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DISTRIBUTION AND THREATS OF *PHENGARIS TELEIUS* (LEPIDOPTERA: LYCAENIDAE) IN NORTHERN SERBIA

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The paper provides an overview on the distribution of recently discovered Scarce Large Blue (*Phengaris (Maculinea) teleius*) in northern Serbia (Selevenj Sands, Ludaš Lake and Subotica Sands). Mapping of the butterfly and its habitat has shown that most of the suitable habitats are limited to protected areas where at least some of the wet meadows with *Sanguisorba officinalis* host plant are suitably managed and regularly mown. Given the known maximum dispersal distances of *P. teleius*, the suitable habitat patches possibly support two separate meta-populations. Fragmentation and isolation of remaining colonies represent the main threats to long term survival of the species in Serbia. Based on IUCN criteria for regional red lists, the species qualifies as Endangered (EN) in Serbia and requires immediate conservation actions. Our results suggest that mowing is of high importance for maintaining suitable habitat. Until more is known about local ecological requirements of the species, general mowing recommendations should be followed with avoidance of mowing between mid June and mid September and providing a mosaic of different mowing regimes.

Key words: new species record, biogeography, habitat management, dispersal, conservation.

INTRODUCTION

The Scarce Large Blue (*Phengaris teleius* (Bergsträsser, 1779)) is a widespread Palaearctic species with its range extending from France to Japan (Tolman & Lewington 2008). In most of its western range in Europe, the populations and range are in strong decline over the last decades (Wynhoff 1998*a*, Van Swaay & Warren 1999). The species is confined to occasionally mown wet meadows with the larval host plant *Sanguisorba officinalis* L. (Thomas 1984). A direct threat for *P. teleius* is the loss and fragmentation of suitable habitats mainly due to cessation of traditional agriculture, water drainage and infrastructure (Van Swaay & Warren 1999). Being obligate myrmecophiles, Large Blues (*Phengaris* spp.) are characterized by complex relationships between butterflies, ants and their habitat. Abundance of *P. teleius* is mainly affected by density-dependant factors (Nowicki *et al.* 2009). It is related to habitat net-

work parameters, such as patch isolation and size (Nowicki *et al.* 2007) and habitat quality parameters, such as host plant availability (Dierks & Fischer 2009, but see Nowicki *et al.* 2007) and especially host ant abundance (Dierks & Fischer 2009, Wynhoff *et al.* 2011).

Large Blues have been intensively studied with the aim of improving their conservation status (Wynhoff 1998*b*, Nowicki *et al*. 2007, Thomas *et al.* 2009), and over the years these butterflies were recognized as flagship species for butterfly conservation in Europe (Munguira & Martin 1999, Settele *et al.* 2005, Settele & Kühn 2009). *P. teleius* is listed as vulnerable in the Red Data Book of European Butterflies due to estimated declines in population size of more than 30% in the last decade (Van Swaay *et al.* 2010). Much of the conservation efforts in Europe have been initiated and facilitated by its inclusion in Annex II and Annex IV of the Habitats Directive (European Commission, 92/43/EEC) and in the Convention on the Conservation of European Wildlife and Natural Habitats (Council of Europe T-PSV/PA (2011) 7), forming a legal base for protection of the species and its habitat. In north-western Europe the conservation efforts have already shown results with a successful reintroduction in the Netherlands (Wynhoff 1998*b*, Van Langevelde & Wynhoff 2009). In order to sustain *P. teleius* populations mowing of wetland areas should be performed once in a season, avoiding the period between mid June (or July) and mid September to allow for larval development on the host plant (Johst *et al.* 2006, Grill *et al.* 2008, Nowicki *et al.* 2009, Wynhoff *et al.* 2011).

In contrast, the range of *P. teleius* in the eastern part of Europe is not completely known, mostly due to lack of basic faunistic surveys. This also applies for Serbia, where the majority of the faunistic studies have been published in the last few years providing several new species records for the country (Jakšić *et al.* 2007, Dincă *et al.* 2010, Popović & Đurić 2010, Popović & Milenković 2012, Popović *et al.* 2014). The northern part of the country, in particular, has been neglected due to the fact that it is almost entirely flat terrain and the landscape is mostly dominated by modern agriculture. To fill this gap, parts of Northern Serbia were surveyed in 2012 and 2013 resulting in the discovery of *P. teleius*. In order to provide as much information possible on this threatened butterfly to assess its Red List status and to propose habitat management in Serbia, we mapped the distribution of adults and their potential habitats. Additionally, we coarsely estimated the connectivity of the habitat patches and checked the effects of essential habitat parameters on butterfly presence and abundance.

MATERIAL AND METHODS

In order to compose the distribution map of the Scarce Large Blue for the wider region we used known published data for Romania (Rákosy & Vodă 2008), Hungary (Bálint

et al. 2006), Slovenia (Verovnik *et al.* 2012) and unpublished data from Croatia (Martina Šašić, pers. comm), Slovenia and Serbia. Additionally, polygon centroids from Natura 2000 network (EUNIS 2013) were used. The records older than 1980 are not shown on the map.

Distribution of *P. teleius* in northern Serbia was studied in detail during field surveys August 5, 11–18, 2012 and August 7–17, 2013 using Garmin eTrex 20 GPS devices for mapping. The surveyed area extends from Donji Tavankut village in the west to the river of Tisa in the east, and included all suitable-looking habitats identified from Google Earth satellite images. In order to assess relative abundance of adults 10 minutes transect counts were conducted on each patch by the same person. All habitat patches visited in 2012 were revisited in 2013 and an average butterfly count was calculated. The connectivity of local populations was visualised by plotting 5 km as maximum possible migration distance (Nowicki *et al.* 2005, Van Langevelde & Wynhoff 2009) around butterfly occurrence points on the map.

Basic habitat quality parameters were assessed in 2013 on 73 patches containing *S. officinalis* host plants. A single „patch" was defined as an isolated habitat with *S. officinalis* (*sensu* Nowicki *et al.* 2007), although nearby patches were considered different if suitable habitats were separated by different mowing regimes. We visually estimated the number of host plants (three categories: 1–15, 15–150 and more than 150 plants), plant height (four categories: leafs only, short, medium and tall plants), time of mowing (five categories: unmown, mown in June, first half of July, second half of July, or August) and percentage of overgrown habitat. Additionally we estimated patch size and patch isolation as the closest distance to the nearest *S. officinalis* patch using GIS data.

All statistical analyses were conducted in R 3.0.2 (www.r-project.org), while GIS data were analysed using both QGIS 2.0.1 (www.qgis.org) and R software. To assess which habitat parameters predict butterfly distribution data were analysed with Generalized Linear Model (GLM). Where possible, the data were log transformed prior to GLM analysis to match linearity assumption. In order to link butterfly presence-absence data with habitat parameters a Binomial family GLM was used. For butterfly counts along transects linkage with habitat parameters a Negative Binomial family GLM was used (available in MASS package in R). We were unable to use Poisson family model as it didn't yield good fit due to over-dispersion.

RESULTS

The first *P. teleius* individual was observed on August 5th, 2012 on a small patch of suitable habitat near the forest in Selevenj Sands. Most of that meadow was recently mown, and the adults were found flying near the few remaining flowering host plants at the forest edge. This observation initiated further surveys of butterfly and habitat distribution in the nature reserve Subotica Sands and Ludaš Lake in 2012 and 2013 (Fig. 1).

In 2013, a total of 278 *P. teleius* individuals were recorded in five 10 × 10 km UTM squares in northern Serbia with average of 2.8±4.7 individuals per patch (Fig. 2). Although we screened a much wider area only three patches hosting *P. teleius* were observed outside, but very close to the protected areas. The largest planimetric distance between occupied patches was 18 km and three geographically separate areas of distribution were evident. There were

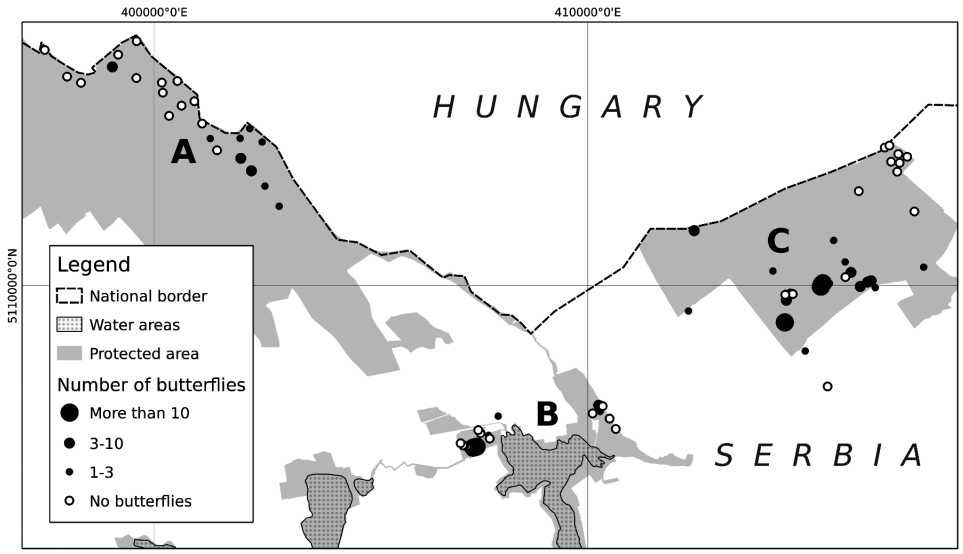

Fig. 1. Map of the surveyed area (in UTM 10×10 km) showing the separate areas Subotica Sands (A), Ludaš Lake (B) and Selevenj Sands (C) in the northern part of Serbia. Filled circle size denotes numbers of recorded *Phengaris teleius* during the 10 min transect counts. Open circle indicates the presence of suitable habitat with *Sanguisorba officinalis* but without the butterfly.

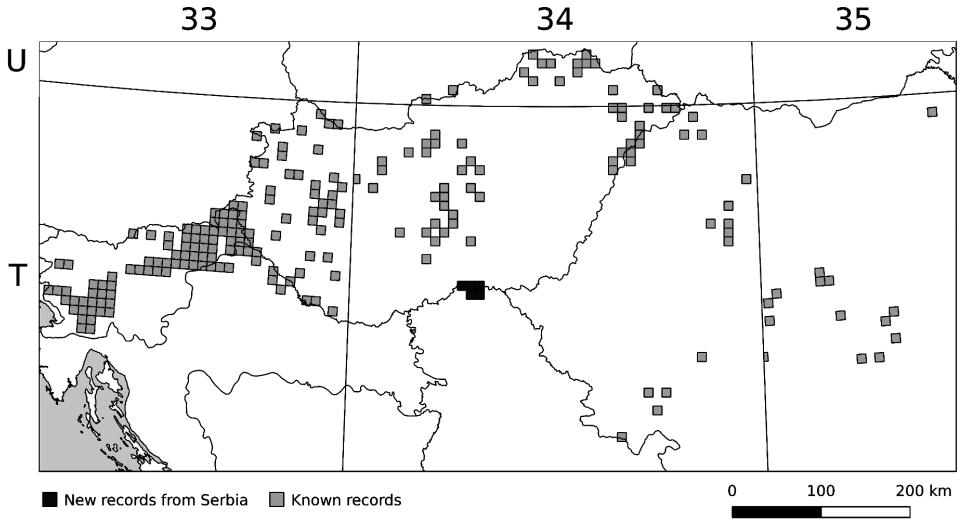

Fig. 2. Distribution of *Phengaris teleius* in south-eastern Europe (Slovenia, Croatia, Hungary, Serbia and Romania). The squares indicate the presence of the species after 1980 plotted on 10×10 km UTM grid.

no suitable habitat patches between these areas that could serve as stepping stones and facilitate dispersal. Therefore, taking into account the maximum dispersal distance of 5 km, the entire region potentially supports two separate meta-populations (Fig. 3), with the minimum distance of 7 km between areas A and B and 3 km between areas B and C. The majority of butterflies (average of 3.3±3.9, and maximum of 91 individual in a single patch) were recorded in Selevenj Sands, where large interconnected wetland area is mown at different times of the year (Fig. 1, area C). In Ludaš Lake (average of 2.8±5.2, maximum of 20 individuals in a single patch), the most suitable meadows are also a mixture of mown and unmown plots (Fig. 1, area B). Less butterflies were observed in Subotica Sands (average of 1±1.5 individuals) (Fig. 1, area A). The majority of them were recorded on the meadows under strict management regime for the conservation of rare plant species, where a few 1m wide meadow strips are left unmown each year.

In the surveyed area the larval host plant *S. officinalis* was recorded in 74 habitat patches, while the adults were observed in 37 patches (50%). The average patch size was 3.06 (0.02–25.69) ha. *P. teleius* butterflies were almost exclusively recorded on regularly mown meadows. Most of these meadows (72%) were mown at least once per year and the majority of them (82%) con-

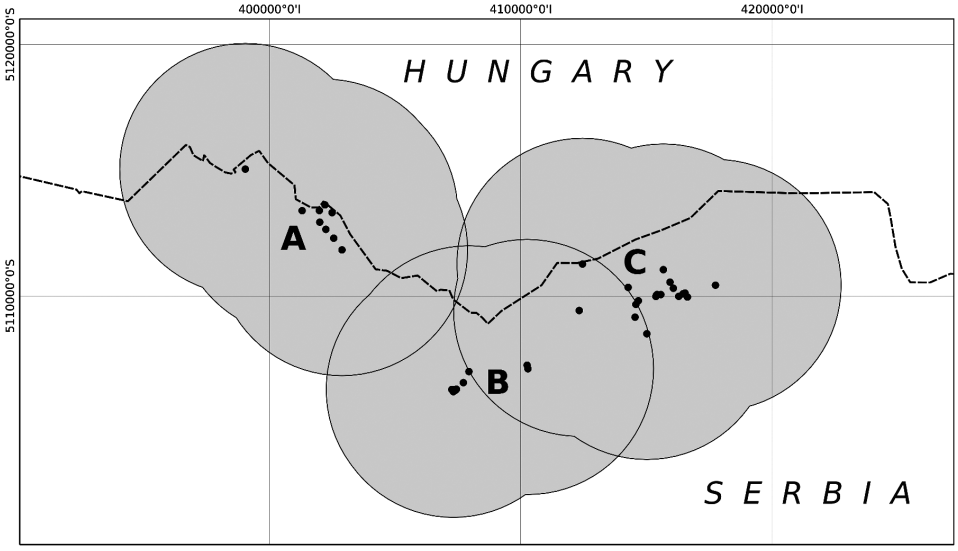

Fig. 3. Map of the surveyed area (UTM 10×10 km) in northern Serbia showing the potential connectivity of the *Phengaris teleius* populations among Subotica Sands (A), Ludaš Lake (B) and Selevenj Sands (C). The dashed line marks the border between Serbia and Hungary. Black dots denote the patches of habitat supporting butterflies, while the grey circles represent maximal butterfly migration distance of 5 km. The minimal distance between occupied patches of areas A and B is 7 km, and 3 km between areas B and C.

Table 1. Results of Generalized Linear Model with Negative Binomial family distribution connecting *Phengaris teleius* counts on a 10 minute transect with selected habitat parameters.

Variable	Regression coefficient ± SE	P
Intercept	–64±7e+07	-
Mowing in June	1.22±0.74	0.09
Mowing in July I	1.41±0.47	0.02
Mowing in July II	1.29±0.67	0.05
Overgrown habitat %	–0.26±0.15	0.09

Only significant variables were included. Please refer to Material and Methods section for a complete list and explanations of the used variables. The overall model goodness of fit: Pearson $\chi^2 = 66$, P = 0.19.

tained more than a 150 *S. officinalis* plants. None of the surveyed patches was overgrown by shrubs and bushes more than 50%, with *Phragmites australis* being the most dominant tall plant species present on 80% of the patches.

The Binomial family GLM model suggested that mowing in early July may positively affect butterfly presence (r = 1.41±0.78; $P_{(r)} = 0.07$; Pearson χ_2 = 58; P = 0.21). Negative Binomial family model came up with a few significant or almost significant variables (Table 1). It suggested that butterfly abundance is negatively correlated with habitat overgrowing and that the adults were most abundant on patches mown during June and July.

DISCUSSION AND CONCLUSIONS

In 2012, *Phengaris teleius* was observed for the first time in northern Serbia. This extends its known range in the Pannonian Basin further to the southeast, with the nearest known Hungarian populations about 50 km away (Bálint *et al.* 2006, EUNIS 2013). No records from southeastern Hungary are published, although the presence of the Scarce Large Blue just over the border is likely, given the distribution of the newly discovered populations. Additional populations could also be discovered in Serbia, since the larval host plant *S. officinalis* is much more widespread, especially in the southern and south-western parts of the country (Kurtto *et al.* 2004). It is worth noticing that the neighbouring Romanian populations are situated close to the border with Serbia, just on the opposite side of the Danube River (see Fig. 2). Therefore it is likely that there are some undiscovered populations of *P. teleius* close to Negotin and Kladovo, where a large wetland area was recently converted for agriculture.

In the surveyed region the area outside the species habitat matrix could be considered highly permeable (see Ross *et al.* 2005, Haynes & Cronin 2006,

Eycott *et al.* 2012), with low woodland cover and flat terrain facilitating long distance movements of the adults in mosaic agricultural landscape. However, the maximum observed migration distances for *P. teleius* based on MRR studies are up to 5 km (Nowicki *et al.* 2005, Van Langevelde & Wynhoff 2009) which is shorter than the minimum distance between areas A and B (7 km) and the migration between them is therefore unlikely. In a similar study from Slovenia, the maximum migration distance was 2.5 km, however, the countryside there is much more hilly and wooded (Zakšek *et al.* 2005). *P. teleius* butterflies are known as extremely sedentary species moving only several hundred meters and rarely abandoning their home patches (Thomas 1984, Nowicki *et al.* 2005, Van Langevelde & Wynhoff 2009). Considering this fact there could be even three separate populations in the surveyed region. This has important conservation implications as smaller isolated populations have a much higher extinction risk (Saccheri *et al.* 1998, Nowicki *et al.* 2005).

The threat status of the Scarce Large Blue in Serbia can only be evaluated tentatively, as we do not have any information on the distribution of the species in neighbouring south-eastern Hungary and the potential rescue effect of these populations (IUCN 2012). In case there is no rescue effect the species could be assessed as Endangered (EN) in Serbia following the criteria B1ab (i,ii,iii,v)+2ab(i,ii,iii,v) of IUCN (2001) due to (1) small area of occupancy and extent of occurrence (AOO = 44 km^2, EOO = 100 km^2), (2) severe fragmentation and (3) projected continuing decline caused by habitat loss and water drainage. This places *P. teleius* on top of the list of priority species for conservation in Serbia. Being listed under the Convention on the Conservation of European Wildlife and Natural Habitats, all known occupied sites should be incorporated in the current proposal for Serbian Emerald Network (Council of Europe T-PVS/PA (2012) 18). In addition, the species is listed in Habitats Directive and newly discovered sites should be proposed as Special Areas of Conservation (SACs) upon the accession of Serbia to the European Union, allowing species specific management of these sites. As most of the occupied patches are already within protected areas, only small adjustments in existing management of wet meadows could ensure the future survival of this butterfly in Serbia.

It is clear that Serbian populations of *P. teleius* are strongly dependant on regularly mown wet meadows with *S. officinalis* host plant. It seems that the number and size of the host plants did not affect butterfly abundance, which was already observed in a more comprehensive study by Nowicki *et al.* (2007), but see Dierks and Fischer (2009). This also complies with the our field observations, as *S. officinalis* was medium sized (72%) and highly abundant (82%) in almost all of the patches suggesting that the host plant may not be the limiting resource for butterflies. In contrary to our expectations, we could not confirm any connection between patch size and isolation and but-

terfly presence (Nowicki *et al.* 2007, 2013). This is probably the result of small sample size and our patch definition in accordance to mowing regime and not landscape characteristics.

The mixture of meadows with different mowing regimes in Selevenj Sands and Ludaš Lake host the most numerous butterfly populations (Fig. 1). This is in line with the recommendation by Nowicki *et al.* (2009) that butterfly populations may benefit from application of rotational mowing schemes and with the results from neighbouring Hungary where mosaic mowing may be favourable to the species (Kőrösi *et al.* 2009). A management regime leaving stripes of grassland uncut, as applied in Subotica Sands, may also provide a good example of suitable habitat management for the species, as it was practised for many years, but the effects of such leftovers should be studied more in detail. Apart from general recommendations (Johst *et al.* 2006, Grill *et al.* 2008, Wynhoff *et al.* 2011), our data suggests that mowing in July is also acceptable and even preferable (Table 1). Although this should be taken with caution until more data is available, we noted that the meadows mown in July are able to produce flowering sprouts of the host plant. The absence of butterflies from some meadows with *S. officinalis* in the study area may be a direct consequence of inappropriate mowing regimes in the past few years (Fig. 1, area C, easternmost points). It is important to note that the host ant species providing the highest survival rate for the Scarce Large Blue caterpillars differs within Europe, as does the composition of the *Myrmica* ant community in occupied meadows (eg. Tartally & Varga 2008, Witek *et al.* 2010). Therefore we urgently need to assess the primary host ant species and *Myrmica* ant communities in Serbia in order to apply adequate conservation measures that would benefit their populations as well (Thomas *et al.* 2005, Thomas *et al.* 2009, Wynhoff *et al.* 2011). Before that is known we suggest following general recommendations on the mowing period and preservation of mosaic of habitats in different mowing regimes at small spatial scale.

The discovery of *P. teleius* in Serbia will hopefully trigger further investigations especially those aiming at the host ants, larval and adult ecology. It is also important to study the metapopulation structure of the newly discovered colonies and start regular monitoring of all existing suitable habitats. This will provide essential information for effective conservation measures and safeguarding of the future of this species in Serbia.

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