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Habitat selection by *Luciola pedemontana* (Coleoptera Lampyridae) in a lowland landscape in Northern Italy: implications for conservation

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Abstract
During the last decades firefly populations faced a general decline all over the World. This negative trend can be related to some critical factors, such as urbanization, artificial night lighting, soil and water pollution and agricultural intensification. This paper reports the results of a research on *Luciola pedemontana,* aimed at assessing the influence of land use on its habitat selection. The study area is located in the central western Po flood plain (Northern Italy), where a great part of the land is still devoted to agriculture. Fireflies were monitored in 2006 and 2007 along a pathway (22.7 km length) from May to July. Land use around areas populated by *L. pedemontana* (100, 250 and 500 m radius buffers) was analyzed and related to firefly abundance. Twenty firefly populations were recorded. *L. pedemontana* abundance was negatively linked to urban land amount (250 m radius buffer). On the other hand, a positive relation to wood availability was recorded (500 m radius buffer). Hedgerows and ditches supported the suitability of agricultural landscape for *L. pedemontana*. Furthermore, historical data endorse the hypothesis that after the Second World War firefly populations suffered from changes connected with human land use, mainly due to urban sprawl and agricultural intensification. Therefore, in order to restore suitable conditions for *L. pedemontana* conservation, some actions can be planned: urban sprawl management, light pollution reduction, promotion of extensive agricultural patterns and implementation of ecological networks.

Key words: firefly / hedgerows / ditches / agricultural intensification / urban sprawl / light pollution / ecological networks

Riassunto
In tempi recenti si è registrato in tutto il mondo un declino delle popolazioni di lucciole (coleotteri lampiridi). Tale fenomeno è da ricondurre a fattori come urbanizzazione, inquinamento luminoso, contaminazione del suolo e delle acque, agricoltura intensiva. L'articolo riporta i risultati di uno studio sul coleottero lampiride *Luciola pedemontana* finalizzato a valutare gli effetti dell'utilizzo del suolo sulla selezione dell'habitat da parte di questa specie. L'area di studio è localizzata in pianura padana, in un contesto territoriale prevalentemente agricolo. La popolazione di *L. pedemontana* è stata monitorata nel 2006 e nel 2007 lungo un percorso di rilevazione (lunghezza 22,7 km) da maggio a luglio. È stato analizzato l'uso del suolo intorno alle aree popolate da *L. pedemontana* (aree circolari di raggio 100, 250 e 500 m) e i dati sono stati messi in relazione all'abbondanza della specie studiata. Si è rilevata la presenza di 20 popolazioni di *L. pedemontana*. L'abbondanza della specie era negativamente correlata alla presenza di aree urbanizzate (500 m), mentre esisteva una correlazione positiva con aree boscate (250 m). La disponibilità di siepi e filari si è rivelata un fattore favorevole per la specie. Le risultanze della ricerca suggeriscono che il declino delle popolazioni di coleotteri lampiridi sia causato da trasformazioni del paesaggio (urbanizzazione e nuovi modelli di produzione agricola). Interventi come il contenimento della crescita urbana diffusa e dell'inquinamento luminoso, unitamente alla creazione di una efficace rete ecologica e all'implementazione di modelli di produzione agricola meno intensivi potranno essere di supporto per le popolazioni di *L. pedemontana*.

Parole chiave: lucciole / siepi/fossi / agricoltura intensiva / urbanizzazione diffusa / inquinamento luminoso / reti ecologiche

INTRODUCTION

Observing fireflies is a fascinating experience for both children and adults, which give evidence to their value as a factor in improving landscapes (Natori *et al.,* 2005; Ineichen, 2008). Therefore, because of their shared appreciation, fireflies can work as both potential umbrella and flagship species (Dawood and Saikim, 2016). However, despite their appreciation, during the last decades firefly populations faced a general decline all over the World (De Cock, 2009; Jusoh and Hashim 2012; Lewis, 2016). Such a decline can be related to some critical factors, such as urbanization (Kazama *et al.,* 2007), light pollution (Thancharoen *et al.,* 2008; Ineichen and Rüttimann, 2012; Owens and Lewis, 2018) soil and water pollution (Fu *et al.,* 2006) and –last but not least– new agricultural patterns (Billeter *et al,,* 2007; Koji *et al.,* 2012).

Italy is no exception in terms of firefly decline, anyway it still preserves a good level of biodiversity. Indeed, Italy hosts as many as 18 species belonging to the Lampyridae family (Fanti, 2022), a significant richness degree supported by the diversity of climate, orography and latitude across the Nation.

Firefly populations are particularly affected by land use. Landscape is recognized as an important factor in structuring all biological communities, especially in highly dynamic areas, such as cultivated lands (Schmidt *et al.,* 2004; van Vliet *et al.*, 2005; Dearing *et al.*, 2012; Drummond *et al.*, 2017; Ridding *et al.*, 2020; Wanger *et al.,* 2020). One more driver of landscape anthropization is the enlargement of urban areas, which in Italy raised from 1.34% to 4.55% in the period from 1960 to 2000 (Smiraglia *et al.,* 2015).

In Italy the most commonly recorded fireflies belong to *Luciola* genus, namely *L. italica* and *L. pedemontana* (Audisio *et al.,*1995; Brunelli *et al.,* 1997; Bonaduce and Sabelli, 2006; Fanti, 2022) whose males are significantly more visible than females, as they actively emit flashes of light while flying in search for females (Bugnion, 1929; Papi, 1969; Brunelli *et al.,* 1977; Picchi *et al.,* 2013).

L. pedemontana has been known as *Luciola lusitanica* for long (Miksic, 1969; Audisio *et al.,* 1995; Brunelli *et al.,* 1997) but *L. lusitanica* is currently recognized as a species complex distributed across Eurasia, from Portugal to Russia, including at least three distinct species. The species that can be recorded in southeastern France and Italy was classified as *L. pedemontana* by Fanti (2022).

In Northern Italy *L. pedemontana* nuptial flights can be usually observed from May to July and occur from nightfall to midnight, while males flight tends to sharply decline late at night. Adults density usually peaks in June. The length of flight season is influenced by rainfall amount and distribution (unpublished data). Sex ratio is significantly male biased. Unlike males, females do not fly, as they glow to attract males, while resting on herbs or soil. After mating, females lay their eggs on the soil.

L. pedemontana optimal habitat consists of sparse woods and ecotonal environments, such as river, ponds and channel borders, pastures next to woods, hedgerows or ditches, whose common trait is the availability of snails, slugs and other small invertebrates, on which firefly larvae prey along their development cycle.

Here, the results of a research on *Luciola pedemontana* (Curtis, 1843) habitat selection are reported. The research was initially planned in order to achieve a basic data asset to be used for a mid term comparison (15 years) of firefly abundance and distribution in relation to landscape structure evolution. Anyway it was not possible, for several reasons, to carry out the second sampling phase. Given the fact that up to today no information on *L. pedemontana* habitat use is available, data coming from the first monitoring phase have been published. This case study aims at evaluating to what extent land use can affect *L. pedemontana* survival and distribution and the impact that landscape structure can have on the conservation of this species.

MATERIALS AND METHODS

Study area

The study area lies in the central western part of the Po floodplain, where a great part of the land is devoted to agriculture. *L. pedemontana* is quite common in the study area, while *L. italica* is missing. The river Po works as a geographic barrier so that *L. italica* can be found north, while *L. pedemontana* south of the river (Camerini, 2008). The study area comprises five municipalities (Bastida Pancarana, Castelletto di Branduzzo, Lungavilla, Pancarana, Pizzale) located in the province of Pavia (Fig. 1).

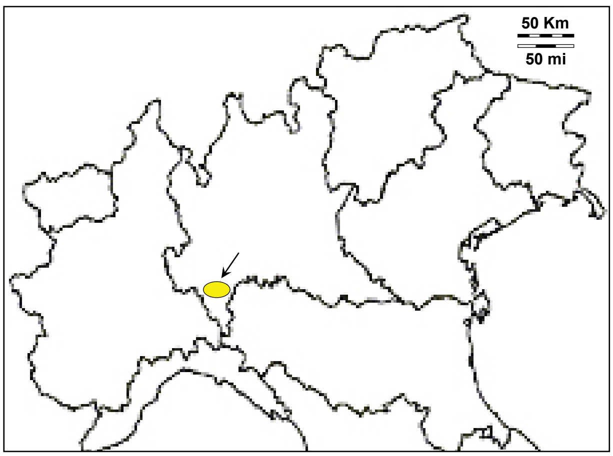

Fig. 1. Study area location (large scale vision).

Data on land use evolution recorded by the Italian Institute for Environmental protection (years 1954, 2012) is shown in table I (ISPRA 2015, 2016). The study area mainly includes arable land scattered with sporadic woods and hedgerows. During the last decades the main changes in land use were the spread of both urban areas (+83.2%) and woods (+35.5%) and the decrease of both arable land (-3.9%) and woody crops (-27.1%). The increase of woods was the result of clay quarries recovery and tree planting in riverside lands. The density of human population living in the complex of five municipalities was 122.6 Inhabitants/km^2 in 2011 (ISTAT, 2012). From 1951 to 2011 the population living in the territory including the study area decreased by 14.8%. The co-occurrence of both a decrease in population size and an increase in urbanized land is the result of "urban sprawl", a pattern of urbanization which is common to almost the entire Po flood plain.

The territory of the two municipalities of Bastida Pancarana and Pancarana is touched by the river Po and includes wooded riverside areas, which are periodically flooded. In the southern part of the study area (Castelletto B. and Lungavilla) several abandoned clay quarries evolved into woods, marshes and ponds; they can be considered as local reservoirs of biodiversity. A complex of those restored quarries was recognized as a regional nature reserve (Riserva "Stagni di Lungavilla"); this natural reserve was included in the study area.

Fireflies identification and monitoring

In order to monitor *L. pedemontana* populations, a pathway (22.7 km length) crossing the study area was traced (Fig. 2). The pathway included both unpaved roads crossing the riverside area and the paved municipal roads connecting villages. This pathway was travelled by a mountain bike (MTB) from the third decade of May to the third decade of July in 2006 and 2007. Nine surveys were carried out during both summers.

During summer 2005 this pathway was also travelled twice (27-05 and 15-06). Those preliminary test surveys were aimed both at assessing the time needed for monitoring fireflies and at identifying preliminarily the distribution of *L. pedemontana* populations along the pathway. *L. pedemontana* males tend to start flying just after dusk, when illuminance falls under 0.3 lux (unpublished data). At that point the abundance of flying males rapidly raises and it remains at high levels for about 60 minutes; after that, just as quickly, it tends to decline. Since males begin usually to fly about 35' after the time of astronomical sunset (unpublished data), the start of males flight could be easily predicted, together with the best moment to start monitoring. The beginning of surveys ranged from 22.00 to 22.10, depending on nightfall, and lasted until 23.00-23.15. No survey was carried out on rainy or stormy nights.

Three following nights were needed to complete a weekly survey. The pathway was therefore divided in three parts. The first one included the northern pathway sector (record sites 1÷6), the second one crossed the southern part of the pathway (record sites 7÷14) and the third one led again to the starting point located in Bastida Pancarana (sites 15÷20).

The MTB was used to move from one record site to the other rapidly and check for the presence of fireflies

Tab. I. Land use in the five Municipalities including the study area (% of land ± S.E).

Year	1954	2012
Urban land	5.6 ± 1	10.2 ± 1.5
Arable land	73.2 ± 9.1	70.4 ± 5.1
Woody crops	11.9 ± 5.7	8.7 ± 2.6
Meadows	0.6 ± 0.3	0.6 ± 0.1
Woods	3.8 ± 1.4	5.1 ± 0.9
Water bodies	4.9 ± 2.7	5 ± 2.3

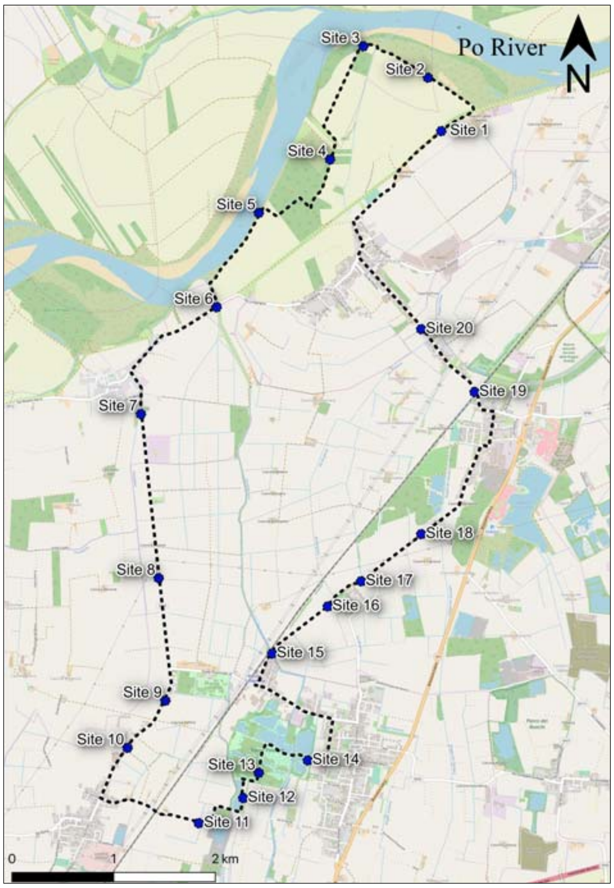

Fig. 2. Monitoring route and location of *L. pedemontana* record sites.

along the pathway, but flying males were recorded by walking along the pathway at a moderate pace. Fireflies flying within a transect 4 meter wide at both sides of the road were counted. After a first record, the road was walked back for a second count. The measure of 4 meters was selected, because it matches the width of the ditches at the side of the roads in recording sites n. 7, 8, 9, 10, 11, 12, 14, 15, 16, 17. All the other sites were marked by barrier taped poles. Data on firefly abundance were recorded on a form and finally achieved by averaging the results of the double record. The precise location of record sites was marked on a map (1: 2.500 scale). In addition a portable global positioning system device was used for geolocation.

Landscape structure analysis

In order to analyze land use, record sites were fixed on TR (Technical Regional) maps of Lombardy. Starting from the central point of the road stretches where fireflies were recorded, circular plots of 100, 250 and 500 m radius were drawn, according to a method already adopted in the past for the study of *L. italica* in the urban area of Turin (Picchi *et al.*,, 2013).

Land cover area inside the plots was then determined for each site. Landscape structure was analyzed by using both QGIS 2.14 and data coming from DUSAF 2.0 (year 2007). DUSAF is a geographical database periodically updated as a part of a project promoted and funded by Lombardy Region; its data are the result of aerial photographs interpretation (ERSAF, 2012).

DUSAF data base comprises a total amount of 28 land use categories. For the purposes of land use assessment, six macro-categories were taken into account: urban land, arable land, woody crops, meadows, woods and water bodies (ponds and rivers).

The land cover area inside the plots was thus determined for each record site.

Statistical analysis

Data coming from firefly surveys were statistically elaborated by using "Biostat" software (Analystsoft). Data sets were analyzed to assess their normal distribution according to Kolmogorov-Smirnov test. The Mann-Whitney U test was applied to compare differences (i.e. pairwise testing) between two independent groups of data whose values were not normally distributed.

The Kruskal Wallis test (H) was used to assess the statistical significance of differences –if any– between the medians coming from groups of data which did not follow a normal distribution.

The potential correlations between the number of firefly specimens in sampling sites and the amount of the main land use categories (urban land, arable land, woody crops, meadows, woods, water bodies) were analyzed by means of Spearman's rank correlation coefficient.

RESULTS

As a result of the two years survey, fireflies were recorded in 20 sites. The mean abundance of males/survey is summarized in table II, which also reports the geographical coordinates. Fig. 3 and Fig. 4 display the seasonal trend of monitoring results in summer 2006 and summer 2007.

The seasonal trend of flying males is described approximately by a bell curve graph. *L. pedemontana* males started to be recordable from the third decade of May. Then their abundance raised at the beginning of June, peaking around the middle of the month and decreased at the end of June. In July the number of males tended to level off.

Figure 5 summarizes the distribution frequencies of land use categories within buffers (100 m, 250 m, 500 m radius). Differences are not statistically significant ($P>0.05$), but it has to be noticed that the availability of both woods and meadows tends to decline when the buffer radius increases; the amount of urban and arable land

Tab. II. List of record sites (number of flying males/survey), insect abundance and geographic coordinates.

Site	Latitude	Longitude	Mean abundance±SE
Site 1	45°05'51.45"	9°05'32.11"	2.6 ± 1
Site 2	45°06'08.18"	9°05'26.92"	27.3 ± 4.5
Site 3	45°06'18.34"	9°04'57.06"	7.6 ± 5.1
Site 4	45°05'42.54"	9°04'42.83"	1.6 ± 0.6
Site 5	45°05'25.63"	9°04'10.97"	0.6 ± 0.2
Site 6	45°04'55.86"	9°03'51.59"	13.4 ± 7.1
Site 7	45°04'21.37"	9°03'17.10"	0.8 ± 0.4
Site 8	45°03'29.30"	9°03'25.35"	2.9 ± 2
Site 9	45°02'50.55"	9°03'28.09"	6.7 ± 2.2
Site 10	45°02'35.49"	9°03'11.42"	4.9 ± 2.2
Site 11	45°02'11.36"	9°03'43.74"	2.3 ± 0.9
Site 12	45°02'19.40"	9°04'03'09"	5.6 ± 2.1
Site 13	45°02'27.94"	9°04'10.37"	5.4 ± 1.9
Site 14	45°02'31.92"	9°04'32.85"	2.5 ± 1.2
Site 15	45°03'05.97"	9°04'16.73"	3.2 ± 1.2
Site 16	45°03'20.43"	9°04'41.73"	10.9 ± 5.1
Site 17	45°03'28.68"	9°04'56.48"	5.4 ± 1.8
Site 18	45°03'43.41"	9°05'23.94"	4.2 ± 1.7
Site 19	45°04'28.92"	9°05'47.32"	0.5 ± 0.2
Site 20	45°04'48.59"	9°05'23.61"	1 ± 0.5

Tab. III. Spearman correlation between *L. pedemontana* abundance and land use. (* significant correlations)

Land use category	Buffer radius (m)	R Spearman	P	N
Arable	100	+ 0.11	0.67	34
Urban	250	- 0.3	0.29	28
Arable	250	-0.06	0.79	38
Woody crops	250	-0.07	0.87	20
Meadows	250	+ 0.4	0.29	18
Woods	250	*+0.67*	*0.03**	22
Water bodies	250	-0.16	0.69	16
Urban	500	*-0.56*	*0.04**	28
Arable	500	+ 0.12	0.6	40
Woody crops	500	+ 0.04	0.9	30
Meadows	500	- 0.34	0.3	22
Woods	500	+0.32	0.23	32
Water bodies	500	+0.27	0.45	28

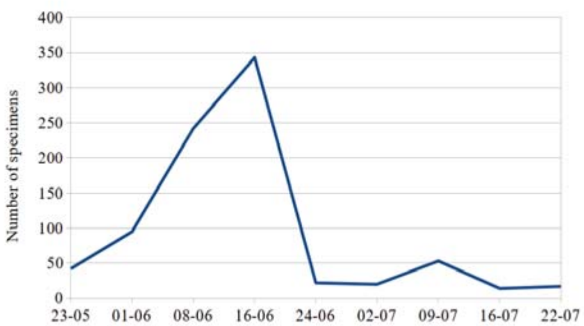

Fig. 3. Seasonal trend of *L. pedemontana* flying males monitored in all record sites (year 2006).

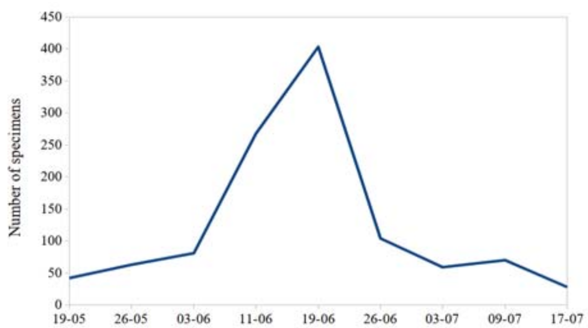

Fig. 4. Seasonal trend of *L. pedemontana* flying males monitored in all record sites (2007).

shows an opposite trend. *L. pedemontana* abundance is positively related to the area covered by woods (250 m radius buffer). On the other side, within the 500 m radius buffer a negative relation occurs between firefly numbers and urban land (Tab. III).

An important disturbance factor related to urban land is reasonably artificial night-lighting (Owens *et al.*, 2018). The abundance recorded in study sites located at a different distance from streetlights and other artificial light sources (< 100 m; 101-200 m; 201-300 m; >300 m) shows an increase of *L. pedemontana* abundance when the distance tends to be longer (Kruskal Wallis test: $p<0.05$) (Fig. 6).

Three major habitat patterns colonized by *L. pedemontana* can be identified as follows:

– riverside habitat (record sites n.1, 2, 3, 4, 5, 6);
– borders of ponds coming from recovery of abandoned clay quarries (record sites n.12, 13, 14, 18);
– countryside microhabitats, which are usually very close to ditches and/or hedgerows (record sites n.7, 8, 9, 10, 11, 15, 16, 17, 19, 20).

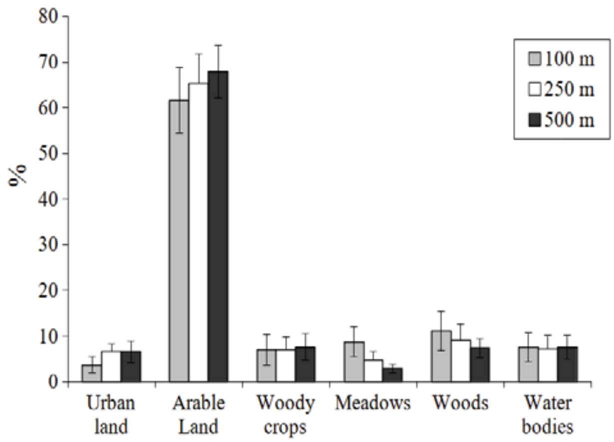

Fig. 5. Distribution frequency of land-use categories within buffers (100, 250, 500 m radius) around record sites (standard error is shown).

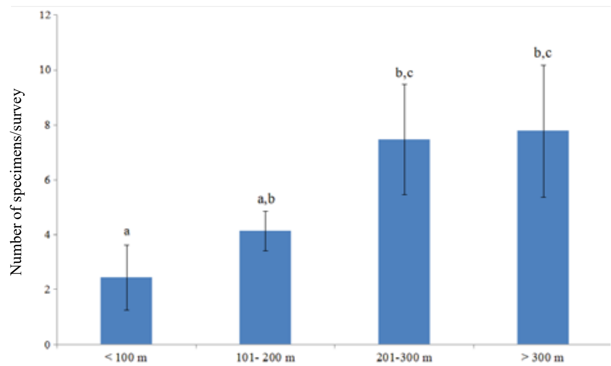

Fig. 6. Average *L. pedemontana* abundance/survey (S.E is shown) in sampling sites at increasing distance (meters) from artificial light sources. Letters (a,b…) refer to pairwise statistical comparisons.

If the mean abundance of *L. pedemontana* is expressed in relation to the monitoring pathway length, a different habitat suitability appears by comparing riverside sites (5.8 km length) to other sites (countryside + pond borders - 16.9 km). Indeed, the mean abundance in sites 1÷6 (9.1 specimens/km) is nearly three times (3.3 specimens/km) the one of other study sites (P<0.01 - Mann Whitney test).

Landscape structure around those three habitats (250 m buffer) is displayed by Fig. 7.

– Riverbed, riparian vegetation (mainly *Salix alba* woods) and woody crops (poplar plantations) are the key elements of riverside landscape; around those record sites there is no trace of human settlement within a distance of 250 m.
– Record sites close to ponds are well provided with meadows (mainly *Medicago sativa* cultivations) and riparian vegetation (*Salix alba* and *Populus alba*).
– The landscape surrounding the countryside record-sites mainly consists of arable land (Fig. 7); in comparison with the other two habitat types, urban land (12.2%) is larger. Record sites n.9, 16, 17 are close to stately homes, including large parks and gardens.

A common trait shared by every record site classified as "countryside" (except for site 11) is the occurrence of ditches, along which fireflies in flight were recorded. Also sites n. 3, 6, 13 and 14 were provided with those linear elements. The minimum depth of those ditches was 1.8 m. Some of them were bordered by hedgerows (sites 9, 15, 16, 17, 19, 20).

DISCUSSION

The better suitability of riverside habitats in comparison with the ones of countrysides was somehow an expected data, since this part of the study area does not include any urban settlement; in addition, the landscape matrix of riverside areas includes a good deal of semi natural habitats (SNHs). The "countryside" study area, on the other hand, except for the strips of land next to ponds, is mainly composed by arable land managed according to intensive patterns; furthermore, it includes urban settlements resulting from the sprawl that took place after the World War II. The effect of those critical factors are a poor density of *L. pedemontana* and the tendency to isolation of their populations. Such a critical situation, that is common to most of the Po flood plain, is the result of dramatic changes which occurred very recently, if we refer to the time scale of biological evolution.

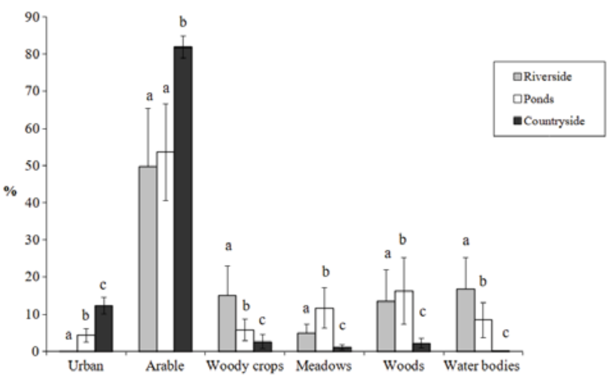

Fig. 7. Land use in *L. pedemontana* habitats (250 m radius buffer around record sites – SE is shown). Letters (a,b…) refer to pairwise statistical comparisons.

At the beginning of XIX century the Po floodplain consisted of a harmonious blend of meadows, vineyard and cereal fields, interspersed with marshes and woods. Borders of fields (generally small sized) were provided with a dense belt of willows, poplars, elms and mulberries. As a result of this combination, land cover looked like a boundless forest, which was defined "*piantata padana*" (planted Po plain). This kind of landscape pattern gradually declined, mainly during the XX century (Groppali and Camerini, 2008). The area occupied by the "planted plain" in Piedmont, Lombardy and Veneto (northern Italy) formerly decreased -23.3% in the period 1911-1929 (Sereni, 1979). A consequence of those changes was the progressive decline of hedgerow density: comparing historical maps to the actual situation, Groppali (1992) demonstrated that from 1860 to 1990 in an agricultural area next to Cremona (central Po plain) two third of tree and shrub rows were removed. Just to give one more example, in the study area of Seveso river basin (18.127 ha; north-central Po plain) Bocca *et al.,* (2012) recorded a dramatic removal (-73%) of hedges, rows and wooden strips from 1954 to 2000.

The most dramatic changes of landscape structure occurred starting from the '50s, when Italian landscape was rapidly reshaped by the establishment of new agricultural patterns. Together with urbanization, those processes conducted to a large-scale change of land use. From 1960 to 1990, more than half of the land in Italy (51.6%) changed from one land-use class to another. In the time frame 1990-2000 such a trend was confirmed; 22.34% of land cover changed across the Nation (Falcucci *et al.,* 2007). A significant urban sprawl was recorded in the most populated areas, such as coasts and lowlands. One implication of urban areas spread has been the increase of artificial light at night (ALAN), which works as a dramatic limiting factor for nocturnal organisms (Bird and Parker 2014; Owens *et al.,* 2020; Owens and Lewis, 2021).

On the other hand, complexity is the key word which summarizes the characters of a biodiversity-friendly countryside landscape; it implies a good availability of SNHs joined to a rich and diversified mosaic. The evolution of agricultural landscapes in Europe (including Italy) unfortunately followed the opposite direction.

Significant effects of the agricultural intensification were both farm specialization and increase of field size (Van Vliet *et al.,* 2015). The agricultural Italian census documented a constant decrease of farms number (-62% in the time range 1961-2010). A great part of agricultural land from farms ending their production was transferred to farms still on the market (Groppali and Camerini, 2006). Fields once belonging to different farms were often joined to shape a unique field; such a process promoted a massive removal of linear elements such as enclosures, hedgerows or ditches once separating the adjacent fields. One more factor leading to agricultural landscape homogenization was the decline of crop rotation and the spread of monoculture.

Agricultural landscapes dominated by arable land (>80%) are usually far to be "biodiversity friendly" (Tscharntke *et al.,* 2021). The present case study gives one more evidence to this theory: sites provided with the highest levels of arable land *L. pedemontana* survival tends to be difficult (Tab. II; Fig.7), but is supported by the availability of linear elements (ditches, hedgerows). Adult *L. pedemontana* females and larvae are usually strictly associated with microhabitats populated by slugs, snails and other hygrophilous terrestrial invertebrates which larvae feed on. Agricultural landscapes mainly made of arable lands are not usually a suitable habitat for such hygrophilous organisms, especially in areas like the one here studied, where the summer climate is significantly dry. Within the agricultural landscape-matrix dominated by arable land organisms like slugs and snails are usually confined to field margins, inside hedgerows and ditches or non-crop habitats like woods, uncultivated areas or wetland edges.

CONCLUSIONS

All in all, *L. pedemontana* populations are particularly exposed to the threats above discussed, also because of the particular biology of this species.

For example, adult males are good flyers, therefore a gene flow among distinct populations can occur, as long as suitable habitats can be interconnected by linear elements (ditches, hedgerows) working as an ecological network.

Unlike males, *L. pedemontana* adult females are sedentary, so in case of local extinction of a population, even after the recovery of a suitable habitats, re-colonization by females or larvae is a process which can take a very long time.

In conclusion, survival and rescue of *L. pedemontana* populations in the Po floodplain are to be supported by a series of landscape management actions, which could be useful for the whole community of organisms which can potentially colonize agricultural landscapes (Camerini *et al.*, 2021). In this sense fireflies can be regarded as good indicators of "*biodiversity-friendly*" landscapes.

These the actions to be applied on landscape scale:

- support to farm management based on extensive agricultural patterns;
- organization of an effective ecological network;
- urban growth management;
- light pollution mitigation.

Moreover, the goal of agronomic policies should be the promotion of management practices capable of improving the heterogeneity of agricultural landscapes and reducing chemical inputs. The complexity of agricultural landscapes could be achieved by promoting patterns based on the cultivation of diversified and small sized crop fields and the conservation and recovery of SNHs. Such a strategy implies the adoption of long rotation cycles, which in turn could be helpful for supporting weed control and reducing pest populations (Lichtenberg *et al.,* 2017; Tamburini *et al.,* 2020).

In conclusion, the future of *L. pedemontana* in Italian lowlands seems to be strictly linked to the actions which should be urgently adopted in order to ensure the double mission that modern agriculture should achieve: producing food and preserving a fair amount of biodiversity.

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