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Effects of climatic factors on yearly population sizes of *Isophya costata* (Orthoptera)

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Abstract. *Isophya costata*, protected under EC, post-glacial endemic relict in the Carpathian Basin, is an important indicator species of dicot-rich hayfields and steppe grasslands. Significant changes in yearly population sizes of *I. costata* were observed in its area-margin. Based on this, population dynamics and habitats of *I. costata* have been monitored between 2007 and 2014. Our results showed that annual population sizes were heavily affected by macroclimatic factors in March – monthly precipitations below 25 mm or above 55 mm had been found as a negative impact on yearly densities of the species.

Key words: *Isophya costata*, density, macroclimate, vegetation, habitat-structure.

Introduction

Isophya costata Brunner von Wattenwyl, 1878, a subendemic post-glacial relict species of the Carpathian Basin, is protected under EC and national legislation. Its known occurrences outside Hungary are limited to the Viennese Basin (Austria) and Transylvania (Romania) (Heller et al. 2004, Bauer & Kenyeres 2006a, Nagy & Rácz 2014).

Former studies emphasized the continuous decline of the species due to habitat loss and degradation caused by land cultivation, abandonment of hay making, etc. (Nagy 1974). During the recent decade, however, a number of new occurrences have been discovered as a result of systematic research (Bauer & Kenyeres 2006a, Nagy & Rácz 2014).

Isophya costata can be linked to dicot-rich hayfields, fens, steppe grasslands and loess grasslands (Nagy & Szövényi 1999, Nagy & Rácz 2014). A detailed study on habitat preferences showed that the key factor determining its occurrence was total cover of mesophytic dicots, providing the required food source and vegetation architecture (Kenyeres et al. 2004, Bauer & Kenyeres 2006a). Originally, *Isophya costata* must have been a typical species of dicot-rich loess grasslands and closed steppe grasslands, but it had later adapted to man-made hay meadows with similar vegetation structure. Currently the majority of known populations occur in the latter anthropogenic habitats and much less steppe grassland and loess grassland populations remained (Kenyeres et al. 2004, Bauer & Kenyeres 2006a, Kenyeres et al. 2009). Nymphs emerge as early as in March, and the adult insects have died by July at latest. The unmistakable sound of the adults can greatly help in locating the specimens (Heller et al. 2004).

Population sizes of orthopterans are strongly influenced by climatic parameters (Kemp & Sanchez 1987). Based on that, the orthopterans are good, but as yet rarely researched focal taxon of climate change (Cannon 1998). In relation this, macroclimatic requirements of *I. costata* have also not been studied yet.

Population and habitat conditions of *I. costata* in the Lake Fertő region have been studied since 2007 within a monitoring program of Fertő-Hanság National Park Directorate. During our research, significant changes in yearly population size were observed. Question of our study was that yearly population size reflects just the abundance of available mesophytic dicots, or affected also by climatic conditions during hatching and the early nymphal period.

Study area and methods

The sampling sites were situated in a grassland area, 150–400 meters west of Lake Fertő (Sopron: Halász-rét, elevation above sea level: 115–117 m) (Fig. 1). The surveyed habitat types included (a) a mesophytic hay meadow /*Pastinaco-Arrhenatheretum* (Knapp 1954) Passarge 1964/, dominated by *Arrhenatherum elatius* and *Dactylis glomerata, Knautia arvensis, Pastinaca sativa, Ranunculus acris, Lathyrus pratensis*; and (b) semi-arid mowed grasslands dominated by *Bromus erectus*. The vegetation structure of selected sampling sites differed from each other: Study site 1 was characterized by multi-layered canopy dicot-rich tall grass meadow with some hydrophilic elements (e.g. *Alopecurus pratensis, Cirsium canum, Symphytum officinale*); Study sites 2 and 3 were characterized by drier habitats, dominated by *Bromus erectus*, with steppe-grassland species (e.g. *Salvia nemorosa, Festuca rupicola, Filipendula vulgaris*) favorable for *I. costata*.

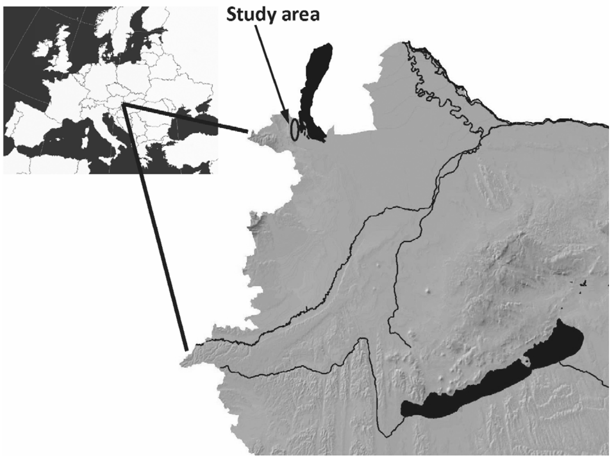

Figure 1. Study area.

Local population of *I. costata* was monitored yearly from 2007 to 2014 by transect method at 3 sampling sites (coordinates: Study site 1 – N 47.682, E 16.671; Study site 2 – N 47.685, E 16.666; Study site 3 –N 47.691, E 16.667). The species was sampled in 5 transects on each site, each transect was 10 m long and 1 m wide. Annual sampling dates fell in the same time of the year with the highest expected number of detectable fertile adults (end of May to early June). Samplings were carried out in late afternoon on warm rainless days through visual detection (complited by acoustic detection). Based on census data from transects and total area of suitable habitat, we estimated population size at each sampling site.

During the project period, triennial vegetation surveys (2008, 2011, 2014) were also carried out through quadrat sampling (4×4 m quadrats, 5 quadrats in each sampling site, percentage cover estimates). During the surveys, vegetation height and the number of vegetation layers were also recorded. To compliment these data, we measured microclimatic conditions too. Temperature (°C) and humidity (%) were measured in the quadrats at five points (at ground level and at 10, 20, 30 and 120 cm) by TESTO 615 and TESTO 625 digital hygrothermographs. To rule out possible deviations in measurement conditions, for the analyses we used relative values (data measured at 120 cm subtracted from those measured at lower levels).

Macroclimatic data (monthly rainfall and mean temperatures) were supplied by the North-Transdanubian Water Directorate (ÉDUVIZIG) from its Fertőrákos weather station (N47°42′52″, E16°39′54″; average distance from sampling area: 3 km).

From the above primary data, we calculated the following secondary values: average *I. costata* density per square meter for each sampling site; estimated number of adult *I. costata* for each sampled habitat; total grass cover; cover of dicots; cover of mesophytic plants [based on Borhidi (1995): plant species classified as WB4 or higher]; number of plant species; vegetation species diversity.

For determination of the requirements related to macroclimate, the following data were used: (a) monthly precipitation and temperature data from the first half of the given year and the prior winter; (b) climate data averaged in different ways (for the entire winter period from November to March, for January to March, for February to April, etc.).

Data were subjected to Pearson's correlation test and to linear and polynomial regression analysis using PAST 1.95 software (Hammer et al. 2001).

Results

Population size

During the monitoring period from 2007 to 2014, significant changes in population size of *I. costata* were observed. In 2010 with extreme high Q1-Q2 rainfall and in 2007, 2009, 2012 and 2014 with extreme low spring rainfall, population density was rather low (0.16–0.28 adult/m^2). On the other hand, in 2008, 2011 and 2013, with average late spring rainfall, density figures were much higher (0.32–0.42 adult/m^2).

Correlation analysis

a) Isophya costata population and microclimate

No significant correlation was revealed between population size and microclimatic data.

b) Vegetation and microclimate

In terms of vegetation and microclimate, significant correlations were found between vegetation height and temperatures measured at every level (T_ ground level: *r* = -0.9697, p<0.001; T_10cm: *r* = -0.9757, p<0.001; T_20cm: *r* = -0.9107, p=0.001; T_30cm: *r* = -0.7721, p=0.015; T_average: *r* = -0.9418, p<0.001).

c) Isophya costata population and macroclimate

Pearson's correlation test showed significant negative correlation between population size and March mean temperatures (*r* = -0.7119, p=0.048). No correlation was revealed between population size and rainfall in spite of the observation that March rainfall figures seem to influence changes in population density and population size. Largest population sizes occurred when March rainfall was between 25 and 55 mm (Fig. 2).

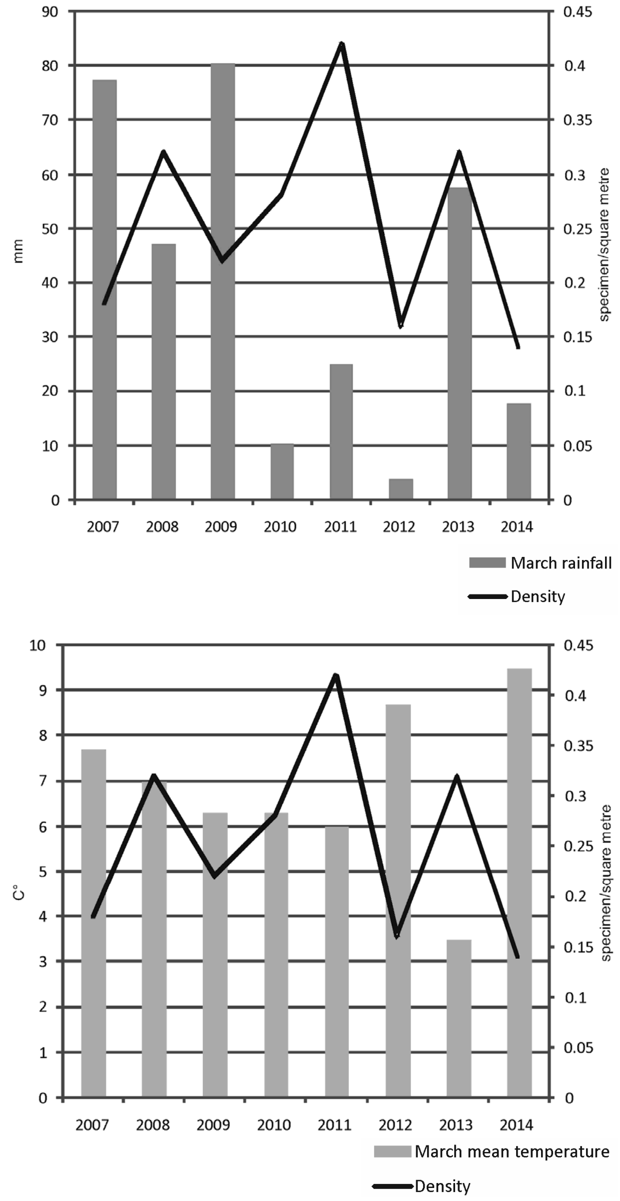

Figure 2. March rainfall, March mean temperatures and density of *Isophya costata* in the highest density sampling site (2007–2014)

d) Vegetation and macroclimate

Significant positive correlations were found between total vegetation cover and monthly precipitation figures in February (*r* = 0.6729, p=0.047) and May (*r* = 0.6727, p=0.047); and between vegetation height and monthly mean temperatures in February (*r* = 0.8875, p=0.001). A significant negative correlation was revealed between vegetation height and monthly mean temperatures in April (*r* = -0.7563, p=0.018).

e) Isophya costata population and vegetation

Pearson's correlation test showed significant positive correlations between *I. costata* population density and the total cover of mesophytic dicots (*r* = 0.7664, p=0.016), the total vegetation cover and the number of plant species present (pop. size of *I. costata*/total cover of vegetation, *r* = 0.7745/p=0.014; pop. size of *I. costata*/species number of plant species, *r* =0.9327, p<0.001).

Models used

Regression analysis was applied to variables with high cor-

Table 1. Significant results of linear (Lr) and polynomial (Pr) regression analyses (r values, p<0.5 with bold).

	Density of *Isophya costata*	Cover of mesophytic dicots
Cover of mesophytic dicots	Lr: (+) **0.014** / Pr: 1.477	-
March rainfall	Lr: 0.985 / Pr: **0.456**	Lr: 0.694 / Pr: 1.843
May rainfall	Lr: (–) **0.082** / Pr: **0.463**	Lr: 0.818 / Pr: 1.844
Average humidity in the grass	Lr: 0.791 / Pr: 1.805	Lr: (+) **0.429** / Pr: 1.500
Average temperature in the grass	Lr: 0.839 / Pr: 0.589	Lr: 0.649 / Pr: 0.664

relation coefficient and microclimatic parameters. It revealed a positive linear connection (best fit: linear model) between the cover of mesophytic dicots and the population size of *I. costata* and between the average humidity at grass levels and the cover of mesophytic dicots. On the other hand, connection between March rainfall and the population size of *I. costata* could be described by a polynomial model. Finally, the changes of May rainfall data and the population size of *I. costata* could be approximated by negative linear model (Table 1).

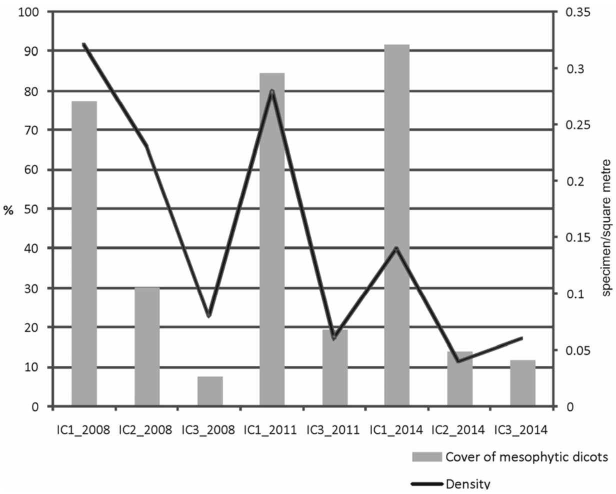

Figure 3. Density of *Isophya costata* and cover of mesophytic dicots in the studied quadrats (2008, 2011, 2014).

Discussion

Based on the above results and in harmony with prior observations (Kenyeres et al. 2004, Bauer & Kenyeres 2006a), hay meadows rich in mesophytic dicots should be considered the optimal habitat for this species in the eastern border zone of its distribution range. The habitat structure of hay meadows, independently of their geographic location, suits the habitat preferences of sensitive grasshopper species in several ways (Sağlam & Çağlar 2007): high relative cover of dicots, diverse vegetation architecture, microclimate, etc. On the other hand, we found that grass level microclimatic conditions, which influence the occurrence and population size of many other orthopterans (Guido & Chemini 2000, Squitier & Capinera 2002, Bauer & Kenyeres 2007), did not have a significant impact on the local population size of *I. costata*. It is known that the cover of mesophytic dicots has a significant effect on grass level microclimate (Bauer & Kenyeres 2006b, 2007). However, the strong correlation between the population size of *I. costata* and the total cover of mesophytic dicots in our data can rather be explained by specific feeding and habitat architecture needs of the species (Kenyeres et al. 2004, Bauer & Kenyeres 2006a).

From the analyzed macroclimatic parameters, March precipitation and mean temperature figures seem to have the most impact on population size of *I. costata*. It can also be an indirect relationship considering that the spring/early summer vegetation structure (grass height, cover of dicots, etc.) of the hay meadow in the highest density sampling site was influenced by the precipitation in March. Furthermore, complex vegetation structure has been proven to determine population density of species in a given site. It follows that dry spring weather can not only be disadvantageous for hatching success but also offer suboptimal habitat conditions for the developing insects. We found that March rainfall below 25 mm or above 55 mm could be considered unfavorable for *I. costata* (Fig. 2). The upper threshold can be attributed to the fact that the development of eggs laid in the soil is already going on at full speed in March (nymphs emerge in early April at latest). However, higher than optimal March rainfall can often result in high surface water level, which hinders egg hatching and early larval development. Thus, the amount of rain in March ideal for the species falls in an optimal range, too much or too little precipitation is equally disadvantageous. It is also proven by the fact that the relationship between the concerning variables was revealed by neither Pearson's correlation test nor linear regression analysis, but was shown by polynomial regression analysis (Table 1). In terms of spring rainfall and surface water levels, the habitat needs of the insect should come from the fact that its primary habitat must have been Pannonic loess steppes before the appearance of man-made hay meadows (Bauer & Kenyeres 2006a). This particular habitat type is typical of drier climates but due to its structure and species composition, its vegetation exhibits more mesophytic traits than expected from its geographic location.

In summary, the population size of *I. costata* in a given habitat is influenced by several factors: (1) the presence of dicots is a prerequisite for the species' occurrence; (2) the appropriate amount of dicots also offers an optimal grassland structure in which the species can move, hide from its predators, and which ensures suitable microclimatic conditions; however (3) disadvantageous macroclimatic conditions can override the two factors mentioned above.

We must note, that significant changes in yearly population size sometimes do occur in other *I. costata* populations elsewhere in Hungary too. It calls for extending the current research, so that we can make further steps to lay the precise foundations for successful in situ conservation of this endemic European protected species.

Species conservation

Right after discovering the species in the area, we had already designated a smaller part of its habitat (highest density occurrence) where hay should not be cut before July. To ensure this, we talked to the land management supervisors and the actual field workers several times on the spot. As a result, management practices to preserve and strengthen the population of *I. costata* on this designated area have been aptly carried out during recent years.

In terms of species conservation, it is important to note that fluctuation in yearly population size can also occur naturally, according to our results. However, to prevent population decrease due to habitat degradation, burning and trampling should be avoided and, at least in a part of the habitat, grass cutting should be in harmony with the phenology of the species (i.e. grass should not be cut until July, mowing grass should be in patches). In this way, a multi-layered canopy dicot-rich grassland structure, favorable for the species, can be ensured.

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