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I love my ecotone: Habitat selection by the Western green lizard (*Lacerta bilineata*)

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Abstract. Habitat changes under the influence of natural or anthropogenic processes can significantly affect the survival of organisms. In general, natural changes are mostly stochastic in nature with less impact on the affected area, while human interventions are much more frequent and generally irreversible alternation of habitats. The Western green lizard (*Lacerta bilineata*) is a medium-sized lizard that is less tolerant to environmental changes. Studying habitat use is essential for the future conservation of this species. Our research was conducted in the northern part of Italy in Parco Belgiardino, which is part of the southern Adda Park. The study area was selected because of its diversity of habitats and the strong population of *L. bilineata*. Habitats were codified as follows: isolated trees, anthropic area, forest, river coast, ecotone, shrubs, meadows, meadows with bushes. Observations were made using the Visual Encounter Survey method. The position of 146 individuals were recorded in total. Geographic analyses were performed using GIS. Data were analysed by logistic regression composition analysis. Logistic regression showed significant differences in selection among available habitats. The compositional analysis indicates a significant difference in habitat utilisation and a non-random habitat selection. Both statistical methods confirmed that ecotone is the preferred habitat of *L. bilineata*, probably because it includes various microhabitats, most importantly sunny regions for thermoregulation, and a greater variety of food sources.

Keywords. *Lacerta bilineata***,** habitat, ecotone, conservation

Introduction

Knowing the environmental choices of the animals based on the availability of the habitats allows to construct models and predict the population distribution over time (Guisan and Thuiller, 2005; Elith and Leathwick, 2009). The Western green lizard (*Lacerta bilineata* Daudin, 1802) is widespread in central-south-western Europe and is found throughout the north-east of the Iberian Peninsula, France, western Germany, western Slovenia, Switzerland, Italy and the island of Jersey (Nettmann and Rykena, 1984; Nettmann, 2001). In Italy, it is present in all regions up to 600 m a.s.l., except for Sardinia (Gasc et al., 1997; Razzetti et al., 2000; Corti and Cascio, 2002). The Western green lizard inhabits open areas, and particularly favours ecotonal zones (i.e. the transition environments separating closed and open habitats, such as forests and grasslands) (Korsós, 1982; Nettmann and Rykena, 1984; Ioannidis and Bousbouras, 1997; Sacchi et al., 2011). In Italy, *L. bilineata* has been reported to use ecotones between diverse kinds of habitats, especially slopes with eastern and western exposures (Schiavo and Venchi, 2006). In general, the species does not appear to have a marked habitat preference, since it has been found in a very wide range of habitats, including the edges of woods, irrigation canals, roads, the edges of uncultivated fields or grasslands, vineyards and orchards, bushes in rocky areas, and remnant vegetation zones in urban areas (Scali and Zuffi, 1994; Schiavo, 1994; Razzetti et al., 2000; Corti and Cascio, 2002; Caldonazzi et al., 2002; Scali and Schiavo, 2004). Despite this wide use of different areas, many authors indicate ecotone as the preferred habitat *of L. bilineata,* but few detailed studies on habitat selection exist (Scali and Zuffi, 1994; Sacchi et al., 2011). Ecotones have been progressively reduced across much of its range, particularly with the extension of arable lands in Northern Italy (Scali and Schiavo, 2004). For example, in southern Lombardy (Lodi Province) *L. bilineata* has nearly disappeared

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outside the protected areas (Franzini, 2008). Qualitative observations lead to the conclusion that *L. bilineata* is less tolerant to changes in environment than are, for example, lizards of the genus *Podarcis*, especially where removal of the high-herbaceous and shrubby vegetation with attendant destruction of the ecotonal bands occurs (Venchi and Schiavo, 2000). Ballarini Denti et al., (2007) justify the inclusion of this species in the Annex IV of the “Habitat” Directive 92/43 / EEC as a species that requires strict protection. Currently, the fragility of *L. bilineata* in Lombardy is also evidenced by the high priority score assigned to it by the regional legislation (D.G.R. n. 7/4345 of 20.4.2001).

The Western green lizard has also been recognised as a “focal species” by the thematic group, Amphibians and Reptiles, within the larger “Ecological Network of the Lombard Po Valley” project (Bogliani et al., 2007). Alterations in natural or man-made habitats together with climate changes can significantly affect the survival of organisms (Brooks et al., 2002; Garden et al., 2010; Mantyka-Pringle et al., 2012). In general, natural modifications are mostly accidental, with stochastic effects on the impacted area, while human interventions are much more frequent and generally result in irreversibly replacing the original habitat with very different ones. The natural ecosystem consists of many species of plants and animals, genetic diversity is very high, food chains are long, ecological succession takes place over time, natural nutrient cycling, and is naturally sustainable.

The artificial ecosystems have instead low species diversity, genetic variation is very low, food chains are simple and often incomplete, no ecological succession, incomplete nutrient cycling and is naturally unsustainable. One of the main effects in areas with a strong anthropogenic impact is the loss of ecotones, the transition zones between different habitats that are preferred by many species (Gibbons et al., 2000; Gardner et al., 2007). In this paper, we analysed the habitat preference of *L. bilineata* in a large population found in a regional park along the Adda River. Our main aim was to determine the habitat selection criteria that could explain the occurrence of the species in order to supply more detailed information for future management and conservation programs.

Material and Methods

Study area.—Adda Sud Park is part of the “Padana region”, an area with continental climatic features attenuated by the moderating influence of the Adriatic Sea and the presence of the Alps, which obstruct the cold north winds. Temperatures vary considerably from an average January value of 1 °C to an average July value of 24 °C and precipitation from an average January value of 53 mm to an average July value of 13 mm.

The study was carried out in the Belgiardino Park (WGS84 45.3320–45.3385°N; 9.4801–9.4963°E), an area of about 67 ha at an altitude of 70 m a.s.l., inside the larger Adda Sud Park. The area is characterised by

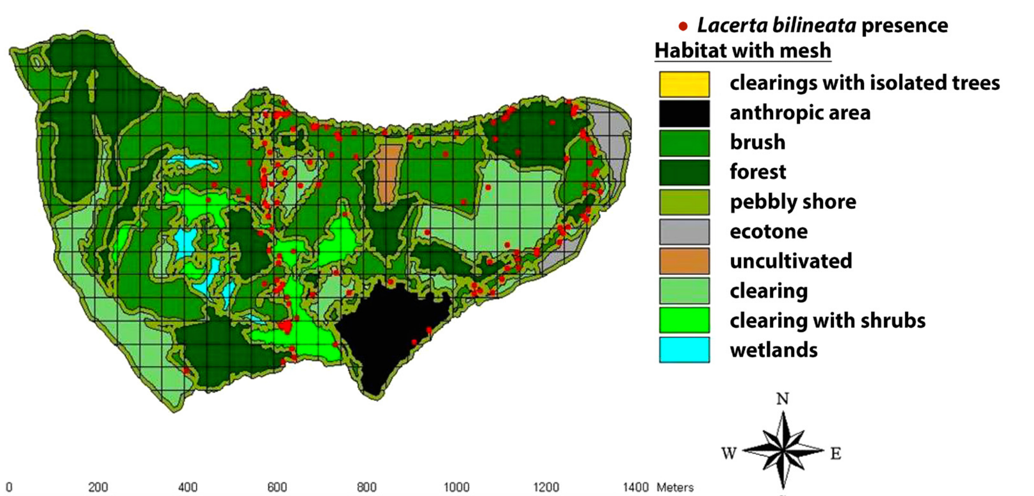

Figure 1. Study area Parco “Bel Giardino” in Pavia, Italy.

various habitats (woodland, scrubland, glade, glade with isolated shrubs and trees, uncultivated area, gravel and wetlands), and hosts a very rich reptile assemblage including five other species (*Natrix natrix, Zamenis longissimus, Hierophis viridiflavus, Vipera aspis, Podarcis muralis* and *Emys orbicularis*). The plant formations along the river Adda include shrub willow (*Salix eleagnos* and *Salix purpurea*), with arboreal species dominated by *Salix alba, Populus canadensis, Populus nigra, Populus alba,* and *Alnus glutinosa*. Mixed forest is also present, and is dominated by *Quercus robur, Ulmus minor, Populus nigra,* and *Acer campestre*. Plant assemblages along roads include rows and shrubs formed by introduced species (*Robinia pseudoacacia, Morus alba, Platanus hybrida,* and *Ailanthus altissima*) along with native species such as *Alnus glutinosa, Quercus robur, Salix alba, Ulmus minor, Acer campestre, Sambucus nigra, Rosa canina, Prunus spinosa* and *Populus* ssp. Various representatives of the Graminacea, Apiaceae and Compositae families occur in the glade. Swimming pools, restaurant, archery field, and rest areas are in the anthropic area. The park is also used for pastoral and hunting activities.

The study area was characterised on the basis of the habitats observed in the field and then redesigned in the orthophoto in the form of polygons with the aid of Google Earth 2010. Ecotones were identified using GIS software (ESRI ArcView 3.2) as 10 m-wide contact areas between different habitats. The habitats have been coded as follows: isolated trees, anthropic area, brush, forest, pebbly shore, ecotone, uncultivated, clearing, clearing + shrubs and wetlands (Table 1). A grid was then created with meshes of 50x50 m, within which the presence of lizards was recorded and of which the environmental composition was calculated as a percentage of the various habitats present. From the subsequent analyses, all marginal meshes whose surface was less than 500 m² (N = 16) were excluded; the number of meshes remaining was 306. The percentage of territory covered occupied by the various habitats in the study area was calculated.

Data collection.—Data were collected one day every two weeks from April to September in 2008 and 2009. Field surveys began at 9:00 and continued until 17:00. We used the Visual Encounter Survey method on the trail (Blomberg and Shine 1996) and line transect with 10 m distance between lines, for the observation and identification of lizards as we traversed the whole study area. After each observation of an individual, its location (WGS84 coordinates) was recorded by GPS (Garmin Vista Cx). Lizards were not captured, so we were not able to assess the sex of all individuals. Only adult lizards were considered for this study since juveniles may be dispersing or may have not established fixed home ranges. A total of 147 records were collected overall.

Statistical analysis.—With the data obtained from the spatial analysis, we calculated the surface area of codified habitats in m^2, the percentage of the various habitats, and the numerical and percentage presence of lizards in each habitat (Table 2). The mesh with and without records of lizards (i.e. 68 vs. 78) was compared.

The logistic regression is a regression model that can be applied in those cases in which the dependent variable y is of the dichotomous type (that is, it can only take two values, represented with 0 and 1). Logistic regression is used to estimate the probability

Table1. Description and extension of the habitats present in Adda Sud Park.

Habitat	Description	Total area (ha)
Isolated trees	*Platanus hybrida, Robinia pseudocacia*	0.01
Anthropic area	Recreation and sports area	3.35
Brush	Mostly small trees *Alnus glutinosa, Sambucus nigra, Quercus robur, Salix spp; Populus spp.*	15.41
Forest	Area dominated by *Quercus robur, Acer campestre*	12.73
Pebbly shore	Gravel area without vegetation	12.73
Ecotones	Buffer 10 m wide along with the interface between the habitats	20.10
Uncultivated	Thick cover of *Phragmites australis*	0.67
Clearing	Almost total herbaceous coverage	9.38
Clearing + shrubs	Herbaceous vegetation with the presence of *Rubus caesius, Rosa canina, Crataegus monogyna*	3.35
Wetlands	Permanent presence of water with variable level	0.67

of an event occurring. It is a technique that relates the observed factors to the occurrence / non-occurrence of a given event to estimate the probability that this event will occur in certain circumstances. A series of logistic regressions were calculated on the data collected for this work to evaluate the correlation between the presence/ absence of lizards in a mesh and the presence of the different environmental parameters detected in that shirt (forest, bush, ecotone, etc.). A logistic regression using the forward stepwise LR technique was used to evaluate the relationship between the presence/absence of lizards in a mesh and the relative abundance of the different environmental descriptors detected in each mesh (Pereira and Itami, 1991; Pearce and Ferrier, 2000; Compton et al., 2002; Keating and Cherry, 2004; Duchesne, Fortin and Courbin, 2010).

The compositional analysis (Aebischer et al. 1993), which yields statistical comparisons among habitats and orders habitats in their relative preference. To evaluate habitat as a categorical data is easier than to measure more physical and vegetation habitat variables, which might provide an easier assessment of the habitat suitability for *L. bilineata*.

Compositional analysis is a statistical test that uses a series of MANOVA to analyse two series of data in which the variables are represented as proportions and has been developed to overcome the limits imposed by current sampling techniques on use habitat, time and resources (inappropriate sample size and level of sampling, the autocorrelation of data, non-independence in the proportion of the use of the habitat, differential use of habitat by groups of individuals, arbitrary definition of availability of habitats).The test performs a logarithmic transformation of the percentages of use of resources by individuals or groups of individuals and the availability percentages of each resource out of the total; the values thus obtained, called respectively y0 and yA, allow to calculate the differences between the total availability of the resource and the fraction of itself that is used. At this point, the hypothesis H0 is tested that there are no preferences in the use of resources. Finally, if H0 is rejected and these differences are significant, the different types of resources are ordered hierarchically, from the least (rank = 0) to the most (rank = max) to used. In the ordering matrix. The significance in the difference in use habitat is indicated by an index for each pair of resources, which can take values from --- (significantly lower resource usage) to +++ (significantly lower resource usage higher) and the ordering of resources depends on the sum of these indices. This allows you to assess whether two types of resources, although having different systems, are interchangeable. The applications of this technique range from the assessment of the effect of age and gender on the use of the soil, the analysis of the home-ranges and the availability of food, the analysis of the use of time and resources.

Compositional analysis (Aebischer et al., 1993; Pendleton et al., 1998) was used to test the hypothesis that lizards exhibit environmental preferences of habitats within the study area. For the analysis, we excluded the uncultivated areas and the wetlands, which were poorly represented in the study area and were never used by the species. Spatial analysis was performed with GIS software (ESRI ArcView 3.2), logistic regression was performed using "SPSS" (Statistical Package for Social Science) version 13.0 for Windows, while compositional analysis using "Rsw" software (Resource Selection for Windows) version Beta 8.

Table 2. Surface areas and percentages of the various habitats and numbers of *L. bilineata* present.

Habitat	Surface (m^2)	Surface (%)	N° *L. bilineata*	% *L. bilineata*
Isolated trees	52.382	0.008	3	2.04
Anthropic area	31280.095	4.667	2	1.36
Brush	156795.575	23.394	29	19.73
Forest	126668.925	18.899	8	5.44
Ecotones	203981.086	30.434	81	55.10
Pebbly shore	11733.158	1.751	0	0.00
Uncultivated	5246.098	0.783	0	0.00
Clearing	92624.054	13.819	8	5.44
Clearing + shrubs	34467.391	5.143	16	10.88
Wetlands	7394.091	1.103	0	0.00

Results

Logistic regression showed significant differences between habitat selection (χ^2 = 25.891, df = 8, P < 0.001). The significant covariates extracted were the ecotone, brush, and clearing with shrubs. The overall classification accuracy of the model was 77.10%.

The results of the compositional analysis indicated a significant difference in the use of resources (Λ = 0.0566; χ^2 (7 df) = 195.2936; P <0.0001). By ordering the habitats from the least used to the preferred, we obtained the following result: 1) anthropic, 2) pebbly shore, 3) clearing with shrubs, 4) forest, 5) clearing, 6) thicket, 7) isolated trees and 8) ecotones (Table 3).

Discussion

The results of the present research clearly indicate that the *L. bilineata* prefers areas with high environmental diversity and that they avoid monotonous habitat types, both with open and high forest cover. In particular, ecotonal zones in which there is a transition between different habitats are preferred. The preferred ecotones are those between the areas of clearing and those with greater vegetational development, such as woods or bushy areas (Sacchi et al., 2011; Prieto Ramírez et al., 2018). The compositional analysis has effectively indicated the ecotones as a preferential habitat for *L. bilineata*, followed by isolated trees, bush, clearing, wood, clearings with shrubs, gravel beds, and anthropic habitat.

From the available literature, however, the wetlands are never among the preferential environments for the lizards, which are essentially thermophilic and xerophilous (Arnold et al., 1978; Cowgell and Underwood, 1979; Corti and Cascio, 2002). Logistic regression indicated that the most important habitats for the *L. bilineata* were the ecotone, the bush, and the clearing with shrubs. The partial discrepancy between the results of the two analyses can be explained by the fact that the extension of the area with isolated trees was very small (less than 1% on the total area) and the same also applies for the clearings with shrubs (5.1% of the total area). Both areas could still be considered as ecotonal zones, due to their vegetative discontinuity. Both statistical methods used for the analysis of the data confirm that the ecotone is the determining habitat for the species, in accordance with what has been reported by other authors, although those studies lacked statistical quantification (Arnold et al., 1978; Nettmann and Rykena, 1984; Korsós, 1984; Ioannidis and Bousbouras, 1997; Corti and Cascio, 2002). The ecotone provides high availability of trophic resources, being characterised by a rich entomofauna (Dabrowska-Prot, 1995), and *L.bilineata*, like most Palearctic reptiles, prefers sunny areas that ensure their optimal thermoregulation and non-continuous vegetation that guarantees the possibility of shade for shuttle thermoregulation and shelter in case of danger (Korsós, 1982). The data also show that *L. bilineata* are located in places where maximum summer temperatures are around 30 °C, and our data is in agreement with the thermophilic description for the species (Cowgell and Underwood, 1979; Schiavo, 1994; Corti and Cascio, 2002; Schiavo and Venchi, 2006). Bushes are among the important areas for *L. bilineata* and allow the

Table3. Sorting matrix in the use of habitat. The different types of habitat are ordered hierarchically, from the least (rank = 0) to the most (rank = max) (used. In the ordering matrix, the significance in the difference in use habitat is indicated by an index for each pair of habitats, which can take values from - - - (significantly lower habitat usage) to +++ (significantly higher habitat usage).

Habitat	Isolated trees	Anthropic area	Brush	Forest	Ecotones	Pebbly shore	Clearing	Clearing + shrubs	Rank
Anthropic area		- - -	- - -	- - -	- - -	- - -	- - -	- - -	0
Pebbly shore	+ + +		-	-	- - -	- - -	- - -	- - -	1
Clearing + shrubs	+ + +	+		-	- - -	- - -	- - -	- - -	2
Forest	+ + +	+	-		-	- - -	- - -	- - -	3
Clearing	+ + +	+ + +	+ + +	+		- - -	- - -	- - -	4
Brush	+ + +	+ + +	+ + +	+ + +	+ + +		-	- - -	5
Isolated trees	+ + +	+ + +	+ + +	+ + +	+ + +	+		- - -	6
Ecotones	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +	+ + +		7

exposure of the animals to the sun, while woods do not allow adequate thermoregulation due to thick cover. The lizards observed in forest areas were normally near the paths, which can be considered as ecotonal zones. The clearings and pebbly shore are not very likely to be suitable habitats due to the absence of refuge areas and, consequently, the exposure of individuals to predation, in particular by birds. The recreational area located at the beginning of the study area is an artificial habitat with a high degree of environmental modification and a high anthropic impact, factors to which the green lizard seems to be particularly sensitive (Schiavo and Venchi, 2006).

In conclusion, it can be stated that *L. bilineata* in the study area is a stenoecious species and that it is very selective in terms of habitat choice. Ecotonal bands are necessary for the species, but with the progressive degradation of natural environments due to anthropic activities related to urban expansion, infrastructure construction, and intensive agriculture, these environments become increasingly rare in the Po Valley. The information gathered by researchers in recent years and even the simple comparison with the perception of those living in the countryside suggest a progressive decline of this species in many areas of northern Italy. This is a serious conservation problem for the species. In order to protect green lizards, which has ecological requirements similar to those of many other reptiles, but also of small mammals, passerines, and invertebrates, it would be appropriate to start a habitat management pilot project involving the restoration of rows and hedges on the edge of agricultural areas. The increasingly extreme agricultural exploitation in the area reduces these ecotonal environments, which also have a fundamental function as ecological corridors. These results can be used to inform the development of management policies for the conservation of *L. bilineata* and provide guidance on how to address possible environmental restoration interventions within agricultural areas.

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