Fireflies and land use in an urban landscape: the case of Luciola italica *L. (Coleoptera: Lampyridae) in the city of Turin*

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Fireflies and land use in an urban landscape: the case of *Luciola italica* L. (Coleoptera: Lampyridae) in the city of Turin

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Abstract Research was carried out in the city of Turin (Northern Italy) in order to assess the suitability of the urban environment for fireflies.The study started in 2007 with an artistic and scientific project promoted by Parco Arte Vivente (PAV—Park of living art). Citizens joining the project recorded 18 areas where they could observe fireflies, which were identified as *Luciola italica* L. (Coleoptera Lampyridae). All of the 18 areas recorded by citizens were then visited during the summer of 2009 and the abundance of *L. italica* was estimated using transects. In 12 sites the presence of the firefly was confirmed. The habitat structures of *L. italica* were woods interspersed with clearings in the urban districts in the hills, and parks along rivers in the lower and more populated part of the city. In sites where fireflies were observed, the level of illuminance measured was significantly lower than in areas where *L. italica* was absent. The analysis of the landscape around the study areas showed a negative correlation between the extent of urbanization and fireflies abundance. Survival of *L. italica* populations in the urban area of Turin is influenced by the extent of green areas and the level of artificial illumination. Parks lying among rivers preserve a level of darkness suitable for fireflies and are connected by woody strips growing along the banks of rivers, that probably function as ecological corridors.

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Introduction

Unlike the majority of insects, fireflies are often well known and a source of considerable interest to the general population. When they flash or glow in the summer evenings, they contribute a unique dimension of beauty to the season and can bring people into a broader awareness and appreciation of the wonders of nature (Natori et al. 2005). Unfortunately, during the last decades the chance of observing fireflies has become less frequent. A monitoring project in the United Kingdom (Tyler 2002) points to a probable decline of the glow-worm *Lampyris noctiluca* since the early 1900s (Gardiner 2009). It is a common opinion that a similar decline is generally occurring all over the World. A critical factor was intensive agriculture (Tabaru et al. 1970) with a sharp increase of pesticide input, the removal of hedges, woods, ponds and uncultivated land patches that can work as habitat refuges for wildlife (Gardiner 2009; Shinsaku et al. 2012). Along with these factors, firefly declines have also been linked to the increase in artificial illumination associated with the growth of urban areas (Thancharoen et al. 2008; Tyler 2002).

Although cities are not usually considered suitable habitat for fireflies, with the right conditions some species can maintain sustainable populations also in urban green spaces (Viviani et al. 2010; Ineichen 2008; Ineichen and Rüttimann 2010).

The check list of the Italian fauna includes 21 species belonging to the family Lampyridae (Audisio et al. 1995), a richness promoted by the diversity of climate, altitude and latitude across the nation. Unlike other European countries, such as the United Kingdom (Tyler 2002) or Switzerland (Ineichen 2008) in Italy there is no monitoring of fireflies. Consequently, there are no solid data to determine the population trends of Italian fireflies, even though it is acknowledged that genus *Luciola* includes the species that more commonly can be observed flashing during spring and summer (Bonaduce and Sabelli 2006). In the Po plain, where the city of Turin is located, the genus Luciola includes *Luciola italica* L. and *L. lusitanica* Charp. They are so similar that the idea of classifying them as two subspecies of the same species is becoming increasingly accepted (Bonaduce and Sabelli 2006).

L. italica seems to develop a single generation/year, but specific observation (adults and larvae breeding) are needed in order to confirm this hypothesis. Males of *L. italica* can be observed as they actively fly in search for females during the early night hours. Adult females are winged as well, but are less visible as they tend to spend most of the time resting on grass-blades or hiding on the ground (Bugnion 1929). They are usually active in the early hours of the night, when they wait for the flight of males and start glowing in response to male flashes. Larvae are not easily detectable, since they live in the soil litter of moist environments, such as woods and hedgerows, where they can find their prey, such as slugs, snails and small invertebrates. This research reports the results of an educational and scientific project on *Luciola italica* (Coleoptera Lampyridae) populations in the city of Turin (Piedmont—Italy) promoted by The Park of Living Art (Parco Arte Vivente or PAV). PAV was founded in Turin in 2006 as a meeting point between Biology and Contemporary Art (Brombin and Camerini 2009). The workshops and courses offered by the PAV Educational Department, involving both artists and biologists, pay great attention to biodiversity in all its forms (Brombin 2009).

A project called "Immigration" by Francesco Mariotti started with the representation of night lighting landscapes inspired by fireflies. "Immigration" used plain materials such as recycled plastic bottles that supported myriads of LEDs, which simulated the magic of fireflies' pulsating light (Mariotti 1996). However, "Immigration" was not only an artistic project. The artistic work was the starting point for the development of a more broadly encompassing environmental education project called "Glow Up!" aimed at collecting scientific data on the urban ecology of Turin firefly populations.

The Glow Up! project (Brombin and Camerini 2009) proposed a creative path inspired by the theme of fireflies and light. Together with the educational and the artistic activities, citizens were asked to identify places in Turin where they could observe fireflies. Data coming from volunteers worked as a link between citizens and scientists. The involvement of citizens in both the educational and scientific activities was the main focus of the project and the availability of data recorded by citizens facilitated a scientific survey on *L. italica*. The aim of the research was not a complete inventory of firefly distribution within the urban area of Turin, but an analysis of the records coming from citizens. The project's specific research objectives included:

- identification of firefly species observed by citizens taking part in the Glow Up! project;
- analysis of firefly habitat selection;
- evaluation of landscape structure and light pollution as ecological factors;
- identification of ecological networks influence on firefly distribution within the urban area.

Methods

Turin (45°03′N–007°40′E), capital city of Piedmont, has a population of 911.000 inhabitants distributed over a surface of 130.2 km^2. Its altitude ranges from 239 m ASL (center of the city) to 715 m ASL in the eastern part of the city. The Po River and three of its tributaries cross the city: the presence of these water courses favoured the creation of a number of green areas. Fifty-one parks cover 18.2 km^2, about 14 % of the urban area. Additionally, Turin streets and parks are scattered with 160,000 trees.

The work was developed in three steps between 2007 and 2009:

- 2007: educational and artistic project "Glow Up!" (step 1);
- 2008: first identification of fireflies along the Po River banks in Turin (step 2);
- 2009: survey of fireflies in the areas of Turin where they had been observed by the citizens taking part in the Glow Up! project (step 3).

The Glow Up! project (step 1) involved groups of elderly people, communities of disabled people, students from the Architecture faculty of the Politecnico di Torino, and 15 schools of Turin and its suburban area, ranging from primary school to high school. Altogether, more than 1700 people were involved. Each participant was given an educational kit including information on PAV's activities and firefly biology and was asked to draw the fireflies and their light and to describe the feelings evoked by their vision (Brombin and Camerini 2009). People were asked to record the sightings of fireflies in the urban area and to give information about the type of habitat (public park, river bank, woods….), the time of sighting, the weather condition and the disturbance factors (e.g., artificial light, car traffic). The results of this sampling were the starting point for subsequent investigations in the city of Turin.

In 2008 (step 2) Valentino and Michelotti Parks (Fig. 1—sites 2, 3), which stretch along the Po River's banks, were visited to collect and identify the firefly species that would be studied.

In spring 2009 (step 3), sites where firefly sightings were recorded by citizens in Turin were identified by means of a GPS device. Every site was then visited in daylight in order to get preliminary information on accessibility and safety of the sites for nighttime visits. During those preliminary surveys, photographs documenting the environmental characters of sites and surrounding landscape were also taken. Vegetation structure (meadows, bush and tree layer) was roughly estimated. The existence of potential disturbing factors, such as streetlights or building illumination, was also recorded.

Those visits had the only aim of giving a first general knowledge of site features based on a solely visual approach; the precise estimation of land cover (i.e., vegetation structure) was then made by using GIS data. During those preliminary surveys, the land surrounding the sites of sighting was also examined to verify the absence of any substantial changes in land use compared with 2007 photographs available from Google Earth.

Previous research carried out from 2004 to 2007 (province of Pavia, in the Po plain) showed that the flight activity of adult males is prominent in May and June, while the abundance of males tends to decline thereafter, in the hottest and driest period of summer (Camerini G.,

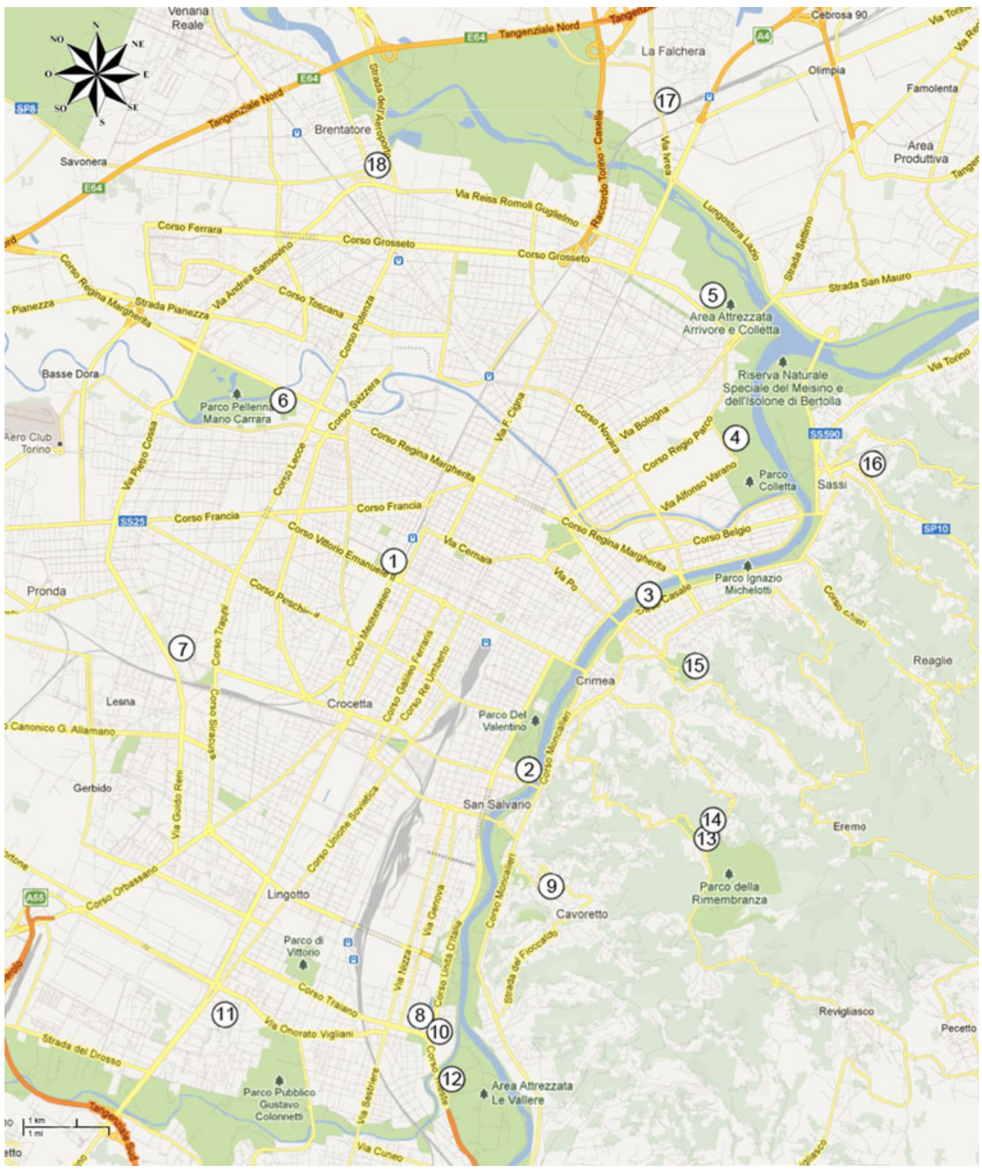

Fig. 1 Map of the urban area of Turin showing the 18 study sites (Map data © Google 2013)

unpublished data). Males start flying 50–55 min after sunset, when darkness falls and the level of light rapidly drops. In accordance with information on *Luciola lusitanica* biology by Bugnion (1929), it was observed that flight activity of *L. italica* males is maximum between 10 and 12 pm. On the basis of these findings, the schedule for the 2009 survey was planned.

The actual firefly survey lasted from May to June 2009. The survey staff included at least four observers and each site was visited twice. The first round of surveys took place between 23rd May and 4th June, and the second one between 10th June and 22nd June. Each survey period started at 10 pm and ended around 12 pm. The order in which the sites were visited was reversed for the second round. No survey was carried out in cold or rainy days when weather conditions were unsuitable for firefly flight.

Firefly abundance was estimated according to a transect method (Cratsley and Lewis 2005; Viviani et al. 2010). The number of flashing fireflies crossing a 10 m-linear transect was counted. The transect was traced by means of a yarn and was placed in the areas were citizens had observed fireflies, recording the position by means of a GPS. Each observation period lasted 20 s and was repeated after 2 min. The same double count was then repeated after 10 min and the mean value of abundance was calculated as a result of the repeated counts. Firefly abundance was finally calculated as the average of the counts obtained during the first and second round of survey. All records coming from citizens taking part in the Glow Up project referred to fireflies glowing while flying. Samples of flying males were temporarily captured and immediately examined during the survey in each site; the aim of those observations was a preliminary identification of the genus *Luciola*. In addition, two/three specimens were collected in each site and preserved in 70 % alcohol solution. These were later observed under a stereomicroscope for final species identification. Specimens are preserved at PAV.

Temperature and illuminance levels present at the transect were also recorded for each site visit. The amount of light was also measured (by recording minimum light level) in sites where the presence of fireflies was recorded by citizens, but not confirmed by the following scientific survey. Illuminance was measured by means of a luxmeter Delta Ohm HD2302 (resolution 0.01 lux). That resolution allows to measure with accuracy illuminance across the range 0.2–0.3 lux, that marks the critical level of disturbance for *L. italica* (G.Camerini, unpublished data).

Data concerning firefly abundance, land use and light levels were analyzed with Biostat software. Parametric tests for assessing differences between means (i.e., ANOVA) or non parametric tests for assessing differences between medians (Kruskall-Wallis, Mann–Whitney) were applied in order to compare groups of data.

To investigate the relationships between firefly presence/abundance data and land use, the survey transects were located on CTR maps (Regional Technical Maps) of Piedmont, and then transferred onto orthophotos of the Turin urban area (GoogleEarth). Starting from the central point of the survey transect, circular plots of increasing radius were drawn (250, 500, 1,000 m). In the areas where the presence of fireflies was recorded by citizens but not confirmed by the following scientific survey, plots were drawn starting from the point where citizens had previously recorded fireflies.

Four categories of land cover were classified by using ArcView 3.2a: rivers and ponds; urban land; meadows, bare ground and arable land; wooded areas (including hedgerows and wooded areas in parks and gardens).

Land use categories were identified according to information coming from previous studies on *Luciola italica* ecology (G. Camerini, unpublished data). Both in the plain and in the hilly landscapes of southern Lombardy *L. italica* habitat includes countryside landscapes scattered with woods, while urban areas work as disturbing factors mainly because of artificial night lighting.

From this categorization, the land cover area inside the plots (250, 500, 1,000 m) was thus determined for each of the observation sites. An Analysis of Similarity (ANOSIM) was conducted to test whether the land cover in the sites where fireflies were found both by citizens and scientists was different from the one of sites where the observation of fireflies was recorded by volunteers but not then confirmed by the scientific survey. ANOSIM uses a dissimilarity matrix (Euclidean distances, in this case) to group sites, and provides an *R* statistic that ranges from -1 to $+1$ to reflect the degree of dissimilarity or similarity, respectively, within and between groups. To test for significance, the ranked similarity within and between groups is compared with the similarity that would be generated by a random chance, called permutation. Samples are randomly assigned to groups in comparison and R is calculated for each permutation. In this case 999 permutations were run by the statistical program "Primer v5" (Clarke and Warwick 1994). The observed value of *R* was then compared against the random distribution to determine whether it was significantly different from the one that could occur at random.

Land use data coming from plots of different radius (250, 500, 1,000 m) were also used to develop a Bray Curtis similarity matrix. Then a cluster analysis (group average) and a Non Metric Multi Dimensional Scaling (NMDS) ordination were conducted using Primer v5 (Clarke 1993). The aim of those ordinations was to test the degree of similarity between the 18 studied sites that were grouped according to landscape composition. The MDS level of stress was calculated, with a value <0.05 being used to indicate no prospect of misinterpretation (Clarke and Warwick 1994). Finally, *L. italica* abundance was related to landscape structure variables by means of Spearman's correlation coefficient (r_s).

Results

People taking part in the Glow Up! project (step 1) recorded 49 observations of glowing fireflies in flight, corresponding to the presence of *L. italica* in 18 sites (Fig. 1). In sites 1, 6, 7, 8, 10, 11 and 18 a single observation of a few firefly specimens was recorded by citizens. The highest number of records occurred in parks along Po River (sites 2 & 3) that can be visited at night during spring and summer by Turin citizens, unless river banks are closed to public use because of river flooding. Sighting sites were green areas mainly located in the hills of the Eastern part of the city and along the course of the Po River and of its three tributaries.

In spring 2008 (step 2), firefly populations living along the banks of the Po River in Turin were surveyed; specimens were identified as *Luciola italica* adult males.

The study performed in 2009 in the urban area of Turin (step 3) confirmed that the sightings coming from the Glow Up! project were adult males of *Luciola italica*. Out of 48 sampled specimens of *L. italica* collected in Turin in 2009 and identified by microscopic observation, only two were females, coming from sites 13 and 16. They were taken from grass blades next to the ground. A few females belonging to *Lamyiris* sp. were also found, but since *Lampyris* female is wingless and males do not glow in flight, there was no matter of confusion about the identification. No other firefly species was recorded during the survey.

Not all the sightings coming from citizens in 2007 (step 1) were confirmed by the survey carried out in 2009 (step 3). Fireflies were not recorded in 6 of the 18 study areas (Fig. 1—sites 1, 7, 8, 10, 11, 18). The abundance of fireflies recorded in 2009 is summarized in Table 1.

Among the 18 sites, five of them lie on the hilly and less urbanized area of the city (sites 9, 13, 14, 15, 16). The remaining 13 are in the lower and most populated part of the city (Fig. 1). Six of them (sites 1, 7, 8, 11, 17, 18) are green areas inside the urban landscape, not facing the river watercourse, while seven sites (2, 3, 4, 5, 6, 10, 12) lie along the banks of the rivers that cross the city. *L. italica* records coming from volunteers were confirmed by the following scientific survey in each of the five sites located in the hills. In the sites close to rivers, fireflies were recorded both by volunteers and scientists, except for site 10. A comparison between the abundances of populations in the hills and those close to the rivers does not show a significant difference (Mann–Whitney test: n1 = 5; n2 = 7; U = 22; $P = 0.47$).

The site characteristics of *L. italica* were oak (*Quercus pubescens*, *Q. petraea*) and chestnut (*Castanea sativa*) woods interspersed with clearings in the hills. In the lower part of the city *L. italica* has colonized public parks along rivers. Vegetation includes naturally regenerating species, such as poplars (*Populus nigra, P. alba*), white willow (*Salix alba*), pedunculate oak (*Quercus robur*) and several ornamental species.

In the six green areas located in the innermost part of the city, except for site 17, fireflies observation by volunteers was not confirmed by the following scientific survey.

The land use around the 12 areas where the presence of fireflies was confirmed (PRES areas) is different from that around the six areas where the absence of fireflies was recorded (ABS areas). The similarity analysis (ANOSIM) demonstrates that the two groups of samples can be significantly separated ($R = +0.537$; $P < 0.01$).

In all of the 18 studied sites, the proportion of green areas (woods, meadows, arable land) tends to decrease going from the 250 m plot to the 1,000 m plot; however, this difference is not significant, both for PRES areas (ANOVA; $F = 3.13$; d.f. = 2, 33; $P = 0.057$) and for ABS areas (Kruskal–Wallis test; n = 18; H = 3.38; $P = 0.184$). Conversely, the proportion of urban land tends to increase going from the innermost to the outermost plot, but while the difference is not significant in the ABS sites (Kruskal–Wallis test, n = 18; H = 2.54; $P = 0.28$), it is significant in the case of PRES sites (ANOVA; $F = 3.91$; d.f. = 2, 33; $P = 0.03$).

Significant differences between PRES and ABS sites also emerged from an additional comparison of landscape patchwork. The availability of green areas (woods, arable land, meadows) in 250 m radius plots was higher in PRES sites (Mann–Whitney test: n1 = 12; n2 = 6; U = 0; $P = 0.001$). A similar tendency was recorded both for 500 m (U = 5; $P = 0.004$) and 1,000 m radius plots (U = 3; $P = 0.002$). Conversely, the extent of urban area was significantly higher in ABS sites, as resulting from Mann Whitney test based on 250 m radius plots data (n1 = 12;n2 = 6; U = 0; $P = 0.001$). Such a trend was confirmed both for 500 m (U = 4; $P = 0.003$) and 1,000 m radius plots (U = 2; $P = 0.002$).

Green areas located in the innermost of the city are smaller and isolation is more critical in comparison to green areas lying along rivers. The dimension of green areas along rivers is on average 397.520 m^2 versus 23.220 m^2 in innermost areas (Mann–Whitney test: n1 = 6, n2 = 7; U = 1; $P = 0.043$). The minimum distance separating each area from the nearest is on average 215 m for the inner sites and 52 m in the case of sites along river banks. Although the difference between medians is not significant (Mann–Whitney test: n1 = 6, n2 = 7; U = 8.5; $P = 0.074$) the comparison suggests that green areas in inner sites are habitats of poor quality.

Table 1 Abundance (no. of individuals/10 m of transect) of males of *Luciola italica* in the 18 study site observed during spring 2009 (step 3)

Nr site	Place	Nr specimens/10 m transect	Habitat
1	**Parco Tribunale**	0	Green area in the innermost of the city
2	Parco Valentino	4	Park along river
3	Parco Michelotti	12.5	Park along river
4	Parco Colletta	32.5	Park along river
5	Orti urbani	7.5	Park along river
6	Parco Pellerina	10	Park along river
7	**Parco Ruffini**	0	Green area in the innermost of the city
8	**Palazzo del Lavoro**	0	Green area in the innermost of the city
9	Via XXV aprile	6.5	Hills (woods and clearings)
10	**Parco Italia '61**	0	Park along river
11	**Parco G Farina**	0	Green area in the innermost of the city
12	Parco Vallere	18	Park along river
13	Collina Pecetto (1)	8.5	Hills (woods and clearings)
14	Collina Pecetto (2)	13.5	Hills (woods and clearings)
15	Via San Martino	3.5	Hills (woods and clearings)
16	Colle Superga	5	Hills (woods and clearings)
17	Via Falchera	16.5	Green area in the innermost of the city
18	**Piazza Stampalia**	0	Green area in the innermost of the city

Bold and underlined characters mark sites where fireflies were recorded by citizens but not found as a result of the following scientific survey

L. italica abundance appears to be related to landscape structure (Table 2). Within the 500 and 1,000 m plots, no significant correlation was detected, but within the 250 m plots there was a significant, negative correlation between firefly abundance and urban land density. In the 250 m radius plots around PRES sites that lie along rivers (sites 2, 3, 4, 5, 6 and 12) wood coverage was on average 40.6 %, while the area occupied by meadows, bare ground and arable land was on average 39.6 %. In those sites urban land did not exceed 11 %, except for sites 2 and 3, where the percentage was marginally greater than 25 %. Nevertheless, in these two sites the relatively high proportion of urban land was balanced by a high woodland cover (54–56 %).

The influence of landscape structure on *Luciola italica* is further supported by the agglomeration analysis based on the land cover distribution. Although the cluster grouping of ABS areas is not located at one extreme of the dendrogram, it can be separated from PRES areas clusters (Fig. 2), except for site 10. A corresponding graphical representation is given by Non Metric Multi Dimensional Scaling (Fig. 3). In the configuration, five clusters were superimposed on the basis of similarity levels ranging from 76 % (cluster C) to 86 % (cluster A).

Table 2 Correlation between *L. italica* abundance and urban land; correlation between *L. italica* abundance and woods, meadows, bare ground, arable land

Plot radius (m)	Urban land	Woods, meadows, bare ground, arable land
1,000	$r_s = 0.007$	$r_s = 0.007$
	$P = 0.983$	$P = 0.983$
500	$r_s = -0.154$	$r_s = -0.063$
	$P = 0.633$	$P = 0.846$
250	$r_s = -0.587$	$r_s = 0.475$
	$P = 0.045$	$P = 0.118$

rs Spearman rank correlation coefficient (rs)

P *P* value

Sites 14 and 16 (cluster A), are located in the hills in the eastern part of the city; the landscapes around them is dominated by woods, which cover at least 70 % of the ground in plots of different radius (250, 500, 1,000 m).

The influence of landscape structure clearly appears in the 250 m radius plots. ABS sites (cluster E), in the inner city, have in common a very high degree of urbanization with an average urban cover of 63.9 %. A second cluster (D) groups areas 2, 3, 15 and 17; urban land around all those sites is on average 30.4 %. In PRES sites 4, 6, 9, 12 and 13 (cluster B) the extent of urban land tends to decrease further, being on average 10.6 %. Cluster C includes site 5, where fireflies were found, and site 10, where they were missing; they have in common a similar density of woods, but the amount of urban land around site 10 (42.9 %) is much more than the one around site 5 (10.8 %).

The different rate of urbanization detected around the studied green areas deeply affected the level of light pollution. The illuminance was on average 0.08 ± 0.06 s.d. lux (range 0.01–0.17; n = 24) near transects in the PRES areas versus 0.47 ± 0.26 s.d. lux (range 0.16–0.9; n = 12) in the ABS sites, measured in the areas of maximum

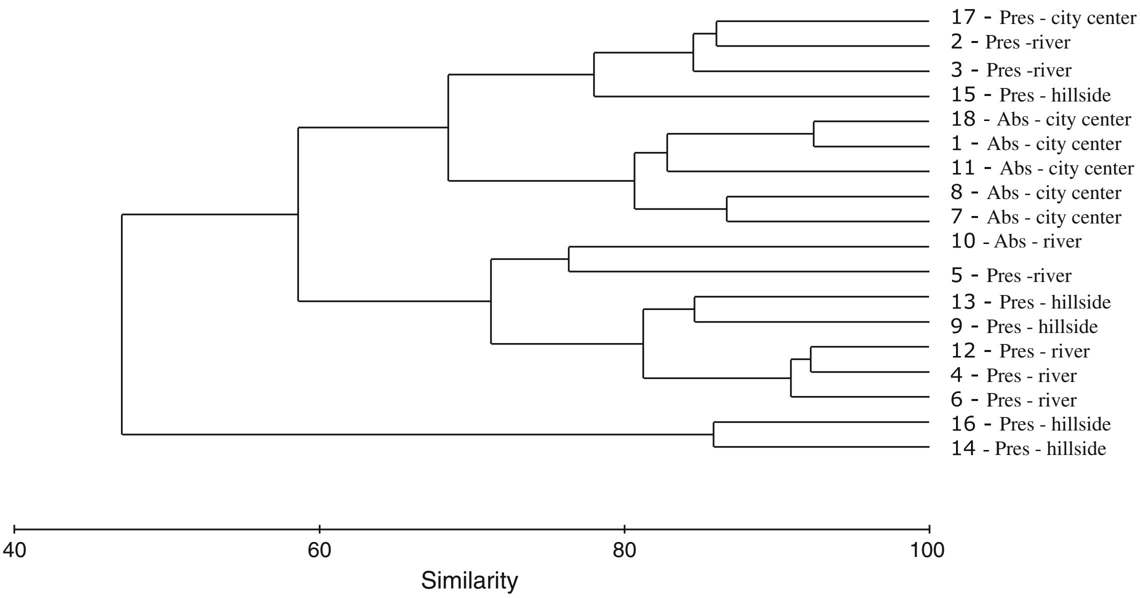

Fig. 2 Group average cluster analysis of the study sites based on land cover in 250, 500, 1,000 m radius plots

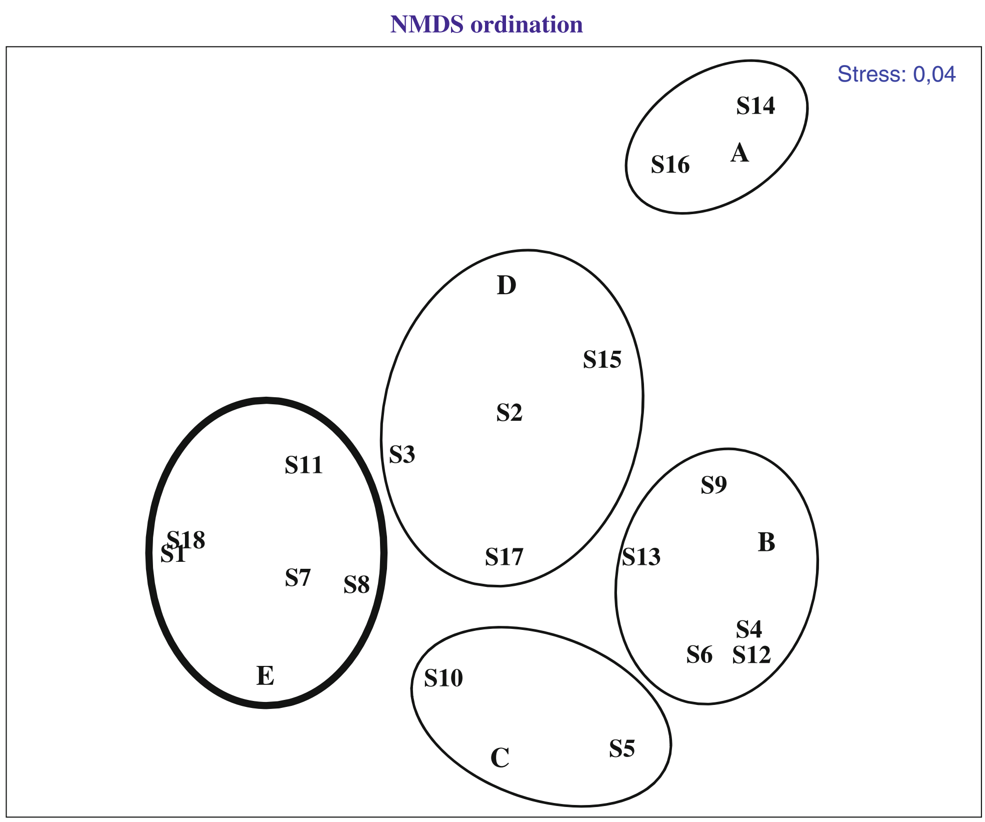

Fig. 3 MDS grouping of the study sites based on land cover in 250, 500, 1,000 m radius plots. Sites were clustered and circled according to the similarity degree of land cover (see Fig. 2). Cluster E (marked by a *thicker circle*) includes five sites where fireflies were recorded by citizens but not found as a result of the following scientific survey

darkness. The difference is significant (Mann–Whitney test: n1 = 12; n2 = 24; U = 3.5; $P = 0.001$). Since it was observed that *L. italica* males started flying in the early hours of the night when illuminance dropped under 0.25 lux, then an average illuminance level less than 0.1 lux is suitable for *L. italica*.

Discussion

A key outcome of our work was the involvement of citizens and students in the Glow Up! project. Volunteer involvement can be an important tool for supporting scientists in monitoring programs (Cooper et al. 2007). As human population tends to grow, the future management of urban and suburban areas will be needed in order to support biodiversity. Collaboration between scientists and volunteers living in urban areas offers a chance to involve citizens by meaningful inputs into environmental management actions (Pfeffer and Wagenet 2007). It is hoped that the involvement of students and citizens in the research on fireflies will form the basis of further volunteer support, and to highlight this potential PAV shows the results of the artistic and scientific works coming from the Glow Up! project in its own exhibition centre. One of PAV's missions is the use of art as a tool for supporting the idea that biodiversity can and should be enriched in human dominated landscapes such as the cities where, except for synantropic and generalist species, the environment is generally not suitable for wildlife (Haila 2002; McKinney 2008). Isolation and fragmentation of green areas are also limiting factors, making difficult the colonization of urban central core areas by wildlife (Deichsel 2006; Gaublomme et al. 2008; Gibb and Hochuli 2002). For nocturnal animals, including fireflies, one more critical factor is disturbance caused by artificial lights (Frank 1988; Lloyd 2006; Thancharoen et al. 2008). The problem of light pollution gets increasingly worse as urban spaces are growing worldwide (Chalkias et al. 2006); it has been estimated that about two thirds of mankind live in areas where the threshold set for polluted status has been exceeded (Cinzano et al. 2001).

Luciola italica shows levels of sensitivity to artificial light similar to those found for the species living in the cities of Campinas e Sorocaba (Viviani et al. 2010). Most of the species detected in the two Brazilian cities did not tolerate levels of illumination higher than 0.2 lux, which is similar to the condition noticed by this study.

In the hills around the city of Turin the habitat is suitable for fireflies, as there are plenty of available green areas and artificial light has a minor impact. In the lower and more urbanized part of the city the green areas (public parks) are included in a matrix that is hostile to wildlife. However, the border of woods and green areas of the hills (eastern city) faces the right bank of the Po, thus connecting the lower to the higher districts of Turin (Fig. 1) .

The Po River and the parks along its banks work as an ecological corridor running from North to South (Fig. 1), while the Po River's tributaries work as corridors from the West to the East. The nature of their riverbanks can determine the degree of illumination; for some length, riverbanks are sharply sloping and, being inaccessible to the public, they are only partially provided with artificial lights. If a suitable degree of darkness is preserved (illuminance <0.1 lux), riverbanks can work both as a greenway for fireflies and as a proper habitat.

A good tree and bush coverage is important as a habitat requirement, but also as a factor that can limit disturbance coming from artificial light, thanks to the shield offered by tree canopy. In this sense, the area covered by watercourses is also to be considered an additional positive factor, working as a corridor free of artificial illumination.

On the other hand, the colonization of green areas in the inner city appears to be difficult (i.e., the 6 ABS sites). Unlike green areas in the hills and those located along the riverbanks, inner green areas tend to be smaller and poorly connected. The lack of ecological corridors is a critical factor (Hunter 2002). Wildlife movements are key processes in determining the viability of populations (Rudd et al. 2002). Fragmentation and light pollution limit the chance of colonization of those areas by viable populations. It must be underlined that in those areas only a single firefly observation was recorded by citizens taking part to "Glow Up" project. Sporadic observation of fireflies in those innermost green spaces of the urban area recorded by citizens were probably due to the dispersion of males, not the result of a sustained population existence.

The results of this research indicate that fireflies theoretically unfit for the urban environment can persist in it. Dimension and interconnection of green areas are not the only prerogatives which ensure wildlife survival, but also the environmental quality of the patches is important (Ockinger and Smith 2008). For fireflies, this means first of all availability of adequate green areas scattered with bushes and trees and reduced light pollution. Such green areas have to be connected by a network of corridors where the same ecological requirements have to be satisfied: a good amount of coverage by trees and bushes and a maximum illuminance that must not exceed 0.2 lux.

Light pollution is a worldwide recognized problem and several solutions have been proposed and discussed with the aim of saving energy and preserve adequate levels of darkness that can benefit living organisms and reduce the interference with night vision (Cinzano et al. 2001; Lloyd 2006). On the other hand, there is the requirement to improve artificial illumination for increasing safety of people who make use of urban green areas at night. A careful planning of the illumination system, which takes advantage of the most modern technology, can combine ecology applied to green areas planning with management of artificial night lighting in urban areas. Options such as the use of more efficient lamps and devices limiting upward light emission are to be taken as a reference both for any new installation or for adapting the existing street lights systems. The choice of lamp type is important, too, because of the potential interference with nocturnal animals; yellow lights, for example, can negatively affect fireflies (Lloyd 2006). Fireflies are affected by the quantity of light diffused on the ground; for this reason a good street lighting in green areas, such as urban parks, should channel lights downwards along footpaths, preserving an adequate degree of darkness at sides. As a result of a careful artificial night lighting plans, cities like Turin, which are endowed with a conspicuous extent of green areas, could offer to the public the pleasure of the spectacle of fireflies again.

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