m	400 m	1600 m
AICc	343.3	341.6	338.0	424.9	423.1	419.9	241.9	246.0	245.7
ΔAICc	5.3	3.6	0	5	3.2	0	0	4.1	3.8
%Urb	0.024 ± 0.009	0.025 ± 0.008	0.036 ± 0.010	0.027 ± 0.016	0.033 ± 0.015	0.051 ± 0.018	0.02 ± 0.004	0.017 ± 0.004	0.021 ± 0.005
	(0.009)	(0.003)	(<0.001)	(0.085)	(0.027)	(0.006)	(<0.001)	(<0.001)	(<0.001)
Isolation	1.29 ± 0.478	1.35 ± 0.471	1.4 ± 0.460	2.41 ± 0.854	2.5 ± 0.842	2.58 ± 0.826	0.133 ± 0.231	0.198 ± 0.238	0.227 ± 0.238
	(0.010)	(0.005)	(0.003)	(0.006)	(0.004)	(0.003)	(0.565)	(0.407)	(0.344)

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Table 2 AICc and Δ AICc values for models performed with urbanization at small, medium and large scale. The best models, namely those with the lowest value of AICc, are reported in bold. Δ AICcs are calculated as the difference between the AICc of the examined model and the AICc of the best model. Models with Δ AICc < 2 could be considered as equivalent of the best model.

		100 m	400 m	1600 m
Coleoptera	AICc	558.5	561.2	560.0
	ΔAICc	0	2.7	1.5
Hymenoptera	AICc	579.9	578.0	575.4
	ΔAICc	4.5	2.6	0
Hemiptera	AICc	448.0	446.8	445.5
	ΔAICc	2.5	1.3	0
Collembola	AICc	602.6	601.9	596.8
	ΔAICc	5.8	5.1	0
Acari	AICc	570.1	563.8	567.6
	ΔAICc	6.3	0	3.8
Araneae	AICc	424.7	424.2	419.3
	ΔAICc	5.4	4.9	0

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Table 3 Estimated parameters \pm standard errors and p-values (in brackets) of final models selected for each taxonomic group. Significant results are reported in bold.

Taxon	Scale of response	%Urb	%Urb ²	Temp	Temp ²	Isolation	%Urb: Isolation	Temp: Isolation	%Urb: Temp
Coleoptera	Small	-	-	-0.434 \pm 0.121 (<0.001)	-	-	-	-	-
Hymenoptera	Large	0.206 \pm 0.180 (0.252)	-	-	-	-0.472 \pm 0.098 (<0.001)	-0.208 \pm 0.104 (0.045)	-	-
Hemiptera	Large	-	-	0.089 \pm 0.184 (0.629)	-	-0.352 \pm 0.184 (0.056)	-	-0.408 \pm 0.187 (0.029)	-
Collembola	Large	0.251 (0.252)	-	-	-	-0.137 (0.436)	-0.563 (0.002)	-	-
Acari	Medium	0.920 \pm 0.275 (<0.001)	-	-0.581 \pm 0.168 (<0.001)	-0.148 \pm 0.093 (0.003)	-0.466 \pm 0.207 (0.025)	-0.546 \pm 0.210 (0.009)	0.417 \pm 0.239 (0.082)	0.401 \pm 0.137 (0.003)
Araneae	Large	-0.014 \pm 0.008 (0.102)	-	0.103 \pm 0.046 (0.026)	-	-1.06 \pm 0.422 (0.012)	0.015 \pm 0.006 (0.020)	-	-

Figure captions

Fig. 1 Map of the sampling plots with buffers (black circles) and impervious areas evidenced (dark grey).

Fig. 2 Predicted values and confidence intervals for daily, diurnal and nocturnal temperatures modelled against urbanization cover (%Urbanization) in both control (solid line) and isolated (dashed line) sites. Predicted values modelled against %Urbanization were calculated using the buffer included in the selected model for each temperature measure.

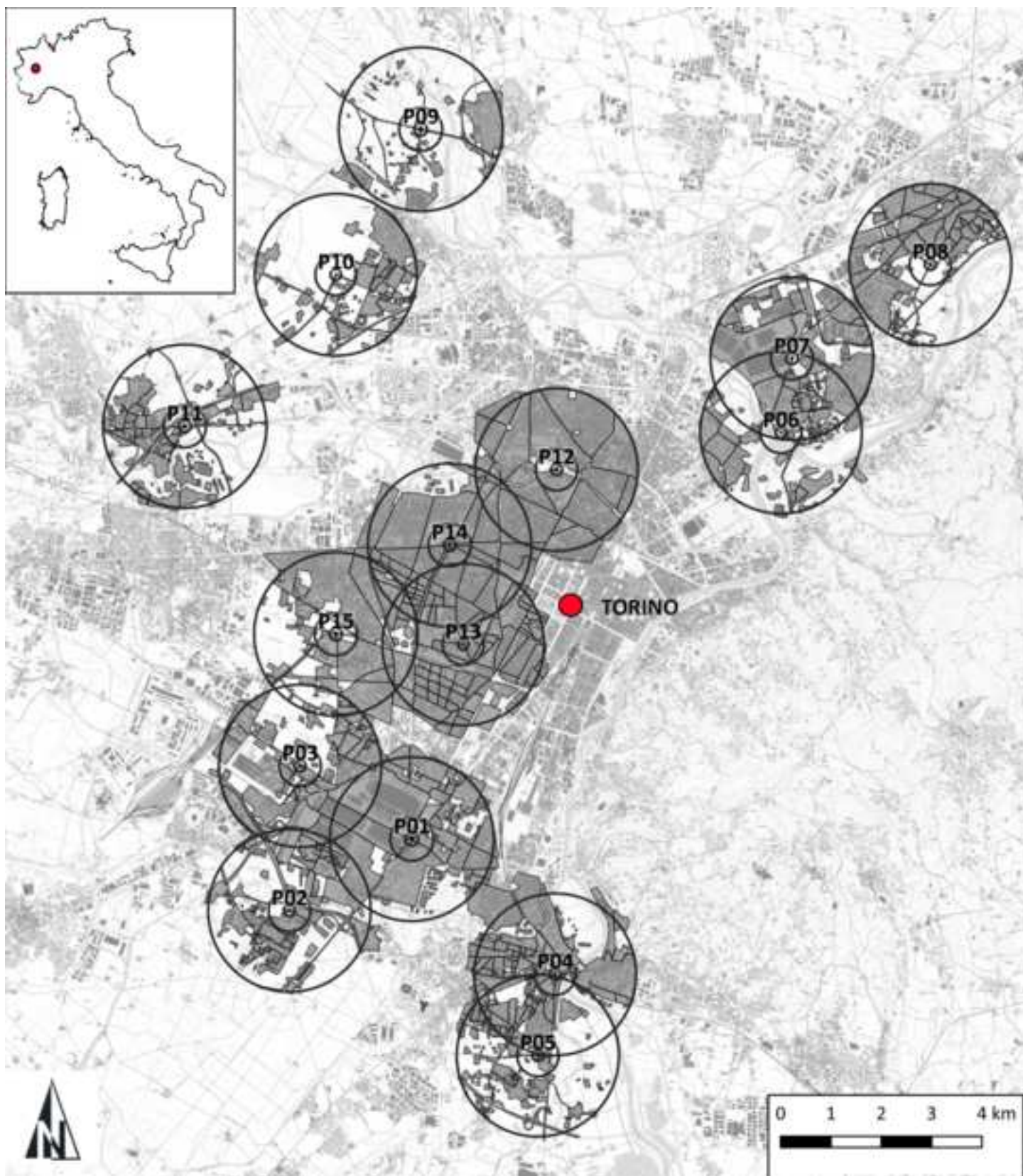
Fig. 3 Total abundance of ground arthropods sampled during the study.

Fig. 4 Predicted values and confidence intervals for activity density of the different groups modelled against urbanization cover (%Urbanization) in both control (solid line) and isolated (dashed line) subplots, with observed values (green dots = control subplots; grey dots = control subplots). Predicted values modelled against %Urbanization were calculated using the buffer included in the selected model for each taxonomic group.

Fig. 5 Predicted values and confidence intervals for activity density of Coleoptera, Acari and Araneae modelled against daily temperature in both control (solid line) and isolated (dashed line) subplots, with observed values (green dots = control subplots; grey dots = control subplots).

Fig. 6 Boxplots representing observed activity density values for each taxonomic group in control and isolated sites. Asterisks indicate significant differences according to statistical models (significance level: *0.05, **0.01, ***0.001).

Fig. 7 Predicted values and confidence intervals for activity density of Acari and the interaction between urbanization and temperature. Lines represent the temperature effect at low (0%, continuous line), intermediate (50%, dashed line) or high (100%, dotted line) urbanization cover.



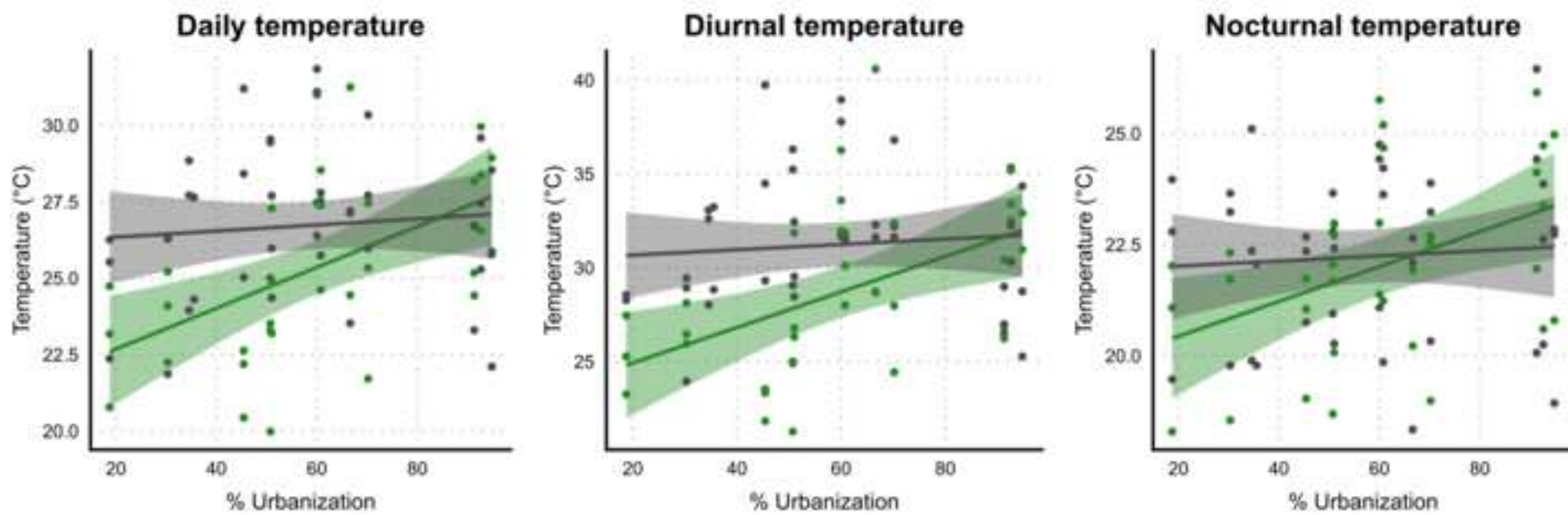
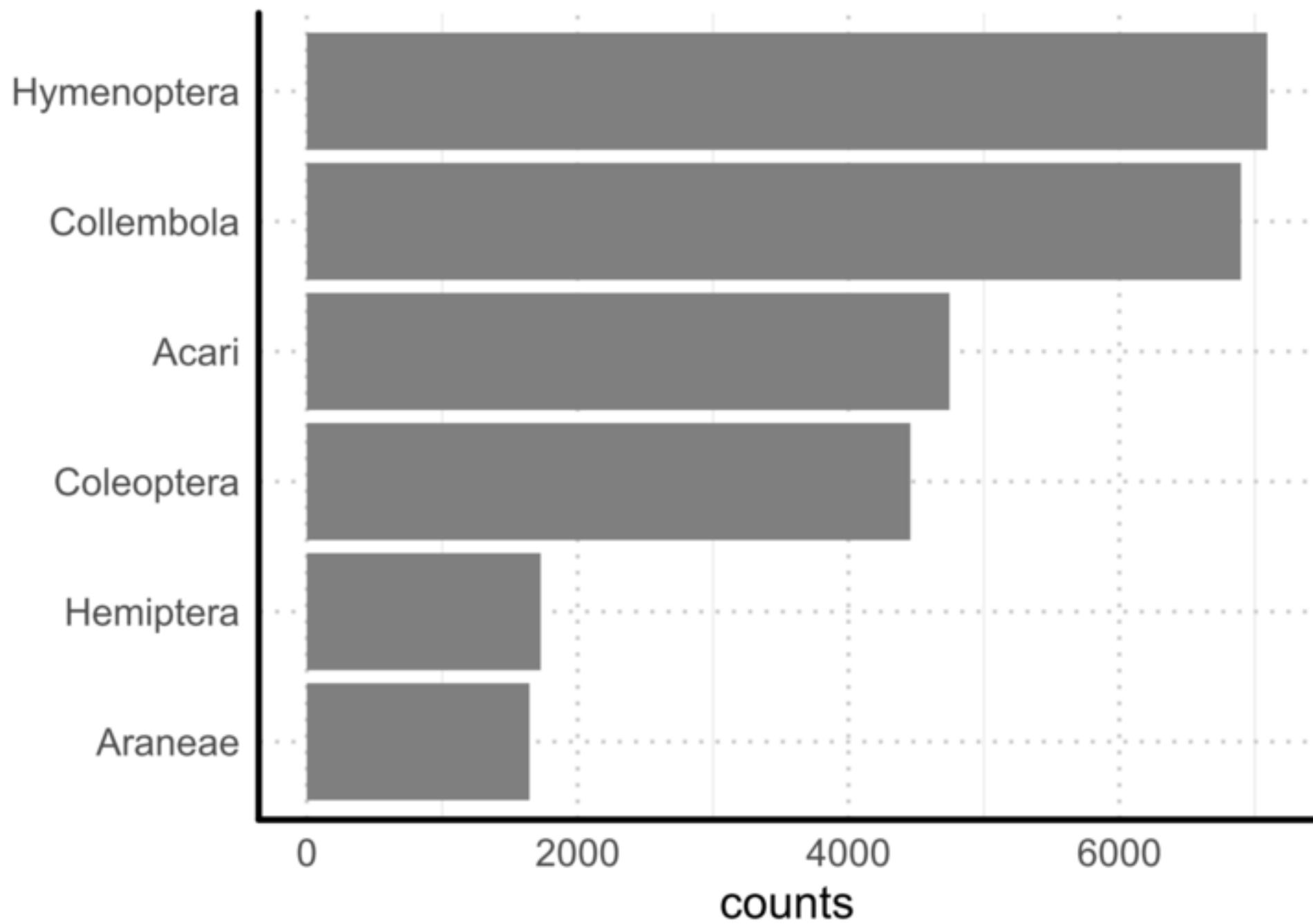
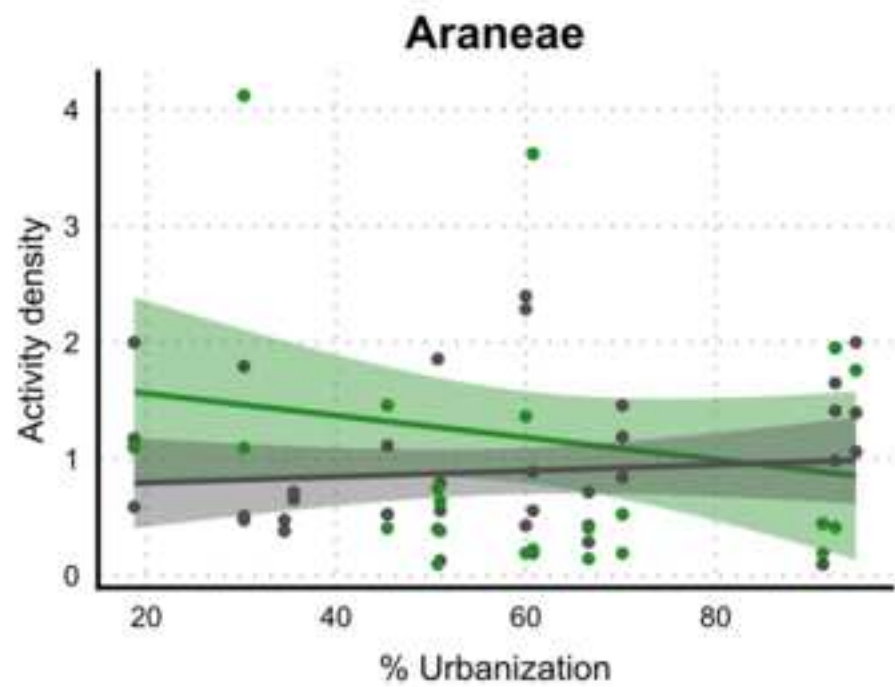
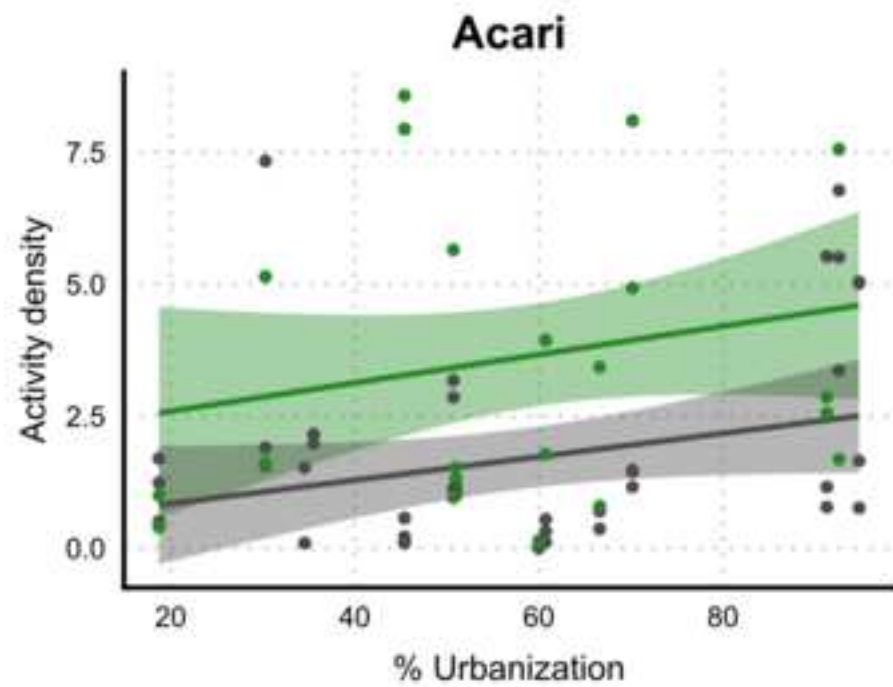
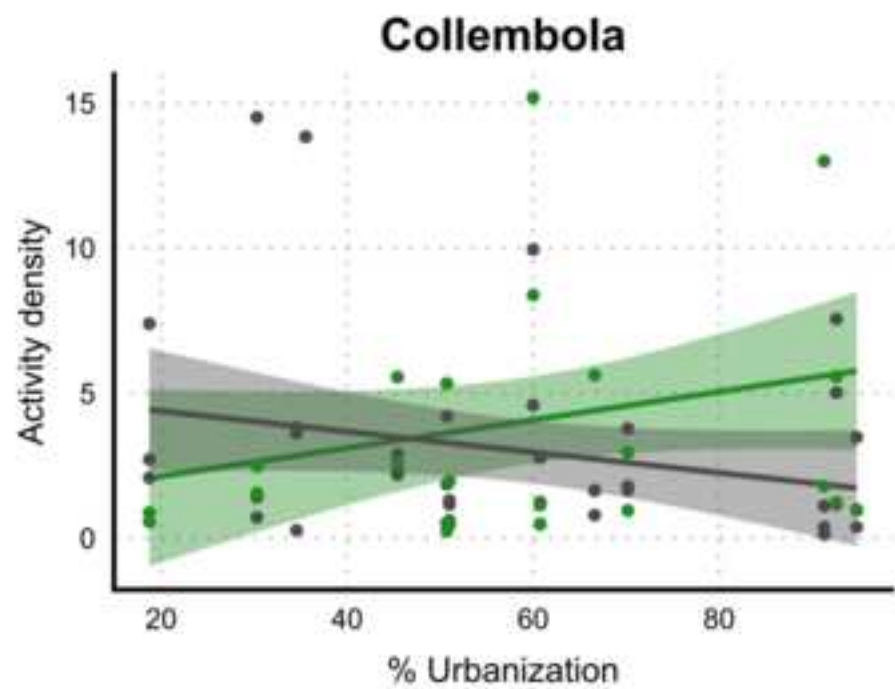
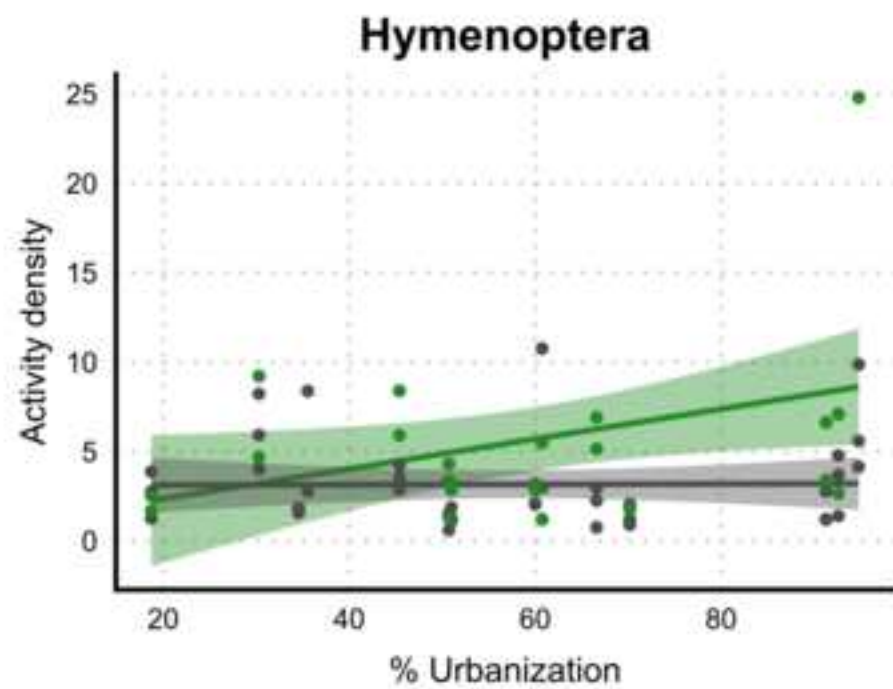
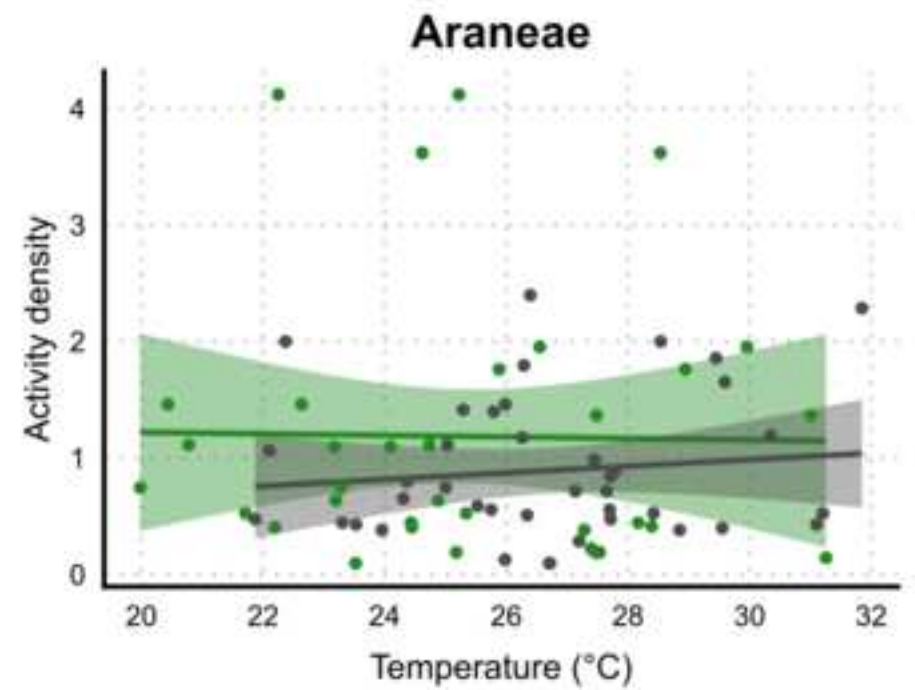
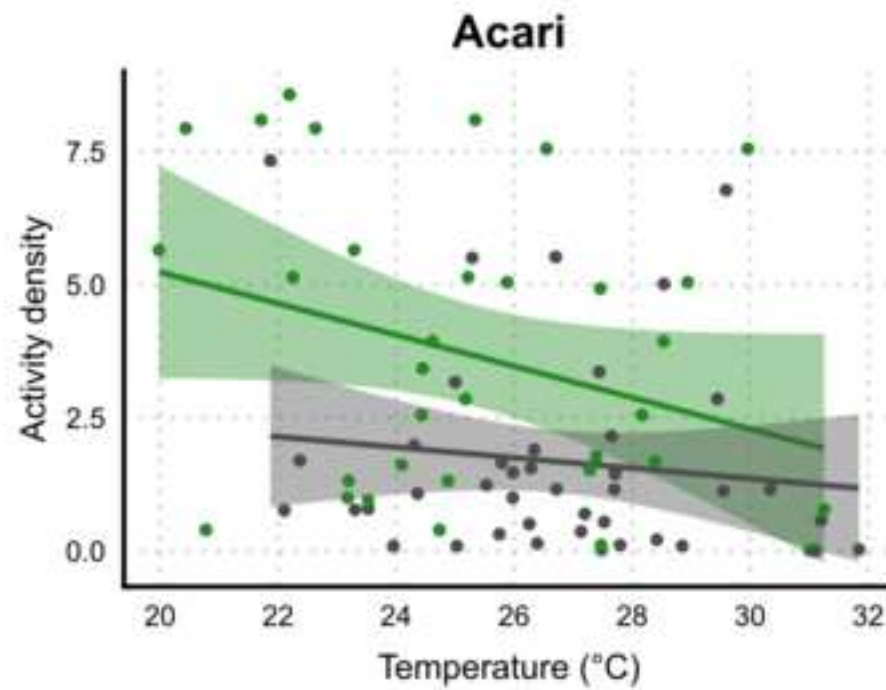
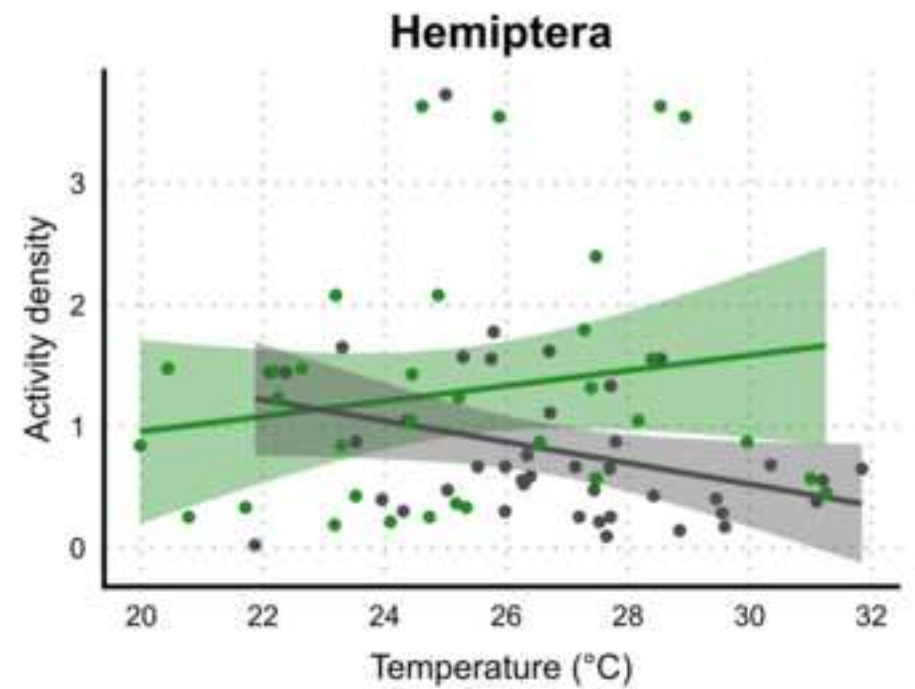
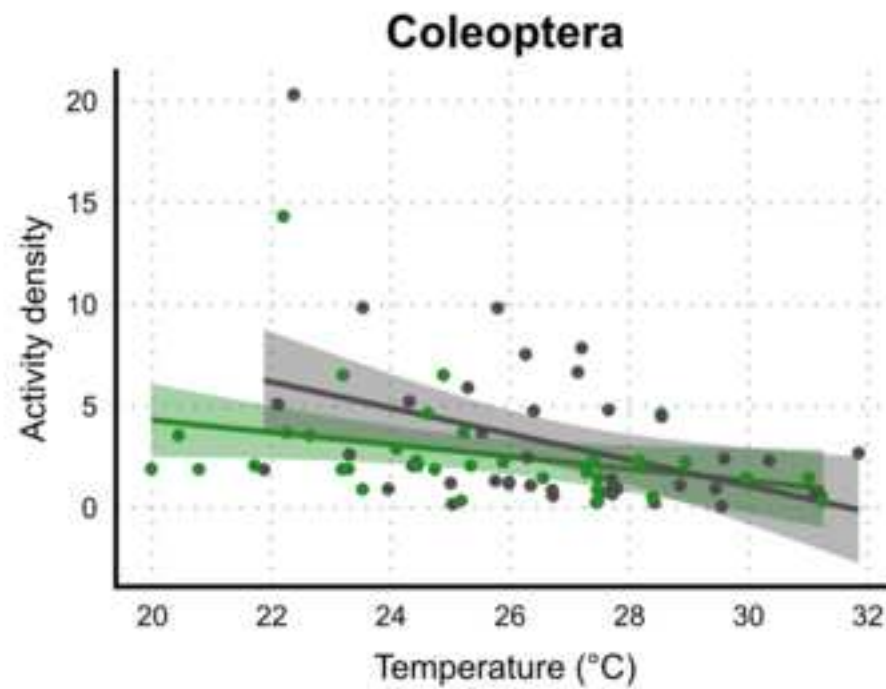


Figure 3







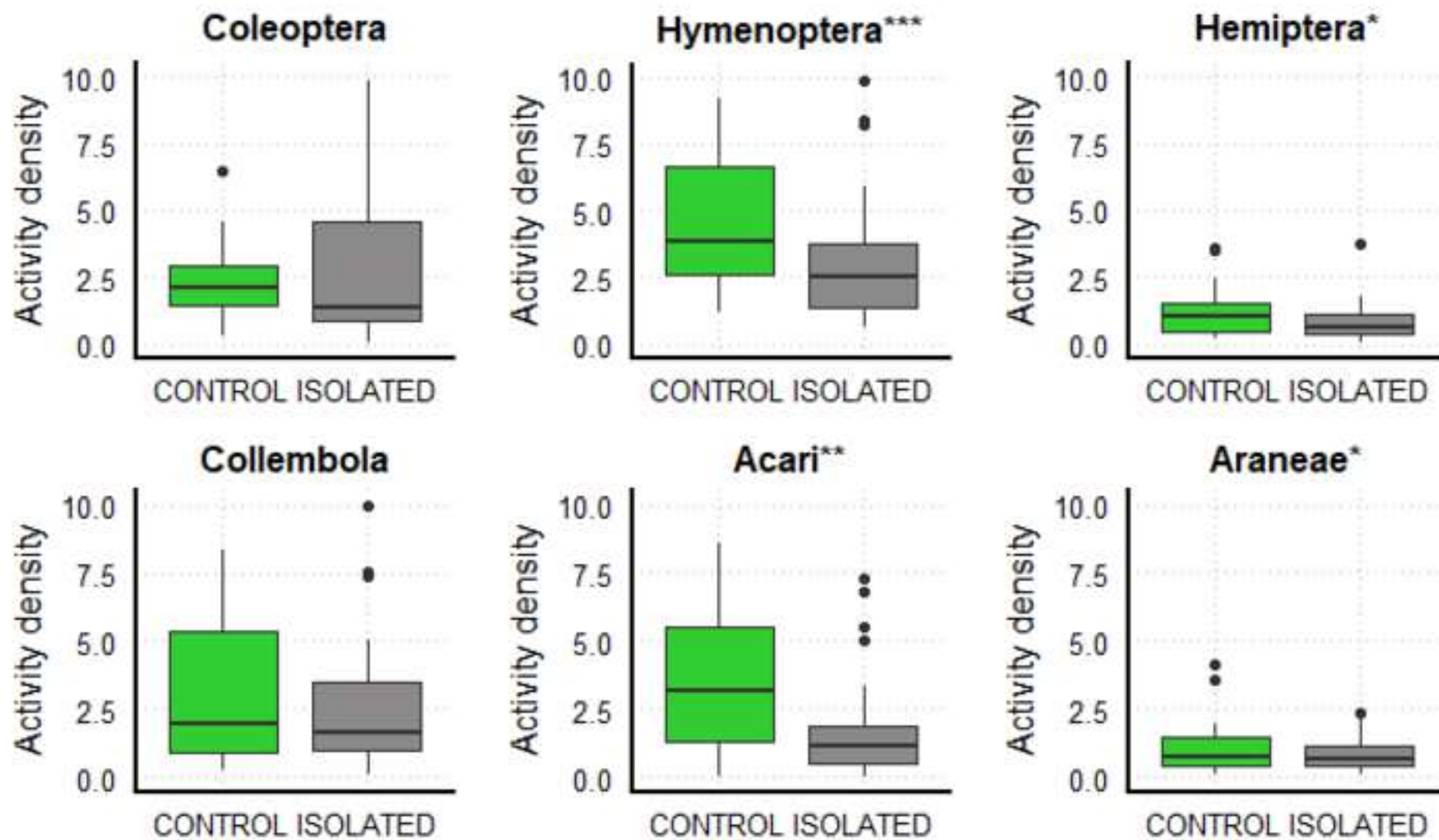
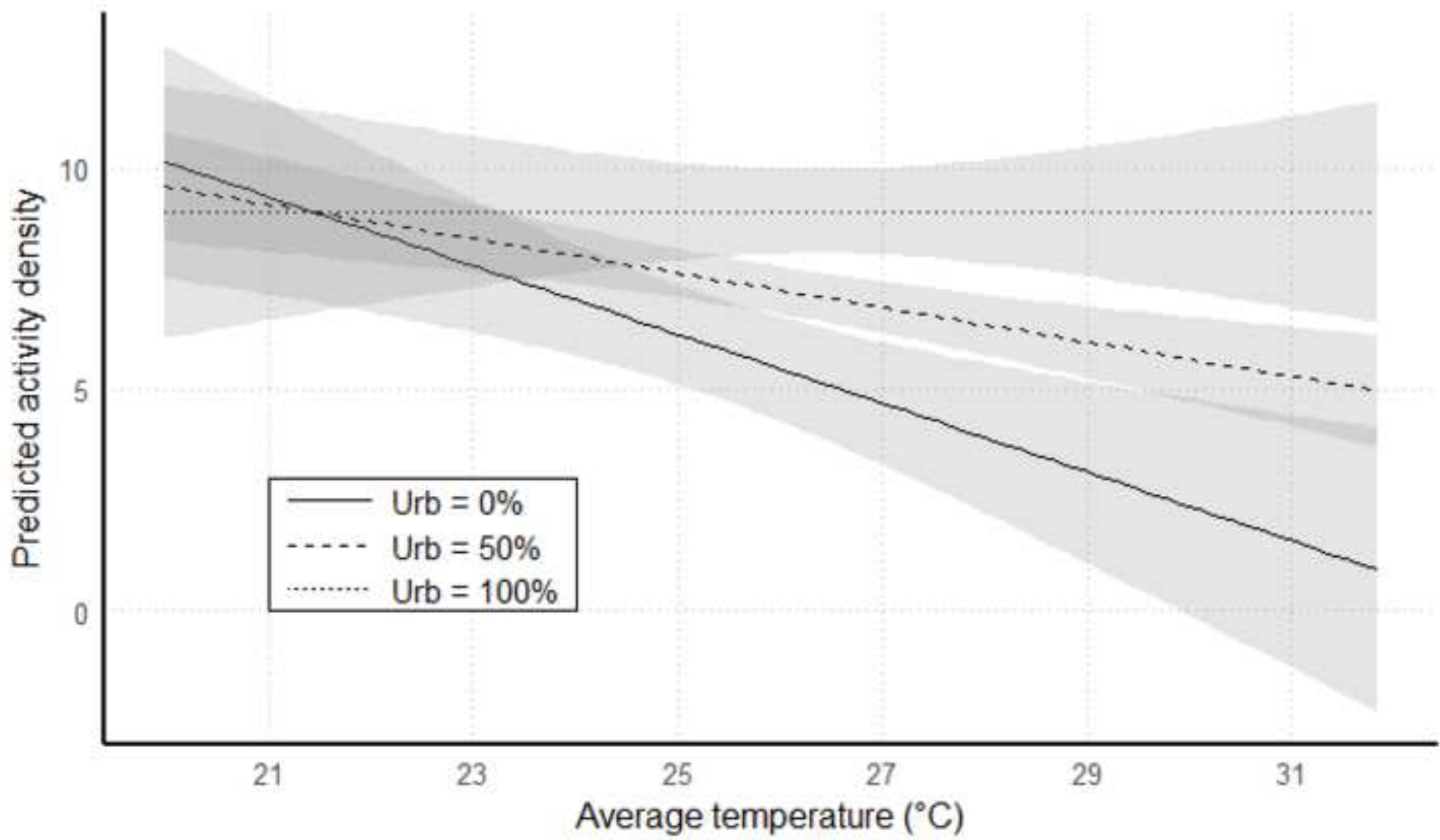


Figure 7



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Co-Editor-In-Chief: I agree with the recommendation of the Associate Editor and suggest you find a native English speaker who can help improve the readability of your manuscript. Upon receipt of a corrected manuscript, we will be able to accept your manuscript.

Dear Dr. Isaia,

Thank you for your resubmission and attention to addressing the comments of the reviewers. I think the manuscript is acceptable pending an additional read from a native English speaker.

All the best,
Susannah Lerman, PhD
Associate Editor
USDA Forest Service

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