*Studi Trent. Sci. Nat.*, *Acta Biol.*, 82 (2005): 61-67 ISSN 0392-0542


# The grasshoppers (Insecta, Orthoptera) of a sub-mediterranean zone of the Trentino region (North-East Italy)

Barbara AGABITI*, Ruggero VALENTINOTTI & Cristina SALVADORI

Agrarian Institute of S. Michele a/A, Via E. Mach 2, I-38010 S. Michele all'Adige (TN), Italy
*Corresponding author e-mail: *barbara.agabiti@iasma.it*

SUMMARY - *The grasshoppers (Insecta, Orthoptera) of a sub-mediterranean zone of the Trentino region (North-East Italy)* - The aim of this work is to study the Orthoptera-fauna of an esalpic area, characterized by a kind of sub-mediterranean climate, situated in the souther part of the Trentino region (North-East Italy). The Authors report the results about the distribution of the species of Orthoptera (Insecta, Orthoptera) collected during two years of sampling (2003-2004) and the results of a statistical analysis of the data. To better characterize the distribution of Orthoptera within the studied territory, we have carried out a cluster analysis regarding the environments of sampling and a GLM considering several environmental variables: altitude, solar radiation, wetness index, proximity to rivers, lakes, prairies, main streets, coppice woods and high forests. We performed a Principal Components Analysis (PCA) using only the significant variables from the GLM. The collected data have been processed by the software R 2.1. (Core Team 2005) for the statistical analysis. The significant variables are basically the altitude, the solar radiation, the proximity to major roads and to the lakes. It is relevant the presence of some species such as: *Anacridium aegyptium*, *Antaxius difformis*, *Oedipoda germanica*, *Calliptamus siciliae*, *Pseudoprumna baldensis*.

RIASSUNTO - *Ortotteri (Insecta, Orthoptera) di un'area sub-mediterranea del Trentino (Italia nord orientale)* - Scopo di questo lavoro è lo studio dell'Ortottero-fauna di un'area esalpica, caratterizzata da un clima sub-mediterraneo, nel sud del Trentino (Nordest Italia). Gli Autori riportano i risultati sulla distribuzione degli Ortotteri (Insecta, Orthoptera) raccolti durante due anni di campagne di cattura (2003-2004) e i risultati di un'indagine statistica. Per comprendere meglio la distribuzione degli Ortotteri nell'area studiata abbiamo condotto una *cluster analysis* sugli ambienti di cattura e un GLM considerando le seguenti variabili: quota, radiazione solare, indice topografico, vicinanza ai fiumi, ai laghi, ai pascoli, alle strade principali, ai cedui e alle fustaie. Quindi abbiamo condotto una PCA solo con le variabili significative per il GLM. I dati sono stati elaborati con il software R 2.1. (Core Team 2005). Le variabili più significative sono risultate la quota, la radiazione solare, la vicinanza alle strade e ai laghi. È rilevante la presenza di alcune specie quali: *Anacridium aegyptium*, *Antaxius difformis*, *Oedipoda germanica*, *Calliptamus siciliae*, *Pseudoprumna baldensis*.

*Key words*: Orthoptera, statistical analysis, ecology, Trentino
*Parole chiave*: Orthoptera, analisi statistica, ecologia, Trentino

## 1. INTRODUCTION

The region of this investigation is particularly interesting due to the climatic peculiarities that characterize it (Poldini & Martini 1995). From a geological point of view, the territory is characterized by a carbonate substrate consisting of grey limestones of Lias (180 million years ago) (Odasso 2002). The Trentino region has a continental-temperate climate, but the area around the Garda Lake has a sub-mediterranean climate with clear xeric characters (Gratani & Varone 2003; Salmaso 2005). It is an area in which the role of the broadleaf thermophilous species is predominant (Odasso 2002). The vegetation of this area is characterized by thermophilic woods with typical mediterranean plants. The Orthoptera fauna in this area is therefore different compared to the rest of the territories in Trentino (La Greca 1956; Galvagni 1950a, 2001), with a larger number of xerothermophilic elements and a mediterranean and afro-tropical distribution (La Greca *et al.* 1995; Andreetti & Osella 2001).

The aim of this work is to test if the distribution of Orthoptera is linked to the type of habitat or not and to find the explanatory variables that better describe the distribution of the Orthoptera species.

## 2. STUDY AREA

The study area includes the Val Giudicarie, Val Lagarina, Val di Ledro, Valle dei Laghi, Monte Baldo, Altopiano di Folgaria and the Gruppo del Pasubio (Fig. 1).

During the months between May and September of the 2003-2004 years, 40 samplings were carried out in this area.

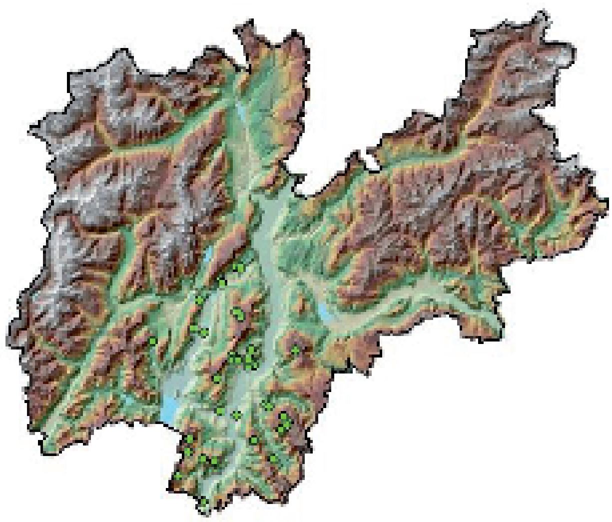

Fig. 1 - Study area, the dots indicate the sampling stations.
*Fig. 1 - Area di studio, i punti rappresentano i campionamenti.*

## 3. MATERIALS AND METHODS

The specimens were captured using pitfall traps, alcohol aerial traps and moving nets. A certain number of specimens were raised to allow the researchers to listen to their songs, or to wait for the appearance of secondary morphologic characteristics necessary for the specific identification. Regarding the identification of the specimens, we have followed the keys of Harz (1969) and of Fontana *et al.* (2002). Moreover, 384 dried specimens of Orthoptera from the collections of the Museum für Naturkunde of Berlin and the Museo Tridentino di Scienze Naturali of Trento were examined. Every sampling station was geo-located with a GPS, then the geographical features (points) and the associated attributes of every field survey were stored in a relational geo-database structured for that purpose. For the statistical analysis, we used a matrix for the environmental data. The studied variables (divided into morphometric and proximity parameters) are listed in the table 1.

All the examined data were analysed using the open source GRASS GIS software with the statistical package R. All the analysis were carried out using grids with a cell resolution of 40 by 40 meters. The morphometric parameters (slope, aspect, wetness index and potential solar radiation on the ground) were generated from DEM (Digital Elevation Model) raster layer. Slope (in percent) and aspect were calculated in GRASS GIS with r.slope.aspect module. Aspect was converted from azimuth angles to eight cardinal directions (N, NE, E, SE, S, SW, W, NW). The wetness index is defined, for each pixel, as the logarithm of the rate between the upslope contributing area and the local slope. High values of wetness index are typical in situations of flow convergence and soil saturation (hollows) while convex areas display low values. This index has the form:

Tab. 1 - GIS derived environmental variables.
*Tab. 1 - Variabili ambientali ricavate dal GIS.*

| Name | Description |
|---|---|
| Morphometric parameters | |
| Dem | Altitude |
| Slo | Slope |
| Asp8 | Aspect |
| Topo | Topographic index |
| Energy | Potential annual solar radiation |
| Proximity parameters | |
| Proxcedu | proximity to coppice stands |
| Proxfust | proximity to high forest stands |
| Proxpasc | proximity to pastures |
| Proxfium40 | proximity to rivers |
| Proxlag | proximity to lakes |
| Proxvia40 | proximity to main roads |

$$\text{wetness\_index} = \ln\left(\frac{\alpha}{\tan\beta}\right) \quad (1)$$

where, in terms of the raster DEM, $\alpha$= the upslope area, per unit contour length, contributing area to a cell and tan ß= the local slope angle acting on a cell (Quinn *et al.* 1995). Solar radiation was obtained from the r.sun module of the GRASS GIS using the shadowing effect of the topography option. This module evaluates the net solar radiation on the ground for each day of the year and creates a map for each day. A map for a whole year was obtained by summing the potential daily solar radiation maps. Proximity parameters were separately calculated from the compartments of the “woodland management plans” (classified as coppice, high forest and pasture) and from the layers of rivers, lakes and transportation routes. First of all, we have carried out a Chi-squared Test for the sampling environment to define whether there is a relationship between the different type of environments and the species of Orthoptera there collected. Then we determined the correlation (Pearson's index) between the variables, and there was no significance (maximum correlation = 0.75). The correlation was tested between Asp8 (since it is a dummy variable, the only one used) and Energy, using the GLM itself. Even in this case nothing significant was found. So both variables were taken into account. Then we assessed the degree of normality of the variables, and a square root transformation was applied to the variables Dem, Slo and Energy. A log transformation was applied to the other proximity variables.

After that, we fit the GLM model and found the best set of explanatory variables. A backwards selection was used and then we repeated the same GLM with those variables (one by one) to find the percentage variance explained by single independent variables. Finally, with these variables we performed a Principal components analysis (PCA) based on a correlation matrix; for the environmental variables matrix we applied a square-root transformation. For the statistical analysis the *vegan* package for R (Oksanen 2005) was used. The sampling stations were represented as vegetation on rocks (a dry environment characterized as rare vegetation on a rocky soil), litter, bushes, grassland, moors, trees, understory and alpine prairies; moreover, we considered 6 altitudinal belts (Galvagni 1950, Galvagni 1950a; Fontana *et al.* 2002; Odasso 2002): lowland (0-200 m. a.s.l.), submontane (201-800 m a.s.l.), inferior mountain (801-1300 m a.s.l.), superior mountain (1301-2000 m a.s.l.), subalpine (2001-2200 m a.s.l.), alpine (2201-3700 m a.s.l.).

## 4. RESULTS AND DISCUSSION

Of the 105 known species of Orthoptera of the Trentino territory (Cobelli 1886, 1906; Harz 1969; La Greca *et al.* 1995; Hellrigl 1996; Heller *et al.* 1998), 66 species belonging to 6 families we collected in the investigated area (Tab. 2).

We have considered the collected species according to the habitat and the corresponding altitudinal belts where they were collected. As far as the altitude distribution of Orthoptera is concerned, the superior mountain plane is the one with the greatest number of species (Fig. 2). Some species are widely distributed in altitude as they are present from the sub mountain belt to the sub alpine belt, for example *Chorthippus p. parallelus* (Zett. 1821), *Euthystira brachyptera* (Ocskay 1826), *Glyptobothrus b. brunneus* (Thunberg 1815), *Omocestus viridulus* (L. 1758) and *Stauroderus scalaris* (Fischer-Waldheim 1846); other species are exclusive of low elevations such as *Barbitistes vicetinus* Galvagni & Fontana 1993, others of high elevations as *Aeropus sibiricus* (L. 1767), *Podisma p. pedestris* (L. 1758) and *Pseudoprumna baldensis* (Krauss 1883).

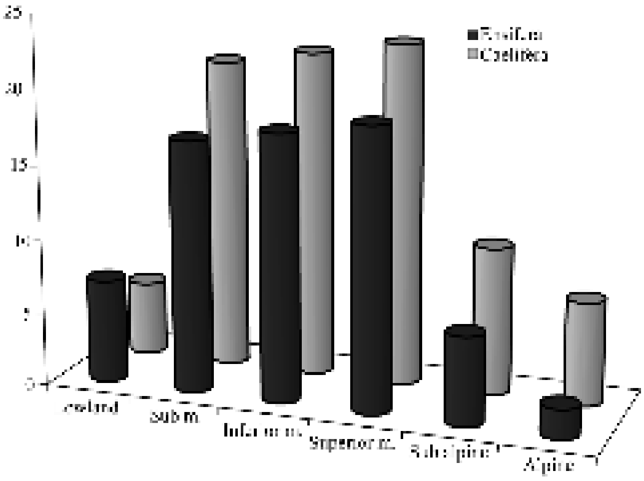

Fig. 2 - Number of species of grasshoppers per altitudinal belt.
*Fig. 2 - Numero di specie di Ortotteri per fascia altitudinale.*

It is clear that the understory, bushes and basically humid areas like litter have a high number of Ensifera, whereas the Caelifera are predominant in grasslands and alpine prairies (Fig. 3).

The presence of some species is relevant due to their particular biogeographical and ecologic interest. Signi-

Tab. 2 - Number of species of Orthoptera collected per family.
*Tab. 2 - Numero di specie di Ortotteri raccolte per famiglia.*

| Suborder Ensifera | | Suborder Caelifera | |
|---|---|---|---|
| Family | Num. of species | Family | Num. of species |
| Gryllidae | 4 | Acrididae | 28 |
| Rhaphidophoridae | 1 | Catantopidae | 5 |
| Tettigonidae | 26 | Tetrigidae | 2 |
| Total | 31 | | 35 |

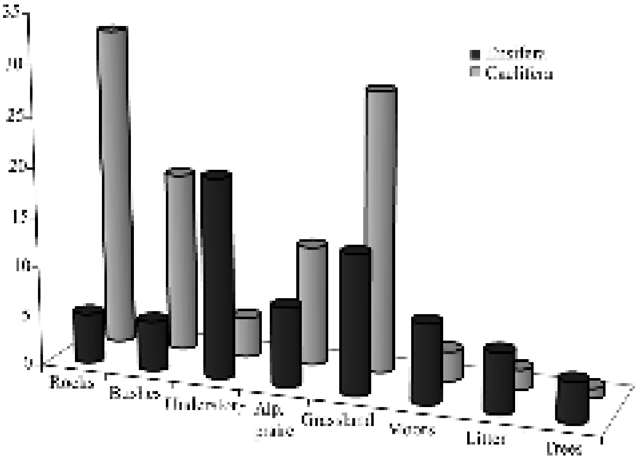


Fig. 3 - Number of species of grasshoppers per environments.
*Fig. 3 - Numero di specie di Ortotteri per ambiente.*

ficant species, from an ecological point of view, for the forest habitats are as follows:

- *Antaxius difformis* (Brunner von Watt., 1861) lives in the juniper bushes near the conifers woods and in the understory; it is endemic of the alpine arch.
- *Barbitistes obtusus* Targioni-Tozzetti, 1881 is a species linked to the shadowy and bushy habitats; it lives in the fir-woods, in the understory and in the bushes near the forest; it is index of good forest condition.
- *Barbitistes vicetinus* Galvagni & Fontana, 1993 is an endemic species of the Vicentino territory (North-East Italy), it prefers broadleaf thermophilic woods.
- *Leptophyes laticauda* (Frivaldsky, 1867) is a species that often cohabits with *Barbitistes obtusus*, because it is also linked to the high grassy vegetation near the forest; it is a very elusive species.
- *Meconema meridionale* Costa, 1860 is a typically arboreal species, which prefers the thermophilic woods of oaks.
- *Yersinella raymondi* (Yersin, 1860) is a forest species; it lives in the understory while its nymphs are easily found in the litter; it is very sensitive to the environmental modifications so it is an index of good state of the forest.

Significant species, from an ecological point of view, for the grassland habitats are as follows:

- *Anacrydium aegyptium* (L., 1764), an afro-tropical species, is typically found in dry habitat.
- *Calliptamus siciliae* Ramme, 1927 is a xerophilic species; it lives in the dry grassland, the rocky slopes and sometimes in the cultivated land.
- *Xiphidion discolor* (Thunberg, 1815) and *Psophus stridulus* (L., 1758) are typical species of dry prairies, and basically xerothermophilic.
- *Decticus v. verrucivorus* (L., 1758) is common in the high altitudes and it is very sensitive to environmental modifications; it lives in the clearings of broadleaf woods. In France, this species is protected (Bellman & Luquet 1995).
- *Glyptobothrus alticola* (Ramme, 1821) is a xerothermophilic species endemic in the East Alps, where it inhabits thin and rocky pastures, devoid of tree vegetation.
- *Aeropus sibiricus* (L., 1767) and *Podisma p. pedestris* (L., 1758) live in the alpine prairies; they are stenothermophilic-cold species, and considered to be indicators of good natural conditions.
- *Oedipoda germanica* (Latr., 1804) cohabits often with *Oedipoda caerulescens* (L., 1758) and *Calliptamus siciliae* Ramme, 1927 in vegetation on rocks and on bare slopes near broadleaf forest; it has almost disappeared because of the destruction of its natural habitats. In France, it is considered locally extinct species (Andreetti & Osella 2001). The main cause of the reduction of its distribution is the expansion of the cultivated lands, where *Calliptamus siciliae* and *Oedipoda caerulescens* can live all the same.
- *Pseudoprumna baldensis* (Krauss, 1883) orophilic species endemic of Monte Baldo.
- *Poecilimon ornatus* (Schmidt, 1850) lives in the cold and wet grassland with high grassy vegetation; it can be very abundant in the nettle bushes with *Pholidoptera griseoaptera* (De Geer, 1773) (as in a sampling locality near the Rif. Graziani at 1620 m a.s.l. of Monte Baldo).
- *Tettigonia cantans* (Fuessly, 1775) is an hygrophilic and stenothermophilic-cold species. It lives in the bushy grassland also in high altitude; it can be very abundant, except in intensively pastured grassland.

A Chi-squared test related to the environment types was carried out (7 degrees of freedom):

(2) $\chi^2_{(7)} = 57.265024; \alpha = 0{,}01$

The test was significant, therefore rejecting the null hypothesis that the distributions observed are not significantly different, and do not depend on the types of capture environments. After that, we performed a cluster analysis to determine the significance of similarity of the sampling environments, using a presence/absence matrix; we chose the index of Bray-Curtis for the calculation of the distance matrix, which is more recommended for a boolean matrix (Reynolds 1988; Clarke

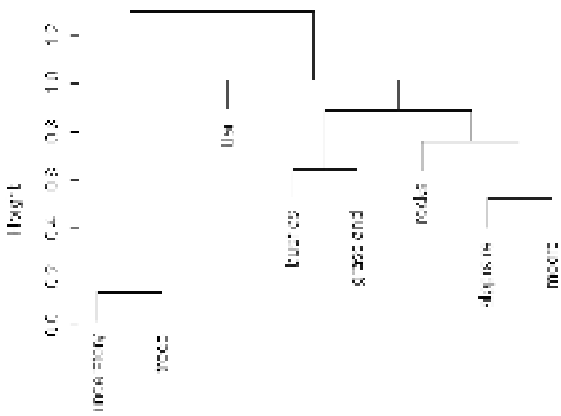

Fig. 4 - Cluster dendrogram.
*Fig. 4 - Dendrogramma.*

& Warwick 1995; Lepš & Šmilauer 1999) and the squared Euclidean's distance (Ward's method) (Fowler & Cohen 2002) as clustering function (Fig. 4).

The cluster dendrogram shows that the environments more similar are understory and trees, bushes and grassland, alpine prairies and moors; these two last are both typical of high altitude. Slightly different from the others are litter and rocks. This is comprehensible as the species that live in this two habitats have very peculiar ecological needs. In order to better understand and underline the factors that determine the distribution of Orthoptera in various environments and their associations, we conducted another type of multivariate analysis. First we analysed our data using a GLM to find the best set of explanatory variables between altitude (Dem), the potential solar radiation (called Energy, the potential annual accumulation), the wetness index (Topo) which is the ratio between the drained area and the slope, proximity to rivers (Proxfium), lakes (Proxlag), pastures (Proxpasc), main roads (Proxvia40), coppice woods (Proxcedu) and high forests (Proxfust). The GLM was created considering one variable per time to test the power of the variable. The response variable is the Richness per sample. Then another GLM was made with all the explanatory variables together to which was applied a "backwards selection" (starting with all variables and dropping one at time) (Dalgaard 2002); the parameters that best explain the collected data, according to the model, are: Proxlag, Proxvia40, Dem and Energy. The results are summarized in the table 3.

Tab. 3 - Results of the GLM.
*Tab. 3 - Risultati del GLM.*

| | AIC | 1-(residual devinace/ null deviance) |
|---|---|---|
| Model with all variables | 256.31 | 0.461 |
| √DEM | 250.25 | 0.177 |
| √Energy | 248.93 | 0.065 |
| Log(Proxlag) | 251.16 | 0.075 |
| Log(Proxvia40) | 250.82 | 0.013 |

The model explained 46% of the total variance; among the variables the greatest percentage of variance is explained by Dem (17%). The score coefficients are shown in table 4.

From the results in table 4, we can construct the formula of our model:

*Richness*= -55.7+log(Proxlag)*0,0011-log(Proxvia40) *0.0022+√Dem*21.14+√Energy*0.01

Then, we performed a PCA (Fig. 5), but only the four significant explanatory variables were used.

No transformation was applied to the species data, since it is a boolean matrix; a square-root transformation (Tab. 3) was applied to the environmental variables matrix instead. The first two axes explain the 22% of the total sum of all unconstrained eigenvalue (53.72) (Tab. 5). The percentage of explained variance is not too high, but it is due to the presence/absence matrix species data (Lepš & Šmilauer 1999). The variables are represented by arrows with length proportional to the correlation between ordination and the environmental variable. The variable Dem is the one with the greatest strength of the gradient, the second variable is Energy; the variables Proxlag and Proxvia40 have a certain correlation between them (0.72 from the Pearson's correlation matrix).

Tab. 4 - Score coefficients from the GLM per variables.
*Tab. 4 - Valori delle variabili ricavati dal GLM.*

| Score Coefficients | | | | | |
|---|---|---|---|---|---|
| | Estimate | Std. Error | t value | Pr (>\|t\|) | |
| (Intercept) | -55.683058 | 17.65388 | -3.154 | 0.0033 | ** |
| Log(proxlag) | 0.001125 | 0.000503 | 2.237 | 0.03179 | * |
| Log(proxvia40) | -0.002268 | 0.001054 | -2.152 | 0.03838 | * |
| √Dem | 21.146587 | 6.666087 | 3.172 | 0.00314 | ** |
| √Energy | 0.010679 | 0.006378 | 1.674 | 0.10301 | |

Tab. 5 - Output of the PCA with the eigenvalues score.
*Tab. 5 - Autovalori della PCA.*

| | Inertia | Rank | |
|---|---|---|---|
| Total | 65 | | |
| Constrained | 11.28 | 4 | |
| Unconstrained | 53.72 | 35 | |
| Eigenvalues for constrained axes | | | |
| RDA1 | RDA2 | RDA3 | RDA4 |
| 5.373 | 2.764 | 1.748 | 1.397 |
| Eigenvalues for unconstrained axes | | | |
| PC1 | PC2 | PC3 | PC4 |
| 6.971 | 4.828 | 4.308 | 3.602 |

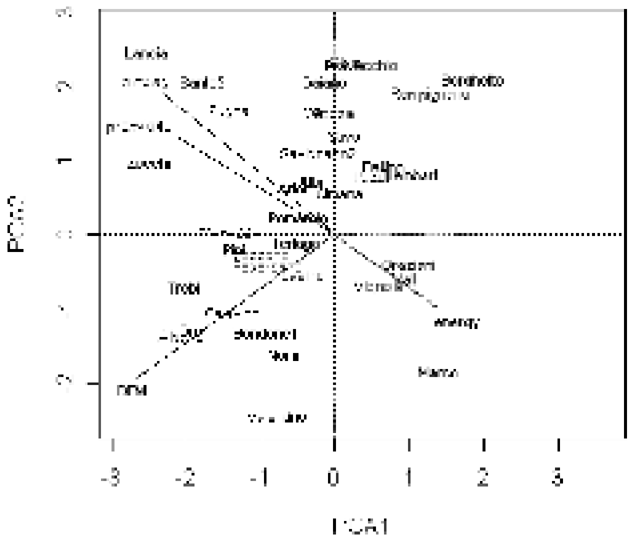


Fig. 5 - PCA performed with R *vegan* package.
*Fig. 5 - PCA ottenuta con R vegan package.*

## 5. CONCLUSIONS

The investigation revealed that the type of environment is the determining factor in the distribution of the Orthoptera species. The climate of this area in Trentino, which is basically dry, the not excessively high altitudes and the predomination of broadleaf woods allow the settlement of a more xerothermophilic fauna compared to other areas in Trentino. The presence of typical xerothermophilic species with an afro-tropical distribution as *Anacrydium aegyptium* (L., 1764), *Calliptamus siciliae* Ramme, 1927 and *Stauroderus scalaris* (Fischer-Waldheim, 1846) are evidence of these environmental attributes. Moreover, the more rarefied presence of the species such as *Oedipoda germanica* (Latr., 1804), *Xiphidion discolor* Thunberg, 1815 and *Decticus v. verrucivorus* (L., 1758) shows that there is a rarefaction of some aspect or type of habitat that results the reduction of these species. Furthermore, the greater accessibility of this area, due to the width of the Valle dell'Adige that characterizes it as the corridor for the penetration of fauna coming from the South, has allowed the entrance of the southern species as *Barbitistes vicetinus*, endemic of the neighbouring Veneto, and *Calliptamus siciliae* Ramme, 1927, native to the South of Italy. The effect of the altitude in the distribution of Orthoptera is clear since it determines primarily the kind of vegetation. Solar radiation is important too because each species has a clear tendency of heliophily or heliophoby. The distance from a water resource is also a determining factor for the presence of insects in general. Among the studied environmental variables, the altitude, solar radiation, proximity to the lakes and proximity to the main transportation routes are the most significant for the Orthoptera's distribution, according to the GLM model and the PCA.

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*Accettato per la stampa: 10 luglio 2006*