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Cover picture: A female of *Coenonympha oedippus* depositing an egg on a grass blade (© M. Bräu)

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Contents

Editorial: **Oedippus in Oedippus**

Matthias Dolek, Christian Stettmer, Markus Bräu & Josef Settele

Oedippus in Oedippus – we immediately liked this combination, when looking for an adequate journal for the present compilation of studies on *Coenonympha oedippus*, the False Ringlet, and decided for a special issue. We also felt, that it is a very good start for the new issues of Oedippus, which from now onwards are published as an open access journal by Pensoft in Bulgaria. This shift in publication policy also marks the change in editorship from Otakar Kudrna to Josef Settele which also coincides with the new presidency of the "Gesellschaft für Schmetterlingsschutz" (Society for Lepidoptera Conservation) and the move of the society to Halle (Saale) in Germany.

Coenonympha oedippus is one of the rarest and most endangered species in Europe. Moreover, it is rather resistant to reveal the secrets of its life to ecologists and conservationists. Thus, naturally an active exchange of information developed between research groups working on this species in different countries of Europe. All groups were hoping that the combined efforts would take them further than any single effort. This resulted in a workshop back to back with the 2009 meeting of Butterfly Conservation Europe (BCE) in Laufen/Germany. The meeting and the Workshop were financially supported by the Bavarian Academy for Nature Conservation and Landscape Management (ANL), the Helmholtz Centre for Environmental Research (UFZ) and the Bavarian State Ministry for Man and the Environment. The results of this workshop are presented now in this special issue. It includes the latest and most interesting information on the ecology and conservation management of *Coenonympha oedippus* in Europe.

However, this is only one side of the coin. This special issue also marks a new dimension of cooperation on European level. This kind of cooperation is rather widespread in large EU-funded projects, but not in conservation-oriented efforts to halt the decline of butterflies and other invertebrates. Another example of this European cooperation is the formulation of the European Action Plan for *Colias myrmidone* (Marhoul & Dolek 2010) and the background information, also financially supported by the ANL and summarized by Dolek & Hager (2008). This development is certainly encouraging as it helps getting conservation efforts more focused. But it is also an alarming signal, as it shows that more and more butterfly species are facing continent-wide extinction (overview in Van Swaay et al. 2010)! It is crucial that Researchers and Conservationists get into contact with other countries to discuss the fate of a certain species as only few very isolated populations exist.

We are hoping that with the foundation of Butterfly Conservation Europe (BCE) and with these first examples of close cooperation for the conservation of butterflies on European level future exchanges of knowledge and conservation techniques are stimulated for the sake of our heritage.

We expect politicians to support this development, which helps to advance and implement action plans to ensure the long term survival of butterflies like *Coenonympha oedippus* and *Colias myrmidone* in Europe.

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Distribution, habitat preferences and population ecology of the False Ringlet *Coenonympha oedippus* (FABRICIUS, 1787) (Lepidoptera: Nymphalidae) in Slovenia

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Abstract

The False Ringlet has a disjunct distribution in Slovenia with few remaining isolated populations in central part and more extensive distribution in the northern Istria and north-western Primorska. Its habitats differ greatly among these regions and range from alkaline fens to abandoned sub-mediterranean dry grasslands. In recent years several studies focused on central Slovenian populations were made, therefore the distribution, habitat preferences, phenology, behaviour and movements of adults, ecology of early developmental stages, population size, metapopulation structure are well known. Unfortunatelly the conservation efforts are lagging behind the knowledge and the False Ringlet remains one of the most threatened species in Slovenia.

Keywords: *Coenonympha oedippus*, False Ringlet, Slovenia, Ljubljansko barje, MRR, population ecology, butterfly conservation

Introduction

Despite its small size, Slovenia hosts an important part of the European population of the highly threatened False Ringlet (*Coenonympha oedippus*). It is listed as endangered (EN) in the Red List of threatened animals in Slovenia (Ul Rs 82/2002) and both habitats and the species itself, are protected (Ul Rs 46/2004). The species has a disjunct distribution in Slovenia, with three main centres: the coastal flysch region in northern Istria, the predominantly limestone region of north-western Primorska (Komen karst plateau, Goriška Brda, lower Soča River valley, north-western margin of Vipava valley), and marshy areas in central Slovenia south of the capital city, Ljubljana (Ljubljansko barje and its surroundings). Due to different soils, the habitats of the species differ greatly, a rather unexpected feature for populations close to the edge of the species` distribution. In the central part of Slovenia it flies in alkaline fens and wet meadows; in the north-western Primorska and Istria region, it is present on submediterranean dry grasslands in different successional stages up to light woods.

The species was first recorded in central Slovenia on Ljubljansko barje near the village of Podpeč, where it was collected by Johann Hafner on 25.6.1903 (specimen in Slovenian Natural History Museum). Further records from this part of the species range are published in Hafner's contribution to the knowledge of the Lepidoptera fauna of Slovenia (Hafner 1909), one of the most significant publications of that time. The same author also found the species in the north-western Primorska region, near Gorica (Hafner 1910). In Istria, the species was recorded in 1921 at Strunjan near the coast (Kolar 1921). The Sava river valley, east of the town Litija, at the easternmost edge of the False Ringlet distribution in Slovenia (Sajovic 1910) is also among the first known sites. The species has not been recorded at that site in the last 50 years and this population is one of several populations that have become extinct in the central part of Slovenia.

In the last ten years of more focused and intensive field work, many new localities have been found, especially in Istria and Goriška Brda (Čelik et al. 2005). The butterflies fly in much lower densities in drier habitats, but appear to be

Table 1. General information about the studies on *C. oedippus* in Slovenia.

Type of study	Study area	Time of study	Material and/or field methods used	References
Distribution	Slovenia, general	2003–2004 (compilation)	publications, collections*	Čelik et al. 2004, 2005
	Ljubljansko barje, SW Slovenia	2005–2008	unpublished data	unpubl. (authors)
Habitat	Ljubljansko barje	1995–1996, 2001, 2008	vegetation surveys in all suitable patches	Čelik 1997, 2003, 2004, Čelik et al. 2008, 2009
	SW Slovenia	1997, 2001, 2002	floristic and/or vegetation surveys in occupied patches	Čelik 2003
Phenology	Ljubljansko barje	1995–1996, 2001, 2008	MRR	Čelik 1997, 2003, 2004, Čelik et al. 2008
	Istria	2008	transect counts	unpubl. (authors)
	Slovenia, general (from distribution records)	see Distribution	see Distribution	see Distribution
Nectar plants	Ljubljansko barje	1995–1996, 2001, 2008	MRR, individual tracking	Čelik 1997, 2003, Čelik et al. 2008
	SW Slovenia	1997, 2001, 2002, 2005, 2006	individual tracking	Čelik 2003, unpubl. (authors)
Oviposition and host plants	Ljubljansko barje	1995–1996, 2001, 2008	MRR, individual tracking	Čelik 1997, 2003, Čelik et al. 2008, Čelik et al. 2009
Lifetime and behaviour of adults	Ljubljansko barje	1995–1996, 2001, 2008	MRR, individual tracking	Čelik 1997, 2003, 2004, Čelik et al. 2008, Čelik et al. 2009, Čelik in prep
Movements of adults	Ljubljansko barje	1995–1996, 2001, 2008	MRR	Čelik 1997, 2003, Čelik et al. 2008, Čelik et al. 2009
Patch occupancy	Ljubljansko barje	2001, 2008	Checking for presence in whole study area	Čelik 2003, Čelik et al. 2008
		1900–2000	Compilation of distribution records	Čelik 2003
Population size	Ljubljansko barje	1995–1996	MRR (subpopulation in patch Po, cf. Fig. 5)	Čelik 1997
		2001, 2008	MRR (whole study area)	Čelik 2003, Čelik et al. 2008, Čelik in prep.

* Collections: public (Natural History Museum of Slovenia), scientific research (Jovan Hadži Institute of Biology of SRC SASA), private (members of Slovenian Entomological Society and Society for Research and Conservation of Butterflies in Slovenia)

more widespread. On the other hand, only a handful of sites are still occupied in central Slovenia. Among these, the largest known metapopulation in Slovenia, on the eastern part of Ljubljansko barje, and small neighbouring populations, have been studied in detail, starting with a pilot study on the main local population in 1995 and 1996 (Čelik 1997). Studies on the population ecology, habitat preferences and autecology were repeated in 2001 (Čelik 2003, 2004) and 2008 (Čelik et al. 2008) including the whole metapopulation.

In this paper, we summarize all present knowledge about the False Ringlet in Slovenia, from its distribution, habitat preferences, metapopulation structure, to major threats and conservation. We hope thus to trigger further research on this rapidly declining species, both in Slovenia and Europe.

Material and methods

The general information on the methodology and material used in the presentation of *C. oedippus* in Slovenia are summarized in Table 1. Details that are important for understanding the results are explained in the following sub-chapters.

Habitat

During the flight-period of the species, vegetation surveys (relevés) were performed in each habitat patch, applying the standard Central-European phytosociological method (Braun-Blanquet 1964). On the basis of floristic and structural variations, the vegetation types were determined at the syntaxonomical levels of association, sub-association or variant. In each relevé, the height (min, mean, max) of the herb vegetation was recorded by direct measurements. The size of each patch was calculated from aerial photographs (Ortophoto DOF050 1:5000; GURS) using Arc Map 9.2 (ESRI, 1999–2006). The non-parametric Mann-Whitney test was applied to compare the difference in average patch area among different distribution regions of the species in Slovenia.

Movements of adults

The within-patch flight distance of an individual was calculated as a straight line connecting two consecutive points of capture. The migration distance of an individual was measured as the Euclidian distance between the closest edges of patches where consecutive captures took place. The migration rate was calculated as the quotient between the number of migratory individuals and the number of all recaptured individuals in the study system. The non-parametric Sperman rank correlation coefficient (r_s) was used for analyzing the relationship between patch area and within-patch distances moved by adults. The non-parametric Mann-Whitney test was applied to compare the difference in the average within-patch flight distances between the sexes.

Patch occupancy

Forward stepwise multiple logistic regression was used to analyze the relationship between environmental variables and the presence of *C. oedippus* in habitat patches. Three groups of environmental variables were recorded for each habitat patch: (i) habitat structure (patch area, permeability of patch boundary), (ii) habitat composition (percentage cover of host plants, percentage cover of nectar plants, percentage cover of Dicotyledones in herb layer, height of herb vegetation) and (iii) habitat connectivity (patch isolation, permeability of matrix). The permeability of the patch boundary was calculated as the proportion of the patch perimeter bordering open habitat types that were regarded as permeable to adults (Čelik 2003). The percentage cover of food plants and Dicotyledones (except nectar plants), and height of herb layer were derived from vegetation relevés (see sub-chapter Habitat). Four isolation indexes were used for the effects of the spatial isolation of patches, as proposed by Hanski et al. (1994). The permeability of the matrix was described by two attributes: dimension (the distance between patch *i* and the nearest occupied patch) and composition (openness of habitat types between patch *i* and the nearest occupied patch) (Čelik 2003). Stepwise multiple logistic regression procedures were performed with the logit of the probability of finding *C. oedippus* (P) in a patch as the dependent variable, with Logit (P) = ln[P/(1–P)], and the environmental variables mentioned above as independent variables (for details, see Norušis 1993).

Population size

MRR data were analyzed using MARK software (White 2008, Cooch & White 2008) and *POPAN* formulation of the Jolly–Seber approach within the framework of constrained linear models (Schtickzelle et al. 2002), as incorporated in MARK (Čelik in prep.). For patches in which MRR data sets were insufficient to obtain accurate estimates in the MARK program, the population size was estimated by multiplying the number of marked individuals in the patch by a conversion coefficient as proposed by Hanski et al. (1994).

Statistical analyses

All statistical analyses were performed using SPSS 8.0 (SPSS Inc. 1989–1997) and SPSS 13.0 (SPSS Inc. 1989–2004).

Results and discussion

Distribution

The False Ringlet was recorded in approximately 100 sites in Slovenia, the majority in Istria and the NW Primorska region (Fig. 1). Its range has severely contracted in central Slovenia, since the species has become extinct in isolated sites near Litija in the Sava river valley, at Medno north of Ljubljana, in the southern suburbs of Ljubljana and in the southern and central parts of Ljubljansko barje (Čelik 2003). Its eastern and south-eastern edge is now the only stronghold of the species in central Slovenia. Small populations have also been found around Grosuplje, east of Ljubljansko barje, where the butterfly has become extinct at the only known historical site. These populations are isolated and very small, occupying suitable habitats of about 1 ha or less. There are recent records at two sites, but one is threatened due to overgrowing with reed. At one site, only two specimens were seen at

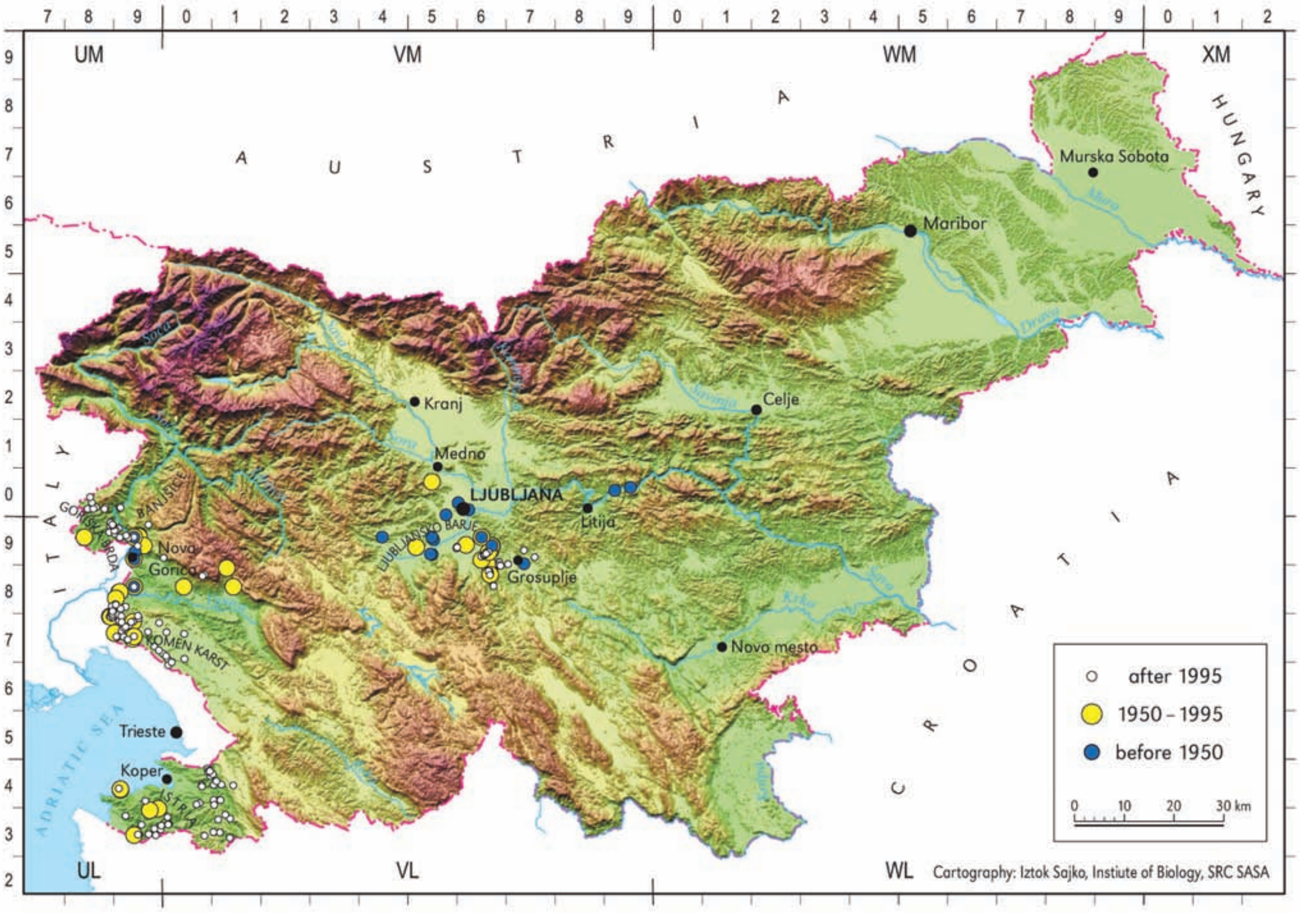

Fig. 1. Distribution of False Ringlet *Coenonympha oedippus* (Fabricius, 1787) (Lepidoptera: Nymphalidae) in Slovenia. (for source of distribution records, see Material and Methods).

the time of discovery in 2000, and no further specimens have been observed since (Verovnik, pers. observ.).

In the western part of the species distribution in Slovenia, the rate of newly discovered sites is still higher than known extinctions. If we exclude the historical records, which are usually linked to major towns or cities, there are just a few sites in which the species has become extinct, mostly due to intensification of land use or abandonment. A prime example is the site on cape Ronek, where the butterflies lived on humid grasslands above the coastal cliffs, which have been partially transformed into olive groves and partially overgrown by Flowering Ash (*Fraxinus ornus* L.). However, there are much greater densities of sites further inland, where the species possibly forms a still viable metapopulation. The same applies for the Komen karst plateau in the NW Primorska region. In the surroundings of Nova Gorica, the lower Soča river valley and in the Goriška Brda region, the species is much sparser.

The False Ringlet is an almost exclusively colline species, with the vast majority of records from altitudes below 400 m. The only exceptions are records from the southern foothills of the Banjšice plateau (470–500 m) (Čelik, pers. observ.), a possibly extinct population on Sveta Gora near Nova Gorica (650 m) (Čelik 2003) and a single unconfirmed record from Mt. Čaven (1100 m) (Čelik et al. 2004, 2005). Since there are no suitable habitats on Mt. Čaven, the butterfly was probably blown from the slopes of the Vipava valley.

Habitat preferences

The species inhabits two major habitat types in Slovenia. In central Slovenia (Ljubljansko barje and its surroundings), the habitats are alkaline fens (*Caricetum davallianae* Dutoit 1924, *Schoenetum nigricantis* Koch 1926), semi-natural wet meadows with Purple Moorgrass on oligotrophic soil (*Molinietum caeruleae* Koch 1926 subass. *caricetosum davallianae* and subass. *caricetosum hostianae*) (Fig. 2) and damp meadows of rushes and Purple Moorgrass (*Junco-Molinietum* Preising in R. Tx. et Preising ex Klapp 1954) on mesotrophic soil (Čelik 2003). The density of the vegetation is low, usually allowing exposure of the ground to light. The minimum height of the herb layer ranges from 15 to 70 cm (median: 30 cm), the mean height from 25 to 100 cm (median: 50 cm) and the maximum height from 50 to 180 cm (median: 100 cm). High values of maximum height are reached only by individual plants of, e.g., *Cirsium palustre* (L.) Scop., *C. oleraceum* (L.) Scop., *Solidago gigantea* Aiton and *Filipendula ulmaria* (L.) Maxim. A high level of groundwater and the gley soil, with the upper layer drying out in summer, create a warm and humid microclimate during the flight season of the adults (Čelik 2003).

In the NW Primorska region and Istria, the species inhabits early successional stages of abandoned, floristically poor, slightly overgrown submediterranean–illyrian dry grasslands (*Danthonio–Scorzoneretum villosae* Ht. et Ht–ić (56)58, *Carici* *humilis–Centaureetum rupestris* Ht. 31) (Čelik 2003) (Fig. 3). It is characteristic of these successional stages that grasses (e.g. *Bromus erectus* agg., *Brachypodium rupestre* (Host) Roem. & Schult, *Chrysopogon gryllus* (L.) Trin., *Dactylis glomerata* L., *Briza media* L., *Festuca valesiaca* agg., *Danthonia alpina* Vest, *Koeleria pyramidata* (Lam.) PB.) already dominate in the herb layer. The growth habits of grasses makes them more competitive in the grass turf than colourful flowering Dicotyledones, especially annual herbs. Patches of shrubs (e.g. *Cotinus coggygria* Scop., *Juniperus communis* L., *Prunus spinosa* L., *Frangula rupestris* (Scop.) Schur, *Spartium junceum* L.) and young thermophyllic trees (e.g. *Fraxinus ornus* L., *Quercus pubescens* Willd., *Q. cerris* L., *Pinus nigra* Arnold, *Robinia pseudacacia* L.) appear scattered over entire abandoned meadows. The mean height of the herb vegetation ranges from 30 cm to 60 cm; some individual plants (e.g. *Bromopsis erecta* s. lat., *B. rupestre, C. gryllus*) are more than 120 cm tall. In the composition and architecture of the herb layer, such overgrown grasslands are similarly monotonous (in terms of floristic composition) as the wet meadows that the species inhabits in the central part of the country. The warm and humid microclimatic conditions during summer are maintained by the combination of deeper soil, higher density and taller height of the herb layer than on typical submediterranean dry grasslands, and by the shade provided by woody vegetation. Desiccation of the larval host plants in drier and more open grasslands in late summer (when early larval stages are present in the habitat) is probably the limiting factor in the distribution of this species in SW Slovenia (Čelik 2003).

Fig. 2. Habitat of *C. oedippus* in central Slovenia: unimproved wet meadows with Purple Moorgrass (*Molinietum caeruleae* Koch 1926).

Fig. 3. Habitat of *C. oedippus* in SW Slovenia: abandoned, floristically poor, slightly overgrown submediterranean–illyrian dry grassland *Danthonio–Scorzoneretum villosae* Ht. et Ht–ić (56)58.

In the NW Primorska region and Istria, the areas of occupied habitat patches are significantly smaller (median: 0.04 ha) than in central Slovenia (occupied, median: 2.52 ha, Mann-Whitney Z = –4.40, P<0.001; unoccupied, median: 0.77 ha, Mann-Whitney Z = –4.81, P<0.001) but the density of patches is much higher in SW Slovenia. This difference is mainly a consequence of the changes of land use and abandonment in the last two hundred years, resulting in a different landscape composition (Čelik 2003).

Phenology, behaviour of adults and ecology of early developmental stages

In central Slovenia, the adults fly in one generation from early June until mid July. This corresponds well with the situation in the NW Primorska region but, in 2008, a single fresh specimen was observed near Sečovlje in the coastal part of Istria on 14 August, possibly belonging to a partial second generation. The duration of the flight season is 35–40 days, with males emerging before females (Čelik 1997, 2003, 2004). From the daily survival estimation, the maximum life expectancy of adults is estimated at 9 days for males and 12 days for females (Čelik in prep.). The maximum lifetime observed was 18 days for males and 26 for females (Čelik 2004, in prep.).

Males spend more time flying (71% of their daily activity) than females (24% of their daily activity) (Čelik et al. 2009), which is in accordance with a patrolling strategy as male mate-locating behaviour (Čelik 1997). Strong wind greatly reduces the flight activity of butterflies in open habitat patches and adults retreat to rest on the lower part of plant stems. Adults feed very rarely, females more frequently than males (Čelik 1997). *Potentilla erecta* is the only observed nectaring plant of the False Ringlet in Slovenia (Čelik 1997, 2003). Copulation is not limited to a specific time period and was observed from 9.30 to 18.30 CEST and could last more than one hour (Čelik et al. 2009).

The spatial and seasonal pattern of the within-patch microdistribution of adults is determined by the composition and architecture of herb vegetation (vegetation height, the homogeneity of the host plant stand, the shading of the ground and/or the lowest parts of herb layer) (Čelik et al. 2009). These affect the dynamics of butterfly emergence and the selection of oviposition sites. In central Slovenia, the preferred sites have low herb vegetation with mean height of 25 cm and moderate shading. The abundance of the nectaring plant in the patch does not play an important role in adult microdistribution (Čelik et al. 2009).

The oviposition plants of the species in central Slovenia are *Carex hostiana* DC., *C. panicea* L., *C. davalliana* Sm., *Molinia* *caerulea* s str. and *Gratiola officinalis* L.. The eggs are deposited singly, on the edge of the blade or on the grass stem (*M. caerulea*); oviposition height is about 5–15 cm (*C. davalliana*, *G. officinalis*) or 15–25 cm (*C. hostiana*, *C. panicea*, *M. caerulea*) above the ground (Čelik et al. 2009). The larvae were observed feeding on *Molinia caerulea*, *Carex flava* s. lat. x *hostiana*, *C. hostiana*, *C. panicea*, and *C. davalliana* (Čelik 1997, 2003, 2004). They pupate on the food plants (Čelik 1997).

Within-patch movements of adults

The within-patch distances of both sexes are in positive correlation with patch size (males: $r_s = 0.32$, $P<0.001$, females: $r_s = 0.17$, $P<0.01$). Males and females move a mean distance of 58 m and 40 m, respectively (Fig. 4), the difference between sexes is significant (Mann–Whitney Z = –6.60; $P<0.001$).

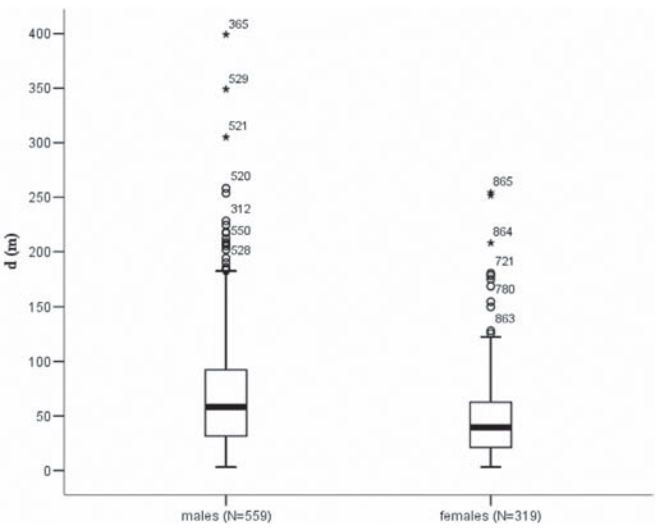

Fig. 4. Difference in within-patch distances (d) between males and females of *C. oedippus* on Ljubljansko barje in 1996, 2001 and 2008.

Maximum within-patch distances of males (399 m) and females (252 m) are estimated at 80% and 50% of the maximum possible movement in the patch (= max. diameter of patch in the research area), respectively. Only 21% of movements of males and 8% of females are greater than 100 m, and only 3% and 1% further than 200 m, respectively. In addition to patch size, the distances and seasonal pattern of male movements is also dependent on the microdistribution and density of freshly emerged females (Čelik et al. 2009).

Patch occupancy and size of local populations

Data on the distribution of the species and on the changes of the landscape on Ljubljansko barje during the last hundred years show that the species has declined in correlation with the loss and fragmentation of its habitat caused above all by intensification of agriculture and urbanization (Čelik 2003). Altogether, 21 patches of suitable habitat for *C. oedippus* were found on Ljubljansko barje (Fig. 5), varying in size between 0.3 and 6.2 ha. Only eight patches were occupied in 2001 and one additional patch in 2008 (Kon, Fig. 5). Old distribution records (Čelik 2003) show that at least 7 patches (Pa1, Pa2, Bjr, Mat, Sk3, Drm, Rst, cf. Fig. 5), unoccupied in 2001and 2008, were populated by the species until the late 1970s or early 1980s. Three of them (Bjr, Sk3, Drm) became unsuitable between 2001 and 2008 (Čelik et al. 2008).

The best logistic regression model (model $Chi^2 = 18.38$, df = 2, P<0.001), which explained the most variance in patch occupancy (88%) shows (Fig. 6) that patch occupation is determined by the interaction between the percentage cover of the nectar plant (*P. erecta*) and the percentage cover of Dicotyledones, and the patch area (Čelik 2003).

The percentage cover of host plants is not an important parameter in patch occupancy because host plants had a continuous distribution within all occupied and unoccupied patches (Čelik 2003). Combining the effects of all the aforementioned patch variables suggests that, in the case of near continuous distribution of host plants, patch occupation mostly depends on the architecture of the herb layer, not on the abundance of host plants within a patch. Namely, with increasing cover of Dicotyledones within the herb layer, the suitability of the patch for *C. oedippus* decreases because the

Table 2. Changes in patch area (AREA), patch vegetation (VEGETATION) and population size (N_{total}) of *C. oedippus* in occupied patches on Ljubljansko barje between 2001 and 2008. For $change_s$: percentage change (%); positive change (+); negative change (–); no change (0) (for explanation, see sub-chapter 3.5)

Changes in:	Patch								
	Po	**Mo**	**Dr**	**Vd**	**Pt**	**Pb**	**Gb**	**Ko**	**Kon**
AREA	– (8%)	+ (2%)	+ (16%)	+ (28%)	0	0	0	0	0
Floristic composition and structure of **VEGETATION**	–	+	–	+	–	–	–	–	+
N_{total}	– (84%)	+ (36%)	– (70%)	+ (76%)	– (74%)	– (64%)	– (54%)	– (90%)	*

* The changes in N_{total} cannot be evaluated because the patch was occupied only in 2008.

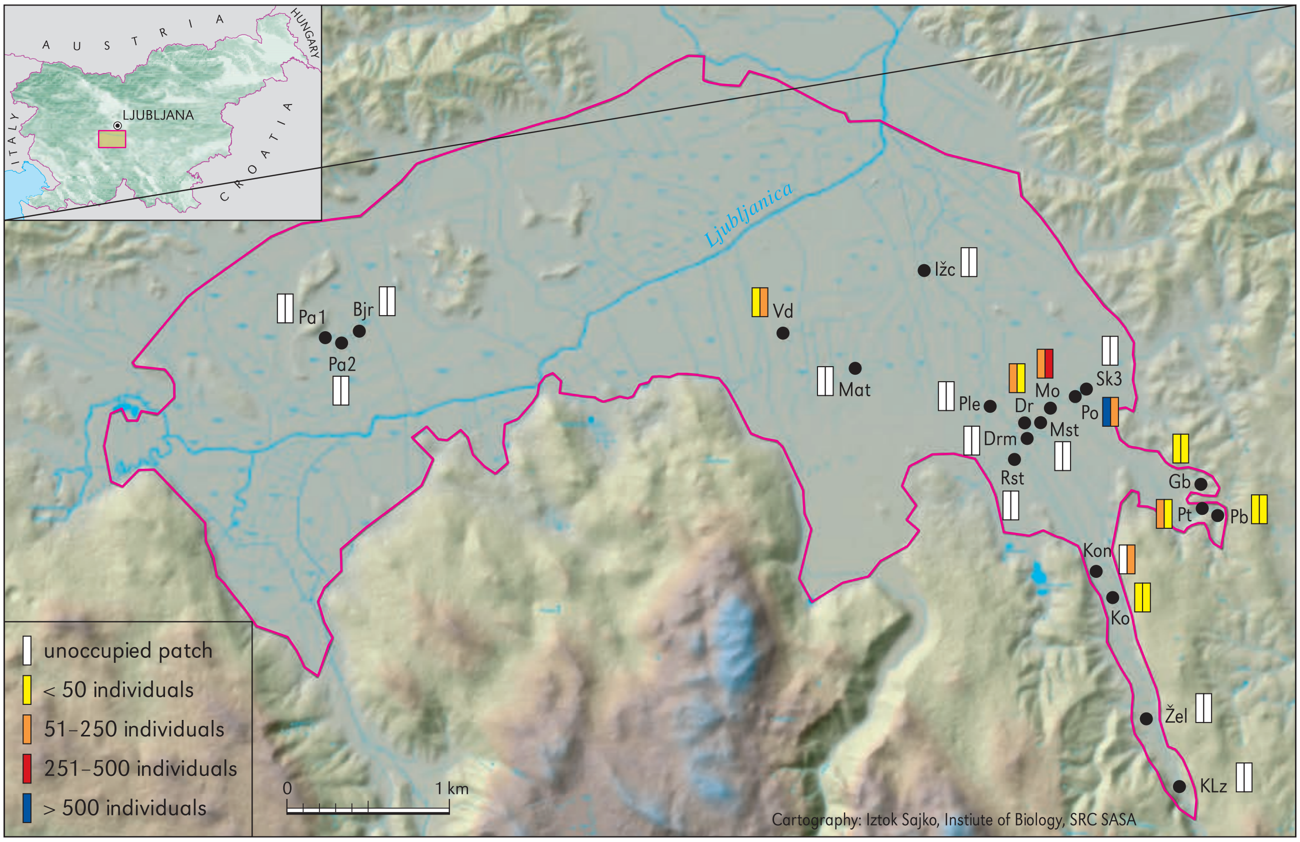

Fig. 5. Patch occupancy and size of patch populations of *C. oedippus* on Ljubljansko barje in 2001 and 2008. For population size: left half of rectangle = population size in 2001, right half of rectangle = population size in 2008.

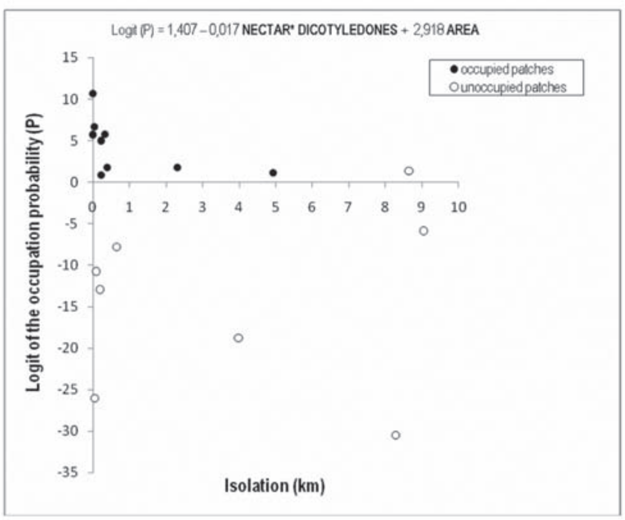

Fig. 6. Explanation of patch occupancy of *C. oedippus* on Ljubljansko barje in 2001 with the best logistic regression model (Logit (P)) and patch isolation. AREA = patch area; NECTAR = percentage cover of nectar plant; DICOTYLEDONES = percentage cover of Dicotyledones (for explanation, see Material and Methods)

stand of host plants becomes less homogeneous and the shading of the lower parts of the herb layer becomes greater (Čelik et al. 2009). However, some remote patches with a suitable combination of patch size and structure of herb vegetation were not occupied, so isolation must play an important role as well (Fig. 6).

In 2001, the total metapopulaton size of *C. oedippus* on Ljubljansko barje was estimated at about 1100 individuals (Čelik 2003, in prep.). A decrease of 30% was observed in 2008 (Čelik et al. 2008, in prep.). Only in two patches (Mo, Vd) had the population size increased (Fig. 5), while a major decline of population size was observed in other patches, reaching between 54% and 90% loss (Table 2).

The abundance in the largest local population (Po, Fig. 5) decreased only by 15% between 1996 and 2001 (Čelik in prep.) but between 2001 and 2008 its decline was drastic reaching 84% loss (Table 2). It was more pronounced (Table 2) than in most of the smaller populations (four out to five, Fig. 5). The observed changes in local population size were highly correlated with changes in the floristic composition and structure of the herb vegetation, and less with patch size changes (Table 2). Namely, in all patches with a negative change in herb vegetation, the population size declined irrespective of a change in patch area. Three types of negative change in floristic composition and structure of vegetation were recorded (Čelik et al. 2008): (i) a decrease in the percentage cover of host plants, (ii) a decrease in the homogeneity of the host plant stand due to an increase in the percentage cover of the herb Dicotyledones, or the common reed (*Phragmites australis* (Cav.) Trin. Ex Steud.) or rushes (*Juncus effusus* L., *J. inflexus* L.) and (iii) overgrowing with young bushes (*Frangula alnus* Mill., *Alnus glutinosa* (L.) Gaertn.). The quality of the habitat is thus the limiting factor rather than patch size.

Dispersal

Dispersal among patches was very limited, since in both 2001 and 2008 it was observed only between three patches: Po, Mo and Dr (cf. Fig. 5). Only 12 migratory individuals (8 in 2001, 4 in 2008) were found and all were males (Table 3) (Čelik 2003, Čelik et al. 2008). Migration rates of about 5% (6.7% in 2001, 4.5% in 2008) indicate a low dispersal ability of *C. oedippus*. The False Ringlet can thus be considered to be highly sedentary in central Slovenia. The maximum migration distance was 340 m. It is shorter than the maximum observed within-patch movement of males (399 m, cf. subchapter 3.4), which indicates that the permeability of the matrix is also an important parameter in determining the migration rate of *C. oedippus* (Čelik 2003). This is also well exemplified in the case of the three easternmost patches (Pt, Pb, Gb; cf. Fig. 5) in the network, where no migration was observed despite proximity, with the minimum inter-patch distance being 225 m. These patches were separated by elevated woods which form a physical barrier disabling successful migration.

Table 3. Dispersal characteristics of *C. oedippus* on Ljubljansko barje in 2001 and 2008.

Year	Network of patches	No. of migratory ind.	Migration rate (%)	Sex of migratory ind.	Migration distance (m)
2001	Po–Mo–Dr	8	6,7		
	Po–Mo	6	7,1	♂♂	65
	Mo–Dr	2	3,2	♂♂	340
2008	Po–Mo	4	4,5	♂♂	65

However, unsuccessful dispersal cannot be detected by the MRR method, and passive drift of an individual from a patch, caused by winds, is possible, especially in more active males. In view of their greater flight activity during the day and longer within-patch distances moved, the probability of males encountering the patch boundary and then emigrating is also higher than for females (Čelik 2003).

A higher density of suitable patches and distribution records of the species on Ljubljansko barje until the 1970's (Čelik 2003) suggests that connection via migration may have existed in the past between the current network of local populations (Po, Mo, Dr) and more distant sites. From this point of view, the existing metapopulation of *C. oedippus* on Ljubljansko barje should be considered to be of a non-equilibrium type.

Threats and conservation

Judging from the situation on Ljubljansko barje and in central Slovenia as a whole, a decline in both distribution and population size is evident. Despite that, there are neither active conservation of the species nor an existing species action plan, and the deterioration of its habitats continues. A major road construction that would have intersected the main population was fortunately banned, but other reasons for species decline, such as land drainage, improvements of grasslands, overgrowing of fens and wet meadows, grass burning in spring and mowing within the flight season (Čelik 2003, Čelik et al. 2008, in prep.), are still present. Most of the populations in central Slovenia are now within the NATURA 2000 network, which should provide some protection and species specific management and, hopefully, it will not be too late when it happens. Due to the vicinity of Ljubljana and the accessibility of sites, the False Ringlet was severely collected 20 to 50 years ago, apparently with no or very little impact. Certainly strict protection of the species will not be of any help if the habitat loss continues.

The situation is less studied and clear in the NW Primorska region and Istria, where new sites are still being discovered almost every year. At least in some parts of Istria and the Komen karst plateau, the density of these sites is so high that a metapopulation is feasible and should be studied in the future. Despite much lower densities of adults, these patch networks could host the most vital populations in Slovenia. However, even in these regions, the habitats are under threat due to large scale abandonment, which creates early successional stages that benefit the species but, in the long run, it will result in local extinctions. Urbanization and intensification of agriculture are the main reasons for the destruction and fragmentation of the habitat in the costal part of Istria and in the wine-growing districts of Goriška Brda.

If we wish to guarantee the long term survival of this fascinating butterfly, we should proceed towards active conservation through management of the remaining suitable habitats and providing a dense network of suitable habitat patches and dispersal corridors. This is very urgently needed in central Slovenia, but despite the higher density of momentary suitable habitat patches it will also be necessary in the NW Primorska region and Istria because of short-living successional stages, on the one hand, and intensification of agriculture and urbanization causing disconnection between populations, on the other.

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False Ringlet *Coenonympha oedippus* (Fabricius, 1787) (Lepidoptera: Nymphalidae) in Croatia: current status, population dynamics and conservation management

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Abstract

Since 2004, the False Ringlet butterfly has been listed as critically endangered in the Croatian Red List of threatened species.

Two years of field studies have shown that the butterfly exists in only 8 isolated localities with no contact between patches. Individual populations showed a range from 300 to 600 adult butterflies. The study has also demonstrated that these are highly sedentary butterflies with poor dispersal abilities. Preliminary life history, population structure and spatial ecology data have been used to develop a species action plan.

Keywords: The False Ringlet, *Coenonympha oedippus*, conservation, population, Croatia

Introduction

Butterflies are amongst the best studied insects of the Croatian fauna, numbering 192 species. Even so, recent discoveries of new species still occur: e.g. *Lycaena ottomanus* Lef, *Polyommatus damon* D. & S., *Cacyreus marshalli* Butler and *Danaus chrysippus* L. (Mihoci et al. 2005, 2006, Perković 2006, Polak 2009).

The False Ringlet *Coenonympha oedippus* (Nymphalidae: Satyrinae) was first detected on four wet meadows in Northern Istria in 1999 (Kučinić et al. 1999) and later on four additional sites (Šašić 2005). The species occurs in Europe locally and through Central Asia to Japan (Lhonoré 1996).

Coenonympha oedippus is one of the most threatened European butterflies, with poorly known habitat requirements (Lhonore & Lagarde 1999, Čelik 2004, Čelik et al. 2009). In the Croatian Red list the False Ringlet is classified as Critically Endangered (Šašić & Kučinić 2004). The species is in serious decline in Europe and therefore is entered in the European List of Butterflies as Endangered in Europe (van Swaay et al. 2010) and in the Annexes of the Habitats Directive.

The aim of this study was to get basic population data, life history and spatial ecology to determine factors that influence the presence and density of the species *C. oedippus*. The data have been used to develop a species action plan.

Methods

The study species: The False Ringlet is a univoltine species living in highly fragmented populations on 8 meadows located along creek valleys north-west of the town Buzet in Northern Istria, Croatia (Fig. 1). Adult butterflies are active from mid June to mid July. Only poor data of host plant use (*Poa* spp, *Molinia* spp) and population dynamics were previously known (Lhonore & Lagarde 1999, Čelik 2004).

The study site: Starting in 1999 we have been searching for *C. oedippus* at all potential habitats in Istria. The False Ringlet was first located at 4 sites in 1999 and later at 4 additional sites (Fig. 2). All sites are separated from each other and from further suitable habitats by an agricultural matrix interspersed with woodlands and small villages. The sites are threatened due to abandonment or irregular mowing.

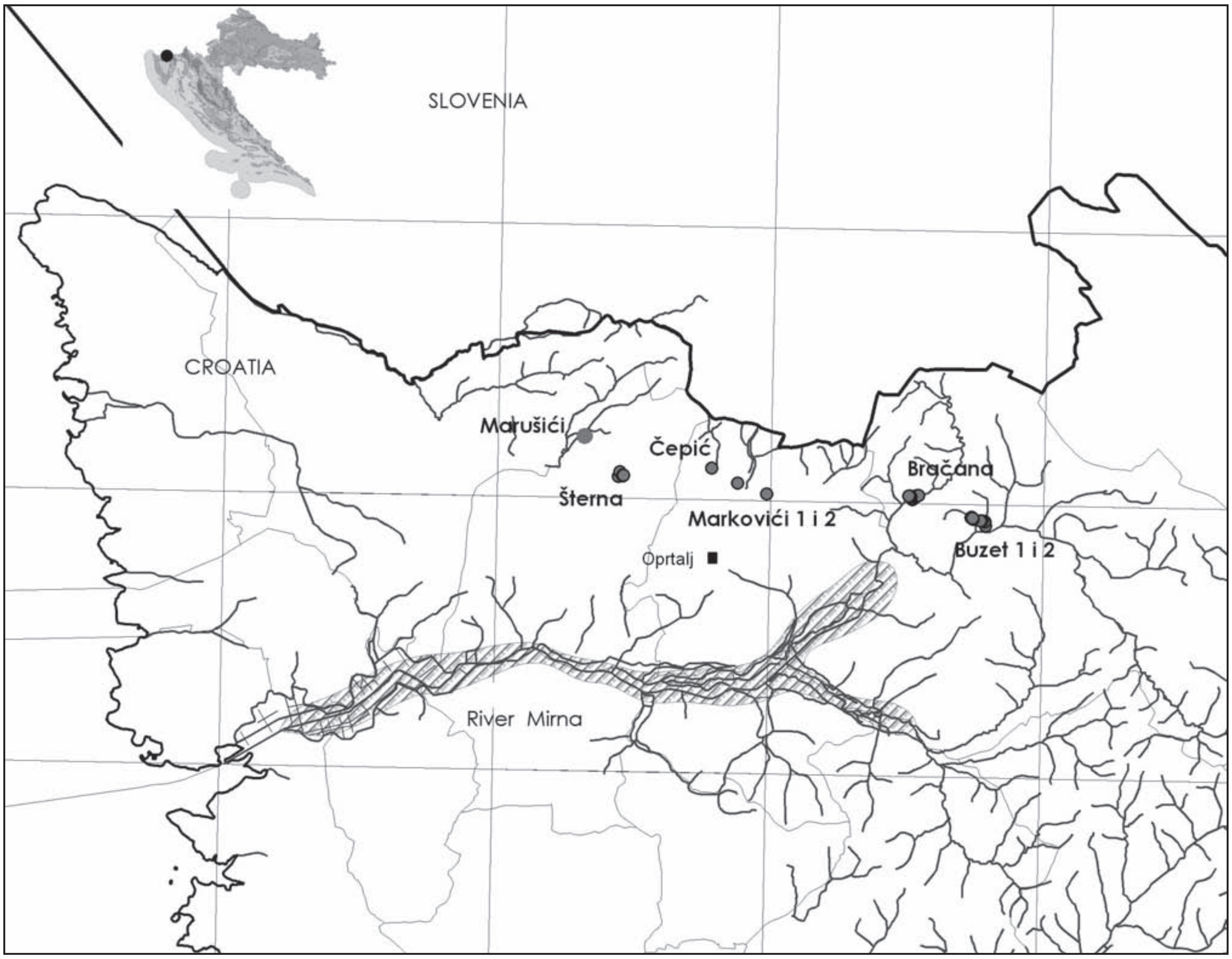

Fig 1. Distribution map of *C. oedippus* in Croatia.

Fig 2. Recently mown *Molinia* meadow on one of the localities in Northern Istria, Croatia.

Mark recapture: The MRR study was carried out at four sites (Buzet 1, Buzet 2, Bračana and Šterna) during the flight season in 2001 and 2002. The size of the sites was between 1.5 and 3 ha.

Routes were walked daily during the flight season. Butterflies were caught, marked on the left ventral side of the hind wing with a Staedler Lumicolor pen and released at the point of capture. The date, time of capture, sex, wing condition, behaviour and vegetation height was recorded for each individual. Mark-release-recapture data were analyzed according to the Jolly Saber model with the programme MARK.

Results and discussion

Habitat requirements

The False Ringlet in Croatia is restricted to periodically wet Molinion meadows along creek valleys on impermeable flisch terrain in altitudes from 26 to 436 m a.s.l. Beside geographical isolation, the meadows are also fragmented by human (non)activities: agriculture, land abandonment, drainage and by forestation mainly with Austrian pine (*Pinus nigra*) and poplars (*Populus* spp).

Habitat requirements of egg-laying females and larvae are considered to be an important aspect of butterfly conservation, but the adults of the False Ringlet seemed to have less specific habitat requirements. Two years of surveying showed that butterflies can be found in meadows with a high water level, but fall dry during the summer, and which support the larval host plants *Molinia* and *Carex*. No factors other than the presence of host plants and a high Ellenberg indicator value of humidity were determined.

Population dynamics – short overview

The adult population size of four meadows in Istria are all together estimated in 2001 to 341 individuals and in 2002 to 690 individuals (the 2001 results are underestimated because marking did not cover the entire flight period). The recapture rate was similar for both years 33 %.

The recapture data did not show any movement of adults between patches, even if the patches were 450 m apart. Both sexes are poor dispersers however males disperse further than females. The MRR results were similar for both years with no fluctuations over this short period of time and are very similar to the results from the study on Slovenian populations (Čelik 2004).

The seasonal recruitment was protandrous. The first males appear a few days earlier than females and reach their maximum density later than females.

Our field data also showed that female butterflies stayed longer on the wing than males. Average wing marks showed an increase with the progression of the flight period but few fresh animals appeared also later. The mean residence time was only 2.1 days and the maximum residence time was 17 days for both sexes.

A total of 627 sightings were made during the study period. Females spent less time flying and more time resting compared to males.

Only 8 feeding events were observed on 4 plant species (*Potentilla reptans, Inula salicina, Dianthus liburnicus, Gratiola officinalis*), even though other nectar producing plants were abundantly available on the edges of the habitat. Copulation and oviposition behaviour were observed only a few times in closed *Molinia* vegetation where butterflies were hidden. Eggs were laid singly on *Molinia coerulea* and also on *Carex tomentosa* where oviposition was found for the first time. The comparison of the behaviour of the sexes with vegetation height showed that females were observed more often on the vegetation with a height from 50-100 cm (host plant category) while males were found more often on open parts of the meadows having a height of 0-50 cm. The majority of butterflies were observed between 10-12 and 15-18 GMT, obviously avoiding maximum air temperatures which sometimes exceeded more than 35ºC.

Two years of study showed a relatively stable but closed population restricted to a few locations with no planned management. Due to the absence of management the habitats are becoming overgrown by shrubs and saplings making them unsuitable for butterflies. At the known localities, only two are mown once a year in summer depending on the weather, but often during the flight period. Other meadows are irregularly mown. One is used as pasture which is overgrazed in the center, but on the edges which are becoming overgrown by shrubs butterfly density is the highest. The future survival of the False Ringlet with its closed population structure, low dispersal ability and limited migration in combination with low connectivity of the landscape is under severe threat.

Conservation status

After this study, an Action Plan for the False Ringlet was compiled for the Ministry of Environmental Protection (Šašić 2001). The species was included on the Croatian Red List of threatened animals (Šašić & Kučinić 2004) and was legally protected in 2006. Cutting the scrubs and saplings from the sites and between close patches to improve the movement of butterflies combined with mowing in the second half of September was suggested.

To date, the implementation of the species action plan in the field with aims of increasing the viability of the existing populations and creating new suitable sites has failed. No efforts were made by the local or the state authorities and the proposed measures were not implemented. Even worse, one site (Buzet 1) was completely destroyed by the building of a parking area during 2007 (Fig. 3). An effective implementation with management and monitoring is urgently needed to avoid the disappearance of this rare European butterfly from the Croatian fauna for ever. The compilation of the Action Plan was a first good step that needs determined follow-up actions immediately.

Fig 3. Recently destroyed site near Buzet.

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False Ringlet *Coenonympha oedippus* (Fabricius, 1787) (Lepidoptera: Nymphalidae) in Poland: state of knowledge and conservation prospects

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Abstract

From the 1970s until the early 1990s *Coenonympha oedippus* was considered an extinct species in Poland. However over the last two decades several sites in three regions have been discovered in the eastern part of the country. Relatively numerous populations inhabiting alkaline spring fens were found near Chełm and Zamość. In 2009 another strong population was discovered in the Narew National Park. Most of the sites are unmanaged at the moment, however regularly lit spring fires are suspected to be beneficial for the thriving of the butterfly habitat at some localities. Otherwise they become overgrown by invasive reed and willow shrubs. Land drainage and eutrophication are regarded as the main threats accelerating successional changes. Almost nothing is known about the dispersal abilities or larval ecology of *C. oedippus* at Polish sites.

Keywords: False Ringlet, *Coenonympha oedippus*, butterfly conservation, Poland

Introduction

According to the Polish Red Data Book of Animals the False Ringlet *Coenonympha oedippus* is one of the most endangered butterfly species in Poland. Its national status was estimated as CR, the same category was also applied to *Parnassius apollo, Polyommatus ripartii*, *Pyronia tithonus, Minois dryas* and *Chazara briseis* (Głowaciński & Nowacki 2004). Fortunately recent data suggest that the situation of *C. oedippus* is less dramatic than it was originally evaluated to be, just a few years ago. However, because of its specific requirements and sensitivity to habitat changes, as well as the overall situation of the species in Europe, *C. oedippus* should be still regarded as a priority species in butterfly conservation, also on a national scale. Although detailed information on the species ecology is still lacking, there are some features which seem to be important for the conservation of the butterfly and we decided to include them in this preliminary summary of the situation of *C. oedippus* in Poland.

Distribution

All known sites of the False Ringlet in Poland are restricted to the eastern parts of the country (Fig. 1). For the first time the butterfly was recorded in the Białowieża Forest (outside the Białowieża National Park) in the valley of the Leśna river (52°39'N 23°40'E) by Krzywicki (1967). It disappeared from that locality in the 1970s (Buszko & Masłowski 2008), but survived well in the Belarus part of that area. It is quite widespread there and has found to be numerous in appropriate habitats. Some of those sites are situated close to the Polish border (Dovgailo et al. 2003, A. Kulak pers comm).

A population in the Zawadówka fen (also known as Sobowice fen) near Chełm (51°07'N 23°24'E) was discovered

Fig. 1. Occurrence of *Coenonympha oedippus* in Poland according to 10 km UTM grid: ● – the historic site in the Białowieża Forest where the butterfly became extinct in 1970ies; ● – present sites: in the Narew National Park, near Chełm and Zamość. Selected national parks mentioned in the text are marked in yellow.

(K. Pałka) as recently as 1992. In 2000 a single specimen of the butterfly was found in the Narew National Park, in the valley of the Kurówka River, Narew's left tributary (53°06'N 22°48'E), during preliminary inventory work (Winiarska 2001). The presence of *C. oedippus* in the NNP was confirmed in 2009 but the butterfly was recorded in a different part of the area i.e. the Rynki fen (53°00'N 22°56'E) (C. Bystrowski). Between 2003 and 2008 five populations were found in the valley of the Sieniocha river (50°38'N 23°33'E) in the Zamość region (W. Michalczuk). Finally, in 2008, a second locality near Chełm, at Kamień (51°06'N 23°34'E), was discovered (K. Pałka).

It is improbable that these recent records are related to new colonisation events, as is believed to be the case for another endangered satyrid, *Minois dryas,* in SE Poland (Warecki & Sielezniew 2008). New observations may rather illustrate inventory gaps which still exist. Recent activities related to Natura 2000 revealed the presence of many previously unknown populations of rare butterflies, including Habitats Directive species.

The common feature of the localities near Chełm and Zamość is the presence of calcareous spring fens which form a kind of mosaic with *Molinietum* vegetation (Fig. 1 and 3). The Zawadówka fen covers about 90 ha and *C. oedippus* is observed almost everywhere there. The other recently found site (Kamień) in the same area is situated about 10 km away and also covers about 90 ha (including 30 ha of *Molinietum* meadows). The estimated areas of the five sites in the Zamość region are 4, 9, 20, 28 and 36 ha.

Almost nothing is known about the habitat of *C. oedippus* in the Narew National Park, where it was observed somewhere in the Kurowo Damp strictly protected area (about 50 ha). It is possible that the species occurred in tall sedge fens *Magnocaricion,* as other types of open vegetation recorded there are only the rather unpleasant reed fens *Phragmition*. Generally the area is dominated by forest and shrub communities with some gaps of open moist grass vegetation.

We failed to find *C. oedippus* there again. It is also not out of the question that Winiarska (2001) attributed the record to the Kurowo fen by mistake and in fact it concerned the Rynki fen where a strong population (or a metapopulation) was discovered in 2009. The area inhabited by *C. oedippus* on the new locality is roughly estimated at ca. 100 ha and encompasses *Molinion* meadows as well as sedge fens (Fig. 4).

Fig. 2. A patch of the habitat of *C. oedippus* at Zawadówka where imagoes were most often observed and two larvae were also found.

It is worth to notice that the butterfly has not been found so far in the Biebrza National Park, which is located in the same region of NE Poland and is famous for its extensive area of fen communities and high richness of butterfly fauna, outstripping the Narew NP significantly (Frąckiel 1999). *C. oedippus* has neither been recorded in the Polesie National Park, which also encompasses a vast area of wet eutrophic wetlands (Pałka unpublished).

Imaginal Ecology

Imagoes are typically observed from mid June to mid July. At a transect route (1050 m) at Zawadówka, established in 2008 for the monitoring of Habitats Directive butterfly species within the frame of the Life project "Conservation and Upgrading of Habitats for Rare Butterflies of Wet, Semi-Natural Meadows" (LIFE06 NAT/PL/000100), a clear peak of the flight period was observed in the end of June/ beginning of July (Fig. 4).

Although the total area in which the butterfly was observed was broad, the density of imagoes was very uneven. The fixed transect was divided into sections reflecting vegetation variability and also provided us with some information on the habitat affinity of the butterfly. The traversed area can be generally described as a mosaic of sedge moss fens *Caricion davallianae, Magnocaricion* and patches of shrubs *Salicetum pentandro-cinerea*. However, over half of all observed butterflies were counted in one section (length 160m), which was rather homogenous and quite distinctive (Fig. 2). The frequency of counts there (ca. 25 individuals per 100m) was nearly four times higher than for the whole transect (ca. 7/100m). The section runs across the *Betulo-Salicetum repentis* vegetation type dominated by *Molinia coerulea, Betula humilis* and *Salix rosmarinifolia*. Other plants recorded there were, among others: *Peucedanum palustre*, *Cirsium rivulare*, *Equisetum fluviatile*, *E. palustre*, *Polygonum bistorta*, *Geum rivale*, *Carex davalliana*, *C. gracilis, Galium uliginosum*, *Potentilla erecta* and *Lythrum salicaria*. Generally the vegetation was lower compared to surrounding areas because of an insignificant proportion of *Phragmites australis*. Other sections included communities of *Caricion davallianae* with a visible expansion of *Phragmites* and willow shrubs. Outside the transect the butterfly was also observed in plant communities containing *Schoenus ferrugineus*.

Two of the five sites near Zamość are very close to each other, separated by a few hundred metres of unfavourable habitat. Distances between other populations are longer i.e. 2-3 km. However, it is not known whether all localities support a metapopulation system. During preliminary inventory studies at the peak of the flight period 3-7 imagoes were counted at randomly chosen transect routes (500-900 m) in four localities, which crossed areas of occurrence of the butterfly.

Larval Ecology

The biology of the early stages of *C. oedippus* in Poland is little known. Only some anecdotal observations on oviposition behaviour were carried out on two localities. In the Zawadówka fen females laid their eggs on top of very narrow (ca. 1mm) blades of *Molinia caerulea, Carex davalliana* and *C. gracilis*. There is also a single record of oviposition on a leaf of *Angelica sylvestris*. Overall vegetation structure and microclimatic conditions of the habitat were probably the most important cues. Females avoided patches of habitat covered with *Phragmites* and a dozen or so plants per square metre formed an effective barrier. In the Narew National Park we observed a female ovipositing on both fresh and dry leaves of *Molinia caerulea* as well as on different plant substrates (e.g. a leaf of *Cirsium palustrae*). However eggs were always laid in close proximity to *Molinia* grasses.

Feeding behaviour of newly hatched larvae, as well as the manner in which they overwinter, were not studied. There are two records of caterpillars observed in the Zawadówka fen at the section of the transect (Fig. 2), where the adult butterflies are most commonly recorded. In May 2007 a larva was found feeding on *Molinia coerulea* during the day. It was taken to the lab and kept in a glass container with a big tuft of foodplant and it finally pupated a few centimetres above ground level. In May 2009 another larva was found falling down to the layer when searching in a tussock of *Molinia grass. Carex davialliana* plants were also present in close proximity. However a few attempts to find larvae of *C. oedippus* after dusk failed.

According to literature, Cyperaceae plants, especially *Schoenus,* are also used as larval food plants of the butterfly (Lhonoré 1996, Van Swaay & Warren 1999). In the Zawadówka fen and at sites near Zamość *S. ferrugineus* is a locally abundant species, and at the latter locality *S. nigricens* can be also found. However it is worth mentioning that at Zawadówka high concentrations of adults were observed in places where *Schoenus* plants were absent. However it is impossible to exclude the possibility that other Cyperaceae species, especially *C. davialliana,* can be used along with *M. coerulea* there.

Fig. 3. One of the sites of *C. oedippus* in the Zamość region which is proposed as a new nature reserve.

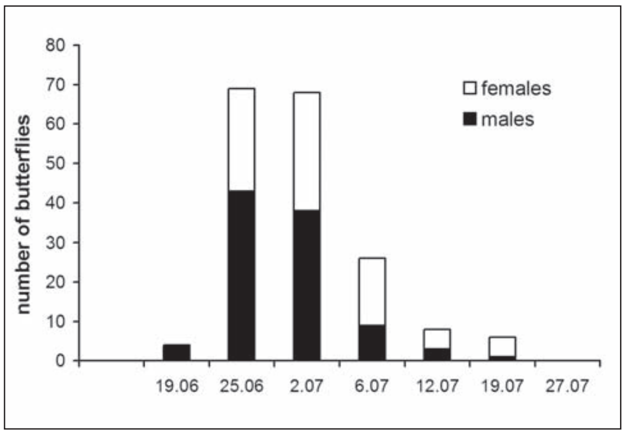

Fig. 4. Counts of *C. oedippus* at the transect (1km) fixed at Zawadówka in 2008.

Decline and Threats

In the Polish part of the Białowieża Forest where *C. oedippus* was observed for the first time, its extinction was probably a result of the disappearance of the habitat. According to Krzywicki (1967) *C. oedippus* used to be an abundant species there in the early 1960s, and it was observed together with other hygrophilous butterflies e.g. *C. tullia,* and *Boloria eunomia*. Former areas of its occurrence are nowadays heavily overgrown with *Phragmites australis* (B. Jaroszewicz pers. comm.), probably also due to drainage and eutrophication. However it would be interesting in the future to obtain detailed knowledge about the habitats of still thriving populations on the other side of the border, i.e. in Belarus.

The expansion of *P. australis* and *Salix* shrubs is a visible sign of local deterioration of the habitat of *C. oedippus* near Chełm. Such changes result from present or past drainage and/or eutrophication. The Zawadówka fen has never been a forest area in the past (Dobrowolski et al. 2005), probably mainly because of floods and inundations. Present expansion of shrubs and trees i.e. *Betula pubescens, Salix cinerea, S. rosmarinifolia, Frangula alnus, Viburnum opulus* and *Alnus glutinosa* is evidence of a soil humidity which is lower than it used to be. Succession, hampered in the past by drainage, is now only effected by spring fires. Recent cessation of that practice has probably contributed to the deterioration of the *C. oedippus* habitat. Another site near Chełm (Kamień), which underwent a drainage process in the 1950s and is still periodically burned, maintains a more open character.

Sites near Zamość are threatened by drainage and also, locally, by peat digging. The expansion of reeds and willows is has also been observed. Two sites are burned every year in April, and two others are burned only sporadically. However, we did not observe any negative effect resulting from the practice even when it was applied to the whole area. This suggests that caterpillars survive early spring fires unharmed, and burning, although generally banned, can even be considered as a favourable form of management preventing adverse successional changes.

Collecting is also suspected to be a potential threat to the best known population at Zawadówka.

Conservation Strategies

Sites of *C. oedippus* are of high conservational value also because of the presence of other rare insects and plants. Therefore all of them have already been included in the Natura 2000 network or they are among those areas proposed for addition to the list. The Zawadówka fen is also already protected as a nature reserve. There are additionally, plans to establish two nature reserves near Zamość which include three sites of the butterfly in that area (Lorens et al 2003, Lorens 2007). At the moment none of the Polish *C. oedippus* sites are included in the list of *Prime Butterfly Areas in Europe* (Buszko 2003). We believe, however, that areas near Chełm and Zamość are deserving of it.

At Zawadówka *C. oedippus* is observed together with other hygrophilous butterfly species e.g. *P. alcon, P. teleius, P. nausithous, E. aurinia*, *C. tullia* and *H. morpheus.* It is also the only place in Poland in which a very rare moth *Xylomoia strix* (Noctuidae) was recorded (Nowacki & Sekuła 1994). A total number of over 1600 Lepidoptera species were recorded from that area (Pałka & Hołowiński unpublished). The Zawadówka fen is also the most abundant site of a critically endangered plant, *Ligularia sibirica* (Asteraceae), in Poland.

In *C. oedippus* habitats near Zamość, as near Chełm three hygrophilous *Phengaris* species were also sympatric. At one site *P. alcon* uses exclusively a unique larval food plant i.e. *Gentianella amarella* (Michalczuk 2005). *Lycaena helle* was also observed at those localities. Some interesting dragonfly species were also found i.e. *Coenegrion ornatum* for which it is the only confirmed site in the country (Michalczuk 2007) as well as *Aeshna juncea, Leucorrhinia albifrons* and *Orthetrum coerulescens*. Some rare plant species are reported from these localities e.g. the already mentioned *Schoenus nigricans*, *S. ferrugineus* and *G. amarella* as well as *Liparis loeselii*, *Swertia perennis*, *Senecio macrophyllus*, *Pinguicula vulgaris* ssp. *bicolor,* (Lorens et al. 2003, Michalczuk 2004, Michalczuk & Stachyra 2003).

In the 1990s when the site at Zawadówka was the only one known in Poland (Buszko 1997), it was monitored from a viewing tower by the municipal police of Chełm and a nature conservation guard, as well as volunteers to prevent over-collecting. However as for many other butterflies, the effect of collectors is secondary relative to the deterioration and isolation of habitats.

Periodic fires have taken over the role of hampering succession in sites affected by drainage. We suggest that controlled burning could therefore be considered as a conservation measure. However, a proper monitoring study should be implemented for the evaluation and optimisation of this strategy in favour of *C. oedippus* and other rare species. Within the confines of the Life project some bushes and trees were removed to improve habitat quality at Zawadówka. The long term effect of the applied measure is difficult to predict. It is plausible that rotational burning is a much cheaper method of management.

Along with the monitoring of particular populations and their habitats, investigations of habitat affinities as well as movement and dispersion abilities of *C. oedippus* are recommended. The Zawadówka fen and the Rynki fen, because of their wide areas, are very interesting for that purpose. On the other hand, the localities in the Zamość region are in close proximity to each other, so it would be important to check whether they form a metapopulation system together.

Acknowledgements

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Ecology of *Coenonympha oedippus* (Fabricius, 1787) (Lepidoptera: Nymphalidae) in Italy

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Abstract

Coenonympha oedippus is a rare and seriously threatened butterfly species all across most of Europe, and is listed in the Annexes II and IV of the EU Habitats Directive.
In Italy this species is restricted to the Padano-Venetian plains, which represent the southernmost part of its European range. 14 of the 108 Italian populations are known to have become extinct.

All Italian populations of *C. oedippus* are closed populations, almost invariably located at reciprocal distances incompatible with adults inter-exchange, as well as with the creation of a meta-population structure. At least in some cases, however, the population density is still high and some populations are very large (Balletto et al. 2005). We studied a *C. oedippus* population in 2 adjoining areas within the «Baraggia» Regional Oriented Reserve, in Piedmont. The first study area is represented by a regularly mown *Molinia coerulea* grassland. The second area has a mixed *Calluna vulgaris* and *M. coerulea* cover. We investigated the adults' population dynamics by mark-release-recapture methods and obtained information on their spatial behaviour by noting the position of every captured and recaptured individual. We also studied females' oviposition behaviour. In the 2 years of our study, adults emerged in mid June and flew until the first decade of July.

The overall estimated population size was of 1404 adults in 2005, and of 2141 adults in 2006. The operational sex ratio was 1.88:1 (♂♂/♀♀). Females generally laid their eggs on *Molinia coerulea*, or otherwise on *Calluna vulgaris*. The larvae consumed on the first plant only.

We discuss possible conservation strategies and try to elucidate reasons underlying the still relatively good conservation status of Italian populations.

Keywords: False Ringlet, *Coenonympha oedippus*, larval ecology, trends, butterfly conservation

Introduction

Coenonympha oedippus is among the most severely threatened European butterfly species, and has become extinct across most of the Continent (Kudrna 1986). In contrast, it is still a relatively abundant species in the North of Italy, where over 100 separate populations are known to occur. Since most animal species tend to become rare at their geographical boundaries, and since the Padano-Venetian plains represent the southernmost European limit of this species' range, in 2005-2007 we have started an investigation trying to discover which biological or local features were at the basis of this seemingly unusual occurrence. To this purpose, we investigated the adults' phenology, population dynamics and spatial behaviour. We also studied the females' oviposition behaviour, as well as the larval food-plants.

In this paper we summarize the current knowledge on the distribution of the species in Italy and present the preliminary findings about adult and larval ecology. As the accumulated data arise a number of additional questions we expect this to become a long-term research.

Distribution

The Italian range of *C. oedippus* is restricted to the northern part of the Padano Venetian plains, to the hydrographical left, i.e. generally to the North, of the River Po (Balletto et al. 2006) (Fig.1).

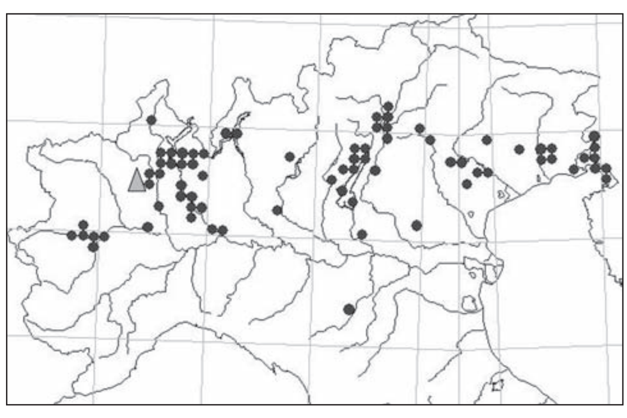

Fig 1. The present distribution of *C. oedippus* in Italy (Balletto et al. 2006). The triangle indicates the study area, Baraggia di Candelo (BI).

Historical records of this species from the hydrological right of this river are limited to an old record by Tognoli (1878) from San Valentino di Castellarano (Reggio Emilia), which either refers to an extinct population, or was based on an error of identification. The first published report of the presence of this species in Italy is due to De Prunner (1798), who observed it in the "Vivariis Regis Venariae", in the western neighbourhoods of Turin.

The geographical variation of *C. oedippus* is slight and most of the existing variation occurs between individuals. Some authors, however, used to recognise the existence of up to 4 "subspecies" across the Italian range of this species, mainly characterised by the size of adults and by the more or less reddish brown colour on the ventral surface of wings. More exactly, *C. oedippus pedemontana* Rocci, 1928 was described from W Piedmont, *C. oedippus mariae* Rocci, 1928 from NW Lombardy, *C. oedippus monticola* Kolar, 1922 from the region of Trento and Bolzano (Bozen), while nominotypical *C. oedippus oedippus* Fabricius, 1787 was thought to be restricted to the Treviso area of Veneto (see Verity 1953). Some other authors assign the Italian populations to "ssp. *monticola*" (see Davenport 1941), but most current authors assign all the Italian populations to the nominotypical taxon.

Imaginal Ecology

Across its European range, *Coenonympha oedippus* has been reported from a variety of wet meadows, such as those with *Molinia coerulea* (Balletto et al. 1982; Balletto & Kudrna (1985), or with *Carex* and *Schoenus* (CORINE: *Cladietum* e *Caricetum*). In some cases it may be found in the wet meadows along the edges of some riverine woodlands with osiers (*Salix*) etc., or more rarely in the dry areas bordering some beech (*Fagus*) forests (Lhonoré 1996a).

In Italy this species is restricted to the wet meadows of the "Molinietum" type (Balletto et al. 1982). Co-occurring butterfly species are: *Coenonympha pamphilus*, *Ochlodes venatus*, *Boloria selene*, *Argynnis adippe*, *Heteropterus morpheus*, *Cupido argiades*, *Minois dryas*, *Gonepteryx rhamni*, *Melanargia galathea*, *Maniola jurtina*, etc (Balletto et al. 1982).

With one notable exception (see below), none of these populations has ever been studied in some detail and no action plan has been developed in Italy for this species, so far.

The habitat in Piedmont

The Government of Piedmont has recently stimulated us to investigate the regional status of this species, which is currently present in this region with 25 populations of various sizes. These are almost invariably closed populations, often located at (reciprocal) distances incompatible with the creation of any meta-population structure, as well as of any amount of adults inter-exchange. However, at least in some cases the population density may be high.

The core area of this study is part of the "Baraggia" Regional Oriented Reserve, where a quite large population was known to occur (Raviglione & Boggio 2001). The aim of this study is to propose a suitable action plan, capable to ensure the long term conservation of *C. oedippus* in Piedmont, as well as in the rest of the Italian range of this species.

The "Baraggia" Regional Oriented Reserve.

The word "Baraggia" locally describes a more or less sparsely wooded habitat characterised by the presence of English Oaks (*Quercus robur*), Birches (*Betula alba*) and Hornbeams (*Carpinus betulus*). The forest is interrupted by large clearings, colonised by *Calluna vulgaris* and *Molinia coerulea*, and the particular soil conditions (clay, not penetrated by water) create a special habitat, where formed a impermeable layer by accumulating silts originating from glacial season.

The Reserve protects only parts of the former Baraggia, which originally extended over a much larger area. At present, only some fragments of it have remained, because of reclamation activities mainly set to favour rice-growing. The same study site includes also a small population of the hygrophilous *Maculinea alcon* (Balletto et al. 2007).

The study area covered about 1 ha and was represented by a regularly mown *Molinia coerulea* grassland (Area 1). A second, adjoining and similar-sized, area had a mixed *Calluna vulgaris* and *M. coerulea* cover (Area 2).

Fig 2. A marked female of *C. oedippus*

In the years 2005 and 2006, we estimated the population size of *C. oedippus* by mark-release-recapture. The site was visited every second day, between 11:00 and 15:00 hours and from 18 June until 8 July, in both years.

In total we carried out 9 capture-recapture sessions. We used individual markings (Fig. 2) and we captured most of the adults in Area 2 (see Tab. 1, 2). To investigate spatial behaviour, we noted the position of every captured adult during the marking and releasing session.

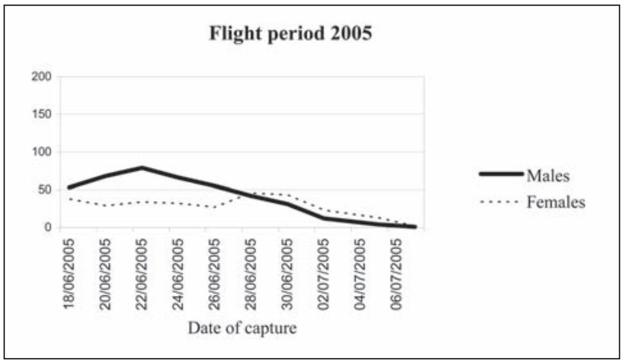

Fig 3. The flight period of *C. oedippus* in the study area in 2005

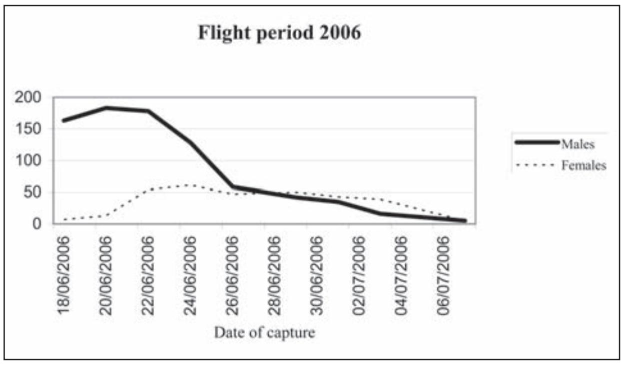

Fig 4. The flight period of *C. oedippus* in the study area in 2006

Table 1

2005	**Area n.1**	**Area n.2**
Males	36%	64%
Females	39%	61%

Table 2

2006	**Area n.1**	**Area n.2**
Males	42%	58%
Females	45%	55%

Tables 1 and 2. Proportion of males and females of C. oedippus captured on the mown (area 1) and unmowed (area 2) meadow in 2005 (Tab. 1) and 2006 (Tab. 2)

Our Piedmontese population demonstrated to be very dense, on European standards: 699 individuals were marked in 2005 and 1141 in 2006. The overall estimated population size was of 1404 adults in 2005, and of 2141 adults in 2006. The operational sex ratio was 1.88:1 (♂♂/♀♀).

We estimated the male and female population sizes by plotting the daily estimates by the Cormack-Jolly-Seber model (recaptures only model, to include recruitment into the populations), using the Mark Programme (Jolly 1982; Seber 1982; Pollock et al. 1990; Tables 3, 4). As is often the case, the capture probability was higher for males.

Table 3

2005	**phi (Survival)**	***SE***	**p (Recapture prob.)**	***SE***
Males	0.75	*0.03*	0.18	*0.03*
Females	0.68	*0.03*	0.11	*0.02*

Table 4

2006	**phi (Survival)**	***SE***	**p (Recapture prob.)**	***SE***
Males	0.79	*0.04*	0.19	*0.04*
Females	0.70	*0.03*	0.13	*0.02*

Tables 3 and 4. The survival rate and recapture probability of *C. oedippus* males and females estimated in 2005 (Tab. 3) and 2006 (Tab. 4)

Males flew all over the area. We recaptured marked males in one nearby patch (419 m) within the reserve, while other patches located further away were never reached by either sex (from 600 to 1470 m of between patches distance). Females were more sedentary than the males and rested near the point of capture, waiting for the males to come.

Oviposition and Larval Ecology

Molinia coerulea, *Schoenus nigricans*, some species of the genus *Poa* and even *Iris pseudoacorus* have been listed in the literature as possible larval host-plants (Lhonoré 1996a; (Higgins & Riley 1970; van Swaay & Warren 1999). During our 2006-2007 field work, however, we observed females laying eggs only on *M. coerulea* and on *C. vulgaris*.

In June 2007 we concentrated on the females' egg-laying behaviour. We recorded females' oviposition behaviour over the first 10 eggs laid by every female for a total of 11 females and 110 eggs (Fig. 5). Eggs were always laid singly, never in groups.

The plants chosen by the females for oviposition were normally green and only on 12 events eggs were laid on dry *M. coerulea* plants.

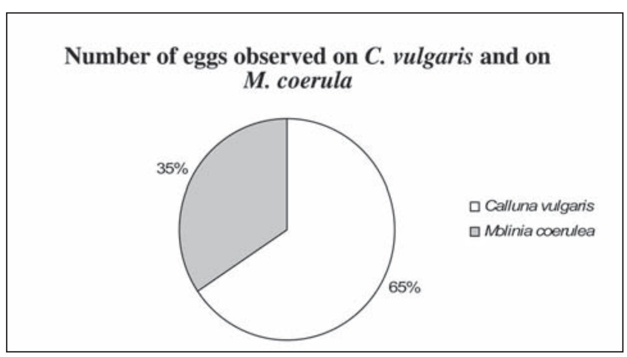

Fig 5. Proportion of *C. oedippus* eggs laid on *Molinia coerulea* and *Calluna vulgaris*

C. oedippus generally laid eggs on the central part of a *M. coerulea* leaf, more rarely at the base or at the top of the plant. Eggs laid on *C. vulgaris* were never deposited on flowers.

A larger proportion of eggs were laid on *C. vulgaris* than on *M. coerulea*, while only two females have laid more eggs on *M. coerulea* (Fig 6). During deposition, females generally fly over a range of up to 60 meters, while the maximum observed movement of a female was of 359 m. Eggs were laid mainly in Area 1 where both plants used for egg-deposition were present.

Fig 6. Proportion of eggs laid on *Molinia coerulea* and *Calluna vulgaris* by 11 *C. oedippus* females

We raised several caterpillars in our laboratory and observed that they invariably moved from *Calluna* to *Molinia* before starting to eat. This is relatively easy also in nature, since *Calluna* and *Molinia* plants are generally very close. *Calluna* is not a larval food plant, but represents a egg-laying site, commonly used by the females at our site.

Decline and Threats

Even though *C. oedippus* is still well represented in Italy, 14 of the formerly 108 Italian populations (Balletto et al. 2007) are known to have become extinct between 1851 and 1987 (Fig. 7), mainly as a consequence of habitat transformation (93%) or destruction (7%).

Current threats are mainly represented by land reclamation for planting rice paddies or poplar groves, by the natural reforestation of some *Molinia* grasslands, as well as by building industrial facilities or, locally, by land drainage and urban expansion, in this order. Threats observed in Italy have thus remained unchanged for over 30 years (Balletto & Kudrna 1985) and are much the same as those observed in other parts of Europe (Collins & Wells 1987; Lhonoré 1996b).

Coenonympha oedippus was listed as an Annex II species since the Bern Convention was signed by Contracting Parties (1979), and at least in the case of Piedmont a number of sites where this species was known to occur were rapidly included into the Regional Reserves network (Casale et al. 1994). Since under the provisions of the EU 92/43/CEE Directive (also known as "Habitats Directive"), *C. oedippus*

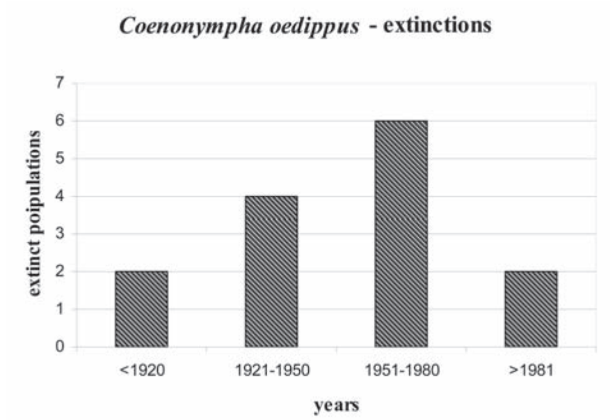

Fig 7. Number of *C. oedippus* extinct population in Italy

is listed as an Annex II and IV species, sites relevant for most of the populations occurring in the rest of the Padano plains have been more recently designated as Sites of Community Interest (SCIs).

Conservation Strategies

Being home to some of the most important European populations of this highly fragile and endangered species at European level puts Italy in a position of special responsibility for preserving it for future generations. Having designated most Italian sites with *C. oedippus* as European SCI is of course an important step in the right direction, but is not sufficient, per se, to insure the long term conservation of this species. Of course the new SCI status of *C. oedippus* sites will make land reclamation almost impossible, at least in most cases and for most purposes. However, much remains to be done. Most important is that, as requested by the Habitats Directive, SCIs are finally, although belatedly, transformed into Special Areas of Conservation and that the necessary Action Plans are really developed and implemented. Most *C. oedippus* sites, and many of the best ones, are still under threat by natural reforestation, mainly by Buckthorn (*Rhamnus frangula*), Birch (*Betula pendula*), Poplar (*Populus tremula*), Hornbeam (*Carpinus betulus*), Reed (*Thypa* spp.) and/or Bramble (*Rubus* spp.) invasion. This can be prevented only by setting out in most cases costly management plans, which for the moment remain only on paper, in the best of cases. Another serious and subtler threat is in indirect land drainage, by increased water subtraction from the water table, for agricultural and/or domestic use.

Another important issue is the need to restore at least some of the meta-population structure that used to characterize many sites of the Padano-Venetian plains, in the recent past. Several of the remaining pristine areas, such as the «Baraggia» Regional Oriented Reserve, have the potential to recreate such a situation. Some apparently suitable habitat patches are currently unoccupied by the species, which might be encouraged to (re-)colonise them either by the creation of suitable corridors or by the transplantation of some gravid females, or both. As we have seen during our field work, in fact, males tend to cover relatively longer distances than females, which show much stricter site-fidelity and the dispersal of both is easily stopped by the presence of even relatively narrow stripes of woodland.

To come to the broader European framework, an important point that needs some reflection is why many Italian populations remain so dense (Balletto et al. 1982 and many unpublished observations), in the face of the sparse population densities generally observed in the rest of Europe. Even though we do not have any final answer to this question we can try to offer some speculation. At least one Italian population that we observed at the «Caselette SCI site» near Turin has apparently the potential for a partial second generation during the season.

This is a totally new observation, although somewhat anecdotal, we observed few adults only once in September 2003 which we are planning to try and quantify during the next flight seasons. The same flight period that we observed, in fact, occurs virtually unchanged all over Europe (Meyer 1992 and many Museum collection data) and even as far East as in NE China, in the area once called Manchuria (our unpublished data). It is to be recalled, however, that the summer of 2003 was a very anomalous season in all of Europe (Schaer & Jendritzky 2004). Whatever all this can mean, having a potential for a partial second generation or a later emergence, may represent an important asset for a population of a hygrophilous species living in the relatively unpredictable weather of the beginning of the (Italian) summer. Probably, reasons for the still considerable abundance and density of the Italian *C. oedippus* populations cannot be traced only to this biological feature, but for all our efforts we found no trace of such a behaviour in the European literature and colleagues from several parts of Europe, whom we interviewed on the subject, were unaware of such a possibility (only one recent exception: a fresh specimen in mid August 2008, see Celik et al., this volume).

Another, perhaps alternative, explanation that we are currently investigating, is that the butterfly larvae find a suitable food-plant phenology immediately on their emergence from hibernation, at the beginning of Spring. This is apparently not always the case, in fact in most of continental Europe.

Acknowledgements

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Structure and size of a threatened population of the False Ringlet *Coenonympha oedippus* (Fabricius, 1787) (Lepidoptera: Nymphalidae) in Hungary

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Abstract

Butterflies react sensitively to changes in habitat quality. Their diversity has been decreasing in Europe due to habitat degradation, fragmentation, management changes and climate change. The False Ringlet (*Coenonympha oedippus*) is one of the 59 butterfly species protected in Hungary. The species occupies marshy meadows dominated by *Molinietum* vegetation. Besides drainage, inappropriate management can also deteriorate these habitats. Nowadays the butterfly remains present in a habitat complex in Hungary, at the north-western part of the Hungarian Great Plain and a newly (2009) rediscovered population in north-western Hungary. Mark–release–recapture method was used to estimate the population size and describe population structure in a 0.65 ha habitat patch from 2005 to 2007. The population size did not fluctuate during the 3 years; the total estimated number of individuals ranged between 130 and 270. The survival probability was 0.81–0.84/day in the case of males, in females 0.70–0.89/day. The catchability was between 0.27–0.53 in males and 0.22–0.38 in females. The structure of the population indicates that the False Ringlet is a sedentary butterfly species, with low dispersal ability. In the study area, drainage seems to be the main threatening factor for its habitat. The studied population has recently moved to neighbouring lower parts of the habitat patch, because the formerly occupied part of the habitat patch had been desiccated and the vegetation had been changed. For the long-term survival of the species at this habitat patch the drainage should be inhibited, while in other habitat patches around, the control of invasive plant species is inevitable beside habitat restoration.

Keywords: False Ringlet, *Coenonympha oedippus*, Hungary, MRR, population size

Introduction

The diversity of butterfly species has decreased in large volume in Europe, some surveys show even larger decrease, than in the groups of bird or plant species (e.g. Thomas et al. 2004). Similarly, the threat status of the species decayed more strongly among butterflies (Van Strien et al. 2009). The main reasons of butterfly diversity decline in Europe are habitat fragmentation (Ehrlich 1988, Maes & Van Dyck 2001), habitat loss (Pullin 2002) and changes of land management (Skórka et al 2007). Due to their sensitivity to temperature, climate change has also enhanced effect on the diversity of butterflies (Lewis & Bryant 2002; Settele et al. 2008).

Agricultural landscapes are affected by either intensification (Thomas 1995) or abandonement, both of which can diminish formerly suitable butterfly habitats (Strijker 2005). The succession after abandonment and the colonization of invasive alien species can decrease the diversity and abundance of native species (Skórka et al. 2007). Species inhabiting wet meadows are among the most endangered ones, because the area of those habitats is declining rapidly as they can be easily converted to agricultural landscapes (Maes & van Dyck 2001, Maes et al. 2004). Drainage is widely recognized as the most important threatening factor for wet meadows, which can affect large areas throughout water table equalization (IUCN 1993).

The False Ringlet (*Coenonympha oedippus*) inhabits wet meadows dominated by *Molinia* species. It is one of the most endangered butterflies in Europe; it is considered as nearly threatened by IUCN (2008) and listed in Annex II and IV of Habitats Directive and Annex II of the Bern Convention. The geographical distribution of the species is highly fragmented and colonies are isolated (Van Helsdingen et al. 1996, Kudrna 2002). The size and distribution of the European populations are declining at several localities and seem to be stable at others, while limited information is available about the populations in Asia.

One of the first publications about the species describes its weak, jumping flight, which is related to the supposed weak dispersal ability (Seitz 1906). The first description of the ecological requirements of the species is from France. Lhonore & Lagarde (1999) mention the problems of fragmentation, isolation and other threatening factors, which endanger the long-time survival of the butterfly. The size and structure of a Slovenian population was studied with mark–release–recapture method by Čelik (2004) from 1995 to 1996. The maximum density of the butterflies was 145 individuals/ha in a 1.27 ha habitat patch, which in contrast to other European habitats consists of areas of *Brachypodium* grasslands and shrubs. Survival probability was 0.77/day for males and 0.80/day for females in the second year (Čelik 2004).

In Hungary, there were several suitable habitat areas for the species earlier, e.g. remarkable populations were described from the Hanság, Kiskunság, Óbuda regions and from Szár according to specimens in the collection of the Hungarian Natural History Museum (Bálint et al. 2006). Due to large-scale drainage in the Kiskunság and Hanság, several wet meadows disappeared, hence their vegetations have been changed (Molnár et al. 2008). The Óbuda area (today the northern part of Budapest) was lost due to urban development.

There is a habitat complex left in the Kiskunság region, in the north-western part of the Hungarian Great Plain, near to Ócsa. However, extinction directly threatens the species in this habitat complex as well due to habitat deterioration and isolation. Habitat degradation is the result of drainage accompanied with aggressive dispersion of invasive plant species. The transformation of vegetation associations caused by desiccation can lead to the spread of invasive alien plant species (e.g. *Solidago* spp.), which are present around the area. In Eastern European wet meadows, *Solidago* spreads forcefully and affects negatively the butterfly communities (Moroń et al. 2009). Since the 1980's the butterfly has left some parts of the habitat, which have become unsuitable and it has moved to lower habitat patches. There was a large population at the Csiffári meadows 2.8 km from the study site (Seregélyes et al. 1986), but that area has become very dry recently and now it is covered by mesophilous vegetation instead of *Molinietum*.

The nearly threatened status of the species motivates the monitoring of the population size. However, to facilitate long-term survival of the species, more accurate population size estimation and the exploration of population structure are necessary. The aim of this study was to estimate some essential parameters of population dynamics (e.g. population size, sex ratio, survival rate, average lifespan) in a single population of the False Ringlet in a three-year period using mark–release–recapture method.

Material and methods

Distribution

The distribution of the species is just partly documented; populations were probably widely distributed in the steppe zone of the temperate region, in *Molinietum* habitats. Outside Europe the species is present in temperate Asia as well: Ural, S and W Siberia, N Kazakhstan, Mongolia, China and Japan (Tolman & Lewington 2008). Based on the database of the IUCN the nearly threatened species is native in Austria, Belgium, France, Germany, Hungary, Italy, Japan, Kazakhstan, Liechtenstein, Mongolia, Poland, Russian Federation, Slovakia, Spain, Switzerland and Ukraine (IUCN 2008). The map of the "Encyclopedia of life" shows 18 localities in France, 8 in Italy, 8 in Austria, 5 in Liechtenstein, 4 in Poland, 2 in Switzerland, 2 in Spain and 1 in Hungary, based mainly on data from museum collections. In Asia 2 localities in Japan and 1 in South Korea are known (EOL 2009). None of the databases contains information about the existing Croatian and Slovenian populations (Sasic, this volume, Čelik et al. this volume), for other countries the information is extremely incomplete, e.g. Italy had more than 100 populations (Bonelli et al. this volume).

In Hungary, former populations of the species existed in the Hanság, Óbuda and Kiskunság region (Fig. 1). The only present population was considered to be in the Kiskunság region, but in 2009 a new, unknown location was found in the north-western part of Hungary.

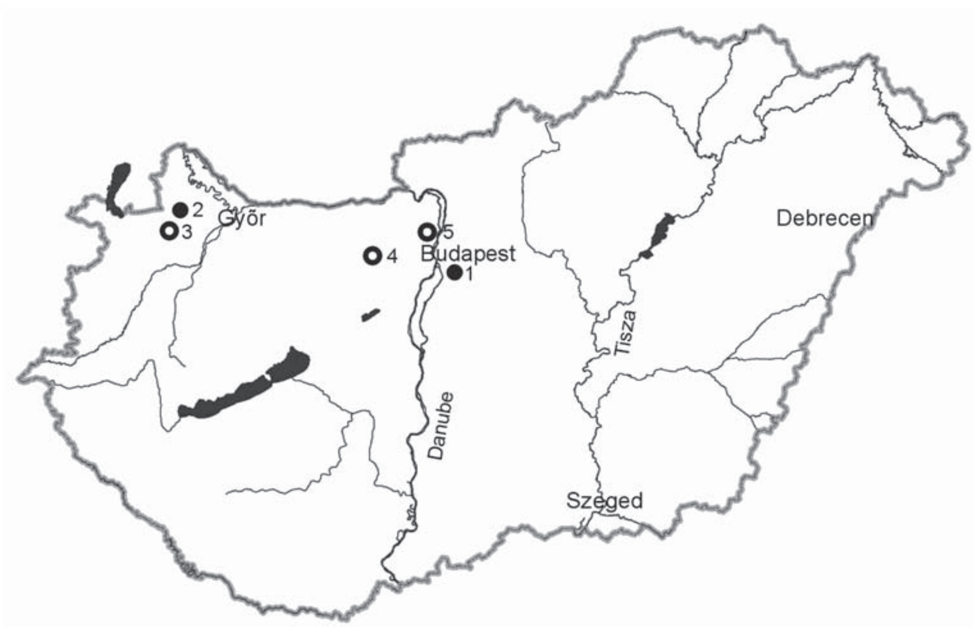

Fig. 1. Present (•) and former (○) populations of the False Ringlet in Hungary. 1 study site at Ócsa (Kiskunság region), 2 new population found in 2009 (Hanság), 3 Hanság, 4 Szár, 5 Óbuda.

Study site

Our study site was 0.65 ha in size, covered with *Molinietum* vegetation and surrounded with bushes and trees (*Salix* spp.) The area tends to be overgrown by common reed (*Phragmites australis*), reed mace (*Typha* spp.) and willow (*Salix* spp.) shrubs. The traditional management was extensive mowing or light grazing. Presently the meadow is mown once in a couple of years. The water table level is lower than ideal due to two reasons. The drainage started in the 1920's (Seregélyes et al. 1986), while later on the advance of gravel mining accelerated the desiccation of the area. The butterfly population has recently moved to lower areas compared to the habitat maps from the 1980's (L. Peregovits personal observation).

Table 1. Results of MRR: capture statistics for *Coenonympha oedippus* in 2005–2007 at Ócsa.

Year	No. of marked individuals		No. of recaptures		No. of captures	
	male	female	male	female	male	female
2005	70	66	139	95	209	161
2006	106	140	234	326	340	466
2007	58	42	26	12	84	54

Species

The species is strictly protected by law in Hungary, considered as nearly threatened by IUCN (2008). Part of its Hungarian habitats are strictly protected in the Ócsa Landscape Protected Area and designated as Sites of Community Interests. The False Ringlet has one generation in Hungary; the flight period is in June–July. Females lay eggs from late June. The polyphagous larvae hatch after 2–3 weeks and start feeding on *Molinia* and *Carex* species.

Sampling method

For population size estimation mark–release–recapture method was used in one habitat patch. Samplings occurred between 16th. June – 1st. July 2005, 17th. June – 7th. July 2006 and 6th. June – 20th. June 2007. The sampling effort was different in the three years: sampling was conducted daily in 2005 and 2006, while every second day in 2007. The butterflies were marked individually with permanent ink pen. A grid of 5×5 m quadrates was laid down in the habitat and capture locations were recorded.

The apparent survival probability and capture probability were estimated for both sexes with the Cormack–Jolly–Seber method using Mark 5.1 (White & Burnham 1999). The best models were selected based on Akaike's information criterion (AIC). Mean lifespan was calculated from survival probability (Cook et al. 1967). The daily population size was estimated with program POPAN 5 (Arnason & Schwarz 1999). The total size of butterflies in a year was calculated with the modified method of Cook et al. (1967). The dominant grasses and sedges were identified in 2005 in the presently and formerly occupied habitat patches of the species.

Table 2. Results of MRR: population structure and parameter estimations.

Year	Daily survival probability ±SE		Mean lifespan		Capture probability ±SE		Estimated total population size	
	male	female	male	female	male	female	male	female
2005	0.84±0.02	0.89±0.02	5.74	8.58	0.4±0.04	0.22±0.03	67.85	69.71
2006	0.82±0.02	0.87±0.01	5.04	7.18	0.53±0.03	0.38±0.02	116.30	157.46
2007	0.78± 0.04		3.95		0.27±0.06		212.80	

Results

The number of marked, captured and recaptured males was higher than those of females in two years, females outnumbered males in capture statistics in 2006 (Table 1).

The model selection resulted gender dependent survival and capture probability in the first two years and gender independent survival and capture probability in the third year. Female survival probability was slightly higher than that of the males in 2005 and 2006. The survival probability in the third year was gender independent and decreased to 0.78. The mean lifespan of females was 8.58 and 7.18 days in the first years, while mean lifespan of males was 5.74 in 2005 and 5.04 in 2006. The mean lifespan had decreased to 3.95 for both sexes in 2007 (Table 2). Capture probability was 0.40 and 0.53 in males and 0.22 and 0.38 in the case of females in the first years and 0.27 in 2007 (Table 2). The estimated total population size was 137 in 2005, 273 in 2006 and 212 in 2007, for the intensive study years 2005 and 2006 this is close to the number of actually marked individuals (Tables 1 and 2).

The highest estimated daily population size changed between 45–81 for males and 29–96 for females (Fig. 2). Males reached their maximum estimated daily population size earlier than females in each year. The butterfly showed the characteristics of protandry, males outnumbered females in the first days of the observation period (Figs. 2 and 3).

Observations of individual movements during the sampling suggested that the butterflies preferred the wettest areas, while avoided open spaces probably due to the more balanced microclimate in the vicinity of bushes; the individuals were sedentary, their flight was short and jumping. They performed short movements. The average distance between

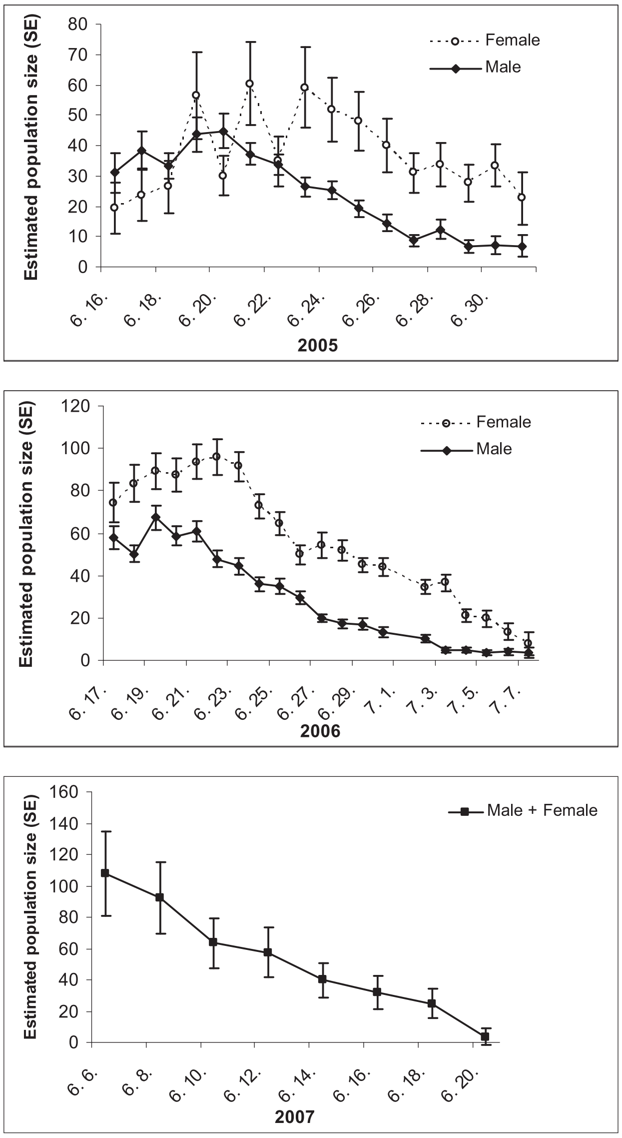

Fig. 2. Estimated daily population size in a habitat patch of *Coenonympha oedippus* from 2005 to 2007, based on MRR studies.

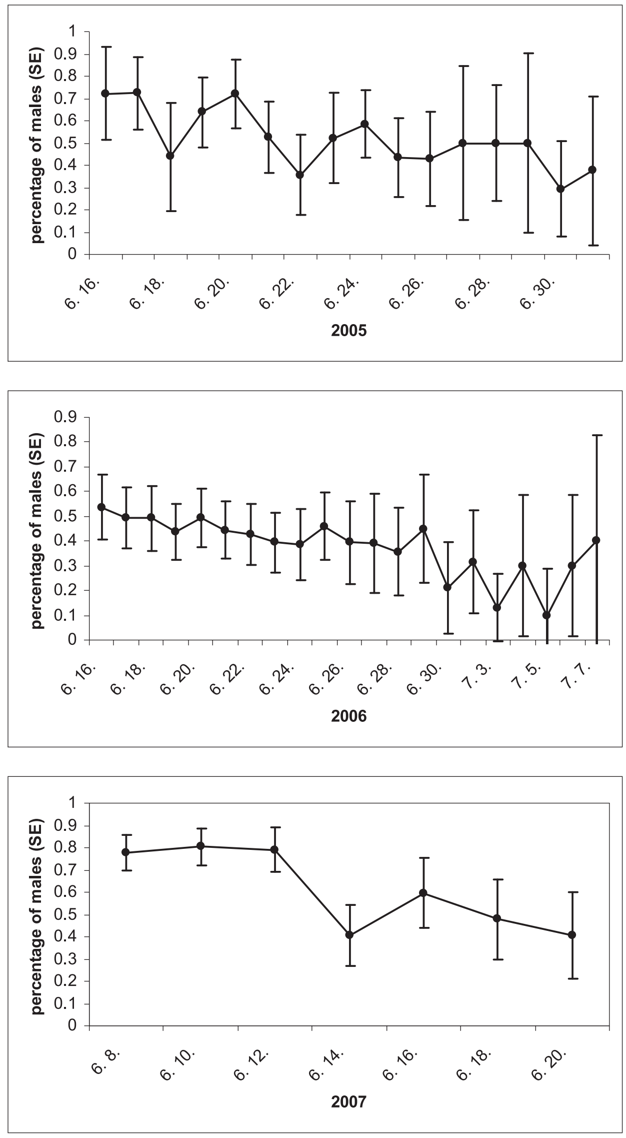

Fig. 3. Percentage of males based on daily capture exceeds female ratio during the first days of sampling in all the examined years.

Table 3. Plant species list in the recent and in the earlier habitat patch, the species composition is changing due to drainage.

	Recent habitat	**Earlier habitat**
Vegetation	species rich *Molinietum*	searing *Molinietum*, with mesophyl patches
Dominant grass species	*Deschampsia caespitosa, Molinia* sp., *Phragmites australis*	*Molinia* sp., *Festuca pratensis, Calamagrostis epigeios*
Dominant sedge species	*Carex acutiformis, Cladium mariscus, Schoenus nigricans*	
Characteristic attendant species	*Equisetum arvense, Inula britannica, Lythrum salicaria, Carex flacca, Cirsium palustre*	*Rhinanthus* sp., *Galium verum, Deschampsia caespitosa, Dactylis glomerata, Briza media*

consecutive recaptures was 38.3 m (52 animals, 1–11 movements/animal). According to the tracking data of individuals, males moved more frequently and flew longer distances (approx. 10–15 m/occasion) than females (0.2–4m), although sample size was not sufficient for statistical analysis.

In the presently occupied habitat patch a species rich *Molinietum* complex exists, while the neighbouring, formerly occupied part of the habitat shows characteristics of a mesophilous meadow with plenty of herbaceous plant species (Table 3).

Discussion

During the three years of the survey, there was no major fluctuation in population size, a promising sign regarding its survival, even though long–term trend cannot be estimated in this time scale. Along with Čelik's survey in Slovenia, protrandric population structure was observed (Čelik 2004), which is a widely recognized phenomenon among butterflies. Early eclosion of males minimizes the energy consumption of females and predation threats before reproduction, while males have enough time to seek for females (Ehrlich 1989). Both males' and females' movement was restricted to short-distance within the habitat patch, similar to Čelik's results (2004). Short flights imply sedentary living habits and closed population.

The apparent survival rate (0.78–0.89) of the species is in the higher region among butterflies. According to Brakefield (1982), survival probability around 0.8 is typical to butterfly species with colonial population structure in temperate climate zones. Although survival rate can be as high as 0.94 in other butterflies species, like *Euphydryas aurinia* (Schtickzelle et al. 2005); or 0.88 for males and 0.84 for females as in the case of *Lopinga achine* (Bergman & Landin 2002). Both butterflies' dispersal ability is similar to sedentary and vulnerable species (Bergman & Landin 2002, Schtickzelle et al. 2005). Our observations on within site movement do not contradict with these results, as the movement lengths of *Coenonympha oedippus* between two consecutive captures are generally short. We can confirm that survival rate around 0.8 might be a sign that the population is closed and dispersal of individuals is low. During 2005 and 2006, the survival rate of the females was higher than that of the males, which is in agreement with the results of Čelik (2004).

Decline of the survival rate in 2007 is a reason to worry, as the shorter lifespan of females can have a direct effect on the quantity of eggs laid. It's proven in the case of *M. rebeli* that the total quantity of eggs possibly laid can be many times higher than the realized number of eggs laid, in other words the females are time-constrained regarding their egg-laying (Kőrösi et al. 2008). Therefore, along with the decrease of the lifetime, the number of laid eggs probably decreases, making the basis of the next generation and the long-term survival of the population uncertain. However, the decline of the apparent survival rate can be a sign of growing dispersion too, because of the declining quality of the habitat patch or any other general problem, i.e. the paramount hot weather in June and July in 2007. The mean lifespan of males was 5 to 6, females 7 to 9 days in the first years, which is slightly higher than estimated in the Slovenian population (Čelik 2004). But in 2007 the mean lifespan was similar to the Slovenian results (Čelik 2004).

It has particular importance that at the beginning of our sampling in 2005 the population was found in a different location, in a deeper site, than during the last surveys in the 80's. In this respect this fact warns of the danger of continuous desiccation. Vegetation contains *Molinia* tussocks only in the current habitat, while the previous habitat patch is now rather a meadow rich in mesophilous species. This is characteristic recently to the whole area – the formerly base-habitat of Csiffári rét (2.8 km form our study site; Seregélyes et al. 1986) has now a strongly desiccating *Astragalo–Festucetum*, where the butterfly is now absent. Assuming that this meadow had been a firmly wet *Molinietum*, the average groundwater level dropped with 20–40 cm since the 80's (Seregélyes et al. 1986).

Although the habitat complex of Ócsa lies within the borders of Duna–Ipoly National Park, the area is not exempt from human impact: there are some gravel pits in the vicinity of the strictly protected area. Gravel mining creates large-surfaced deep lakes, which load themselves with groundwater. As a result of evaporation, these lakes take groundwater from the surrounding areas, which dries them up and change the vegetation (Tari et al. 2008). The region is also well-drained, which causes a lower water retention ability and desiccation as well (Hubayné Horváth 2005).

Another threatening factor of the *Coenonympha oedippus* habitats is the advance of weeds and invasive plant species. Primarily, *Solidago* species occupy a growing percentage of the habitat complex, which could be controlled by regular mowing during flowering time (Weber 2000, Moroń et al. 2009). However, the complete elimination of *Solidago* seems to be unlikely. Wet meadows between groves of trees are used by hunting organizations as well, providing corn and other grains (containing weeds) for the game. This activity creates weed-communities, altering and deteriorating further the vegetation required by the butterfly.

In the absence of management, succession in this area will result in bushy groves, which is not appropriate for the butterflies. According to our observations butterflies also avoid large open areas. To apply appropriate conservation management it is inevitable to learn more about the butterfly's habitat use, considering the different aspects of requirements of all life stages (Dennis et al. 2006, Vanreusel & Van Dyck 2007).

In Hungary *Coenonympha oedippus* is present in this habitat complex and a newly discovered population in north-western Hungary only. Part of the formerly known habitats are vanished, such as those around Óbuda and Szár, other parts are now being reconstructed, such as those in Hanság (Margóczi et al. 2002). There are some areas in the Kiskunság National Park that seem to be appropriate for the butterfly. The isolation of the remained populations (among them this surveyed one) with small size indicates the possibility of inbreeding, which should be excluded or confirmed by genetic surveys. Accordingly, we conclude that the development of conservation actions for *Coenonympha oedippus* is essential and inevitable. Habitat degradation should immediately be stopped, especially the desiccation, and the spread of invasive plants should be controlled, to maintain proper habitats for long-term survival of the species in Hungary.

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Concerning the situation of the False Ringlet *Coenonympha oedippus* (Fabricius, 1787) (Lepidoptera: Nymphalidae) in Switzerland

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Abstract

The presence of the False Ringlet (*Coenonympha oedippus*) (Fabricius, 1787) was known only from very few localities in Switzerland. All populations were considered to be extinct in the 1980s, but one was rediscovered in 2007. Currently the population status is unclear, because the species seems to have disappeared again. It is possible that the Swiss habitats are temporarily colonized from populations in the neighbouring countries Liechtenstein and/or Austria. The causes of disappearance are not known, some possibilities are discussed.

Keywords: False Ringlet, *Ceononympha oedippus*, historical and actual situation in Switzerland, habitat management.

Introduction

In Switzerland as in many other European countries the False Ringlet (*C. oedippus*) is highly endangered. The species was recorded on a few different localities and disappeared from almost all of them. Regarding the last remaining locality the present situation is somewhat unclear.

In this paper we summarize the information on the False Ringlet in Switzerland. We give an overview of the distribution in the country and discuss the fate of the last population in St. Gallen.

Historical and current situation in Switzerland and the adjacent countries

In the 18th century the species was found near Dübendorf in the Canton Zürich (SBN 1994) and one specimen was recorded from Martigny in the Canton Valais in 1906 (Coll. Museum of Natural History, Bern). In the 1930s *C. oedippus* disappeared already in the 1930s from the southern parts of Switzerland. The only known location in the Canton Ticino was situated near Balerna-Chiasso. After the destruction of the biggest part of the habitat the species could not survive, although rescue attempts were made (SBN 1994).

The last known population in the northern parts of Switzerland was reported from the lower Rhein-Valley in the Canton St. Gallen. According to the data available from CSCF (Centre Suisse de Cartographie de la Faune, Neuchâtel) the population is known there since 1955 (collection Emmanuel de Bros, MHNN).

Since the late 1980s this population was considered to be extinct but was rediscovered in 2007. One of us (H. Ziegler) detected one female on 7.7.2007, and approximately two weeks later several individuals. Unfortunately it seems that the small population has disappeared again, because it could not be found the following year (Aistleitner 2008).

In the Rhein Valley, two populations still exist directly adjacent in the neighbouring Principality of Liechtenstein (Carron et al. 2002, Staub & Aistleitner 2006), but there were no more regular observations in Austria during these last years (Aistleitner et al. 2006).

Fig. 1. Female *C. oedippus* from Switzerland (Foto H. Ziegler, 7.7.2007).

Habitat and ecology

The last known site in the Rhein valley can be characterised as small lowland raised bog- complex with different vegetation types. *C. oedippus* was located mainly in Molinia-meadows (Molinion) and alkaline fens (Caricion davallianae). Some parts of the habitat are slightly covered by reed. If the reed becomes too dense, the species disappears. In some places (northern Italy and Savoy) it seems to be addicted to temporarily abandoned borderland between shrubs and open meadows.

The actual and historical known sites in the Canton St. Gallen (Switzerland) and the neighbouring countries are all situated within 3-8 km linear distances. It seems that this distance can be covered from time to time, although the species is known to be extremely sedentary. The different sites are not connected to each other by suitable habitats or stepping stone habitats. How the species managed to cross the "hostile" areas is unknown. Although there is no evidence, a reintroduction by hobby-entomologist can not be excluded. Such illegal and uncontrolled activities regularly occur and are very difficult to detect. Uncontrolled reintroductions of butterflies are known from other Swiss Cantons.

Very little is known about the ecology of the Swiss *C. oedippus* population. The flying period seems to be from the end of June until August, although most observations are from the beginning of July. The natural larval food plant in Switzerland is not known.

Fig. 2. The main (ancient) habitat of *C. oedippus* in the Swiss part of the lower Rhine Valley in the Canton St. Gallen, from where the species disappeared in the 1980ies. (Foto E. Wermeille, June 2001.)

Fig. 3. The site, where *C. oedippus* was observed in 2007, can be characterised as a Molinia meadow, partly covered with tall herbaceous vegetation and some reed. (Foto H. Ziegler, July 2007.)

Threats and conservation

The exact circumstances that caused the extinction of the last Swiss population are not known and are not easy to "reconstruct". Probable reasons are:

— small area (suitable habitat: circa 10 ha) and small population size (2007: less then 10 ind.);
— dehydration: hot and dry periods during the summer (the negative effect might be fortified by the local hot and dry wind called “Föhn”);
— uniform gestion: too early mowing (1. September), mowing of a too large area, no uncut areas (no temporary refugees for caterpillars);
— drainage or other negative water management;
— eutrophication and intensive cultivation of adjacent cultivated area;
— invasion of neophytes, reed, tall forbs or other plants that change the vegetation;
— isolation (linear distance to the next populated habitat: circa 3-8km).

A combination of reasons is probably needed to explain, why the population in the Swiss part of the Rhein valley did not persist.

Based on recommendations of the Swiss Butterfly Conservation (Carron et al. 2002, 2004, Dušej et al. 2004) the management of some important habitats was changed, mainly to preserve some other important butterfly species (for example *Maculinea alcon*). Introduced changes are: (1) mowing date of the litter meadows was shifted to the 15. September; (2) in contrast to earlier practice, the meadows and fens are not mowed completely, but some parts are left unmown over winter. These so called fallow strips are small areas and cover 20-30% of the whole area. The position of the fallow strips is changed every year to avoid a threat of plants that depend on a annual mowing (as some Orchids). This principle was already introduced in some other important butterfly habitats and seems to work. However, there are no long term studies on this principle and there is still a need for further investigation (Dušej 2004, Schmidt et al. 2008).

Beside these recommendations that can be implemented more or less quickly some additional efforts have to be introduced to ensure long term survival or re-establishment, namely restoring of the hydrological conditions and connecting the existing habitats with appropriate biotops.

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Habitat requirements, larval development and food preferences of the German population of the False Ringlet *Coenonympha oedippus* (FABRICIUS, 1787) (Lepidoptera: Nymphalidae) - Research on the ecological needs to develop management tools

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Abstract

For decades the False Ringlet (*Coenonympha oedippus*) was considered to be extinct throughout Germany. It was rediscovered in Bavaria in 1996, however, the population is small and vulnerable, restricted to 3 habitat patches with a total size of 1.11 ha only.

In addition to an annual monitoring scheme, a research project has been started in order to improve the knowledge of the ecological needs of the species and to aid in the development of management tools. Three basic methods are used: field observations on oviposition, searching for caterpillars before and after hibernation in their habitat, and breeding experiments. An overview on the results on oviposition preferences, microhabitat structures of caterpillars and host-plant preferences is given. Successful breeding in captivity of one full generation is described. Recommendations for habitat enlargement and management are discussed.

Keywords: *Coenonympha oedippus*, False Ringlet, Germany, oviposition, larval ecology, butterfly conservation

Introduction

The False Ringlet (*Coenonympha oedippus*) is one of the rarest butterflies in Europe and is declining at an alarming rate in many European Countries (e.g. Heath 1981, Balleto & Kudrna 1985, Kudrna 1986, SBN 1987, Munguira 1995, Schmid 1996, Settele et al. 2008). It is protected by the Habitats´ Directive and it is listed in Annexes II and IV (92/43/EEC, European Communities 1992). For several decades there were no documented records or museum specimens of this species and it was considered to be extinct in Bavaria and throughout Germany until it was rediscovered by M. Schwibinger in 1996. A review of historical sites has now confirmed, that there is just one single population left, which inhabits a small (ca. 1.11 ha) and isolated area.

The vegetation of the habitat patches can be classified as Allio suaveolentis-Molienetum Görs (OBERDORFER 1993), merging with Cirsio tuberosi-Molinietum Oberd. ex Phil. ex Görs 74 in drier parts. In really moist patches the phytocoenosis of Primulo-Schoenetum ferruginei Oberd. 57, (OBERDORFER 1977) is represented. Interspersed are clusters of Cladietum marisci Allorge 22 (Philippi in OBERDORFER 1977). The existence of the population and the precise location have been kept strictly confidential, due to the high risk of over-collection. The conservation authorities have recently decided to publish the ecological data which is presented here, thus revealing the existence of the confidential population.

Since its rediscovery, financial support by the nature conservation authority of the Government of Upper Bavaria enabled annual monitoring of the population. Estimations of population size by transect counts (at least three counts per year) display a high variation and some overall increase of population size. However the population is still rather small and vulnerable (a minimum of 26 individuals was recorded in 1999, and a maximum of 129 individuals was recorded in 2005). There is no doubt that *Coenonympha oedippus* is a species of the highest conservation concern both on a, national, as well as a european level.

In Europe, the False Ringlet shows a very scattered distribution. Most European countries harbour only a few isolated populations, with the exception of northern Italy, Slovenia, and some regions of France.

A similar situation is found in the West Siberian lowlands, while in southeast Transbaikalia *C. oedippus* is very abundant and is present in diverse environments (O. Kosterin in lit.). This is perhaps an indication that this region is in the vicinity of the original area of the species (Gorbunov & Kosterin 2007). Kosterin (in lit.) reports that *C. oedippus* is very abundant in northern Altai, and Chuluunbaatar (2004) also describes it as one of the most abundant species in the Mongolian Altai (Khangai and Khentej).

The climate in these regions is extremely continental and can be described as an arid and cold steppe climate. Tuva (Russian Altai) is at the same geographic latitude as Germany. Daytime temperatures in January reach from - 28 to - 45° C (with extremes reaching - 55° C), while the temperatures in July frequently rise to around 30° C. Concurrently, precipitation is very low (200-300 mm) with hardly any rain in summer and not much snow in winter.

Fig. 1a. A female of *Coenonympha oedippus* depositing an egg on a grass blade (field observation).

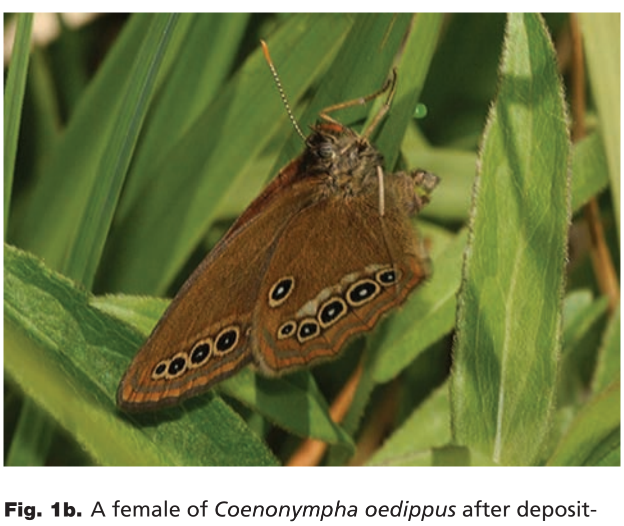

Fig. 1b. A female of *Coenonympha oedippus* after depositing an egg on a grass blade at the German habitat. The egg is well visible (field observation).

Despite the species´ rarity all over Europe, it manages surprisingly well with very different climatic conditions across Europe.

The Italian Piemont region has a mild climate, with continental and slight Mediterranean influences. It has a precipitation of 914 mm with a lot of rain in spring, but it is relatively dry in summer and mid-winter. In contrast, populations in Bordeaux tolerate a maritime climate with mean temperatures in January of + 5.9° C and a precipitation of 907 mm mainly during winter.

According to Osthelder (in Kolar 1928), *C. oedippus* may already have immigrated to central and western Europe during the last interstadial (Allerød) of the Weichselian glaciation about 10.000 years ago. The somewhat warmer interstadials allowed many species of the Siberian Fauna to penetrate the lowland areas north of the Alps. During the last cold period of the most recent glaciation, which spanned only 500 years, climatic conditions of central European areas adjacent to the ice shield could have been quite similar to the current climate of the above mentioned core areas.

After the glaciers retreated and woodlands began to cover most of Europe, *Coenonympha oedippus* may have survived only in places where the forest canopy could not close, e.g. in spring fens with continuously very wet soil or periodically flooded areas along rivers and brooks. This may be the reason why the False Ringlet is also found, apart from wetlands, in very dry environments of the karst regions of northern Italy (Ruehl 1895, Kolar 1919, 1928, Habeler 1972), in Slovenia (Čelik & Verovnik, this volume) and in southern Siberia (Gorbunov & Kosterin 2007), where it lives in folds of dry steppes on southern slopes with narrow strips of mesoxerophilous meadow vegetation and shrub-lands. In Slovenia, the habitats belong to submediterranean–illyrian dry grasslands (*Danthonio–Scorzoneretum villosae* Ht. et Ht–ić (56)58, *Carici humilis–Centaureetum rupestris* Ht. 31). However warm and humid microclimatic conditions during summer are maintained by the combination of deeper soil, higher density and taller height of the herb layer than on typical submediterranean dry grasslands, and by the shade provided by woody vegetation. (Čelik 2003).

In the Russian Altai, *C. oedippus* is found to be a dominant species on a dry mountain steppe, whilst the xerophilous species *C. amaryllis* occurs only in much less dry steppe variants (Gorbunov & Kosterin 2007). As far as we know, however, detailed studies on ovipostion preferences and larval microhabitats in dry habitats are still lacking and are important for a better understanding of the species ecology.

We believe that the present distribution in Europe can be interpreted as a relict distribution (see also Kolar 1928). However, if this was the only limiting factor, more populations should have been historically documented, since the species was of major interest for collectors. In the former areas of occurrence several square kilometres of spring fen and periodically flooded fens existed, and lots of potential habitat still existed until the beginning of the last century (Quinger et al. 1995), when collecting of butterflies was al-

Fig. 2. Egg of *Coenonympha oedippus* deposited on a leaf of *Carex panicea* (field observation).

Fig. 3. Freshly hatched caterpillar of *Coenonympha oedippus* feeding on the egg-shell (breeding experiment).

ready popular. Nevertheless, the False Ringlet seems to have been already very restricted and local.

According to Kosterin (in lit.), potentially suitable localities appear to be widespread in west Siberian lowlands, nevertheless, the species rarely occurs. The same is reported for Khakasia, Tuva and the Katunskii mountains.

Thus it is very likely, that there are additional factors, which restrict habitat use by the False Ringlet. This may be crucial when designing measures for habitat enlargement or reintroduction projects.

This assumption is supported by observations at the German habitat: In 1996, measures were initiated to restore overgrown patches of supposed former habitat immediately adjacent to the existing habitat. Although vegetation of similar species composition could successfully be recreated by removal of bushes and annual mowing, the population did not considerably expand into these areas.

Research on other butterflies for conservation purposes have shown, that detailed knowledge of oviposition preferences and habitat requirements of the premature stages is the key to efficient conservation measures (e.g. Fartmann & Hermann 2006). Consequently, a research project was initiated by the Bavarian Academy for Nature Conservation and Landscape Management (ANL) in 2007, to determine the ecological needs of the False Ringlet thus facilitating the development of management tools.

In this paper, we summarize the preliminary results of this project.

Material and methods

We applied three basic methods: Observation of oviposition, searching for caterpillars before and after hibernation, as well as breeding experiments.

Observation of oviposition

We tried to observe oviposition by individual tracking of females *C. oedippus* during the second half of the flight period in 2007 and 2008. In total, 72 hours were invested by one to three persons simultaneously, on five days in 2007 (15.6 -29.6.) and six days in 2008 (19.6 -5.7.).

We followed females which did not look freshly emerged from pupa, as previous observations indicated that females do not immediately start with oviposition after emergence. We also avoided getting too close to them not to disturb them as we learned that the females are relatively shy.

Each time oviposition was observed, a bamboo-stick (tip marked with bright colour), was placed close to the egg for subsequent control of caterpillars.

Oviposition height above ground was measured and the egg deposition medium determined (plant species, kind of material).

Cover of visible litter from above and cover of dominating plant species within a radius of 0.5 m around the egg were estimated in 10% steps. Additionally, parameters on presence of reed (*Phragmites australis*) and bushes were recorded (distance and direction from the egg, height and density of reed or shrub).

Search for caterpillars

As caterpillars are most easily detected when almost fully grown, we concentrated searching activities on the second half of May (2008). From constant positive results of brailer-catches in the years 2004 to 2007 during species monitoring, we guessed, that this period would be most effective for visual searching in the field.

A total of 43 hours (one to four persons simultaneously) of searching was spent in May 2008. Additionally, we tried to find caterpillars in spring 2008 at the marked oviposition spots of the previous year. The places, where we observed egg deposition in 2008, were partly monitored once before hibernation and again in spring 2009.

Fig. 4. Young caterpillar of *Coenonympha oedippus* with typical feeding traces on leaf margins of *C. panicea* at the end of July (breeding experiment).

Fig. 5. Freshly moulted caterpillar fixed to a leaf in early September (breeding experiment).

Observation from breeding experiments (see below) helped to choose days with good conditions for searching activities.

For each detected caterpillar the behaviour (resting and feeding) and the position above ground (height in cm) were noted. Feeding traces, which could be assigned to *C. oedippus* caterpillars with some confidence were searched and recorded. In every case, the plant species was determined.

Characterisation of vegetation composition and structure followed the method described for the oviposition sites.

Breeding experiments

Test-Breeding: one half grown caterpillar

Initially, a caterpillar found on 11th of May 2008, was used to study its behaviour and discover the adult caterpillars' preferences, thus making it easier to spot them in the field.

It was kept in a plastic vivarium (20 x 30 x 30 cm), in which *Molinia caerulea* and *Carex panicea* were planted. These were taken from the habitat in the previous autumn and cultivated in small plastic flowerpots until spring. The flowerpots were embedded in fen peat and the gaps between the plants were filled with peat material.

The vivarium's top was covered with mesh and held with an elastic rubber band, allowing high air circulation. Humidity was kept at a high level by regular watering. Temperature and humidity were measured with a digital thermo-hygrometer over a long period under different weather conditions. Temperature was found to be only slightly higher than outside the vivarium, while humidity was considerably higher. Both were similar to the values occasionally measured at the species' habitat.

The vivarium was controlled at least daily. After pupation the pupa was transported back to its habitat and exposed in a *Molinia* tussock. Three days later the butterfly had successfully emerged.

Breeding from eggs

To develop methods for captive breeding, we took a single female near the end of its individual lifespan from the habitat. It deposited 37 eggs in the vivarium described above.

On the recommendation of experienced butterfly breeders, 24 of the eggs were removed from the vivarium and transferred to two polyethylene boxes. Twelve eggs were placed in each, while the rest was left in the vivarium.

One of the boxes was supplied with *Molinia caerulea*, the other with *Carex panicea* (fresh leaves).

Initially the freshly hatched caterpillars refused to feed on the *Molinia caerulea* and one died from starvation. The rest were transferred into a second vivarium identical to the one described above, but planted exclusively with *C. panicea*.

The caterpillars of the other box were fed with *M. caerulea* and *C. panicea*. Fresh food was supplied on average every third day. The box was cleaned at least twice a week and the soaked paper handkerchief at the bottom was changed. The box was controlled twice a day, in the morning and in the evening, to ensure that humidity level was adequate; moist but not too wet.

To allow acclimatisation to low night temperatures before hibernation, the last caterpillars were transferred to the vivaria on 13th of October.

Both vivaria were kept outdoors sheltered from rain, but watered at intervals. They had direct sunlight for several hours. The caterpillars were regularly controlled and counted although at times it was almost impossible to detect them all, due to ample possibilities of hiding in the vivaria combined with their perfect camouflage.

From late autumn to April, they were placed in a sheltered place without direct sunlight, but fully exposed to winter temperatures (which reached down to -12°C on 12.01.2009). They were carefully watered on 8th December and 7th March. The vivaria did not receive sunlight before March, but from then on were situated in the same place as the previous year.

In May, the caterpillars were transferred into a larger vivarium to give them the opportunity to select an appropriate place for pupation, part from the fact that the food supply in the small vivaria was not sufficient. For testing reasons, the large vivarium was planted with several plant species taken from the habitat (*M. caerulea, C. panicea, C. flacca, Schoenus ferrugineus*) and additionally with *C. pilulifera* taken from an Italian habitat. Shortly before emergence (this is signalled by a change in colour of the pupa) some of them were placed under a large mosquito-net in a winter garden, where they received sun during part of the day. Air moisture was kept high by regular fogging of water. Flowering *Valeriana dioica*, *Inula salicina* and *Buphthalmum salicifolium* were placed into the net to provide them with nectar,. These flowers had been previously seen to be visited by the butterflies at the habitat.

Results

Oviposition in the field

In 44 cases of observed oviposition behaviour (2007:6, 2008: 38), the egg was subsequently located. On several other occasions, the eggs were not found, either due to the distance from the observer, or the vegetation was too dense, or the female butterfly was just "testing" for oviposition.

Eggs were most frequently fixed on *Molinia caerulea*, usually on living leaves (Fig. 6). *Carex panicea* also played an important role as medium for egg deposition. In several cases, eggs were placed on dead dry leaves of the litter and on one occasion even on a green leaf of *Rhamnus frangula*.

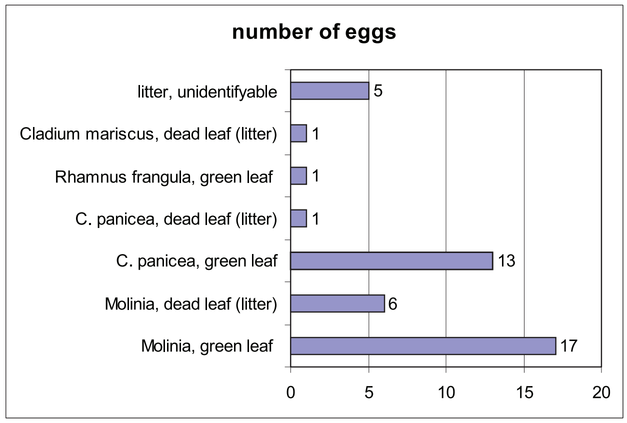

Fig. 6. Egg-laying medium of *C. oedippus* (data from 2007 and 2008, n = 44).

It seems, that oviposition is not very selective (see Fig. 7): Where eggs were laid on *C. panicea* the estimated cover of *C. panicea* was relatively high (n = 27, Z = 2.07, p = 0.03), and at places where eggs were laid on *M. caerulea*, the cover of *M. caerulea* was also relatively high (n = 32, Z = 2.27, p = 0.02). The females deposited their eggs on both plants if they were abundant at the respective egg-laying site. (Fig. 7)

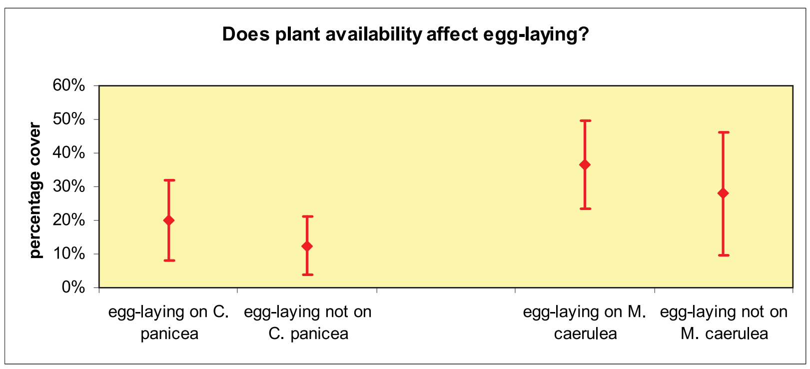

Fig. 7. Plant availability and egg-laying.

In 2008, eggs were mostly fixed to plants at 20-30cm height above the ground, usually a few centimetres below the leaf tip. However, in several cases butterfly females crawled (or let themselves drop down) to the ground for egg deposition. The observed two basic types of oviposition behaviour are probably correlated to air temperatures. We conclude this from the result that oviposition low above ground was only observed at lower temperatures.

Oviposition was mostly recorded in the hottest hours of the day and only in sunshine. Our earliest observations of egg depositions were made at 1 pm and the last at about 4 pm.

Results on caterpillar search

We found 30 half to fully grown caterpillars in the habitat. Nine larvae were feeding on *C. panicea* at the time of detection, only two on *Molinia caerulea*, while all the others were inactive. In total, feeding on *C. panicea* was indicated by fresh feeding traces close to caterpillars in 19 cases, while in only seven cases, feeding on *Molinia caerulea* was likely. From our observations at the time of discovery and during repeated controls of the marked caterpillar locations we can conclude that 21 out of the 30 caterpillars had fed solely on *C. panicea*.

On the 29th of September (before hibernation), only one caterpillar (length 13mm) was found in the habitat. As indicated by feeding traces on the leaf the caterpillar was sitting on, as well as on adjacent leaves, it had previously fed on *C. panicea*. After hibernation, a further two young caterpillars were also found feeding on that plant species.

Structural characteristics of oviposition sites and caterpillar microhabitats

Mean litter cover at the oviposition sites was 41% and showed little variation, except for a few outliers. Litter cover estimated around the detected caterpillars in spring was even higher and less variable (see Fig. 8).

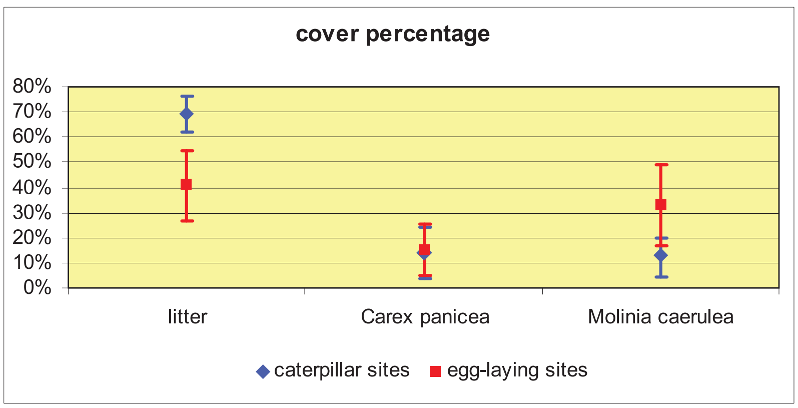

Fig. 8. Cover of litter, *C. panicea*, and *M. caerulea* at egg-laying sites and caterpillar sites

Not surprisingly, visible litter cover decreases with ongoing season. This is due to the growth of vegetation from the time elapsing from caterpillar searching (middle of May) until oviposition (late June and July) ($n = 68$, $Z = 6{,}67$, $p < 0.0001$).

Interestingly, the estimated amount of *Molinia caerulea* at caterpillar microhabitats was less than at places where oviposition took place ($n = 67$, $Z = 5.40$, $p < 0.0001$), while the amount of *Carex panicea* is strikingly similar.

One reason could be that the increase of biomass of *Molinia* in early summer is higher, causing higher relative cover values at oviposition time. Another explanation put forward is that the caterpillars survive better in places with high cover of *C. panicea*.

Measured cover of visible bare litter, not overgrown by living vegetation, was 60% and even reaching up to 85%. In all cases, the sward was not closed and showing gaps, allowing direct insolation at ground level.

Caterpillars were frequently found at the south or west facing edge of tussocks. Often *C. panicea* grows at the edge of *Molinia*-tussocks, sending offshoots into the gaps between them.

Results of breeding experiments

Breeding of a half grown caterpillar

The caterpillar taken from the habitat on May 11th 2008 had a length of about 2,5cm. It fed irregularly, but mostly during the day. Traces of overnight feeding were rarely recorded. Most observations were made around midday when temperatures were high. Feeding activities were, however, also observed in late afternoon and evening.

Feeding could only be observed on *C. panicea* and the caterpillar never left its tuft of *C. panicea* spontaneously. Pupation took place on 31.5.2008, after the caterpillar had reached a body length of about 3cm. The pupa was reintroduced into the habitat on June 19th and by 22nd June the butterfly had already emerged. We can conclude that the pupal stage of this individual lasted about 20 days.

Breeding from eggs

The eggs deposited by the captured female on June 28th and 29th began to hatch after 8-9 days; the last hatching on July 10th. However, not all eggs hatched. There were initial losses of a young caterpillar which refused feeding and of two caterpillars, because the plastic box was initially allowed to dry out on recommendation of an experienced Satyridae-breeder. Further individuals died for unknown reasons, but at the end of July, 27 caterpillars were still alive and most had reached a length of about 1cm.

On October 11th caterpillars with changed colour were observed for the first time. They developed a yellow-straw colour, in perfect camouflage with the successively wilted and coloured leaves. *M. caerulea* retreats nutrients from the leaves to the base (hibernation buds), so the leaves change colour and die off in autumn. In case of the winter-green *C. panicea*, only some leaves turned yellow, whilst most leaves were still green and looked fresh.

Since the beginning of October, feeding was observed only on green leaves of *C. panicea* in the vivaria.

Colour change of caterpillars was not correlated with moulting to the third larval stadium but possibly related to cool (night) temperatures. Moulting of some caterpillars could be directly observed and documented. For that purpose, the caterpillars fixed themselves to grass blades with a self-produced silken seat cushion.

Two more caterpillars died until middle of October, while the remaining 25 caterpillars had mostly reached 1.2 cm length and changed to yellow-straw colour.

Even on the onset of November a green caterpillar could repeatedly be observed feeding on a leaf of *C. panicea* in the sunshine around midday. Surprisingly, in November and early December, during mild weather phases (temperatures 8°C and more), a varying number of caterpillars – now all coloured yellow – were regularly observed sitting on the upper parts of leaves and even on the cover mesh, but without any feeding activity. They rested head down on wilted leaves

Fig. 9. Caterpillar found in the field on *Carex panicea* at the end of September still coloured green. It was still active and feeding (field observation).

and some even remained in that position over night. From 9th December onwards, when temperatures dropped to -5°C overnight, only one caterpillar was still observed, resting about 5cm above ground. During the first days of spring with day temperatures above 10°C (10.02., 28.02., 01.03), no activity was recorded.

After a cold March, temperatures suddenly climbed above 20°C at the onset of April. On 4th April, 25 caterpillars reappeared in the two vivaria and started feeding on *C. panicea*. Thus, no losses occurred. During the following period, caterpillars fed intensively on *C. panicea* during day and night, even at temperatures of only 8°C. Detection of a green-yellow caterpillar feeding on *C. panicea* at the habitat on the 6th of April indicated that caterpillars were active there as well.

Fig. 10. Caterpillar with yellow straw-colour, perfectly camouflaged on a wilted leaf (breeding experiment).

At the time of awakening of the caterpillars, *M. caerulea* had not yet started to grow at the oviposition sites in the habitat and in the vivarium. However, fresh leaves of *Molinia* became available about 10 days later. First feeding on this plant could be recorded from 17th April onwards, when the blades had grown to a sufficient height. Young caterpillars were mostly observed feeding on margins of leaves at heights of 6-13cm and exceptionally at a wider range of 3-15cm. Top down feeding of the grass blades was not recorded before the end of April, when the reared caterpillars had mostly reached a length of about 2cm and were all coloured green again.

After their transfer to the large vivarium, caterpillars fed mostly on *C. panicea* and *Molinia caerulea*, but additionally on *Carex pilulifera* and *Deschampsia caespitosa*. They completely ignored *C. flacca* and *S. ferrugineus*. They started to pupate on 24th May attached to grass stems and foliage at heights of 9 to 21 cm above ground.

Male butterflies emerged from 14th June onwards and the first females appeared on 21st June. While no feeding on the offered flowering plants was observed, sucking on water droplets from fogging was occasionally recorded. After a week of rainy and rather cold weather, egg-laying started on June 28th and lasted until 6th of July. The females deposited about 150 eggs on the mosquito-net and about 50 in the large outdoor-vivarium (since not all of the eggs could reliably be noted, exact numbers cannot be given). The eggs from the net were removed and reared in polyethylene-boxes, where about 120 caterpillars successfully hatched from the 6th July onwards. After they reached the second instar, they were transferred to the vivaria again to continue breeding in captivity.

Discussion

Oviposition behaviour and characteristics of oviposition sites

Sparse information on oviposition behaviour of *C. oedippus* is available. Dierks (2006) observed oviposition 84 times in total during his intensive studies over three years at a population near Bordeaux, but further details are not available. He followed the females, occasionally for more than six hours a day (Dierks in lit.).

Observation of oviposition appeared to be very time-consuming at comparatively low population densities of about 200 adults per hectare, a density similar to our population. Čelik (2004) found a density of 145 individuals / ha for a population in Slovenia (calculated for an area of 1.27 ha in 1996) and observed ovipositions occasionally (13 observations in 1995-1996; Čelik in lit.)

Bonelli et al. (2010) estimated numbers of a population in the Piemont region to 1404 individuals in 2005, and to 2141 adults in 2006 (calculated from mark-recapture experiments) in just one hectare of habitat. They observed oviposition quite frequently (110 events, Bonelli et al. 2010).

Fig. 11. Half-grown caterpillar after over-wintering in the first half of May on *Carex panicea* (field observation).

Fig. 12. Almost fully grown caterpillar feeding on *Carex panicea,* now top-down. This is in contrast to young caterpillars saw-tooth feeding (field observation).

We can confirm the observation already made by Dierks (2006) that females tend to lay several eggs in a series, interrupted by occasional rests. We observed females mostly resting for a longer time in the vegetation, regulating body temperature by opening wings shortly in intervals before starting oviposition. Observations concentrate on the hours around midday, as Dierks (in lit.) confirms for the population at Bordeaux. Egg deposition seems to be highly temperature-dependant und appeared to be largely restricted to sunny and very warm weather conditions.

In our study, tracked females showed no oviposition behaviour on an extraordinary hot day in July. During monitoring, reduced flying activity was repeatedly observed under very hot conditions as well.

Behaviour of the female butterflies did not display any hints for selection of certain egg laying media. Eggs were deposited not only on graminiceous plants, which can serve as host-plants, but also on *Rhamnus frangula*.

The observed egg depositions on *Calluna vulgaris* in Italy (Bonelli et al. 2010) support the hypothesis that the plant species is not a decisive factor in selection of an oviposition spot. *C. vulgaris* is very unlikely to play any role as a food-plant and is also absent in our habitat.

In central Slovenia oviposition has been observed on *Carex hostiana*, *C. panicea*, *C. davalliana*, *Molinia caerulea* and *Gratiola officinalis* (Celik & Verovnik, this volume).

We conclude that mainly structural parameters (possibly correlated to microclimatic characteristics) are relevant key factors for the selection of oviposition spots. The different, probably temperature dependant oviposition modes indicate some selection of egg deposition locations by microclimate as well.

In one type of oviposition mode, the female lands after a short distance flight in the vegetation, very often at the margin of a tussock or tuft of *M. caerulea* or *C. panicea*. It lands at about two thirds height of the vegetation matrix, never on top. Usually, very short after landing, the female curves its abdomen and deposits an egg on any plant, that is present. Occasionally egg deposition was observed after a longer rest, then very suddenly, without any signs of selective behaviour. It is not very surprising, that in this type of egg-laying scheme eggs are mostly placed on green blades of the named host-plants, which are highly dominant in the sward. Due to this mode of egg deposition, the eggs were found mostly at 20-30cm height above ground, usually a few centimetres below the tip of the grass blade.

In Slovenia, eggs are deposited singly as well, in oviposition heights of about 5–15 cm (*C. davalliana*, *G. officinalis*) or 15–25 cm (*C. hostiana*, *C. panicea*, *M. caerulea*) above ground (Čelik et al. submitted).

The second type of oviposition mode we observed is quite different: After landing, the female literally let drop itself into a vegetation gap or crawls down deep to the ground to place an egg on the substrate, which is mostly dead plant material. The eggs were fixed to the substrate just a few centimetres above ground on the surface of the litter layer or on dead leaves somewhat higher.

Gaps in the sward seem to be important for selection of oviposition sites. However, the vegetation structure at these places does not conspicuously differ from the overall character of the habitat. According to the local farmer, the habitat has not been mown or grazed for at least 60 years (abandoned peat ditch), thus the litter cover is very high.

Microhabitat of caterpillars and food-plant preferences

Litter cover was extremely high at places where we found half grown caterpillars. An open vegetation character might be crucial for an early start of metabolism and starting feeding activities. Most caterpillars we found feeding were fully exposed to the sun.

In our breeding experiments, the caterpillars always concentrated in the parts of the vivaria facing south. This behaviour indicates, that the caterpillars are thermophilous as feeding activity concentrated on the warmest hours of the day and days with sunny or at least warm conditions. Thus warm microclimate may be essential for larval development and survival.

Molinia is mostly considered to be the main food resource for wetland populations of *Coenonympha oedippus* in Europe. Besides *M. caerulea*, *Poa palustris*, *P. pratensis* and *P. annua, Carex panicea, Carex remota*, *Carex flava*, *Carex hostiana*, *Carex distans*, *Eriophorum angustifolium, Schoenus nigricans, Deschampsia caespitosa,* and even *Iris pseudacorus* (which is improbable) have been mentioned as food-plants (e.g. Assmuss 1863, Lhonoré 1995, Bink 1992, Weidemann 1995, SBN 1987, Čelik 1997, Bonelli et al. 2010). Almost all listings of "food-plants" in publications have to be treated with caution. They can be misleading, since it is rarely cited if these notes are derived from field-observations or artificial breeding, or are just repeated from other publications.

Fig. 13. Freshly pupated *Coenonympha oedippus* (breeding experiment).

Fig. 14. Pupa of *Coenonympha oedippus* shortly before emergence (breeding experiment).

We successfully tested *Cladium mariscus*, *Poa palustris* and *Poa trivialis* in the vivarium. The latter however does not occur at the habitat.

Our results indicate, that *C. panicea* is the most important host-plant of the German population. Our breeding experiments proof that larval development is exclusively possible on this plant.

An experiment of rearing freshly hatched caterpillars exclusively with *Molinia* under laboratory conditions was aborted as the larvae refused feeding. Possibly the tiny caterpillars are only able to feed on fresh, growing leaves. The cut *Molinia* leaves were probably not accepted, because they dried, curled and wilted quickly. According to Bink (in lit.), caterpillars of *C. oedippus* are specialised on soft shoots of Poaceae, Cyperaceae und Juncaceae. There is, however, no doubt that they can feed on *Molinia* from their first days, because some caterpillars in the vivarium grew up several weeks without leaving the tuft of *Molinia* in which they had hatched.

The question is, whether feeding exclusively on *M. caerulea* ensures the whole larval development until pupation. *M. caerulea* was obviously not edible any more at the end of the season, when feeding was still observed in captivity. It was also not available at the onset of the next season. It is doubtful, whether caterpillars can stand starvation of several days in the critical phase after hibernation, after a long period without feeding. The caterpillars in captivity were feeding very intensively during the first weeks after awakening, indicating an urgent need for food and liquid. As Gradl (1945) reported from captive breeding in the Austrian province of

Fig. 15. Mating couple of *Coenonympha oedippus* at the German habitat (field observation).

Vorarlberg, that caterpillars woke up very early after hibernation (on March 20th due to enduring foehn weather), when *Molinia* was not yet available. He fed them with *Poa pratensis* and *P. palustris* as alternative food. Even if lack of synchronisation with growth of *Molinia* would occur exceptionally over the years, this could exclude occurrence from sites without "transitional" food resources like the winter green *C. panicea* (or other graminaceous plants with soft leaves). The same is discussed by Dierks (2004) for *Pseudoarrhenaterum longifolium*, which does not occur in Germany, and which could serve as interim-food at Bordeaux.

Consequences for habitat restoration and management

In case *C. panicea* is really needed as interim food-resource in early spring, this is very important for habitat management and conservation of the German population. If presence of *C. panicea* in addition to *Molinia* is crucial, special measures have to be taken at a broader scale to enlarge the area, which the population of *C. oedippus* can actually use. Experiments such as the removal of the upper soil layer to establish *C. panicea* on more nutrient rich meadows adjacent to the habitats have been started.

If re-introductions to other former sites of *C. oedippus* are planned, this knowledge is essential for the selection of appropriate meadows.

Furthermore, our results give valuable hints for the appropriate management of habitats.

They could explain, why the *Molinia* meadows restored by the removal of scrub and regular mowing are still not colonised by the *C. oedippus* population, despite their proximity to the habitats, which are currently populated. Initially, there was no alternative to regular mowing for several years in order to recreate meadows with a vegetation composition similar to the still populated habitat patches.

Bischof (1968) reported a breakdown of a population caused by mowing near Chiasso (Switzerland). In a Slovenian habitat, mowing within flight season caused a sudden decrease in abundance, not only caused by emigration (Čelik 2003, Čelik et al. 2008, in prep.). Mowing is very likely to cause high losses of premature stages if performed between spring and late autumn.

Our observations in breeding experiments suggest that caterpillars might still need food until the beginning of November at least in years with late onset of winter temperatures below zero. As the caterpillars feed or rest almost exclusively on their food-plants in heights of about 10-20cm except during cool and unfavourable weather, losses are unavoidable if vegetation is cut close to the ground as usual. However, all caterpillars rarely sit simultaneously at their preferred height, so one unfavourable mowing event is eventually tolerable and will not cause a total loss of all caterpillars.

Another effect of mowing is probably even more important than direct losses: Regular mowing causes a closed homogeneous sward unfavourable for *C. oedippus*. Measured values of litter cover are very high for grassland ecosystems and are found in wetlands only if they are abandoned or unmanaged.

At the regularly mown patches the layer of litter is low, with values of about 10-20%. This is much less than the values measured at the typical spots, where oviposition takes place or caterpillars were found.

Thus we recommend that the populated habitats should remain untouched, with the exception of the partial removal of shrubs at intervals. At the restored areas with high presence of *C. panicea*, the next years will show whether mowing in intervals and high cutting can promote formation of a litter layer, without risking the expansion of reeds or tall herbs.

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