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Assessment of *Pseudophilotes bavius hungarica* ecological niche vulnerability due to land use and climate changes using GIS technics

PhD Thesis Abstract

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Cluj-Napoca, 2012

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Key words: *Pseudophilotes bavius hungarica*, morfology, ecology, population dynamics, conservation, vulnerability, GIS, distribution of potential habitats, climate change, land use, habitats fragmentation and isolation, Maxent

Introduction

Pseudophilotes bavius hungarica is mentioned in the annexes of the Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora (II and IV), European Red List of Butterflies (van Swaay *et al.* 2010), in the Romanian legislation (OUG nr. 57/2007 approved with amendments by Law 49/2011 on the protected nature reserves, natural habitats, wild flora and fauna), and Red List of Romania (EN) (Rákosy 2002).

The name *Pseudophilotes bavius hungaricus* was often erroneously used in literature, as for example all editions of "A field guide to the Butterflies of Britain and Europe" (Higgins & Riley, 1970, 1978; Tolman & Lewington 1997, 2008) and „Verzeichnis der Schmetterlinge Rumäniens" (Rákosy *et al.* 2003). We wish to emphasize that the correct name of this taxon is *Pseudophilotes bavius hungarica* as it was originally described by Diószeghy in 1913 under this name.

Scope and goals

We aimed to assess the vulnerability of ecological niches of *P. bavius hungarica* with respect to land use and climate change, using GIS techniques. A prime objective was ecological characterization of *P. bavius hungarica* (Part I). Bibliographical study was supplemented by a Mark-Release-Recapture study at Suatu, to obtain information on population size estimation, population dynamics, individuals life span etc. Observations were also made related to the morphology and biology of subspecies, which were subsequently synthesized and transformed into an article (Crişan *et al.* 2011) (Chapter 1).

In Chapter 2 we proposed to develop aspects concerning the preservation of this valuable taxon from Transylvania. The theoretical part we combined it with the practice; we began legal proceedings to achieve an ecological corridor for *P. bavius hungarica* at Suatu.

In the second part of the thesis we developed a GIS modeling to identify *P. bavius hungarica* potential habitats from certain well-known presence data and a set of environmental variables (altitude, exposition, slope, land use etc.).

Then, using various climate scenarios and land use modeling we realized once again subspecies *P. bavius hungarica* distribution with the main aim of highlighting potential habitat changes over time. Thus was highlighted especially taxon vulnerablility to isolation due to restriction and habitat fragmentation.

Another goal was to create a reproducible technique that can be applied to other rare or endangered species to assess impacts of environmental conditions change on habitats of species in Romania.

1. Morphological, biological, ecological and population dynamics study of *Pseudophilotes bavius hungarica*

Data on morphology and biology of *P. bavius hungarica* taxon was provided by König (1992) and Jutzeler *et al.* (1997), but incomplete, with fewer details than those presented in this paper.

Transilvanian Blue as it was called by Rákosy can only be found in areas with steppelike vegetation and presence of the larval host plant *Salvia nutans* L. (Lamiaceae) (Kovács *et al.* 2001). One of the known populations in Transylvania, considered to be the healthiest, is located in Suatu (Cluj County), in and around the botanical nature reserve (Fig. 1).

Most of analyses was made in this area, but observations on the larvae and pupa also were made in „Natura 2000" sites: ROSCI0238 Suatu-Cojocna-Crairât, ROSPA0113 Cânepişti and ROSCI0099 Lacul Ştiucilor-Sic-Puini-Bonțida, all of them in Cluj county.

Fig. 1. Terraces with flowering *S. nutans* at Suatu

The pre-adult developmental stages and the adults were observed and studied both in the laboratory and in the field between April 15 and June 15, 2010 and 2011. During the same period, larval host plants, flight pattern, oviposition preferences, host plant, phenology, and meteorological parameters were recorded daily for 60 minutes with time being randomised to avoid systematic effects of the time of day. Twenty-seven larvae, together with their host plant (in pots) and the respective closest ant colony were transferred and reared in the laboratory. These larvae were fed and observed daily for 120 minutes to analyse their mobility, myrmecophily, and parasitism. The ants and parasites were sent to specialists for identification.

1.1. Description of study area

At Suatu, Traditional use of land as extensive grazing for a period of about 25-30 years allowed the natural ecological succession from crops (vines) to steppe vegetation. The first reserve management plan provide late autumn mosaic mowing and extensive grazing, but in recent decades have not been implemented so the habitats known a degradation process translated in particular by developing clusters of shrubs (Mihuț *et al.* 2001, Cremene *et al.* 2005, Baur *et al.* 2006, Enyedi *et al.* 2008, Rákosy 2011). In order to stabilize steep slopes in areas adjacent to the reserve, *Robinia pseudoacacia* L. plantations were established, approx. 25 years ago.

1.2. Materials and methods

The study was conducted at two sites (each 9500 m^2) with high densities of *S. nutans* in and around the Suatu botanical nature reserve.

One of the areas is located inside the natural reserve and the other on the terraces which used to be vineyards 30-35 years ago (Fig. 1). The distance between the two study sites is approximately 1 km and they are partially separated by a belt of shrubs dominated by *R. pseudoacacia.*

Mark-release-recapture (MRR) method was used to estimate the current population size, sex structure and average lifespan of adults of *P. bavius hungarica* from Suatu.

In 2010 MRR study was conducted from April 23 to May 11, from the appearance of the first individuals to the end of the flight period. For each individual there was recorded: sex, time and place where it was captured, and some observations on the activity before capture.

To estimate the daily average flight distance, we calculated the average distance between the points of individual capture and recapture (separately for males and females) divided by the number of days elapsed between the two moments (Billeter *et al.* 2003). To estimate the points of capture and recapture, we considered plot centres where butterflies were found as a reference for calculating distances travelled.

Statistical analysis of data on flight distance was performed with StatView pour Windows 5.0 software (http://www.statview.com).

Using GIS software ArcMAP 9.2 (ESRI 1996) we compared two ortophotoplans of the study sites (from 2004 and 2009) in order to calculate the expansion of the shrub area over 5 years (Fig. 2).

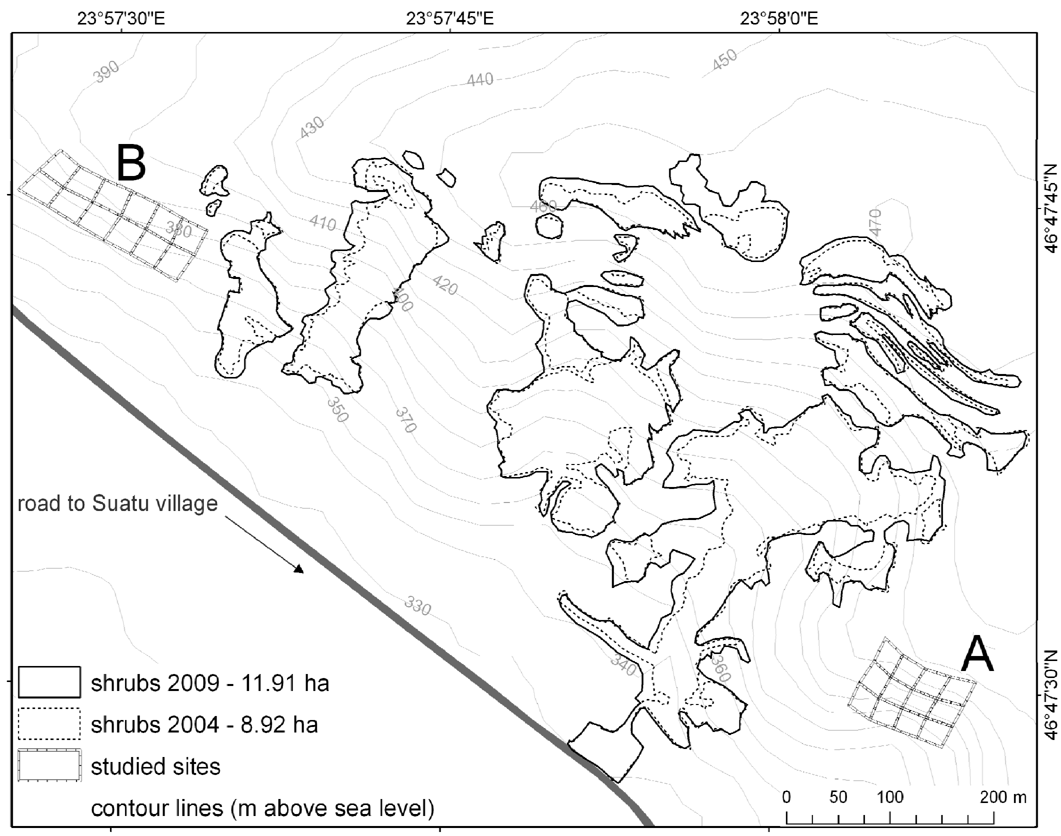

Fig. 2. Area covered with shrubs on the investigated hillside in 2004 (dashed line) and 2009 (continous line)

1.3. Morphological issues [1]

For a more accurate description of the taxon, detailed photographs (macro and scanning electron micrographs) of the eggs, larvae, and pupae were taken. (Fig. 3).

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[1] Crişan A., Sitar C., Craioveanu C., Rákosy L. 2011. The Protected Transylvanian Blue (*Pseudophilotes bavius hungarica*): new information on the morphology and biology. Nota lepidopterologica 34(2):163-168.

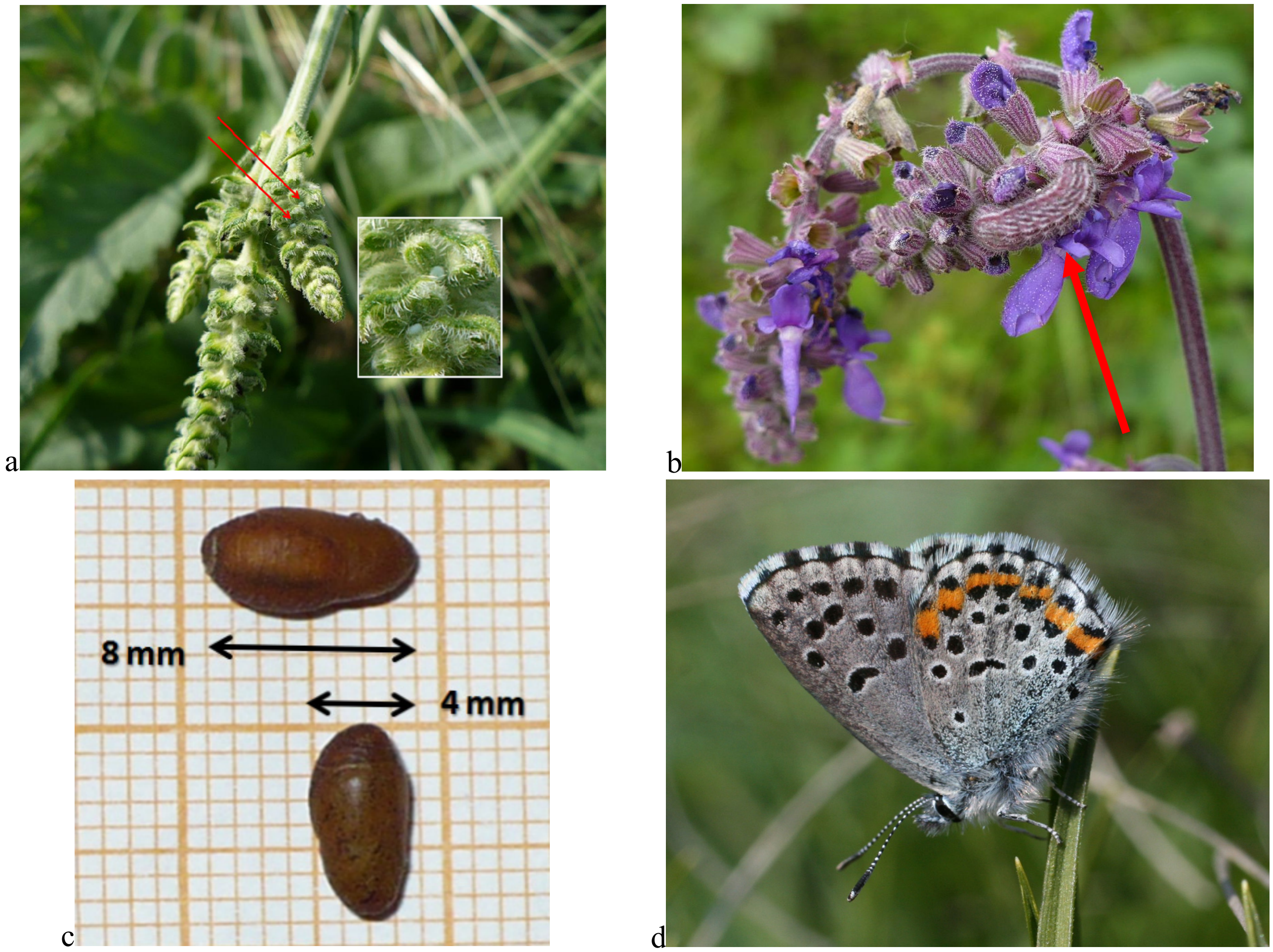

Fig. 3. Egg (a), larva (b), pupa (c) and imago (d – foto: Rákosy) of *P. bavius hungarica*

Flight period begins in late April, but according to climatic characteristics of each year may vary significantly (Fig. 4).

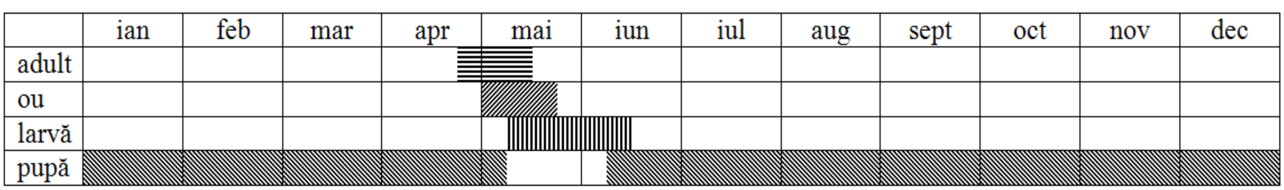

Fig. 4. Developmental stages of *P. bavius hungarica*

Our observations have confirmed the following plants as trophic basis for adults of *P. bavius hungarica*: *Veronica prostrata* (Scrophulariaceae)*, Fragaria viridis* (Rosaceae), *Thymus marschallianus* (Labiatae) and *Euphorbia seguieriana* (Euphorbiaceae) (Crişan *et al.* 2011).

1.4. Population dynamics issues

In the MRR study conducted in April-May 2010 were obtained the following results:

In the area inside the reserve (A) were captured 147 individuals, 74 males and 73 females. 12 individuals were recaptured (<10%), of which 9 males and 3 females.

In the area outside the reserve (B) were marked 331 individuals, of which 119 males and 212 females. 117 individuals were recaptured (> 35%), of which 37 males and 80 females. 37 individuals of which 17 males and 20 females (ca. 11%) were recaptured two or more times.

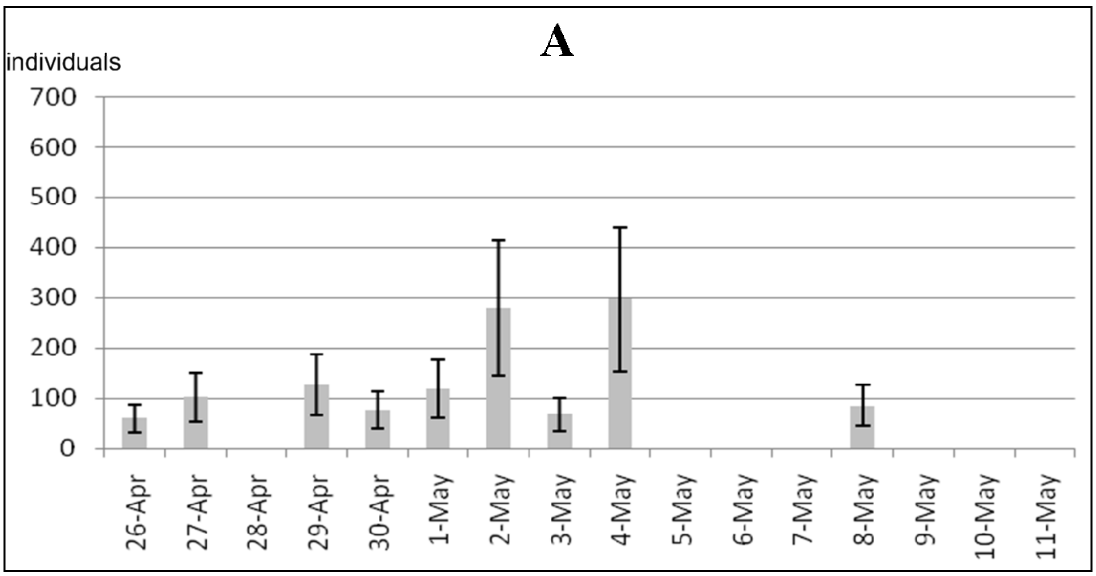

Fig. 5. Number of *P. bavius hungarica* individuals estimate in botanical nature reserve (A)

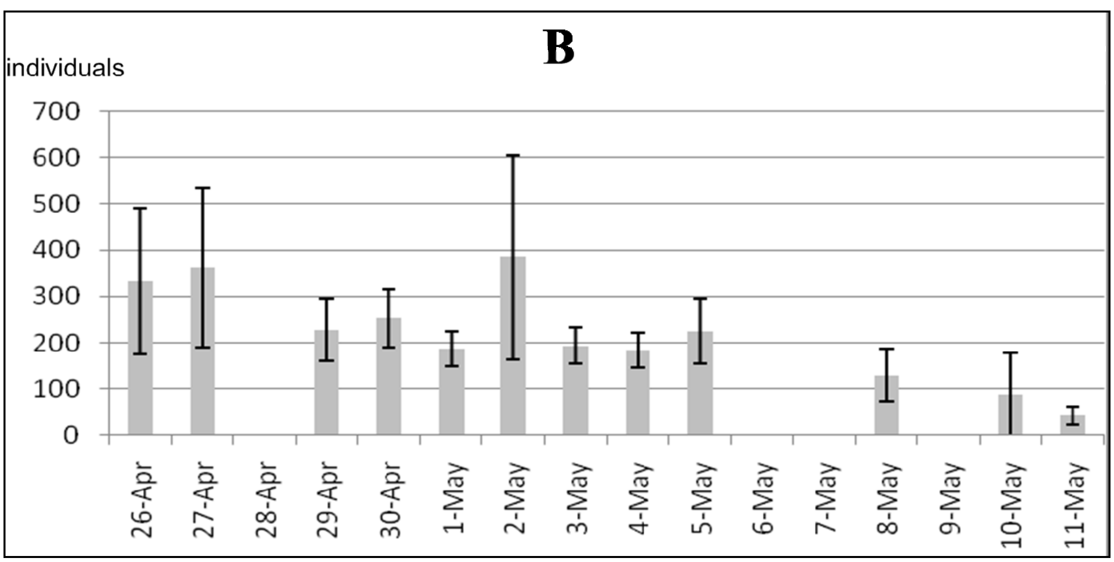

Fig. 6. Number of *P. bavius hungarica* individuals estimate in B plot (former vineyards)

For the study site inside the natural reserve a population of 661 individuals was estimated (Fig. 5), with an average life span of 2.4 days. For the study site outside the natural reserve a population of 1019 individuals was estimated (Fig. 6), with an average life span of 3 days. The maximum life span registered for an individual (a male) was 12 days.

The average daily flight distance of an individual was 31 m for males and 29 m for females. Two exceptions were registered: a female marked in study site A was recaptured in study site B after 5 days (about 200 m/day), and a male marked in study site B was recaptured in the westernmost part of the study site A after 4 days (about 250 m/day).

As a consequence of the ecological succession, the area covered by shrubs between the two study sites is expanding; in 2004 it measured 8.92 ha and after 5 years, in 2009, it already covered 11.91 ha (increasing with about 30%).

2. Protection and conservation measures for *P. bavius hungarica* at Suatu, Cluj

The alteration and degradation of the habitat structures and especially the thickening of the vegetation due to the prevalence of grass species (*Brachipodium* sp. si *Carex* sp.) in preference to *S. nutans* is due to the lack of any management in the natural reserve (Enyedi *et al.* 2008, Rákosy 2011). As a consequence of the habitat degradation within the natural reserve, the size of the *P. bavius hungarica* population decreased significantly over the last years, even in years with maximum population densities. Also, the lack of management probably led to a significantly lower plant diversity within the natural reserve, thus reducing the cover of available food sources and consequently the progressive decrease of the population sizes (Kudrna 1986, Ausden 2007, Dover *et al.* 2011).

Before 1990, extensive occasional grazing (2-3 cows) and a total or partial mowing at the beginning of august occurred, but after this year, these practices were abandoned, the natural reserve being partially fenced and the access of animals totally banned after the year 2000 (Rákosy 2011).

The two *P. bavius hungarica* colonies in Suatu are presently partially separated and isolated by the presence of a *R. pseudoacacia* belt which is expanding. In order to re-establish contact it is necessary to pierce through this belt of shrubs and keep an open passage way between the two colonies (Fig. 7).

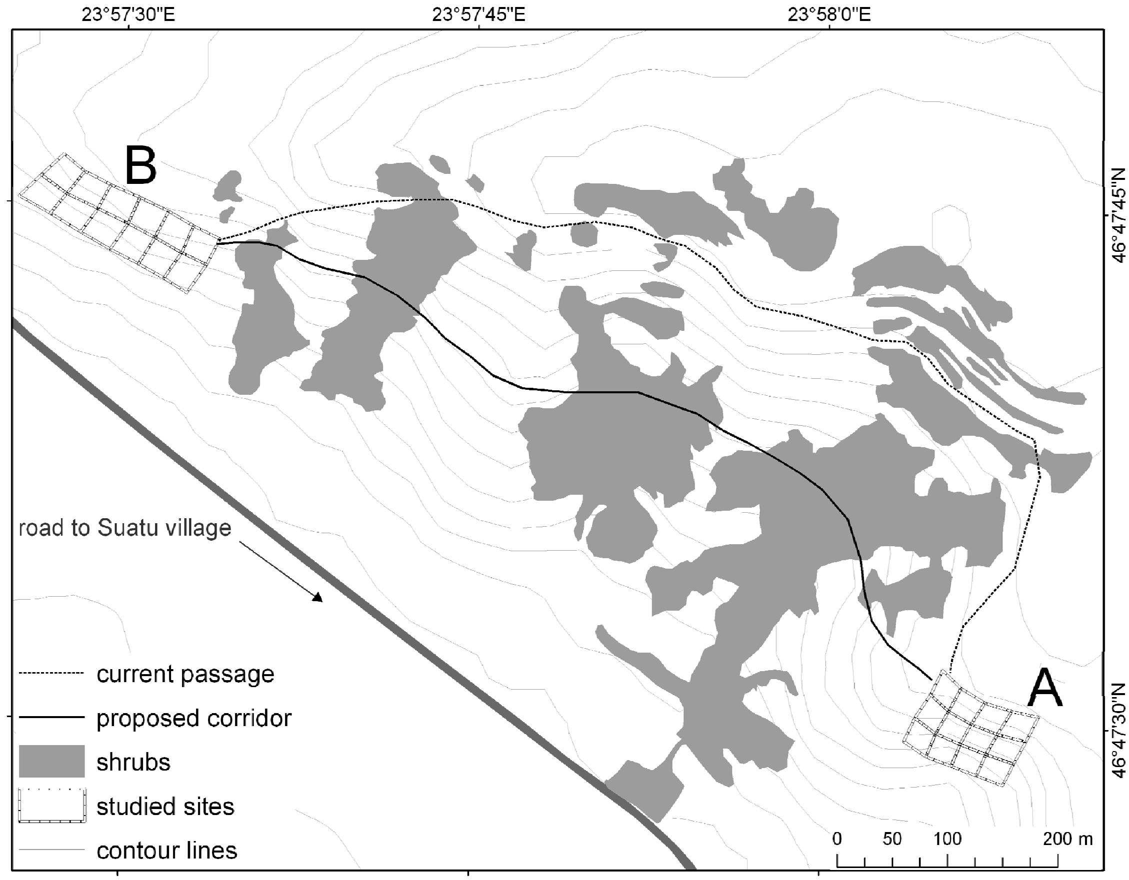

Fig. 7. Schematic map of the current passage corridor for *P. bavius hungarica* (dashed line) and the former, that we suggest being restored (continous line)

Small populations with low flight distances suggest a reduced migration capacity, also seen in other species of the Lycaenidae family and the *Pseudophilotes* genus (Lewis *et al.* 1997, Gutierrez *et al.* 1999, Hanski *et al.* 2000, Roland *et al.* 2000, James *et al.* 2003). The distribution of this species is also restricted by the exclusive dependency on the host plant *S. nutans*.

Suggested management practices:

- mowing alternative areas in early august on approximately 30% of the natural reserve area or extensive grazing (for 2-3 months) with 3-4 cattle;
- fragmentation or total removal of the *R. pseudoacacia* belt which hinders the movement of individuals between the colonies (Fig. 8);
- The inclusion of these recommendations in the integrated management plan of ROSCI0238 Suatu – Cojocna – Crairât.

3. Assessment of *Pseudophilotes bavius hungarica* ecological niche vulnerability due to land use and climate changes using GIS technics

Assessment of ecological niches vulnerability for species, especially for an endangered one as *P. bavius hungarica* (Rákosy 2002), is one of the first steps to propose effective measures to protect it.

There were made a series of definitions for the concept of ecological niche, but Pulliam (2000) and Guisan & Zimmermann (2000) believes that the formulated by G. Evelyn Hutchinson in 1957 is still appropriate. So we understand the ecological niche as: an „n-dimensional hypervolume", every point in which corresponds to a state of the environment which would permit a species to exist indefinitely.

Knowledge of the biology and ecology taxon for all life stages: adult, egg, larva, pupa is vital to assess the vulnerability of ecological niches (Araújo & Guisan 2006) and obviously for the stage of conservation actions.

Species distribution models (SDMs) are widely used in biogeography and conservation biology to assess recent climate change on ecological niches of species (SDMs) (Guisan & Zimmermann 2000, Raxworthy *et al.* 2003, Thuiller 2004, Guisan & Thuiller 2005; Lütolf *et al.* 2006, Pearson *et al.* 2006; Raes & ter Steege 2007; Diniz-Filho *et al.* 2009, Gherghel *et al.* 2009, Hartel *et al.* 2010a ş.a.).

3.1. Modeling potential habitat by overlay method

3.1.1. Current potential habitats distribution map

For realising the potential distribution map for *P. bavius hungarica* the following stages have been completed:

- All known locations (definite presence) of the populations of *P. bavius hungarica* from Câmpia Transilvaniei have been edited on a map. To ensure the accuracy of the modeling, the marking of the points was based on the GPS coordinates (GPS Map 60 CSx, collected in the field), or on localizing on a detailed topographic map (1:25000). Following the field investigations from 2011 a series of new points have been added to those already known until present: Gădălin, Bărăi, Geaca and Valea Florilor (Cluj county). Considering that the analysis has been made at a scale of 100x100 m, it was not allowed in a cell of 1 ha to have more than one record (Lütolf *et al.* 2009), thus from a total of 63 initial points only 47 records have remained.

- Thematic layers have been prepared for the modeling:

1. **Digital Elevation Model** (DEM) - realized based on the results obtained by: "The Shuttle Radar Topography Mission", version 4.1 (http://srtm.csi.cgiar.org), with a resolution of 90 m.

2. **The map of land usage** with the resolution of 100 meters from the European Environment Agency – "Corine Land Cover 2006" version 13 (http://www.eea.europa.eu/).

3. **Maps of the most important bioclimatic variables** downloaded from WorldClim – Global Climate Data (Hijmans *et al.* 2005, http://www.worldclim.org/) – 19 bioclimatic variables for the current situation.

- In ArcMap have been loaded: point type vector file (.shp) with the location of known populations of *P. bavius hungarica*, the Digital Elevation Model (DEM), the land use map (CLC) and bioclimatic variables. The values for each parameter have been extracted for all known certain presence points.

- The datas from the resulting files were synthesized and a table of the values of all parameters used in modeling was compiled.

- Using SPSS 16 program, an analysis was conducted on the corellations between predictors and the phenomenon of presence/absence, correlations between predictors, regression (Generalized Linear Model – GLM) to determine predictors with the greatest importance in taxon distribution.

- Based on the information obtained in the previous step representative intervals were designated, respectively the required values for each of the parameters used in modeling. For the exhibit the interval 135^0-260^0, respectively SSE-S-SV was used. For the slope the interval $7,5^0$-20^0 was used. The following classes for land use were: 221 – land planted with vines, 231 – pastures, 243 – Land principally occupied by agriculture, with significant areas of natural vegetation, 333 –sparsely vegetated areas. For BIO3 the classes: 31-33 were used. For the precipitations of the driest month the interval 26-28 mm was used.

- A model based on maps prepared in the previous step was created, by multiplying (overlay) the map of potential current habitat distribution for *P. bavius hungarica* (Fig. 8) was created. The operations included in the model can be run independently, but were integrated as to allow their subsequent management with greater ease.

3.1.2. Potential habitats distribution map for 2050 year

To achieve the potential habitat prognosys for *P. bavius hungarica* for different time horizons and different scenarios, firstly the appropriate thematic layers preparation was required.

In regards to land use two scenarios were elaborated. The quantification of changes in surface and potential habitats structures of *P. bavius hungarica* was desired in case of land abandonment (growth of areas covered by shrubs), respectively the intensification of agriculture (extension of arable land area).

For each of them a model in ArcGIS was created which based on vector files (polygon) derived from the use of land map (CLC 2006) and user input parameters, realized the use of land map according to the scenarios proposed. Then, same as for the current situation, by multiplying (overlapping) the potential habitat distribution map was realized for *P. bavius hungarica*.

To highlight the fragmentation of habitats the distances between each plot and the nearest neighboring plot (distance between central points of habitats) were calculated.

This method is cited in the literature (Bender *et al.* 2003, Santana *et al.* 2011, etc.), specifying that its relevance decreases as the value of the irregularity/elongation parameter of parcels analyzed increases.

So, for the present situation and for each scenario, the shape of the parcels based on the corrected parameter/area (CPA) was first evaluated, which gives an indication of the degree of elongation in relation to the circle of the same area (Austin 1984, Gafta 2002). The used formula for the CPA calculation was:

$$CPA = P/(2\pi\sqrt{A/\pi})$$

Where P-perimeter and A-area of the parcels with adequate habitats for *P. bavius hungarica*.

As the CPA value is greater than 1 the shape of the parcel is more elongated/irregular, with a more pronounced edge effect (Gafta 2002).

Given the fact that parcels with potential habitat suitable for *P. bavius hungarica* have a moderate CPA value (index of elongation/irregularity), the distance between the centers of polygons is a relevant indicator (Bender *et al.* 2003):

For the study of habitat fragmentation was used additionally the "buffer area" method (Bender *et al.* 2003) which involves creating a buffer zone around each parcel equivalent to the distance that theoretically a *P. bavius hungarica* individual can travel during its existence (daily flight distance*life expectancy (number of days)) and then calculate the interconnectivity of parcels.

For distance calculation was considered the maximum daily flight distance (200 m) and the average life span (3 days), thus the value of 600 m was obtained. Thus it was created, a buffer area around each potential habitat of 300 m, than it was checked how many habitats have become interconnected in this way (Fig. 14).

Three of the potential habitats for *P. bavius hungarica* highlighted following modeling were tested in the field in 2011 season, and in two of them the presence of the species was confirmed.

However this being a model it is expected that some of resulting habitats to not show a real correspondent in the field. It is known that the uncertainties associated with modeling can not be eliminated, but only minimized (Zimmermann 2004, Rocchini *et al.* 2011).

Among the issues that were not integrated in the model and may be (considerable) sources of uncertainties/errors are: edaphic layer (in conjunction with the geologic support) (Coudun *et al.*2006, Titeux *et al.* 2009), overgrazing, the expansion of shrubs (Schmitt & Rákosy 2007, Enyedi *et al.* 2008), burning of grasslands (Dincă *et al.* 2011).

However, modeling is an important tool in identifying areas likely to harbor populations of *P. bavius hungarica*.

3.1.3. Results

A series of potential habitat distribution maps for *P. bavius hungarica* have resulted:

- The current situation (Fig. 8);
- The projected situation according to the expansion of areas covered by shrubs approx. 300% for 2050 scenario (Fig. 9);
- The projected situation according to the expansion of arable land areas with cca. 300%, for the year 2050 (Fig. 10);

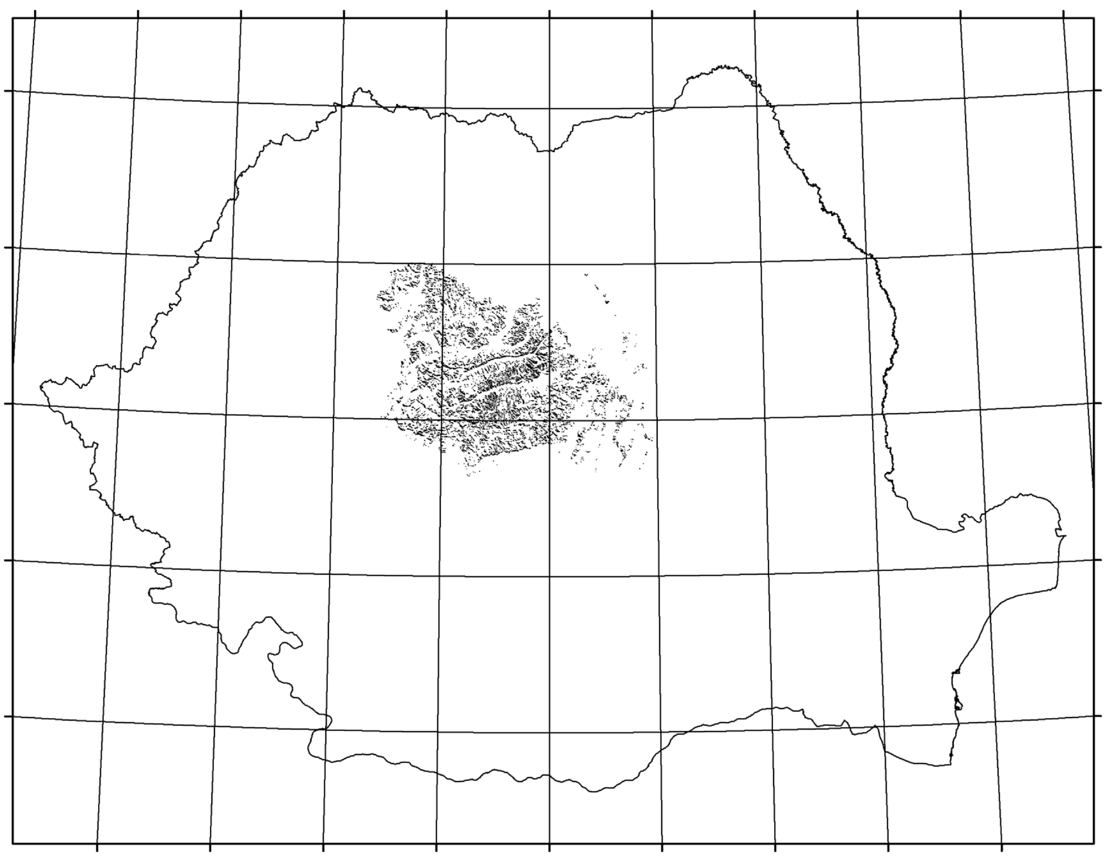

Fig. 8. The current distribution map of potential habitats for *P. bavius hungarica*

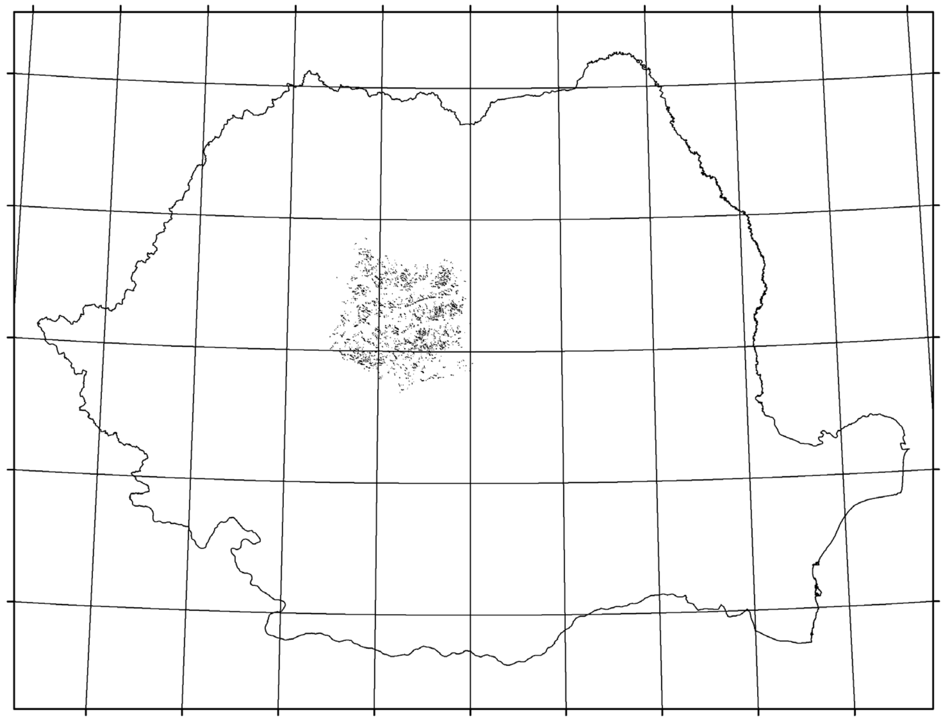

Fig. 9. The distribution map of potential habitats for *P. bavius hungarica* in the year 2050, according to land abandonment scenario (shrubs expansion)

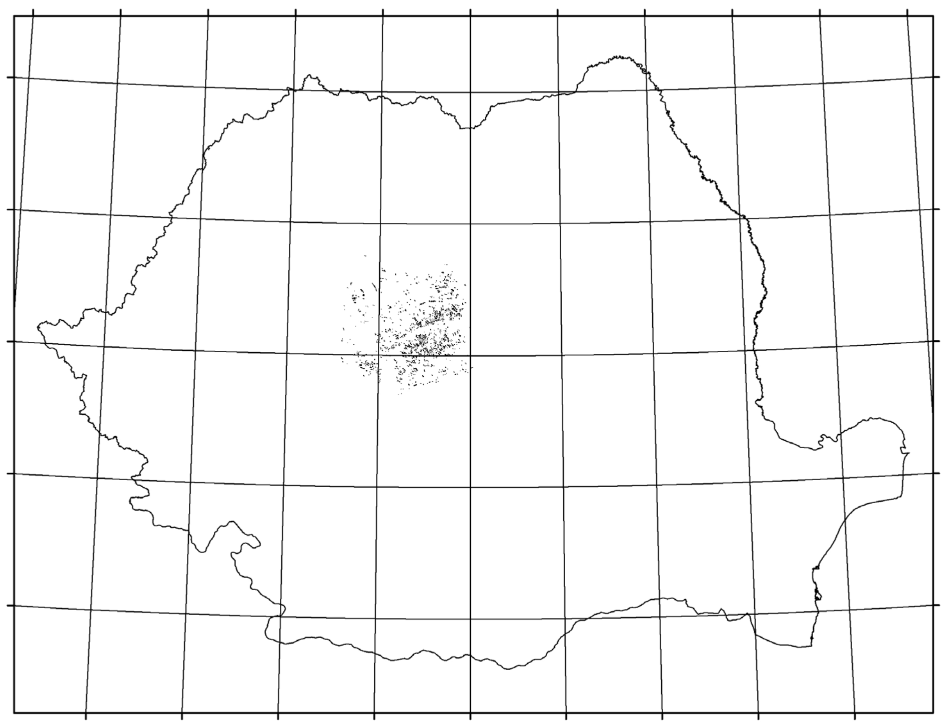

Fig. 10. The distribution map of potential habitats for *P. bavius hungarica* in the year 2050, according to agricultural intensification scenario (expansion of arable lands)

The number of parcels with potential habitats for *P. bavius hungarica* decreased from 9732 that is now current to 3231, according to the most pessimistic scenario of shrub expansion (2050), respectively to 1986 according to the most pessimistic scenario of expansion of arable land (2050).

The surface of potential habitats for *P. bavius hungarica* has also decreased from 87934 ha (9.04 ha / plot) as it is currently, to 26822 ha (8.30 ha /plot) according to the most pessimistic scenario of shrub expansion (2050) (Fig. 11), respectively to 14563 ha (7.33 ha /plot) according to the most pessimistic scenario of expansion of arable land (2050) (Fig. 12).

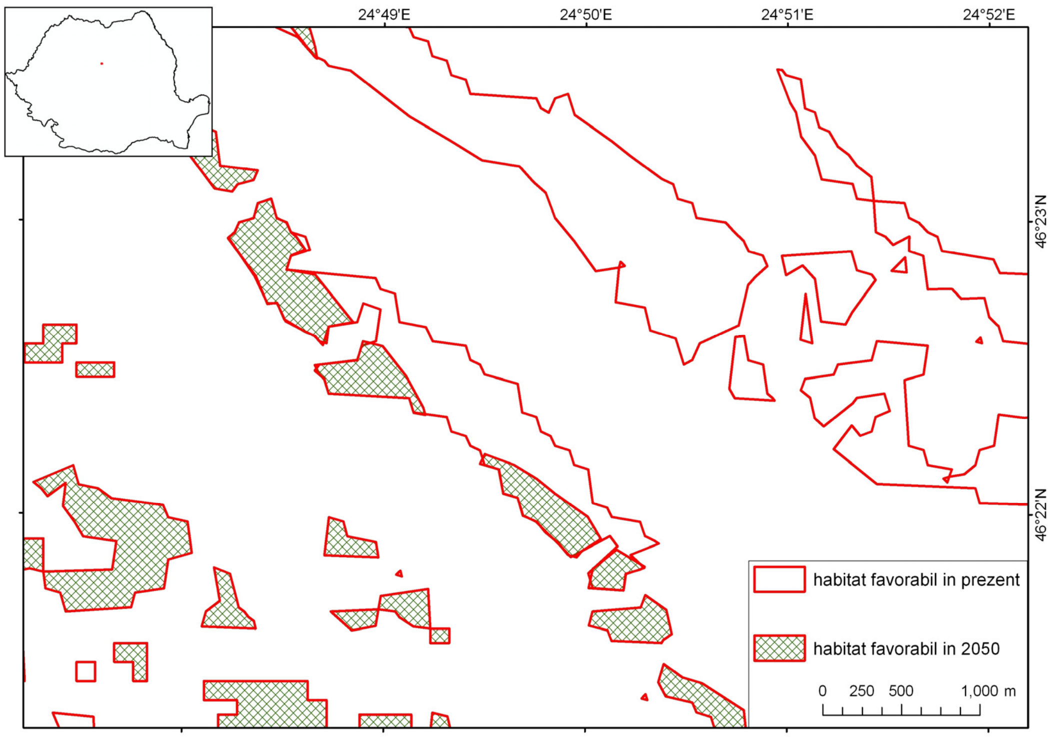

Fig. 11. Resulting example of the modeling of potential habitats for *P. bavius hungarica* according to shrub expansion scenarios

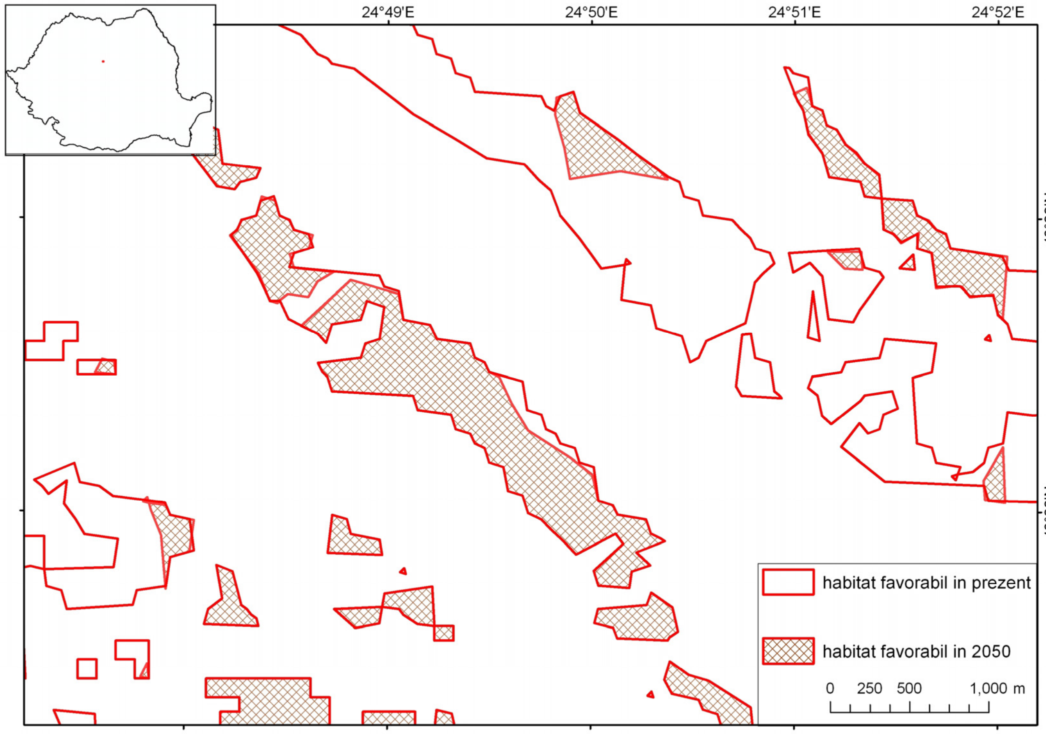

Fig. 12. Resulting example of the modeling for potential habitats for *P. bavius hungarica* according to the increase in agricultural land surface scenario

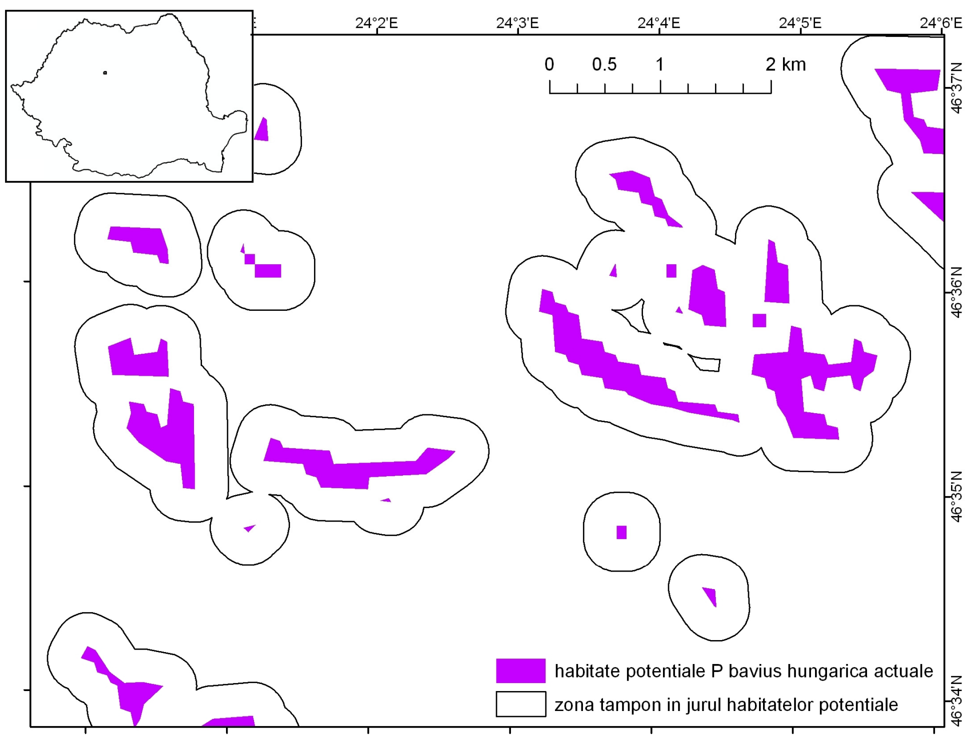

Fig. 13. Illustrations of the current interconnectivity of potential habitats for *P. bavius hungarica*, by creating a buffer area

Other studies have also highlighted the negative influence of the abandonment of use of land as well the intensification of agricultural practices on biodiversity in general and especially butterflies (Schmitt & Rákosy 2007, Enyedi *et al.* 2008, Lütolf 2009, Hartel *et al.* 2010b, Rákosy 2011).

The average of minimum distances between suitable habitats for *P. bavius hungarica* is now 517 m. According to the expansion scenario of shrubs this value will increase to 672 m, and according to the scenario of expansion of arable land the value of this parameter will be 605 m.

Both scenarios foresee (not surprisingly) the increase of distance between suitable habitats for *P. bavius hungarica* over the "threshold" isolation of 600 meters. It is thus highlighted the negative effect that both of the two modes of land use have, overlapped with the changing climatic parameters.

The habitat fragmentation and isolation becomes as evident also through applying the "buffer area" method (Fig. 13). Of the 9732 plots (potential habitats for *P. bavius hungarica*), following the application of buffer zone 1849 (19%) have remained unconnected. Instead, from the resulting 3231 plots according to shrub expansion scenario, 1007 (31%) have remained unconnected, and from the 1986 resulting parcels according to agricultural land expansion scenario, 626 (32%) have remained unconnected.

3.2. Modeling potential habitat distribution by Maxent

3.2.1. Current potential habitats distribution

Because it is recommended that the modeling of the potential distribution to be made through several methods, we chose as additional method the Maxent application (~www.cs.princeton.edu/schapire/Maxent) –which following tests gave satisfactory results even with small samples (<50) (Wisz *et al.* 2008).

Maxent has a robust statistically approach, that identifies areas of distribution of a species based on certain presence and of environmental parameters introduced in modeling using the maximum entropy principle (Phillips *et al.* 2004, 2006, Heikkinen *et al.* 2006 Elith *et al.* 2010).

For modeling the potential habitats distribution using Maxent the following steps were made:

1. A database in .csv format was compiled with the locations where the taxon was identified (it was used the same set of datas as in the previous processing).

2. Thematic layers were prepared for the actual modeling:

a. The climatic datas with the 30'' (approx. 1 km) resolutions have been downloaded and unzipped from WorldClim – Global Climate Data (Hijmans *et al.* 2005) – 19 bioclimatic variables;

b. The layers were made uniform as resolution through the interpolation method.

3. The Maxent v. 3.3.3 application was run with the default settings. (Phillips *et al.* 2004, 2006; Elith *et al.* 2010) (Fig.57).

4. From the final modeling the layers with the correlation (Pearson) coefficient R2>0.75 have been excluded (Habel *et al.* 2011).

5. For the final modeling only 4 of them have been kept, those with the greatestes contribution for the achievement of the model:

- BIO3 – isothermality,
- BIO14 – the rainfall of the driest month of the year,
- BIO6 – the minimum temperature of the coldest month of the year,
- Altimetry map.

The modeling has revealed the endemic taxa character, the distribution of potential habitats being exclusively in Depresiunea Transilvaniei (Fig. 15a).

3.2.2. Potential habitats distribution map for 2050 year

For our study we have used a climate model developed by the Hadley Centre for Climate Prediction and Research (HadCM3) A2 scenario (http://www.worldclim.org/). According to Beaumont *et al.* 2008, the A2 scenario is pessimistic, which foresees a substantial increase in emissions of greenhouse gases, due to uneven economic development, a global population of 15 million inhabitants and a high dependence on fossil fuels.

As for the realization of current potential habitats map, and for the prognosys of potential habitats in 2050 in the application the following 4 rasters have been used: altitude, isothermality (BIO 3), precipitation of the driest month of the year (BIO 14) and the minimum temperature of the coldest month of the year (BIO 6).

The application was run multiple times with different parameters, at different resolutions, until it was obtained the best performance of the model – "Area Under the Curve (AUC)" = 0.99 (Fig. 14).

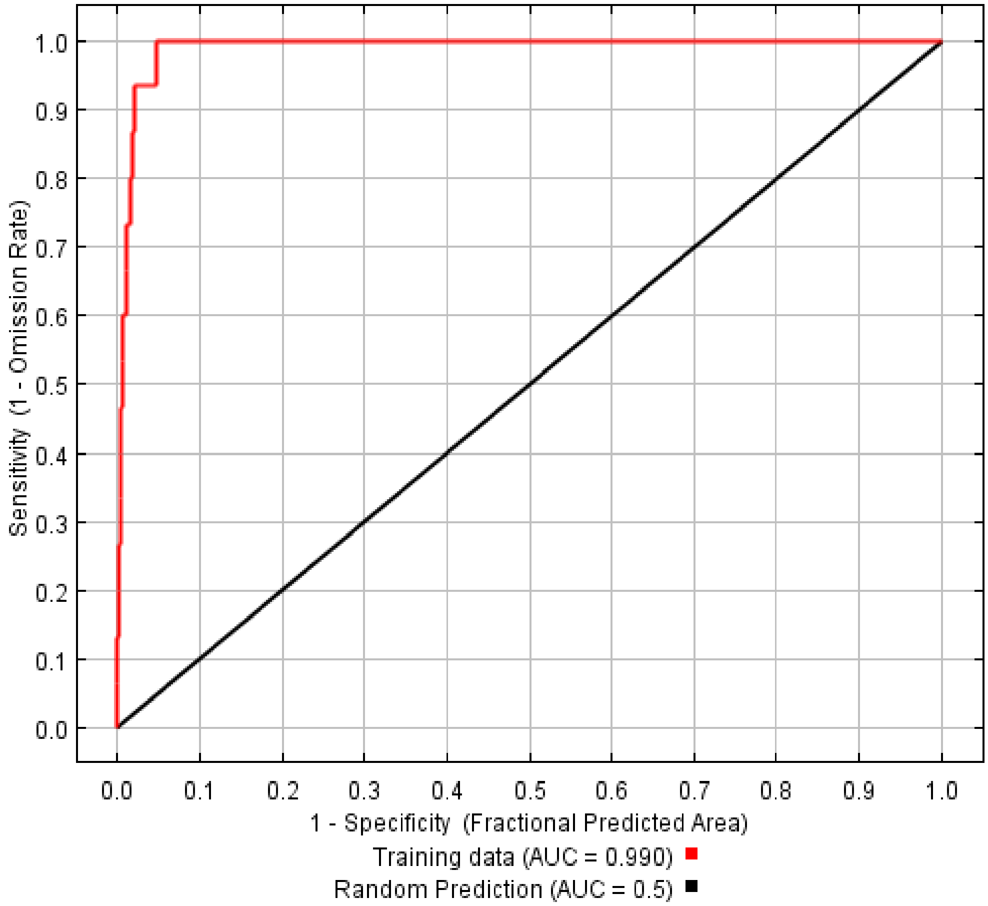

Fig. 14. The modeling performance with Maxent (AUC – red line = 0.99) compared with random distribution (area under the black line = 0.5)

3.2.3. Results

The result of the modeling with Maxent was not surprising and highlighted the significant reduction in potential habitat areas for *P.bavius hungarica* in the conditions of increased carbon dioxide emissions and according to global warming (Beaumont *et al.* 2008) (Fig. 15b).

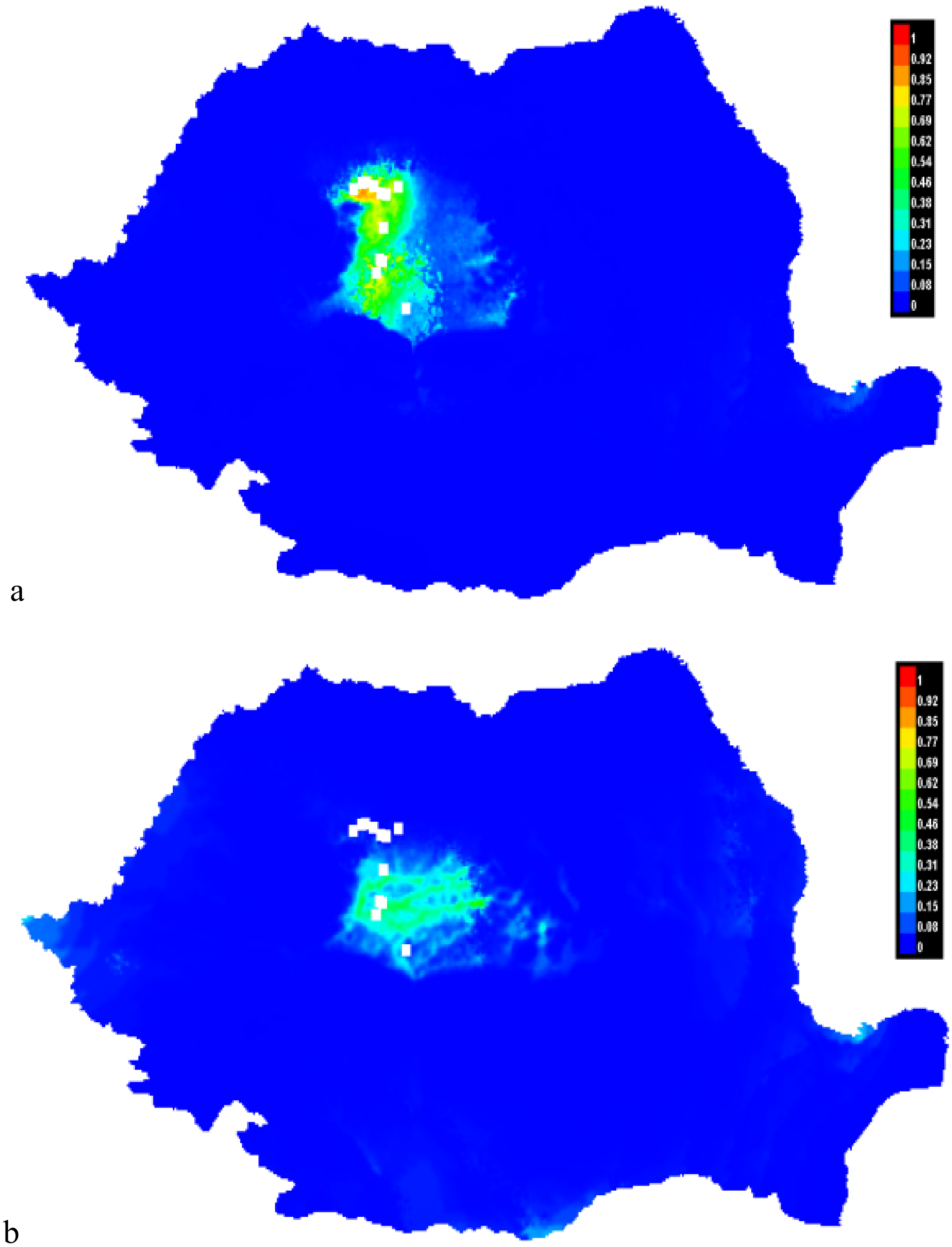

Fig. 15. The map of potential habitats for *P. bavius hungarica* resulted through the maximum entropy method (Maxent):
a) the current situation. b) The situation projected for 2050.
It was used the gradual coloration on a scale from 0 to 1, where 1 is favorable habitat and 0 is inadequate habitat. With white the locations with populations of *P. bavius hungarica* currently known are represented.

Conclusions

- The correct name of the taxa is *Pseudophilotes bavius hungarica* (not *hungaricus*).
- The morphological aspects were detailed and completed with new informations and photographies of higher resolution (macro and SEM), for the adult and also for all the other stages (egg, larva, pupa).
- The flying period of the adults starts at the end oh April and usually continues for 15-17 days, but it can vary significant due to climatic particularities of every year.
- In the field study there were observed plants which can encompass an trophic base for the adults of *P. bavius hungarica*: *Veronica prostrata, Fragaria viridis, Thymus marschallianus* and *Euphorbia seguieriana.*
- The larvae can be infested with the braconid wasp: *Apanteles* sp. and the tachinid fly *Aplomya confinis.*
- The laboratory observations have confirmed the facultative mirmecofily. For the first time it was mentioned the ants species *Camponotus atricolor* in the company of the *P. bavius hungarica* larvae.
- After the study of MRR and the statistical processing of dates in MARK, for the reserve perimeter (for the year 2010) it was been estimated a population of about 661 individuals. For the perimeter situated in the terraces, former vineyards (for the year 2010) it was been estimated a population of about 1019 individuals.
- The average of daily flight distance calculated for the *P. bavius hungarica* individuals was 31 m for the males and 29 m for the females. The maximum daily flight distance was 167 m (one female), and 200 m (one male).
- At Suatu, in the neighborhood of natural botanical reserve, the shrubs vegetation dominated by *R. pseudoacacia* is increasing: in 2004 it measured 8.92 ha and after 5 years, in 2009, it already covered 11.91 ha (increasing with about 30%).
- After 3-5 years with a population of about 1000 or more individuals/year, there are years when the number of individuals decrease dramatically, sometimes couldn't be observed any individual due to causes which aren't totally elucidated.
- GIS modeling result (rasters and vectors overlay and Maxent) revealed significant reduction in potential habitat areas for *P. bavius hungarica* (parcels) due to increased carbon dioxide emissions (global warming) and changes of land use:
    - The number of parcels will come down from 9732 to 3231 according to the most pessimistic scenario of fields abandon (shrubs extending), respectively to 1986 according to the most

pessimistic scenario of agriculture intensification (extending of arable fields).

- Also, the surface of potential habitat for *P. bavius hungarica* will decrease from 87934 ha (9.04 ha / plot) as it is currently, at 26822 ha (8.30 ha / plot) according to the most pessimistic scenario of expansion of shrubs (2050), respectively to 14563 ha (7.33 ha / plot) according to the most pessimistic scenario of expansion of arable land (2050).
- The average distance between plots will increase from 517 m to 672m according to the scenario of expansion of shrubs vegetation, respectively to 605 m according to the scenario of expansion of arable land.
- In the present, from 9732 plots - 19% (1849 plots) are isolated (there are a distance of 600 meters or greater between them). According to shrub extension scenario, from 3231 plots - 31% (1007 plots) are isolated. According to scenario of arable lands extension, from 1986 plots - 32% (626) are isolated.

Knowing that the average daily flight distance of individuals of *P. bavius hungarica* is below 35 m, maximum distance traveled during their lifetime do not exceed 600 m (exceptionally 1 km), justify the assertion that much of the population of these taxon is vulnerable in terms of habitat fragmentation and isolation.

The model developed for *P. bavius hungarica* can be applied to other organisms also.

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Acknowledgments

- **Prof. Dr. László Rákosy** – coordination;
- Dr. Cristian Maloş, Cristian Domşa and Adrian Mureşan – GIS advise;
- Dr. Szabolcs Lengyel and Katalin Varga (Debrecen University) – GIS and statistical advise (ArcGIS 9.3 and SPSS 16);
- Conf. Univ. Dr. Anuța Buiga - statistical advise (SPSS 16);
- Dr. Piotr Nowicki - statistical advise (MARK 6.0);
- Dr. Cristina Craioveanu, Cristian Sitar, Raluca Vodă, Natalia Timuş, Inge Paulini and Răzvan Popa – field work, translation and scientific papers elaboration;

- Tibor-Csaba Vizauer and Bogdan Adumitroaiei – data about *P. bavius hungarica* population from Suatu (2004);
- Dr. Zoltán Varga and Dr. Thomas Schmitt – papers reference;
- Dr. Balint Marko, Dr. Joachim Ziegler and Dr. Andreas Taeger – insects determination;
- Şef Lucr. Dr. Irina Goia – plants determination;
- Dr. Ciprian Mihali, Cristian Sitar and Prof. dr. László Rákosy – some of *P. bavius hungarica* photos;
- Prorector Prof. dr. Luminița-Silaghi Dumitrescu, Camelia Morar, Gabriela Crişan, Adela Matiş, Erzsébet Bogya, Zsuzsánna Borbáth and dr. Cristian Coman - the financial support provided from programs co-financed by The SECTORAL OPERATIONAL PROGRAMME HUMAN RESOURCES DEVELOPMENT, Contract **POSDRU 6/1.5/S/3 – „**Doctoral studies: through science towards society**"**;
- **My dear wife Claudia-Tabita** (biologist) - encouragement and support.