



Can spreading of the Geranium Bronze *Cacyreus marshalli* (Butler, 1898) (Insecta, Lepidoptera, Lycaenidae) in Croatia be assigned to climate change?

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Abstract

Background and Purpose: The Geranium Bronze *Cacyreus marshalli* (Butler, 1898) is the only butterfly introduced (non-native) into the European fauna. It was introduced in 1988 on the Balearic Islands from where it spread across Europe.

Materials and Methods: *Cacyreus marshalli* observations were conducted during the day at all locations. At a number of localities, geraniums as larval host plants were inspected to determine the presence of *C. marshalli* caterpillars.

Results and Conclusions: In Croatia, *C. marshalli* first appeared on the island of Lošinj. The paper presents new distribution data for the Geranium Bronze and its expansion across Croatia (all in the Mediterranean area) and discusses possibilities of spread due to climate change. Further systematic monitoring of spreading of *C. marshalli* in Croatia is necessary for it to be assigned to changing climate and above average temperatures in the last years, in particular since 2000.

INTRODUCTION

There were 10 butterfly species recognized as new faunistic elements in the last 20 years in Croatia, so currently Croatian butterfly fauna numbers 197 species (1, 2). The findings of these species were determined by a number of different aspects. The greatest number of species was recorded due to the lack of research in primarily of peripheral, marginal areas of the country or Croatian mountain areas, e. g. *Lycaena ottomanus* was found in the southern Croatia in Konavle (3), *Coenonympha oedippus* in the northern Istria (4), *Lasiommata petropolitana* on Snježnik Mt. (5), *Polyommatus (Agrodiaetus) damon* and *Colias balcanica* on the Dinara Mountain near the border with Bosnia and Herzegovina (6, 7) and *Polyommatus (Agrodiaetus) ripartii* in a poorly researched area of river Zrmanja surroundings (8). Taxonomic study of the genus *Leptidea* (Real, 1989) revealed the occurrence of *L. reali* (9) in the Croatian fauna. *Colias erate* was found in the northern (Podravina) and *Danaus chrysippus* in the southern part of Croatia (the valley of the river Neretva and the island of Mljet). These findings were probably determined by migratory flights of these species from arid, central and southern Mediterranean regions of Europe and Africa (10, 11, 12).

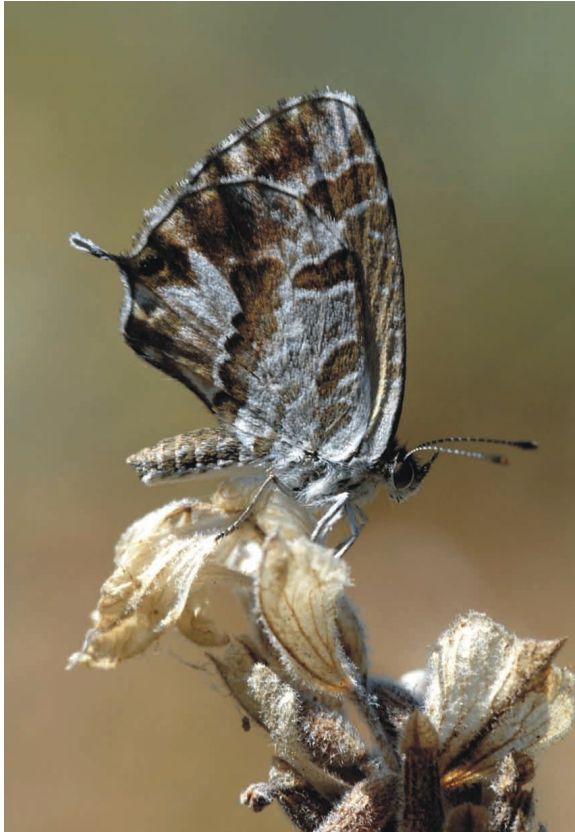


Figure 1. *Cacyreus marshalli* – island of Pag, Lun, Jul 8th 2010, photo: Samo Jenčić.

The first finding of *C. marshalli* (Figure 1) in Europe was a caterpillar imported from South Africa to England in 1978 with *Pelargonium* seedlings. In Africa *C. marshalli*

is distributed across South Africa, Zimbabwe, Mozambique and Zambia (13). In 1988, the first European record related to adults was recorded on the island of Mallorca (Balearic Islands, Spain) (14). The Geranium Bronze is the only one, among 482 European butterflies (15), that is accidentally introduced into Europe, occurs on cultivated geranium species (*Geranium* and *Pelargonium*) representing a non-native faunistic element. Due to the favorable climatic features in Europe this species has spread to the south and south-eastern parts of Europe (16, 17, 18, 14). In Italy was recorded in 1994, Morocco, Portugal and French Mediterranean in 1998, Sicily in 2001, southern Switzerland in 2002 and in 2008 it was recorded for Slovenia (19) and Croatia (20). Whether global warming could play a role in recent distribution of the Geranium Bronze in Europe is still uncertain (14), although it can serve as a good example of apparent response to climate change by spreading across Italy (21). *C. marshalli* was reported also in the northern European countries (UK, Germany, Belgium, and Netherlands) but was unable to survive the winter (14).

In the paper we: 1.) present new findings of the Geranium Bronze in Croatia, 2.) consider expansion in comparison with climatic features of some areas as well as the presence of larval host plants, as European butterflies are good climate change indicators whose distributions may be most affected by climate change (19) and 3.) discuss new range of expansion areas of this species in Croatia.

MATERIAL AND METHODS

Observations of *Cacyreus marshalli* were conducted during the day at all locations in Croatia. Besides finding localities of the species listed in Table 1, during past 10

TABLE 1

Recent localities of observation of *C. marshalli* in Croatia with date of observation, region and differentiation of the Mediterranean area.

Localities	Date	Region	Differentiation
Novigrad	Sept 15 th 2011	Istria	sub-Mediterranean
Savudrija	Sept 16 th 2011	Istria	sub-Mediterranean
Rovinj	Jul 17 th 2011	Istria	Eumediterranean
Jablanac	Aug 15 th 2008, Aug 10 th 2009	Hrv. Primorje	sub-Mediterranean
island Cres – Kovačine	Sept 22 nd 2011	Hrv. Primorje	Eumediterranean
island Lošinj – Veli Lošinj	Sept 15 th 2011	Hrv. Primorje	Eumediterranean
island Rab – Banjol	Sept 09 th 2011	Hrv. Primorje	Eumediterranean
island Rab - Barbat	Oct 09 th 2011	Hrv. Primorje	Eumediterranean
island Rab – Kampor	Aug 9 th 2011	Hrv. Primorje	Eumediterranean
island Rab – Rab	Oct 9 th 2011	Hrv. Primorje	Eumediterranean
island Pag - Lun	Jul 8 th 2010, Jun & Jul 2011, 2012	Hrv. Primorje	Eumediterranean
island Murter	Sept 09 th 2012	Dalmatia	Eumediterranean
Šibenik	Sept 09 th 2012	Dalmatia	Eumediterranean
Stupin Čeline – Rogoznica	Aug 28 th 2011	Dalmatia	sub-Mediterranean

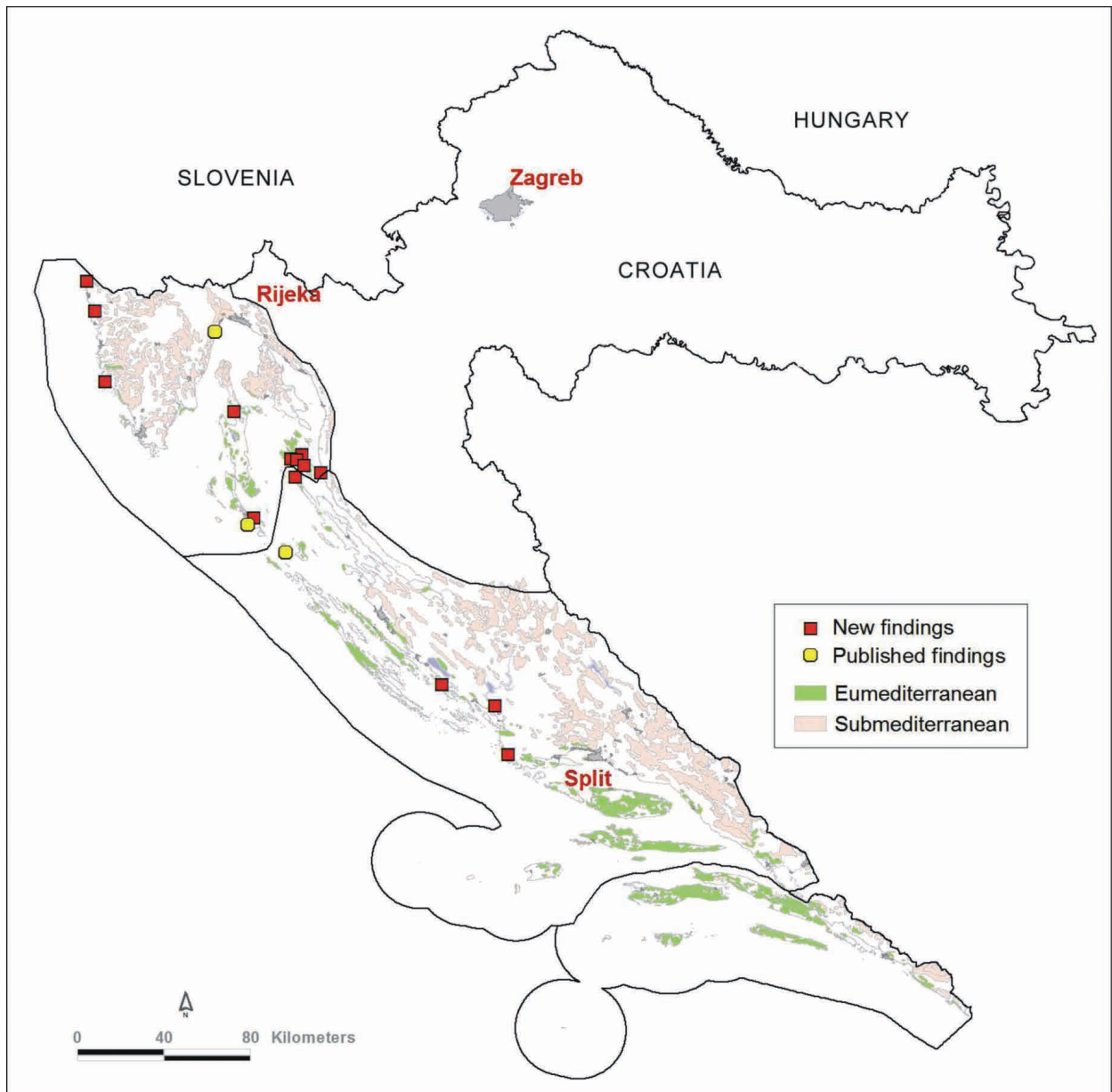


Figure 2. Distribution map of *C. marshalli* in Croatia (subdivisions of the Mediterranean area in Croatia marked by black line, Eumediterranean and sub-Mediterranean differentiation defined according to 30).

years several areas in the Eumediterranean and sub-Mediterranean region of Croatia, on which the species was absent, were investigated. Those localities are (from northwest to southeast): Istria and Primorje region (Učka Mt. from 2007–2012), coastal slopes of the Velebit Mt. (2005–2006, 2010–2012) (22), Dalmatia (Krka National Park from 2011–2012, Šibenik-Rogoznica from 2008–2012, Biokovo Mt. 1994–2004, 2007–2012 (23), Konavle region and Snježnica Mt. from 2005–2008 (3) and Croatian islands Olib and Šćedro (24), Kornati (25), Cres, Lošinj, Unije, Krk, Rab, Pag, Dugi Otok, Kornat, Brač, Hvar, Vis, Korčula, Mljet (26) and Ugljan (27). At a number of localities, in particular on the island of Mljet larval host

plants *Geranium* and *Pelargonium* were inspected to determine possible findings of caterpillars. At several localities the Geranium Bronze was photographed (Table 1). Photo records are stored in a photograph database of the first author and the photograph archives of the Croatian Natural History Museum in Zagreb.

Identification of species was done according to (28) and (29). Systematics is given by the same authors. Data on the biology and distribution of the Geranium Bronze follows several literature citations, e. g. (14, 20, 29). A Eumediterranean and sub-Mediterranean differentiation of the Mediterranean region in Croatia is defined and map of finding sites produced in ArcGIS software (30).

RESULTS

In the last five years research of butterfly diversity in Croatia revealed presence of a tropical butterfly *Cacyreus marshalli* at 14 new localities, although many areas in the Mediterranean region of Croatia were researched for many years (list of which is presented in the previous section). The species was recorded at 3 localities in Istria, 8 localities in island and coastal area of the Hrvatsko primorje region and 3 localities in Dalmatia (Table 1, Figure 2). The largest number of findings, eight, refers to five islands – Cres, Rab, Lošinj, Pag and Murter. Findings in Jablanac and Šibenik are the first mainland findings on the Balkan Peninsula. Finding periods relate to the summer and early autumn months dating from the end of June to October. In the spring and early summer *C. marshalli* was not recorded at any of the sites. All observations of the species refer to adults. So far, the species was not found in the egg or caterpillar stage infesting geraniums in Croatia. Activity of butterflies was recorded in the period from 10 to 17h which generally corresponds to usual daily activities of butterflies in Europe and Croatia. All findings relate to the Mediterranean area of Croatia, out of which 10 localities are in Eumediterranean and the rest are in the sub-Mediterranean area of Croatia (Table 1, Figure 2). Due to these recent findings (period 2008–2011) and the most southern finding site in Stupin Čeline a distribution area of the species extended to the south for approximately 160 kilometers, or above 50 km per year. Therefore, the species spread along the Adriatic coast could be assigned to range extension from north to south as systematic surveys were conducted along the coast in previous years (e.g. Učka Nature Park, Velebit Mt. National Park, Krka National Park, Biokovo Nature Park, Konavle, Croatian Adriatic islands).

DISCUSSION

The first record of *Cacyreus marshalli* in Croatia is from the island of Lošinj in 2008 (20). Published findings of the species in Croatia refer to the island of Silba (Silba town on Jul 23rd 2009 and Aug 4th 2010) (27), the town of Mali Lošinj (20) and the old town of Labin in 2009, although many sites with geraniums were inspected (Vrsar, Rovinj, Pula, Pazin, Žminj, Gračiče) but without evidence of the species presence (14). The mild climate on the island of Lošinj is favorable for the reproductive success of the species and its permanent colonization and both may lead to further spread of *C. marshalli* on the Balkan Peninsula (20). Observations of the species in Slovenia and findings in the autumn season could be related to a possible migration of the species from Italy to the Slovenian part of Istria. Findings in the Hrvatsko primorje region and Dalmatia in Croatia do not suggest such an assumption but could in fact indicate the permanent presence of this species. On the contrary, findings related to the Croatian part of Istria could also have its origin in migration flights of the species into the area of favorable mild climate, although the origin and spreading of this butterfly in Slovenian and Croatian part of Istria should be confirmed with the future systematic research and

monitoring. Anyway, *C. marshalli* has become an integral member of the Croatian butterfly fauna and could not be considered as a migratory species especially in the coastal area and Dalmatia. In the future, observations on the island of Mljet and Konavle could be particularly interesting and could result in verifying the spread of this species along the Adriatic coast. This area, already surveyed (3, 12, authors personal observations), highly thermophilic and rich in geraniums, could be an exceptional space for *C. marshalli* colonization. Previous studies (3, 12, M. Kučinić unpublished data), did not confirm the presence of *C. marshalli* in this area or in the systematically researched and monitored area of many Croatian islands (24, 25, 26, 27) and the Biokovo Nature Park (23, I. Mihoci unpublished data). Current data indicate that *Cacyreus marshalli* cannot overwinter in continental and in the central mountainous region of Croatia and was never found in these areas due to climatic features. If we observe spreading of the species in the last two years (most findings) compared with the average annual air temperatures in Croatia for 2011 and 2012 and anomalies from the 1961–1990 climate normals (31) it can be concluded that the average annual air temperatures in Croatia for 2011 and 2012 were above the multi-annual average (1961–1990). Average annual air temperature anomalies were within the range from 0.5°C to 1.7°C in 2011 and 1.1°C to 2.2°C in 2012. According to percentile classification, thermal conditions in Croatia for 2011 and 2012 have been described extremely warm except in the western part of Slavonia which belongs to the category very warm (31). Even if most findings could be related to warm thermal conditions, further systematic research of spread of *C. marshalli* in Croatia is necessary in order to be assigned to changing climate and above average temperatures since the year of 2000 (with an exception of avg. temp. in 2005 in which thermal conditions were the same as during the 1961–1990 period (31). Future monitoring of spreading the species range to the south and deeper into the sub-Mediterranean in Croatia is crucial in determining distribution patterns of this species as well as detailed analysis of the influence of climate conditions on its distribution in this part of Europe.

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