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Multiannual population size estimates and mobility of the endemic *Pseudophilotes bavius hungarica* (Lepidoptera: Lycaenidae) from Transylvania (Romania)

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Abstract. *Pseudophilotes bavius hungarica* is an endemic butterfly subspecies with high conservation value from Transylvania, yet its populations have not been consistently analysed. We assessed two fragments of a population of *P. bavius hungarica* from a botanical natural reserve and its surroundings with Mark-Release-Recapture method in the years 2004-2006, 2010-2012. The area considered to harbor one of the strongest populations known in Romania. Our study shows a fragmentation of the population and a tendency to decline in the number of individuals over the last 8 years as a result of abandonment of traditional management practices. The short lifespan (3 days) and low mobility (30 meters per day) of this butterfly negatively influences its dispersal capacity, which is aggravated by the spread of native and non-native shrubs (at a rate of 40% in 5 years), isolating population fragments.

Keywords: natural succession; mark-release-recapture; population ecology; mobility; fragmentation; conservation considerations.

Introduction

Food plant specialist Lycaenid butterflies are often good indicators of habitat quality and therefore some are threatened by habitat fragmentation and degradation as a consequence of changes in land use (Erhardt 1985, Thomas 1991, Erhardt & Thomas 1991, Munguira et al. 1993, New 1993, Polus et al. 2007, Thomas 2012).

Pseudophilotes bavius is included in the Annexes of the Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora (annexes II and IV), 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 in the Red List of Romania (EN) (Rákosy 2002, Rákosy et al. 2003). Contrary to the classification in the European Red List (Van Swaay et al. 2010) it is probably more endangered than its threat category suggests due to habitat fragmentation and isolation of small populations (Van Swaay et al. 2012). Furthermore, the taxon *P. bavius hungarica* (Diószeghy 1913) is an endemic subspecies from Transylvania. The Transylvanian Blue is restricted to steppe-like habitats with abundance of the host plant *Salvia nutans* (König 1992). One of the largest known populations in Transylvania is located in and around the botanical nature reserve in Suatu (county Cluj). Historically the population occupied the whole Bánffy hill (which is included in a Natura 2000 site since 2007), and is now restricted to two larger patches of remaining suitable habitat: inside the nature reserve and on a patch of abandoned vineyard terraces outside the nature reserve. Observations on this population began in 1977 in form of yearly observations (Rákosy 1983, 1999). The first Mark-Release-Recapture (MRR) studies in the nature reserve were conducted in 2004 (Vizauer & Adumitroaie 2005) and 2005 (Vizauer et al. 2006).

In this study we assessed the butterfly's population in order to see the effect of habitat reduction and its fragmentation in recent years and the effect of different land use (protected natural reserve with no human intervention and extensively grazed former vineyards) on its population size. Additionally we registered other parameters (flight distance, individual life span etc.) influencing its survival and dispersal ability.

The slope of the natural reserve was originally covered by a semi-natural grassland rich in relict-like steppe species (Borza 1931, Resmeriță 1971, Cristea 1994). This habitat type can be considered as the continuation of the south Russian meadow steppes. It was stabilized following the last post-glacial warmer period by removal of forests and traditional mowing and partly occasional grazing by cattle (Wendelberger 1985, Rákosy 2011). This type of land use was beneficial to most of the rare and endemic species of plants e.g. *Astragalus peterfii*, *Salvia transsilvanica*, *Cephalaria radiata* etc. (Resmeriţă 1971) and also for the development of a population of *P. bavius hungarica* and a high diversity of other Lepidoptera species (Rákosy 1999).

A management plan developed by the nature reserve administration (Mihuţ et al. 2001) proposed in 2001 the alternating mowing of plots at the end of the vegetation period, together with installing infrastructure to prevent access of cattle and sheep to the nature reserve. However, just the access of livestock was prevented and no alternating mowing treatment was applied in the following period. We hypothesize that this lack of management has lead to a significant decline of the population of *P. bavius hungarica* from Suatu (Enyedi et al. 2008, Rákosy 2011) due to reduction of suitable habitat. Furthermore, in order to stabilize steep slopes in areas adjacent to the reserve, *Robinia pseudoacacia* plantations were established approximately 25 years ago. In the same period the natural expansion of autochtonous scrub species such as *Crataegus monogyna*, *Prunus spinosa*, *Rosa* sp. also contributed to the fragmentation of the former open steppe-like habitat with a barrier between the natural reserve and the former vineyards. We verify the possibility of individual exchange between population fragments of *P. bavius hungarica* and analyze the threat of their complete isolation.

Based on these findings we propose a series of criteria for conservation management.

Materials and Methods

Study sites

Studies were conducted on the Bánffy hill in Suatu, 35 km E of Cluj-Napoca (46°47′28″ N, 23°57′59″). Two equal-sized sites (each 7500 m^2), representing patches of suitable habitat for *P. bavius hungarica*, were selected, and each were subdivided into 12 plots (each 25m x 25m) with high density of *S. nutans*. One of the areas is located inside the natural reserve (site A) and the other on the vineyard terraces (site B), which have been abandoned for 30-35 years, possibly longer, both with the same SW aspect and similar slope and altitude (23°, 350-375m a.s.l. and 28°, 370-425 m a.s.l. respectively). In the natural reserve the following plant associations were described by Resmeriţă (1971): *Stipetum lessingianae, Salvio nutantis-Festucetum rupicolae, Festucetum valesiacae-rupicolae, Botriochloetum ischaemi* and *Carici humilis-Brachypodietum pinnati*. In site B located in the abandoned vineyards following plant associations were found: *Salvio nutantis-Festucetum rupicolae, Stipetum lessingianae, Carici humilis-Brachypodietum pinnati, Pruno spinosae-Crataegetum* and small patches of *Prunetum tenellae*. The distance between the two study sites is approximately 1 km and they are partially separated by a belt of shrubs of *Crataegus monogyna*, *Prunus spinosa*, *Rosa sp*. and dominated by *Robinia pseudoacacia* (Fig. 1).

Sampling methods

MRR data from the years 2004, 2005, 2006 were collected in the nature reserve site (A) and in 2010, 2011 and 2012 from both the nature reserve site (A) and former vineyard site (B). Butterflies were captured every day (with exceptions caused by unfavourable weather in 2004, 2005, 2006 and 2010) between 9:00 A.M. and 7:00 P.M, between 21 April – 18 May 2004, 05-18 May 2005, 25 April – 20 May 2006, 23 April – 11 May 2010, 18 April – 3 May 2011 and 26 April – 7 May 2012, on a regular basis by the same two recorders in any one year, but different recorders from year to year. Altogether 9, 7, 6, 10 (site A), 12 (site B), 5 (site A), 6 (site B) and 11 (site A) and 10 (site B) field trips respectively, were conducted in the two study sites, investing the same time and effort in capturing and marking, by both recorders. In the case of each capture/recapture, sex of the captured individual, capture time and coordinates of the exact location were recorded. In the years 2010-2012 exact location coordinates were recorded with a GPS device Garmin GPSmap 60 CSx. The sequence in which plots were inspected was alternated to avoid systematic effects of time of day.

Statistical analyses

MRR data with over 5% recapture rates from the years 2004, 2005, 2010 and 2012 were analyzed to estimate the current population size, flight distance and average life-span of adults of *P. bavius hungarica*. Data were analysed separately for site A in 2004, 2005, 2010 and 2012 and for site B in 2010 and 2012, with the Cormack-Jolly-Seber type constrained models (Schwarz & Arnason 1996; Schwarz & Seber 1999) using the program MARK 6.0 package (Cooch & White 2010). The performances of the models were assessed separately for each site with the Akaike Information Criterion corrected for small sample size (AICc) (Akaike 1973; Hurvich & Tsai 1989). As recommended by Burnham and Anderson (2002), after running predefined models in program Mark, we selected the model with the lowest ΔAICc and the smallest number of parameters. The models considered to best approximate the effects of factors supported by empirical data, are the ones with AICc differing from the minimal one by less than 2. In 2010 the best fitted models did not coincide for site A and site B. We did not select the same model for site A as for site B even though site A had a smaller sample size. This decision was made because the two sites have two different habitat types.

Individual life span was estimated using the formula $\hat{e}=(1-\varphi)^{-1}-0.5$ ($\hat{e}$ is the individual life span, φ is the sur-

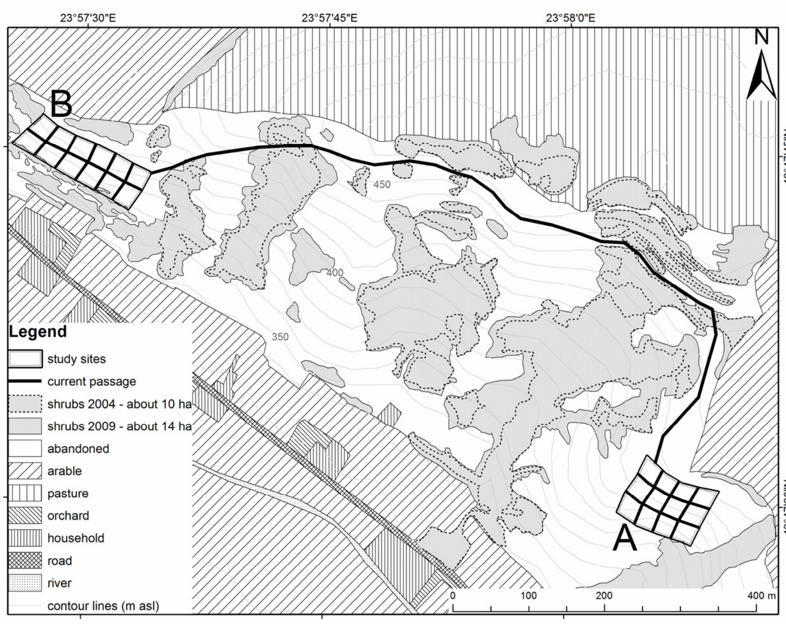

Figure 1. Map of the study sites A and B located on the Bánffy hill in Suatu (Cluj County) representing the land use, expansion of the shrubs over a period of five years between the two study sites and present possible passage corridor between them.

vival probability) (Nowicki et al. 2005). The parameters resulted from analysing the data with the program Mark 6.0, survival and capture probability, were used to estimate daily number of individuals in each capture occasion (i.e. days of capture) and recruitment of new individuals into the population.

We compared the number of marked individuals in all years in site A (2004, 2005, 2006, 2010, 2011 and 2012) and of estimated individuals in the years 2004, 2005, 2010, 2012 with a Kruskall-Wallis test, because datasets were not normally distributed. Pair wise comparisons between numbers of marked individuals and estimated individuals per year were computed with a Mann-Whitney U-test (with the program StatView 5.0). Comparisons between numbers of marked and estimated individuals in the two study sites in the years 2010 and 2012 were computed with the same non-parametric test.

The flight distances between recaptures were calculated (in meters per day: m d^{-1}) pooled for both sites A and B because of a low number of recaptures in site A in 2010 and in site B in 2012. To calculate the mean daily flight distance we calculated the mean distance between the points of individual capture and recapture events, separately for males and females (using ArcMAP 9.2), divided by the number of days elapsed between the two events. Comparisons between flight distances of different years for all individuals and separately for males and females and between males and females over the years 2010 and 2012 and separately in each year were also computed with a Mann-Whitney U-test (with the program StatView 5.0), because datasets were not normally distributed. Because no significant differences were found between daily flight distances of males and females we calculated these values pooled over study sites, sexes and years 2010 and 2012, in order to estimate an overall mobility for this butterfly.

Results

194 individuals were marked in 2004, 426 in 2005, 40 in 2006, 474 (in both sites A + B) in 2010, 35 (in both sites A + B) in 2011 and 115 (in both sites A + B) in 2012. The recapture rates varied largely between 0% (in 2011) and 32% in 2012 (Table 1). The majority (85%) of the individuals recaptured,from all years, were only recaptured on 1 occasion, 13% were recaptured on 2 occasions and 2% were recaptured on 3 ocasions. Most males (82%) were recaptured after 1 (18%), 2(29%), 3(14%) and 4(21%) days. Most females (97%) were recaptured after 1(32%), 2(23%), 3(19%), 4(11%), 5(7%) and 6(5%) days. The population estimates based on the survival (Phi) and capture (p) probabilities for each year varied between years from 60 to 1524 (Table 1).

Individual lifespan varied between 2.4 and 5.4 days (Table 1) and maximum life span registered

Table 1. Summary of the MRR study, population estimates (computed with MARK 6.0 program) and individual life span of *Pseudophilotes bavius hungarica* in the years 2004, 2005, 2006, 2010, 2011 and 2012. (n.p.- not possible).

Year	Study site	Capture/ recapture events	Marked individuals			Recaptured Individuals[a]			Recapture Ratio (%)	Population estimates				Lifespan (days)
			♂♂	♀♀	Total	♂♂	♀♀	Total		No. of indiv.	Model[c]	Survival[d]	Capture probability[d]	
2004	A	9	85	110	195	14	9	23	11.80	825	Phi(.)p(.)	0.660	0.178	2.4
2005	A	7	146	280	426	21	31	52	12.21	1534	Phi(t)p(.)	0.799	0.126	5.4
2006	A	6	29	11	40	1	1	2	5.00[b]	n.p.				
2010	A	10	74	69	143	7	2	9	6.29	1001	Phi(g*t)p(.)	0.409	0.118	2.4
	B	12	119	212	331	31	73	104	31.42	1027	Phi(.)p(t)	0.735	0.194	3.0
2011	A	5	5	4	9	0	0	0	0.00[b]	n.p.				
	B	5	19	7	26	0	0	0	0.00[b]	n.p.				
2012	A	11	29	45	74	12	12	24	32.43	149	Phi(.)p(.)	0.673	0.277	2.6
	B	10	11	30	41	3	6	9	21.95	60	Phi(.)p(.)	0.811	0.270	4.8

[a] individuals recaptured at least once on a different capture occasion in the same study site
[b] recapture ratio too low to use in population estimates with program Mark
[c] the chosen models have delta AICc <2 and the lowest number of parameters
[d] value if constant and average if variable

(a male) was 12 days.

In the nature reserve site (A), we found significant differences in different years between the numbers of marked individuals (Kruskal–Wallis test, H=24.21, p=0.0002) and between the estimated number of individuals per capture occasion (Kruskal–Wallis test, H=25.68, p<0.0001).

In the nature reserve site in 2005 the number of marked individuals and the population estimates per capture occasion were significantly higher than in the other years (Mann-Whitney U-test, p<0.05 in all comparisons) (Fig. 2). The number of marked individuals in the years 2006, 2010-2012 was significantly lower than in the years 2004 and 2005, and 2011 had the lowest number of marked individuals from the analyzed years (Mann-Whitney U-test, p<0.05 in all comparisons).

The year 2012 had the lowest number of estimated individuals per capture occasion from all analyzed years (Mann-Whitney U-test, p<0.05 in all comparisons).

In the abandoned vineyard site (B), we found significant differences in different years between the numbers of marked individuals (Kruskal–Wallis test, H=13.74, p=0.001) and between the estimated number of individuals per capture occasion (Mann-Whitney U-test, N_{2010}=12, N_{2012}=5, $Median_{2010}$=209, $Median_{2012}$=30, U=0.00, p=0.002). In the abandoned vineyard site in 2010 the number of marked individuals and the population estimates per capture occasion were significantly higher than in the other years (Mann-Whitney U-test, p<0.05 in all comparisons) (Fig. 3).

The number of marked and estimated individuals in the two study sites was higher in the abandoned vineyard site (B) in the year 2010 (Mann-Whitney U-test N_A=10, N_B=12, marked individuals: $Median_A$=11, $Median_B$=45, U=21.5, p=0.011; estimated individuals: $Median_A$=47, $Median_B$=209, U=18.0, p=0.006) (Fig. 4).

In 2011 and 2012 there were no significant differences between sites A and B regarding the number of marked individuals and estimated individuals per capture occasion (Mann-Whitney U-test, p>0.05 in all cases).

The mean daily flight distances for both males and females pooled over the two study sites was 27 m d^{-1} (1 SE: 2.24, n=112) in 2010, and 25 m d^{-1} (1 SE: 4.88, n=39) in 2012. In 2010 the mean daily flight distances were 27 m d^{-1} (1 SE: 2.83, n=75) for females and 27 m d^{-1} (1 SE: 3.73, n=37) for males. In 2012 the mean daily flight distances were 33 m d^{-1} (1 SE: 8.45, n=21) for females and 17 m d^{-1} (1 SE: 3.00, n=18) for males. The mean daily flight distance pooled over study sites, over sexes and over the years 2010 and 2012 was 26 m d^{-1} (1 SE: 2.08 SE, n=151) (Table 2).

We found no significant differences in the daily flight distances between different years (Mann-Whitney U-test, p>0.05 in all cases). The daily flight distances were marginally significant higher for females than for males in 2012 (Mann-Whitney U-test, $N_{females}$=21, N_{males}=18, $Median_{females}$=24, $Median_{males}$=14, U=265, p=0.03 respectively).

78% of the females and 76% of the males flew daily over a distance of under 30 m (Fig. 5.).

Considering the mean estimated lifespan of

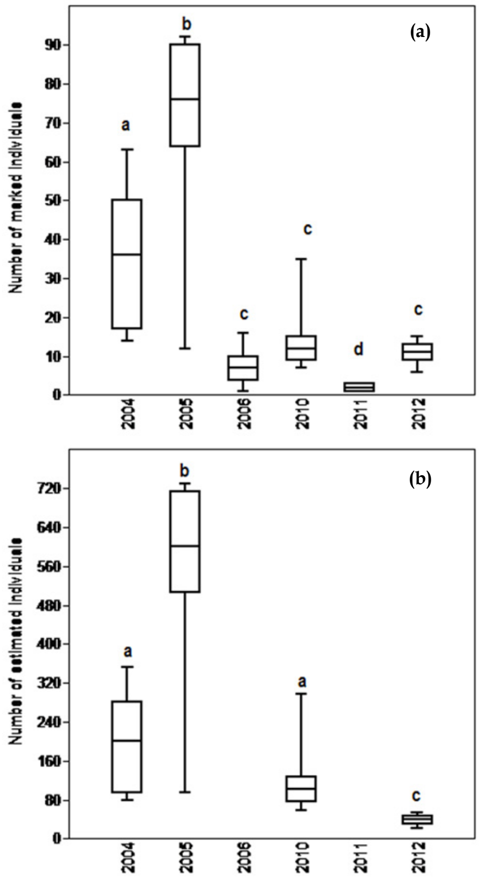

Figure 2. Comparisons between the number of marked individuals (a) and the population estimates per capture occasion (b) in the nature reserve site from Suatu in different years. Box plots represent 25-75 percent quartiles (boxes), median (line inside the box) and standard error (whiskers), and different letters (a, b, c, d) indicate significant differences (Mann-Whitney U-test, $p<0.05$)

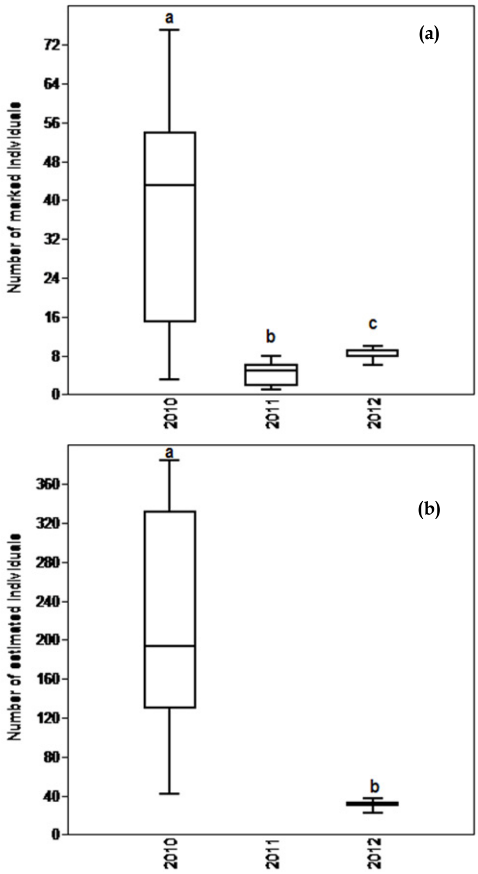

Figure 3. Comparisons of the number of marked individuals (a) and the population estimates per capture occasion (b) in the abandoned vineyard site from Suatu between different years. Box plots represent 25-75 percent quartiles (boxes), median (line inside the box) and standard error (whiskers), and different letters (a, b, c) indicate significant differences (Mann-Whitney U-test, $p<0.05$).

3.4 days, most of the individuals would be able to fly in their lifetime over a distance of approximately 100 m.

In 2010 one female marked at study site A was recaptured at study site B after 5 days (168 m d^{-1}), and a male marked at study site B was recaptured in the westernmost part of study site A after 4 days (200 m d^{-1}). In 2012 two females were marked at study site B and recaptured at study site A after 5 days (183 and 232 m d^{-1} respectively). The passage way, consisting of a strip of open habitat with patches of *S. nutans*, probably used by these individuals, was identified near the top of the hill (Fig. 1).

The area of the shrubs expanded in the time period 2004-2009 by 43.58% (4.21 ha); in 2004 it measured 9.66 ha and in 2009, it covered 13.87 ha (Fig. 1.).

Discussion

The *P. bavius hungarica* population from Suatu (Cluj County) is known to be the largest existing populations of this taxon in Transylvania; the greatest proportion occupied the area of the nature reserve (where our study was conducted in the years 2004-2006) and a smaller proportion in the close surroundings. Presently, this population consists of two larger fragments (where our study was conducted in 2010-2012) occupying two re-

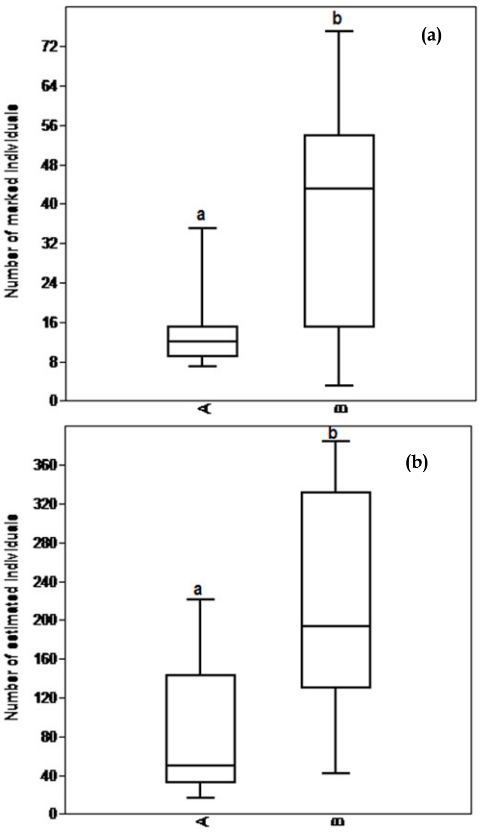

Figure 4. Comparisons in the number of marked individuals (a) and the population estimates per capture occasion (b) between the two study sites (A and B) in the year 2010. Box plots represent 25-75 percent quartiles (boxes), median (line inside the box) and standard error (whiskers), and different letters (a, b) indicate significant differences (Mann-Whitney U-test, p<0.05)

Table 2. Descriptive statistics for daily flight distances (in meters) of *P. bavius hungarica* pooled over the two investigated study sites and over the years 2010 and 2012 for males and females separately, and pooled over sexes.

	Daily flight distances		
	♀	♂	Total
Median:	19	18	19
Variance:	789.342	417.194	655.343
Minimum:	3	2	2
Maximum:	191	118	191
Sample size:	96	55	151
1st Quartile:	12	10	11
3rd Quartile:	31	30	31
Mean:	28.175	23.435	26.449
Standard deviation:	28.095	20.425	25.600
Standard error:	2.867	2.754	2.083

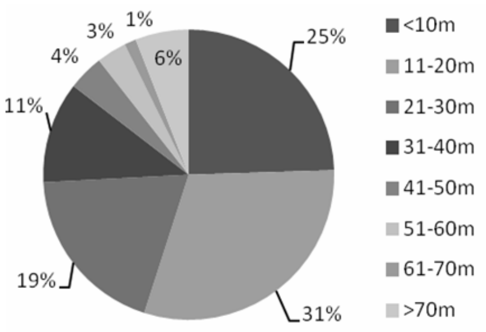

Figure 5. Distribution of daily flight distances in the two individual samples of *P. bavius hungarica* of from 2010 and 2012, in both investigated study sites from Suatu (Cluj County) for both sexes.

maining suitable habitat patches with high abundance of *S. nutans*, one inside the area of the nature reserve and the other on a patch of abandoned vineyard terraces.

Data from MRR studies showed a decrease of the number of individuals, especially in the nature reserve site. While in 2010 the former vineyard terraces seemed to offer a more suitable habitat than the nature reserve, sustaining a larger number of individuals, in 2011 and 2012 the situation changed, and both population fragments had a lower marked and estimated number of individuals than in previous years.

The natural succession of the grassland towards climax vegetation in the nature reserve was not hindered by any land use practice after the year 2001, when the proposed management plan for the nature reserve was not completely implemented (Mihuţ et al. 2001). As a consequence an alteration and degradation of the habitat structures occurred. Abandonment of extensive grazing of steppe-like grasslands from Suatu leads to changes in plant associations from *Stipetum lessingianae* to *Stipetum pulcherrimae* (Enyedi et al. 2008). The first is characteristic for persistently and extensively grazed sites and the second represents long abandoned sites. Plant association transformations brought with them a change in vegetation ground cover and with succession a reduction in bare ground (of 7%) (Ruprecht et al. 2009). *Salvia nutans*, the exclusive larval host of *P. bavius hungarica*, depends on the presence of bare ground, and was attributed by Ruprecht et al. (2009) to the plant alliance (*Stipion lessingianae*) typical for extensively grazed sites. Another study from the Ukrainian steppe also attributes *S. nutans* to plant communities resulted from human activities (Kawada et al. 2005). In Romania, another study described the plant to be a xero-mesophyte that occurs on excessively eroded slopes resulted from degradation of feather grass associations (Baciu et al. 2009). Wakhrusheva & Wakhrushev (2013) describe the significant loss of true steppe plant communities in Ukraine and the Crimean Peninsula due to large-scale intensification of grazing on the one hand, and to the reserve-induced succession resulted from strict protection regimes in the nature reserves.

Previous examples of inappropriate management of nature reserves from the UK showed that some species of butterflies may even become extinct on areas especially designated for them (Thomas 1984, Warren 1992, Warren 1993).

Abandonment of traditional land use practices since 2001 lead to the expansion of autochtonous (*P. spinosa, C. monogyna, Rosa* sp.) and allochtonous (*R. pseudoacacia*) shrubs at a rate of approximately 40% in 5 years (Fig. 1).

The closing canopy of the shrubs prevents the persistence of ground vegetation including nectar sources and larval host plants, *S. nutans*. As *P. bavius hungarica* has a slow flight, it proved to be very sedentary (27 m d^{-1}) (mobility class according to Pollard & Yates 1993) and has a short life span (3.4 days), the presence of suitable nearby habitat patches might be crucial for its dispersal. Other studies have also identified limited dispersal ability in small Lycaenid butterflies (Lewis et al. 1997, James et al. 2003). The low mobility, however, is not necessary an indicator for a higher extinction probability, as sedentary species usually require smaller habitat patches (Thomas 2000). Furthermore, population fragments resulting from fragmentation through shrub expansion could lose within-population genetic diversity and become in time more genetically differentiated, a feature identified for local, isolated populations (Thomas & Harrison 1992, Brookes et al. 1997, Lewis et al. 1997, Castric & Bernatchez 2003, Hampe & Petit 2005, Besold et al. 2008, Adersen et al. 2014).

However, if suitable habitat patches are constantly being reduced, while barriers like thick shrubs will expand, they will eventually reach the point at which habitat size will not be sufficient, leading to higher population densities which in turn will favour migration. Migration mortality might then exceed the reproductive output in the local populations (Thomas 2000) because of lack of suitable intermediate 'stepping stone' habitat patches. In Suatu, what once used to be a single population of *P.bavius hungarica* spread out on interconnected habitat patches with high density of *S. nutans*, has now been separated into two larger fragments with very low individual exchange (2 marked individuals both in 2010 and in 2012).

Between the two population fragments we have identified only one passage through the shrub belt located near the top of the hill. Several individuals were observed transiting this passage, using *S. nutans* stands as stepping stones (Fig. 1).

Thomas et al. (2001) highlighted the importance of managing patches for butterfly populations' conservation to create optimal habitat. After habitat quality, the most important factor in management success for conservation is providing the minimum area of habitat required for a viable population (Dennis & Eales 1997, 1999; Thomas et al. 2002). There are indications that there may be general critical thresholds in habitat loss after which extinction is probable (Bergman et al. 2004; Andrén 1994). Thus development of efficient management strategies is urgently needed for this species to prevent further habitat loss due to fragmentation.

One way of improving the chance of a species' survival in an area, is to enhance the availability, or accessibility, of non-adjacent habitat patches (Ouin et al. 2004), even if they are of suboptimal quality. Suboptimal neighboring habitat would be important not only for ensuring the dispersal ability for the *P. bavius hungarica* population, but also because conserving suitable habitat for one species might provide suboptimal or even optimal habitat for other species too (e.g. Vandewoestijne & Baguette 2004; Belfrage et al. 2005). In the situation of the Transylvanian blue from Suatu we should aim to restore and maintain an optimal habitat quality and size in the two larger remaining habitat patches and create new suboptimal habitat passage ways to prevent total isolation of the two population fragments, following the principle stated by Samways (2007): large optimal habitat patches with good connectivity.

Future studies should also take into account an estimation of the resource qualities (the correlation between plant diversity and the number of butterfly individuals in the population) to estimate the habitat quality required to support a viable *P. bavius hungarica* population. This kind of relationship has been proven before to be very useful by a study on a species of the same genus (James et al. 2003). Also complex population viability studies with genetic analyses complementing ecological data should be done to investigate the long term capacity of the population to survive.

Through this study we identified several issues that may be critical to the long term survival of the strongest known population in its original habitat of *P. bavius hungarica* :

1) The population that used to be until 2006 a relatively homogenous one on the Bánffy hill, has split into two larger fragments.

2) Population size shows a tendency to decrease in both remaining fragments in the last years.

3) The reduced mobility of this butterfly allows it to move over approximately 100 m in its short lifespan (3 days).

4) Habitat on the Bánffy hill has changed through ecological succession (due to abandonment of traditional agricultural practices) that reduces the area occupied by the host plant *S. nutans*.

5) Suitable patch reduction and isolation through expansion of native and non-native shrubs (at a rate of 40% in 5 years) act as dispersal barriers.

6) We identified only one (long) passage way between population fragments on the top of the hill, and lack of other passage ways through the shrub belt prevents individual exchange.

7) There is a lack of conservation measures (e.g. an updated management plan) and in their planned implementation.

These factors, that threaten the persistence of the *P. bavius hungarica* population in Suatu, should be taken into consideration when planning conservation efforts.

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References

Akaike, H. (1973): Information theory and an extension of the maximum likelihood principle. pp 267-281. In: Petrov, B.N., Csáki, F. (eds.) Second international symposium on information theory. Akadémiai Kiadó, Budapest.

Andersen, A., Simcox, D.J., Thomas, J.A., Nash, D.R. (2014): Assessing reintroduction schemes by comparing genetic diversity of reintroduced and source populations: A case study of the globally threatened large blue butterfly (*Maculinea arion*). Biological Conservation 175: 34-41.

Andrén, H. (1994): Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review. Oikos 71: 355-366.

Belfrage, K., Björklund, J., Salomonsson, L. (2005): The Effects of Farm Size and Organic Farming on Diversity of Birds, Pollinators, and Plants in a Swedish Landscape. AMBIO: A Journal of the Human Environment 34(8): 582-588.

Bergman, K.O., Askling, J., Ekberg, O., Ignell, H., Wahlman, H., Milberg, P. (2004): Landscape effects on butterfly assemblages in an agricultural region. Ecography 27: 619-628.

Besold, J., Schmitt, T., Tammaru, T., Cassel-Lundhagen, A. (2008): Strong genetic impoverishment from the centre of distribution in southern Europe to peripheral Baltic and isolated Scandinavian populations of the pearly heath butterfly. Journal of Biogeography 35: 2090-2101.

Borza, A. (1931): Botanic excursion through the "Câmpia". Pp. 196-209. In: Borza, A. (ed.), Guide de la sixième excursion phytogéographique international, Roumanie 1931. Grădina Botanică, Cluj, Romania.

Burnham, K.P., Anderson, D.R. (2002): Model selection and multi-model inference: a practical information-theoretic approach (2nd edition). Springer, New York.

Castric, V., Bernatchez, L. (2003): The Rise and Fall of Isolation by Distance in the Anadromous Brook Charr (*Salvelinus fontinalis* Mitchill). Genetics 163: 983-996.

Cooch, E., White, G. (eds.) (2010): Program MARK "A Gentle Introduction", 9th edn. Cornell University, US.

Cristea, V. (1994): La réserve botanique de Suatu (Départament de Cluj, Romanie). La Riserva Naturale di Toricchio, Camerino, Italia 8: 19-25.

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.

Dempster, J.P. (1989): Insect introductions: natural dispersal and population persistence in insects. The Entomologist 108: 5-13.

Dennis, R.L.H., Eales, H.T. (1997): Patch occupancy in *Coenonympha tullia* (Müller, 1764) (Lepidoptera: Satyrinae): habitat quality matters as much as patch size and isolation. Journal of Insect Conservation 1: 167-176.

Dennis, R.L.H., Eales, H.T. (1999): Probability of site occupancy in the large heath butterfly *Coenonympha tullia* determined from geographical and ecological data. Biological Conservation 87(3): 295-301.

Diószeghy, L. (1913): Adatok a *Lycaena bavius* Ev. életmódjához. Rovartani Lapok, Budapest 20: 105-109.

Enyedi, Z.M., Ruprecht, E., Deák, M. (2008): Long-term effects of the abandonment of grazing on steppe-like grasslands. Applied Vegetation Science 11: 55-62.

Erhardt, A. (1985): Diurnal Lepidoptera–sensitive indicators of change in the semi-natural grassland. Journal of applied Ecology 22: 849-62.

Erhardt, A., Thomas, J.A. (1991): Lepidoptera as indicators of change in the semi-natural grasslands of lowland and upland

Europe. pp. 213-236. In: Collins, N.M., Thomas, J.A. (eds.), The conservation of insects and their habitats. Academic Press, London.

Gutiérrez, D., Thomas, C.D., León-Cortés, J.L. (1999): Dispersal, distribution, patch network and metapopulation dynamics of the dingy skipper butterfly (*Erynnis tages*). Oecologia 121: 506-517.

Hampe, A., Petit, R.J. (2005): Conserving biodiversity under climate change: the rear edge matters. Ecology Letters 8: 461-467.

Hanski, I., Thomas, C.D. (1994): Metapopulation dynamics and conservation: a spatially explicit model applied to butterflies. Biological Conservation 68: 167-180.

Hanski, I., Alho, J., Moilanen, A. (2000): Estimating the parameters of survival and migration of individuals in metapopulations. Ecology 81: 239-251.

Higgins, L.G., Riley, N.D. (1970): A field Guide to the Butterflies of Britain and Europe. Collins Publishers, London.

Hurvich, C.M., Tsai, C. (1989): Regression and time series model selection in small samples. Biometrika 76: 297-307.

James, M., Gilbert, F., Zalat, S. (2003): Thyme and isolation for the Sinai baton blue butterfly (*Pseudophilotes sinaicus*). Oekologia 134: 445-453.

Jutzeler, D., Rákosy, L., Bros, E. (1997): Observation et élevage de *Pseudophilotes bavius* (Eversmann, 1832) des environs de Cluj; distribution de cette espèce en Roumanie. Une nouvelle plante nouricière de *Colias alfacariensis* (Ribbe, 1905). Bulletin de la Société Entomologique de Mulhouse 1997: 23-30.

Karsholt, O., Razowski, J. (1996): The Lepidoptera of Europe – a distributional checklist. Apollo Books, Stenstrup.

König, F. (1992): Morphologische, biologische une ökologische Daten über *Philotes bavius hungarica* Diószeghy 1913. Lepidoptera. Lycaenidae. Entomologische Zeitschrift, Essen 102 (9-10): 168-172.

Kovács, S., Rákosy, L., Kovács, Z., Cremene, C., Goia, M. (2001): Lepidoptera (Fluturi). pp. 81-114. In: Rákosy, L., Kovács, S. (eds.), Rezervaţia Naturală „Dealul cu fluturi” de la Viişoara. Societatea Lepidopterologică Română, Cluj-Napoca, Romania.

Lewis, O.T., Thomas, C.D., Hill, J.K., Brookes, M.I., Crane, T.P.R., Graneau, Y.A., Mallet, J.L.B., Rose, O.C. (1997): Three ways of assessing metapopulation structure in the butterfly *Plebejus argus*. Ecological Entomology 22: 283-293.

Mihuţ, S., Groza, G., Mătase, D., Tăuţ, M. (2001): Rezervaţiile de la Suatu. Inspectoratul de Protecţie a Mediului Cluj, Cluj-Napoca, Romania.

Munguira, M.L., Martin, J., Balletto, E. (1993): Conservation biology of Lycaenidae: A European overview. pp. 23-34. In: New, T.R. (ed.), Conservation biology of Lycaenidae (Butterflies). IUCN, Gland.

New, T.R. (1993): Introduction to the biology and conservation of the Lycaenidae. pp. 1-21. In: New, T.R. (ed.), Conservation biology of Lycaenidae (Butterflies). IUCN, Gland.

Nowicki, P., Witek, M., Skórka, P., Settele, J., Woyciechowski, M. (2005): Population ecology of the endangered butterflies *Maculinea teleius* and *M. nausithous* and the implications for conservation. Population Ecology 47(3): 193-202.

Nowicki, P., Bonelli, S., Barbero, F., Balletto, E. (2009): Relative importance of density-dependent regulation and environmental stochasticity for butterfly population dynamics. Oecologia 161: 227-239.

Ouin, A., Aviron, S., Dover, J., Burel, F. (2004): Complementation/supplementation of resources for butterflies in agricultural landscapes. Agriculture, Ecosystems & Environment 103(3): 473-479.

Pollard, E., Yates, T.J. (1993): Monitoring Butterflies for Ecology and Conservation: the British butterfly monitoring scheme. Chapman & Hall, London.

Polus, E., Vandewoestijne, S., Choutt, J., Baguette, M. (2007): Tracking the effects of one century of habitat loss and fragmentation on calcareous grasslands butterfly communities. Biodiversity and Conservation 16: 3423-3436.

Rákosy, L. (1983): Problema ocrotirii lepidopterelor în România, exemplificări din judeţul Cluj. Ocrotirea Naturii si a Mediului Înconjurător 27: 32-36.

Rákosy, L. (1999): Lepidopterologische Biodiversität eines kleinräumigen steppenartigen Naturschutzgebietes in Siebenbürgen (Suatu, Transsylvanien, Rumänien). Entomologica Romanica 4: 49-68.

Rákosy, L. (2002): Lista roşie pentru fluturii diurni din România. Buletinul Informativ al Societăţii Lepidopterologice Române 13: 9-26.

Rákosy, L., Goia, M., Kovács, Z. (2003): Catalogul Lepidopterelor României/Verzeichnis der Schmetterlinge Rumäniens. Societatea Lepidopterologică Romană, Cluj-Napoca, Romania.

Rákosy, L. (2011): Originea şi geneza landschaftului natural-cultural din Transilvania. pp. 27-38. In: Rákosy, L., Momeu, L. (eds.), Ecologia în România – Tradiţii şi Perspective. Prof. univ. dr. Bogdan Stugren: volum comemorativ. Presa Universitară Clujeană, Cluj-Napoca.

Resmeriţă, I. (1971): Rezervaţia botanică de la Suatu. Ocrotirea Naturii, Bucureşti 15(2): 129-138.

Roland, J., Keyghobadi, N., Fownes, S. (2000): Alpine Parnassius butterfly dispersal: effects of landscape and population size. Ecology 81: 1642-1653.

Samways, M.J. (2007): Insect Conservation: A Synthetic Management Approach. Annual Review of Entomology 52: 465-487.

Samways, M.J., McGeoch, M.A., New, T.R. (2010): Insect Conservation - A Handbook of Approaches and Methods. Oxford University Press, Oxford.

Schwarz, C.J., Arnason, A.N. (1996): A general methodology for the analysis of capture-recapture experiments in open populations. Biometrics 52: 860-873.

Schwarz, C.J., Seber, G.A.F. (1999): Estimating animal abundance: review III. Statistical Science 14: 427-456.

Schmitt, T., Rákosy, L. (2007): Changes of traditional agrarian landscapes and their conservation implications: a case study of butterflies in Romania. Diversity and Distributions 13: 855-862.

Szabó, A. (1982): Contributions regarding distribution in Romania of *Lycaena helle* Schiff. and *Philotes bavius* Ev. species (Lepidoptera, Lycaenidae). Societatea Ştiinţelor Biologice din Republica Socialistă România, Studii si Comunicări, Reghin 2: 299-306.

Thomas, C.D. (2000): Dispersal and extinction in fragmented landscapes. Proceedings of the Royal Society B 267: 139-145.

Thomas, C.D., Wilson, R.J., Lewis, O.T. (2002): Short-term studies underestimate 30-generation changes in a butterfly metapopulation. Proceedings of the Royal Society B 269: 563-569.

Thomas, C.D. (2012): Dispersal and extinction in fragmented landscapes. Proceedings of the Royal Society B 267: 139-145.

Thomas, J.A. (1984): The conservation of butterflies in temperate countries: Past efforts and lessons for the future. Symposium of the Royal Entomological Society London 11: 333-353.

Thomas, J.A. (1991): Rare species conservation: case studies of European butterflies. pp. 149-197. In: Spellerberg, I.F., Goldsmith, F.B., Morris, M.G. (eds), The scientific management of temperate communities for conservation. Blackwell Science, Oxford.

Thomas, J.A., Bourn, N.A.D., Clarke, R.T., Stewart, K.E., Simcox, D.J., Pearman, G.S., Curtis, R., Goodger, B. (2001): The quality and isolation of habitat patches both determine where butterflies persist in fragmented landscapes. Proceedings of the Royal Society B 268: 1791-1796.

Vandewoestijne, S., Baguette, M. (2004): Demographic versus genetic dispersal measures. Population Ecology 46(3):281-285.

Van Swaay, C.A.M., Cuttelod, A., Collins, S., Maes, D., López, M.M., Šašić, M., Settele, J., Verovnik, R., Verstrael, T., Warren, M., Wiemers, M., Wynhoff, I. (2010): European Red List of Butterflies. International Union for Conservation of Nature, Gland.

Van Swaay, C.A.M., Collins, S., Dušej, G., Maes, D., Munguira, M.L., Rákosy, L., Ryrholm, N., Šašić, M., Settele, J., Thomas, J.A., Verovnik, R., Verstrael, T., Warren, M., Wiemers, M., Wynhoff, I. (2012): Dos and Don'ts for butterflies of the Habitats Directive of the European Union. Nature Conservation 1: 73-153.

Vizauer, T.C., Adumitroaie, B. (2005): Dispersal traits of the Transylvanian Bavius Blue butterfly (*Pseudophilotes bavius hungaricus* Diószeghy, 1913) in Suatu (Transylvanian Plain, Romania). Abstract of the presentation for VIth Biology Days 22-23.04.2005, Cluj, Romania.

Vizauer, T.C., Nagy, A., Adumitroaie, B., Virág, I., Căta, M., Cojan, I. (2006): Estimation of population size of the Transylvanian Bavius Blue butterfly (*Pseudophilotes bavius hungaricus* Diószeghy, 1913) in I. Suatu Natural Reservation (Transylvanian Plain, Romania). Abstract of the presentation for VIIth Biology Days, 24-25.03.2006, Cluj Romania.

Warren, M.S. (1992): Butterfly populations. pp. 73-92. In: Dennis RLD (ed.), The ecology of butterflies in Britain. Oxford University Press, Oxford.

Warren, M.S. (1993): A review of butterfly conservation in central southern Britain: I. Protection, evaluation and extinction on prime sites. Biological Conservation 64(1): 25-35.

Wendelberger, G. (1985): Vorstellungen zur Geschichte der Pannonischen Flora und Vegetation. Naturwissenschaftliche Forschungen über Siebenbürgen 3: 43-52.

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