Studies on the Ecology and Conservation of Butterflies in Europe

Vol. 1: General Concepts and Case Studies

Edited by *Elisabeth Kühn, Reinart Feldmann,*
Jeremy Thomas & Josef Settele

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Preface

The use of butterflies as model systems in biological research has increased enormously over the past two decades; far more rapidly than any scientist of the 1980s could have foreseen. Matching this has been a parallel advance in the priority afforded to butterflies by global, national and voluntary conservation bodies, not just as objects worthy of greater conservation effort in their own right but also in recognition of their wider usefulness as sensitive indicators of environmental change (especially of habitat degradation, fragmentation and climate change) and as umbrella species whose targeted conservation benefits wider communities of lesser-known, threatened species. Hand-in-hand with the increased use of butterflies in pure and applied biology has been a burgeoning popular interest in them as objects to be noticed and enjoyed. Today butterfly gardening, watching and photography have largely replaced as leisure activities the more specialised and male-dominated hobby of collecting, and - thanks to the new technologies – the beauty of butterflies has spawned an unprecedented number of high quality images, films and videos: some are described in these volumes. Inevitably, this growing knowledge, interest and the classy images have also made butterflies increasingly useful tools in education.

All these developments are, of course, closely-linked and reinforce each other. For centuries, the beauty and diurnal behaviour of adult butterflies ensured that this group had a disproportionally large following among amateur and professional entomologists, illustrators and scientists. And as knowledge grew about the evolutionary biology of butterflies, it provided a springboard for their use as surrogates for other insects in other disciplines, including ecology and conservation. These developments, in turn, have led to the recruitment of many thousand amateur naturalists to help plot distributions and monitor butterfly population changes, originally in Britain but now in almost every European country. One of the unforeseen benefits has been that a network of local amateurs have not only become increasingly expert in butterfly identification and behaviour but have gained real enjoyment from recording butterflies in the field as well as satisfaction from the knowledge that their hobby was really useful and important. As a consequence, friends and family have been recruited to these pastimes, and so the circle of activities and the generation of increasingly valuable datasets grew. The most spectacular product is the series of very high resolution maps of butterflies that has been published in recent years by many European countries.

In the first five years of the 21st century, Europe has seen ever larger projects involving butterflies as tools for science, conservation and leisure. Prominent among these are the granting of planning permission to the Butterfly World Trust to invest c. 25 million Euro to build on the outskirts of London the biggest (by far) walk-through exhibition of living butterflies in the world, eventually containing more than a quarter of a million (exotic) butterflies and expected to attract many more than the quarter of a million visitors that annually visit its sister butterfly house, Papiliorama, in Switzerland. Also in the UK in 2005 (and one of the 'babies' of the MacMan programme), the National Lottery Fund has approved funding of >2.5 million Euro to restore up to 70 km of degraded grassland ecosystems, targeted for native butterflies (especially *Maculinea* arion) and associated wildlife, along the Atlantic coast of Cornwall. Across Europe, NGO butterfly conservation societies enjoy unprecedented growth, culminating in the foundation in 2004 of the continental-scale "Butterfly Conservation Europe" (www.europeanbutterflies.net). In science, the EU recently funded two massive programmes of research – Fragland and MacMan – the first led by Illka Hanksi (University of Helsinki, Finland; www.helsinki.fi/science/fragland) to use questions about butterfly metapopulations to train PhDs and exchange post-doctoral researchers across European nations; the second, led by Josef Settele (UFZ, Germany; www.macman-project.de), to study both the ecology of endangered *Maculinea* species and their usefulness as 'super-indicators' in conservation. These, and many other developments, ensure that current interest in butterflies is not a passing phase. On the contrary, one product of the two EU programmes has been the training across Europe of a new generation of excellent young scientists, highly skilled in butterfly ecology and conservation, in numbers that dwarf the previous workers in this field.

Thanks to these activities, the biology of butterflies is already better understood than that of any other taxon of non-pest insects. From Wallace and Bates in the 19th century to the ecological geneticists of the 20th century, butterflies have long provided prominent systems for exploring evolutionary biology. More recently, they provided tractable systems for understanding ecological processes, notably in population and metapopulation dynamics, and in conservation biology, where the specialised requirements of the larval stages have shed insights on niche theory, the intricacies of species' interactions, and the extraordinarily subtle ways in which the carrying capacity of a species' habitat can be improved by management or degraded by pollution or modern land-use. More recently still, butterflies have become important tools for predicting how insects may respond to climate change, whilst analyses of the most detailed available mapping schemes have revealed that butterfly populations have experienced far greater declines than either vertebrates or higher plants in recent years, giving credence to the hypothesis that, unless anthropogenic change is mitigated, the world is indeed approaching the sixth major 'extinction event' in the history of life on this planet.

The conference "Ecology and Conservation of Butterflies in Europe" brought together most of the leading and new butterfly biologists and conservationists of Europe. Held at UFZ Leipzig-Halle on 5th to 9th of December 2005, it was composed of 10 sections which were divided into two conference blocks, which are reflected in these two volumes of Proceedings. The first volume "General Concepts and Case Studies" encompasses the "Ecology of Butterflies" (3 sections) and the "Conservation of Butterflies and Global Change" (two sections), while the second volume "Species Ecology along a European Gradient: *Maculinea* Butterflies as a Model" contains 5 sections and encapsulates the final meeting of the four-year EU Framework V MacMan project.

This first volume had its genesis in a plan to launch a book "Ecology of Butterflies in Europe" (EBIE), but this proved impossible to finalise within the original time frame. However, to maintain the momentum of EBIE and to link the ecological advances to conservation, we invited five of the principal authors of EBIE as key note speakers to this meeting, to give presentations and written précis of their extended chapters from the EBIE book: John Dover (UK), Landscape influences on butterflies; Andreas Erhardt & Jovanne Mevi-Schütz (Switzerland), Butterflies and Flowers - Fascinating Interactions; Jane Hill, Ralf Ohlemüller & Chris Thomas (UK), Climate and butterfly distribution changes; Chris Van Swaay & Arco van Strien (Netherlands), Using butterfly monitoring data to develop a European grassland butterfly indicator; and Martin Warren, Tom Brereton & Tom Wigglesworth (UK): Do agri-environment schemes help butterflies?: experience from the UK.

In addition to the papers of keynote speakers, this volume contains 47 extended abstracts and mini-papers of 0.5 to 6 pages, describing new developments in a host of ecological fields that apply to butterfly conservation. Several concern the monitoring and mapping of butterflies, and the use of butterflies as indicators of large-scale processes, both being research areas that were part-funded by two other UFZ-coordinated EU projects: EuMon (European wide methods for Monitoring of habitats and species of the Habitats' Directive; http://eumon.ckff.si; STREP FP VI Contract number: 006463) and ALARM (Assessing LArge scale environmental Risks for biodiversity with tested Methods; www.alarmproject.net; GOCE-CT-2003-506675). Good examples of this work are found in the papers of Balletto et al., Feldmann et al., Heliola & Kuussaari, Henry et al, Pendl, Romo et al., Örvössy et al. However the bulk of the book describes analyses of patterns and processes in butterfly ecology, and their relevance to wider issues in the conservation of biodiversity: these papers encompass a diversity of subjects, including phylogeography (Schmitt), physiology and climatic gradients (Fischer, Garcia-Barros), autecological studies and conservation (Descimon et al., Fartmann, Fred et al, Krauss & Cozzi and Langlois), population (Vandewoestijne et al) community (Ruggieri & Sara) landscape (Bourn & Bulman, Kuusemets et al) and macro- (Konvička et al) ecology, resource partitioning (Turlure et al), habitat modelling (Liebsch et al, Polus), and the use of butterflies as indicators (Kuussaari et al). Taken together, they represent a broad sweep of contemporary thinking in insect conservation ecology which we trust will also be useful to practitioners.

The contributions of both proceedings volumes have been peer refereed, anonymously, by at least two colleagues, whose help is greatly acknowledged. The conference was possible only through the support of many friends and colleagues. In particular we thank colleagues from UFZ: André Künzelmann, Andreas Staak, Christian Anton, Christiane Viehrig, Dana Weinhold, Dirk Immisch, Doris Böhme, Ellen Selent, Martin Musche, Monique Franke, Sarah Gwillym, Susan Walter and Sylvia Ritter; from CONFIRM Ltd: Hildegard Feldmann & Ogarit Uhlmann; and from the Centre of Ecology & Hydrology (CEH Dorset, NERC): Graham Elmes, Karsten Schönrogge, Judith Wardlaw, Zoe Randle and Nicky Gammans. We are also indebted to Frank Nolden, Georg Teutsch, Heike Wolke, Klaus Henle, Peter Fritz and Stefan Klotz (all UFZ) and to Mark Bailey (CEH) for the scientific and administrative support of biodiversity research in general and of research on butterfly ecology and conservation in particular.

Elisabeth Kühn, Reinart Feldmann,
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Section 1.
Ecology of butterflies – TV film

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Bye, bye, butterfly (original: „Bye, bye, Schmetterling")
TV documentation 45 minutes

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The TV film "Bye, bye, Schmetterling" follows the traces of an inconspicuous but constant change in our surrounding nature. Although hardly on the headlines of newspapers and journals, it has a tremendous impact on the environment.

Mowing is one of the normal land use activities in cultural landscapes. It provides the fodder for cows and horses. Mowing regimes in modern agriculture are largely triggered by the nutritional state of the grass and suitable weather conditions. Due to the availability of large equipment, mowing can be performed on huge areas within a very short time span. In combination with the availability and use of fertilisers, several mowing cycles can be performed per year.

This system has extreme consequences for wildlife on meadows. It destroys the habitats of numerous species of formerly rather abundant butterflies and other pollinators.

As a consequence the abundance and diversity of butterflies and much other wildlife has decreased tremendously throughout the last decades. It is not only a "poetic" loss; it is a loss of ecological vitality and a hardly replaceable loss of pollinators.

Within this film we show how many aspects of biodiversity loss are inter-related and directly affect human well-being. We show how a small girl rears a rare and beautiful butterfly – an emotional adventure which aims to bring nature nearer to the next generation.

Although it is not an ALARM film, it was to a large extent inspired by the activities within the Integrated Project ALARM, which is coordinated at UFZ (see: Settele et al. 2005 and www.alarmproject.net). It leads us to many places across Europe and tries to answer questions like: Why do butterflies go extinct? What are the consequences for our environment and for us? How high is the impact of chemical pollution? Which role does fragmentation and habitat loss play? What impact does climate change have? Why do we need environmental monitoring?

Information on the film (in German language) is also available at: http://www.swr.de/betrifft/2005/08/22/index.html

The film was supported by many friends and colleagues, to whom we are extremely thankful: Aldina Franco (University of York, UK); Andre Künzelmann (UFZ Leipzig-Halle, Germany), Arno Kuhn (University of Göttingen, Germany), Barbara Herren (FAO Rome; Italy), Bernard Vaissiere (INRA Avignon, France), Catrin Westphal (University of Göttingen, Germany), Chris Thomas (University of York, UK), Sir David Attenborough (Butterfly Conservation, UK), Holger Loritz (UFZ Leipzig-Halle, Germany), Howard Frost (Yorkshire, UK), Ingo Tornier (CAB Biotechnology Pforzheim, Germany), Ingolf Steffan-Dewenter (University of Göttingen, Germany), Jeff Martin (The Natural History Museum London, UK), Karl-Heinz Baumann (Gomaringen, Germany), Marie-Christine Frost (Yorkshire, UK), Martin Warren (Butterfly Conservation, UK), Richard Belding (DEFRA, UK), Richard Künzelmann (Leipzig, Germany), Sarah Melanie Settele (Halle, Germany), Sigrun Boksch (CAB Biotechnology Pforzheim, Germany), Volker Lichti (Neustadt an der Weinstrasse, Germany)

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Section 1.1.
Ecology of butterflies – Habitat requirements, habitat models & landscape influences

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Habitat models and habitat connectivity analysis for butterflies and burnet moths – the example of *Zygaena carniolica* and *Coenonympha arcania*

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Based on logistic regression, we developed habitat models for the burnet moth *Zygaena carniolica* and the nymphalid butterfly *Coenonympha arcania* in Northern Bavaria, Germany. The relation between adult occurrence and habitat parameters - including the influence of the landscape context - was analyzed on 118 sites.

The presence of the burnet depended mainly on the presence of nectar plants and of nutrient-poor dry grasslands in close proximity, while that of the nymphalid depended on larger areas of extensively used dry grasslands within 100 m and in combination with small patches of taller shrubs and bushes. The optimum date of management for *C. arcania* was after July 15. Models based on parameters that were available for throughout the area yielded satisfactory predictions. Thus, habitat suitability maps could be generated for the entire study area.

Internal as well as external validations confirmed the robustness and general applicability of the models. Their transferability in time and space indicates the high potential of model predictions to be applied to current questions in nature conservation, such as predicting the possible effects of land use changes.

Habitat connectivity analyses based on predicted habitat suitability maps and results from mark recapture studies showed a quite high degree of habitat connectivity but no effect of isolation or habitat size on the occurrence of either species in the study area.

LITERATURE

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Landscape influences on butterflies

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Island biogeography kicked-off interest in conservation at the landscape-scale (MacArthur & Wilson, 1967). Levins (1970) gave us the metapopulation, Hanski (1999) developed the theory and linked it with fieldwork and especially with butterflies. Landscapes in ecology started off as simple representations of real islands surrounded by water. Then, with an awareness of threats caused by increasing fragmentation, isolation, and reduction in extent of habitat and the need to conserve species in nature reserves, rapidly developed to consider terrestrial habitat islands (patches) surrounded by non-habitat (the matrix) (Diamond, 1975; Foreman & Godron, 1986). More recently the 'matrix' has become populated with resources and suddenly the landscape has become heterogeneous, crowded with landscape elements with different permeabilities to dispersing individuals, topographic variability producing buffers against environmental stochasticity, hill-tops for mating, barriers, corridors, and stepping-stones.

Habitat patches are becoming more diffuse and complex: their shape and size are obvious factors affecting immigration and emigration but now we have to consider the make-up of the edge of habitat patches as 'open' edges may promote dispersal from natal patches whereas 'hard' ones, such as forest, may impede dispersal (Dramstad *et al.*, 1996) – but it also depends (probably) on whether the species under consideration is a species with specialist habitat requirements or a 'generalist'. What is a habitat patch anyway? Supplementation and Complementation merely categorise processes we have always been aware of, but focussing on them coupled with much more work on dispersal (distinguishing in scale between patchily distributed local resources and metapopulations) means we are moving away from the idea of a single patch that contains everything (Dennis & Shreeve, 1996). More and more the matrix is looking like a place which contains many resources normally enclosed within that comfortable notion 'the patch' and making life more uncomfortable, complex, and exciting for ecologists!

Management of habitat patches is no longer simply a 'site' issue and no longer can we consider extinctions of species to occur under a purely theoretical 'stochastic' regime. We live in the real world where changes in agricultural practices, economics, tourism and social drivers mean we are dealing with deterministic processes at the landscape level such as intensification, abandonment, an ageing workforce, and high social expectations. Layer this with political considerations such as farm subsidies, CAP reform, international competition, regeneration of declining economies and you have a truly dynamic landscape.

In this paper I look at some of the major attributes of landscapes, examine the definitions of habitat and matrix, the impact of land-use change on populations and communities, and how dispersing individuals are affected by features and resources in the landscape. I then draw on this to identify some of the gaps in our knowledge.

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Butterflies and Flowers – Fascinating Interactions

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Feeding in the adult stage plays an important role for butterflies. A variety of food sources is used by butterflies, but by far most important is floral nectar. However, butterflies do not visit flowers randomly, but have specific flower preferences, which can differ between species and even between the sexes of a species. Furthermore, nectar plant distribution can affect dispersion and habitat use of butterflies.

Nectar sugar is long known to enhance longevity and fecundity of butterflies, but the role of nectar amino acids is less clear. New experimental evidence sheds more light on this controversial issue.

Although butterflies are well-known flower visitors, their role as pollinators has also been debated. We address this issue from the perspective of both the butterfly as well as the plant. We discuss aspects of coevolution between butterflies and flowers and address the question of whether butterflies are mutualists or floral parasites. Using butterfly-pollinated wild carnations (*Dianthus* spp.) as model organisms, we pursue the question whether butterflies can act as selective agents for plant speciation.

We end with the caveat that the fascinating interactions between butterflies and flowers are increasingly threatened. Hence an elementary biological process is at risk, which can only be preserved if whole communities are protected.

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Hamearis lucina prefers west-facing slopes for oviposition in calcareous grasslands in Germany

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Within-patch habitat quality accompanies patch size and isolation as a third major factor that determines the persistence of butterflies in cultivated landscapes. Selected egg-laying sites can serve as a good proxy for a definition of optimal habitat quality (see review in Garcia-Barros & Fartmann submitted). The knowledge of *Hamearis lucina* oviposition sites in Central Europe is still poor.

The study area (hereafter called Diemel Valley) is located in Central Germany along the border between the federal states of North Rhine-Westphalia and Hesse (51°22'N/8°38'E and 51°38'N/9°25'E) at an elevation of 100 to 610 m a.s.l. The climate is suboceanic and varies greatly according to altitude. Calcareous grasslands – the only breeding sites of *H. lucina* in the Diemel Valley – cover about 750 ha (2% of the total area) (Fartmann 2004).

On occupied sites, systematic samples of *Primula veris* on a 5 × 5 or 10 × 10 m grid were searched for eggs. Microhabitat structure was analysed in a radius of 50 cm around each used plant following Anthes et al. (2003) and Fartmann (2004). For comparing occupied and available host plants, 49 vegetation relevés of 16 m² with presence of *Primula veris* according to the Braun-Blanquet methodology were used. They represented all potential *H. lucina* habitat types corresponding to their area proportion in the Diemel Valley (Fartmann 2004, submitted; Anthes et al. submitted).

Oviposition sites (n = 416 eggs) were characterised by high total vegetation coverage (median: 100%). More than three quarters of all eggs were found on places with more than 60% herb layer coverage (median: 100%). On relatively cool northwest-facing slopes or where tree or shrub coverage was high, sites with open turf were used as well. Usually, the coverage of mosses and lichens was low (median: 20%). However, where abundance of higher plants was low, up to 90% coverage was possible. There was always a certain amount of litter; mostly between 10 and 25% (median: 15%). Gravel, stones, rocks; bare ground and trees were of little significance in the egg-laying sites of *H. lucina*. A shrub layer often existed, but at low coverage (median: 10%). The oviposition sites of *H. lucina* were characterised by a cover of mosses and lichens, bare ground and gravel, stones and rocks significantly lower than at randomly selected available *Primula veris* plants (Figure 1). Higher coverage by shrubs and litter was significantly preferred.

Sward height at oviposition sites (median turf height: 20 cm, n_{used} = 416) was significantly higher than that at randomly chosen available plants (median turf height: 15 cm, $n_{avail.}$ = 49, Mann-Whitney U Test, U = 6642.5, $P < 0.005$). The analysis of horizontal vegetation coverage at different heights above ground further showed that vegetation cover was very dense near the ground (median in 5 cm height: 80%, 1. to 3. quartile: 50–100%), but already drastically decreased at 10 cm above ground (median: 30%) and was negligible further up.

When compared to available *Primula veris* sites, oviposition sites were predominantly situated on westerly to southerly exposed slopes ($\chi^2 = 215.1$, df = 4, $P < 0.001$). Aspect and inclination are linked with maximal potential sunshine at the egg-laying sites. Most eggs were found on sites with 4–8 h of sunshine in May (median: 6 h). However, insolation at egg-laying sites further varied according to their aspect: While south- and southwest-facing larval habitats only receive about 4.5 and 5 h direct insolation in May, it was 7 and 9 h on west- and north-facing slopes, respectively.

The results indicate that *H. lucina* requires shrubby semi-dry calcareous grasslands with high total vegetation coverage on west-facing slopes at its northern distribution margin in Central Europe. But why does *H. lucina* prefer west-facing slopes? It appears very likely that southern aspects are usually too hot and dry in May and June, so that host plants are prone to desiccation. Furthermore, a high humidity seems to be necessary for the development of the eggs. Egg-laying on the undersides of leaves, as opposed to the top, and the dense layers of herbs, mosses and litter that are able to store humidity are in line with this hypothesis. Eastern aspects, in contrast, are rarely used, presumably because they do not warm up sufficiently to enable egg development.

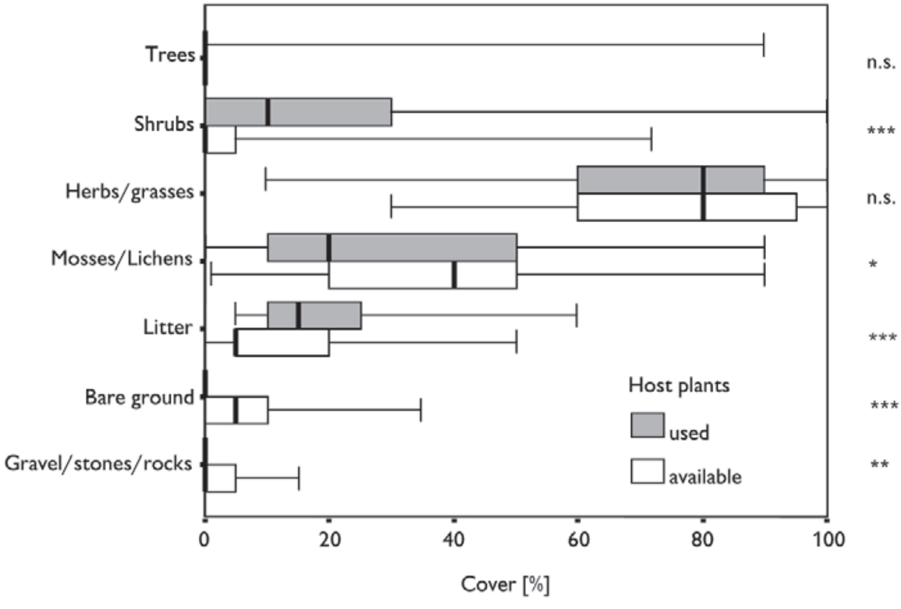

Fig. 1. Coverage of different vegetation layers at available and occupied host plants of *Hamearis lucina* in the Diemel Valley. Box-plots show maximum, minimum, interquartile range, and median coverage (%). * $P < 0.05$, ** $P < 0.005$, *** $P < 0.001$, n.s.: not significant, Mann-Whitney *U* Test. $n_{avail.}$ = 49, n_{used} = 416.

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Consequences of the spatial configuration of resources for the distribution and dynamics of the endangered *Parnassius apollo* butterfly

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Using several years of data from two populations of the endangered Apollo butterfly (*Parnassius apollo)*, we study how the amount and spatial location of patches of larval (host-plant) and adult (nectar plant) resources affects the distribution of females and their larval offspring in the following year. In the coastal population, where the nectar-plant and host-plant patches are spatially segregated, females moved frequently between patches to aggregate on larger host-plant patches close to nectar-plant patches. In the archipelago population, where the nectar-plants and host-plants co-occur, the abundance of females increased with higher proximity to other host-plant patches and with more nectar-plants on the patch. Next year's larval abundance correlated with the abundance of females in the previous season in both populations. A Markov Chain Monte Carlo model of the population dynamics in the two populations in relation to the spatial configuration of nectar and host-plant patches showed that the spatial configuration of larval and adult resources had population-dynamical consequences. In many organisms, different life-history stages use different resources. Incorporation of information on the location and abundance of different resources can provide additional insight for the suitability of a particular landscape in harbouring a population.

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Relative importance of resource size and isolation for landscape distribution of two monophagous butterflies

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Patch size and isolation of host plants are major causes of species extinction. We tested the effects of food plant availability, habitat area and quality as well as habitat isolation for the landscape distribution of the two monophagous butterfly species *Cupido minimus* and *Polyommatus coridon*. Both butterflies and their larval food plants are specialized species restricted to fragmented calcareous grassland. We surveyed all known calcareous grasslands (n = 298) around the city of Göttingen (Germany) to map the occurrence and population density of the host plants and the two butterflies and recorded habitat area, different habitat quality factors and distance to the next conspecific population of each habitat.

Both butterfly species were highly affected by larval food plant availability, which was positively correlated with habitat area. Habitat isolation (up to 5 km for *C. minimus* and 7 km for *P. coridon*) and habitat quality played a minor role for landscape occupancy and population density of both species. These factors may be often overestimated, as they only appear to contribute to landscape distribution in highly fragmented landscapes, where these factors shift towards extremes. Hence, general recommendations for conservation programs are difficult.

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Fritillary butterfly conservation on fragmented fens in Switzerland

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Inappropriate habitat management and increasing habitat fragmentation are among the most important threats to butterflies in Europe. The aim of this project is to assess the habitat management and the impact of habitat fragmentation and the surrounding landscape on occurrence and population densities of the fritillary butterflies *Boloria selene*, *Boloria titania* and *Brenthis ino* in the Swiss Alps. All three butterfly species are specialized on fens in the northern Alps of Switzerland. Butterflies represent good indicators of habitat change for many terrestrial insect groups and are often used as flagship and indicator species in national and international monitoring programmes. The protection of wetlands in Switzerland was decided in the Rothenthurm Initiative in 1987. Following this initiative, management strategies were developed to protect wetlands, e.g. grazing or mowing of fens once a year in autumn. However, management strategies are not always successful and an assessment of the degree of success is necessary.

We selected 36 fens differing in (1) management (mowing vs. grazing), in (2) altitude (800-1400 m a.s.l.) and (3) habitat area (0.9-90 ha). The study sites were further controlled for habitat isolation, landscape context and habitat quality. Within the main flight period of the butterflies (June-August) three independent surveys per study site (20- 60 min, depending on habitat area) were conducted to estimate occurrence of the species and to estimate population density.

Brenthis ino was found on 32 sites and *B. selene* and *B. titania* each on 23 of the 36 surveyed fens.

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Habitat and landscape structure requirements of Clouded Apollo (*Parnassius mnemosyne*)

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INTRODUCTION

The Clouded Apollo (*Parnassius mnemosyne*), a protected species by EU Directive *Natura* 2000, has special habitat requirements. The larva of the Clouded Apollo is dependent on the leaves of a single plant species (*Corydalis solida*). This plant grows along sunny margins of forests and trees where the soil is moist, but not in permanently flooded places, wetlands and hummocks. Therefore, the fumewort grows mainly in river valleys with strips of trees, in floodplains and in wooded meadows.

The adult of the Clouded Apollo requires open meadows that are its mating place and the habitat for the food nectar plants (Meglécz et al., 1999). The study in Finland (Luoto et al., 2001) showed that the presence of Clouded Apollo was significantly dependent on the number of fumewort, on the heterogeneity of landscapes, and on the presence of semi-natural grasslands, deep valleys and areas with low wind speed. At the same time the dispersal distances between habitat patches are short, which means that a dense habitat network is needed for conservation of this species (Välimäki and Itämies, 2003). These kinds of conditions are met in riparian communities of rivers, especially in strips with bushes and trees that propote migration of the Clouded Apollo. Also, in Estonia the Clouded Apollo has been mainly found in riparian meadows with a strip of bushes and trees that are habitats for suitable plants, which provide warmer, sheltered places (Viidalepp, 2000).

METHODS

All known locations and descriptions of Clouded Apollo (*Parnassius mnemosyne*) in Estonia were collected and standardised. A uniform database with GIS was formed using MapInfo Professional 6.5, observation of a Clouded Apollo was linked with its location on the digital cadastral map of Estonia (1:10 000). The analysis of the land cover and plant community types of habitats of Clouded Apollo was made on the basis of the digital cadastral map. For analysis, only these data were used, where it was possible to determine the exact location of the Clouded Apollo on the cadastral map. Also, descriptions from before 1980 were excluded, since the land cover and habitat type on the cadastral map could not respond to the situation when the butterfly was found.

In June 2003, a detailed survey of Clouded Apollo was made along the River Ahja. The number and sex of butterflies was estimated, the habitat description (dominant plants, presence of bushes close to river, land use) was made. At the end of April, all findings of fumewort were marked to the cadastral map.

RESULTS

There were 116 reports of Clouded Apollo from 1903 to 2002 in Estonia. Most of them (85; 73%) are from the period post-1990, in the 1980-s there were 12(10%) and from the earlier period 19(16%) records. There are three main centres of Clouded Apollo in Estonia: the population of the island of Saaremaa, and the North-Estonian and the South-Estonian populations (Figure 1). The Saaremaa population has not been recorded since 1973 and is probably extinct. The first description of Clouded Apollo in North-Estonia was made in 1903. During the first half of the last century, all records were confined to the very east of North-Estonia. Later the species expanded to the west and, especially during the last 10 years, has been found in the valleys of several North-Estonian rivers.

The South-Estonian population was first described in 1985 but has been increasing rapidly in territory and in the number of individuals. Despite the fact that the Clouded Apollo is decreasing in most areas of Europe (Meglécz et al., 1999), the population area and number of individuals is increasing at the Northern boundary of the population. Results show that there is an overall increase in the number of Clouded Apollo in Estonia, with 73% of all sighting having been made during the last 13 years. The exact reasons for this increase in Estonia are unclear but one precondition is the presence of suitable habitats for the butterfly (Meier et al., 2005).

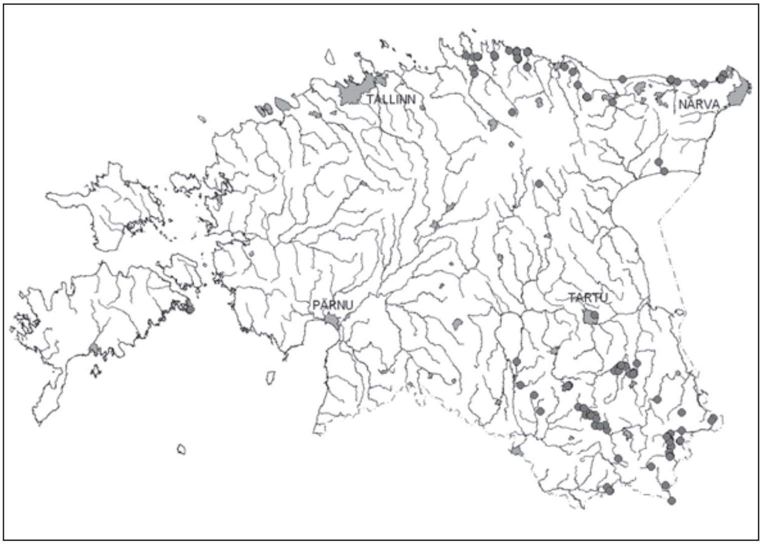

Fig. 1. The river network and distribution of Clouded Apollo (*Parnassius mnemosyne*) in Estonia.

From all findings of Clouded Apollo, 15(13%) have been located on the banks of lakes, 10(9%) on the coastal area of the Baltic Sea and all the rest (91; 78%) on the riparian areas of the rivers. The dominating land cover type was meadow with riparian strips of bushes and trees close to the riverbank. This habitat type was found in about 60% of described sites of Clouded Apollo. 30% constituted meadows and 10% wet meadows that were predominantly situated between meadows with riparian bushes (Meier et al., 2005).

Our detailed study showed, that the Clouded Apollo is mainly related to meadow with riparian strip of bushes and trees especially with grey alder (*Alnus incana*) (Figure 2). This is a typical riparian tree in Estonia, whereas the under floor of narrow riparian alder strip close to water table is the main habitat for fumeworts. Therefore, the Clouded Apollo is mainly found in the dry riparian meadows with alder strip while this habitat is the main habitat of the food plant of the larvae of Clouded Apollo, while this habitat is the main feeding and mating place of adult and while this habitat provides suitable migration and hiding place for the adult of the butterfly. This kind of habitat is linked to traditional agricultural practices in Estonia, like hay making and grazing of cattle and sheep. However, during last years this agricultural practice is considerably decreased and former meadows are overgrowing. There is also pressure to cut down riparian bushes and trees. All can lead to the loss of habitats of Clouded Apollo.

Findings of Clouded Apollo are mainly situated along the banks of rivers. Rivers with riparian strips of bushes form suitable migration corridors for Clouded Apollo and provide habitat patches in the riparian meadows. The appropriate density of habitat patches and existence of migration corridors create appropriate landscape structure for dispersal and survival of butterfly avoiding its fragmentation and disappearance.

Therefore, the conservation of Clouded Apollo should consider its habitat requirements and general landscape structure to ensure all ecological needs of this butterfly.

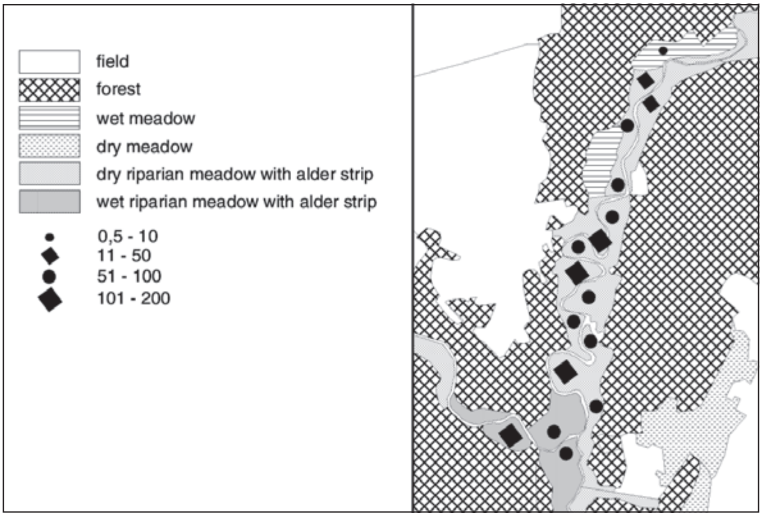

Fig. 2. Habitat type structure and density (individuals per hectare) of Clouded Apollo (*Parnassius mnemosyne*) in the Ahja River valley, South Estonia.

CONCLUSIONS

- The number of Clouded Apollo has increased in recent years in Estonia. There is a new population with a high number of individuals in South-Estonia.
- The larvae and imago of Clouded Apollo require specific habitat – riparian meadow with strips of bushes, that is typical for traditional agricultural landscapes (hay making, grazing), which have nowadays a high risk of being abandoned and overgrown by bushes and trees.
- Rivers with riparian strips of trees and meadows are creating suitable landscape structure for the migration and survival of the Clouded Apollo.
- The protection of Clouded Apollo needs protection of the riparian habitat that should be managed in traditional ways, as well as and the preservation of riparian strips of bushes and trees to preserve multifunctional ecologically balanced landscapes.

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Habitat analysis for *Brenthis ino* in the nature reserve "Ferbitzer Bruch" – management scenarios for a relic population in an abandoned military training area

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After about 100 years of being utilised as a military training area, this kind of land use associated with specific disturbance regimes has been abandoned in the Döberitzer Heide. Parts of it, amongst others also a 400ha-wetland called Ferbitzer Bruch, were selected as nature reserves. The change of land use brought along considerable changes in disturbance regimes, leading to succession and changes in vegetation structure that yielded increased evapotranspiration and, consequently, equally vital changes in the landscape's water balance. Falling ground-water levels affect particularly wet areas. Therefore, many species are threatened with degradation of habitat.

One of these endangered species is *Brenthis ino* (marbled fritillary), now at level 2 in the red list of Berlin-Brandenburg although formerly a widespread species. In the suburban and rural regions of Potsdam, *B. ino* today is found only as two high isolated relic populations in the South of Potsdam and in the Ferbitzer Bruch.

Therefore, we carried out a habitat analysis regarding the most important habitat factors for *B. ino*, to provide information about suitable management measures to preserve the survival of this and related species.

We mapped the incidence of *B. ino* as well as selected habitat parameters – i.e. abundance of the larval foodplant *Filipendula ulmaria* (meadowsweet), patch size, shading, structure of copse – in order to construct a predictive habitat model. This model improves our understanding of specific habitat requirements of *B. ino* and helps to quantify and predict the effect of different management scenarios that consider changes in vegetation and groundwater levels. The ultimate aim of this study is to derive recommendations for appropriate management measures, to improve the survival probability of this relic population.

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Microhabitat preference of the Southern Festoon (*Zerynthia polyxena*)

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The Southern Festoon (*Zerynthia polyxena*) is regarded as a vulnerable species. It reaches its north-western distribution limit in Hungary, where it can be locally abundant. In Central Europe larvae are monophagous on a weed of *Aristolochia clematitis*. The aim of our study was to gather information on host plant use by the adult and on the distribution of eggs and larvae among different host plant patches. The study population inhabited a poplar plantation with black-locust plantation pathches near Csévharaszt on the Hungarian Great Plain (Central Hungary). A host plant map was prepared representing approximately 300×1000 m. Twenty-three host plant patches were choosen for sampling. Each transect was represented by a separate host plant patch and these patches were in different types of microhabitat (poplar- and black locust plantation, clearings and small disturbed hummocks). The density of imagoes was estimated at every transect daily during the flight period. The number of eggs and larvae were counted twice, and a vegetation survey was also carried out in quadrats next to each transect (number and height of host plants, height of other herbaceous plants, percentage of bare ground). Fewer imagoes were counted in each transect in the poplar plantation, than in black locust plantation or open vegetation types. This is probably due to smaller undergrowth, and smaller host plants in poplar plantation, so host plant patches proved to be less attractive for butterflies. Egg numbers were correlated with the number of host plants and the type of microhabitat (there were more eggs in clearings and hummocks, than in the plantation). The number of larvae in quadrats were correlated to host plant height. We conclude that the Southern Festoon's microhabitat preference depends on the openness of the area and the presence and quality of the host plant, which differs in different types of microhabitat probably due to variation in light conditions and disturbance.

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What areas to protect: biases in the historic record of Iberian butterflies faunistics

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Using an exhaustive database with comprehensive information on butterfly faunistics in the Iberian Peninsula and the Balearic Islands, we estimated the completeness of faunistic inventories and the environmental, spatial, and land-use effects associated with the sampling intensities, on the basis of the 50 x 50 km UTM grid. The sources included in this database consist of a combination of labelled data from museum and private collection specimens, published or unpublished field data from biogeographic or faunistic works, as well as from standardized quantitative surveys carried out from 1784 to 2003. The environmental factors selected included four topographic variables (minimum, maximum and mean elevation, and elevational range); four geological variables (degree of clay cover), calcareous and siliceous substrates, plus geological diversity) and eight climatic variables (minimum and maximum monthly mean temperature, mean annual temperature, total annual rainfall, summer precipitation, number of sunny days per year, annual temperature variation, and annual precipitation variation). The land-use factors attempt to represent the degree of human disturbance, by measuring the coverage of the four most widespread human-induced landscapes in the study area: urban and industrial areas, non irrigated croplands, irrigated crops and anthropic pasturelands. Lastly, central latitude and central longitude of each UTM cell were used as spatial variables.

To achieve this, we adopted a former synthesis of seven main eco-physiographic Iberian sub regions, determining the proportion of adequately sampled squares that occur within each of these sub regions.

The degree of sampling effort was assessed by means of accumulation curves based on the Clench function, which relates the sampling effort and the number of species found. Using the General Lineal Models regression procedure, the effect of 22 variables on the estimated sampling efforts was assessed. This combination of methods is proposed in order to evaluate the degree of geographic coverage of existing faunistic data, as well as the amount and nature of bias in the faunistic surveys, as a preliminary step in biodiversity studies.

The percentage represented by the well surveyed cells in each area ranges from roughly 27% to 46 %. With the exception of the Balearic Islands, all the sub regions contained an acceptable and roughly comparable proportion of well surveyed squares. The backward stepwise regression explained a 40% of the variance in the distribution of the number of database records. Entering the sets of variables in order: first environmental, second land use and third spatial, produced significant progressive increments of the percentage of variation explained by the model.

The results confirmed that estimates of sampling effort derived from accumulation curves are less skewed than simple direct estimates such as counts of database records. A degree of spatial dependence was detected in the data; this was comparatively more important than the effects of environmental variables or of those related to land use. However, the last two eventually proved to be locally important. The results confirmed former statements that faunistic activities are often skewed according to relatively simple patterns related to the collectors' behaviour, such as accessibility, and attractiveness of the sampling sites. From the point of view of Iberian and Balearic butterflies, adequate inventories at the scale investigated may probably suffice for further studies on the diversity of this insect group. However, the results enabled us to point out general guide lines for the design of efficient further faunistic work.

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The butterfly community behaviour in a fire-prone secondary succession in Mediterranean woodland (Madonie, Sicily)

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AIM

The butterfly community in a fire-prone secondary succession of Mediterranean woodlands was studied in order to understand species turnover and changes in diversity. The investigated secondary succession started from young burned stages (BA = 24 months) to controls not burned for more than 50 years (CNB = > 600 months).

LOCATION

Mediterranean area, the *Erico-Quercion ilicis* of the Mediterranean belt (300-600 m a.s.l.), in the Madonie Mountains range, a Natural Regional Park, in northern Sicily, Italy.

METHODS

Visual censuses were carried out monthly during 2003 and 2004, from April to September; each census was performed by point-stations held for a standard period of 5 minutes. The stations were spaced with a distance of about 70-100 m to avoid overlap and double counting of butterflies. The trends of the species richness (S), α-diversity (Margalef index) and ß-diversity (Whittaker index) in the secondary succession were analysed.

RESULTS

18 butterfly species were recorded, 16 in 2003 and 16 in 2004. The monthly trend of the butterfly community in the sampling area showed that, apart from fire disturbance, the phenology of the species remained constant in all the studied areas: higher species richness was observed on June and August, with the June peak higher than the August one. Furthermore, the colder 2004 winter affected species presence and frequency all over the succession. Notwithstanding the confounding effects of weather, species richness slightly increased along the succession (12 species in recently BA areas vs 16 species in CNB). Some species (i.e. *Charaxes jasius, Coenonympha pamphilus* and *Melanargia galathea*) were censused in the control areas but not in those recently

burnt. The species trend along the succession becomes more evident when using the Margalef index, which takes in account the number of observed individuals as well as species richness. In addition, the relative frequency of individuals of each species changes along the succession, some appearing more precociously after the fire (*Anthocharis cardamines* and *Polyommatus icarus*), other such as *Gonepteryx cleopatra* being more frequent in the oldest burned sites. However, most of the species (i.e. *Pieris brassicae* and others) are present in all areas. The analysis of the ß-diversity allowed noticing the low rate of species turn-over along the fire-prone succession.

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Resource-based analysis of the habitat in two species sharing the same host plant

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BACKGROUND

Habitat loss, fragmentation and degradation are the major threats to biodiversity. According to Southwood (1977), habitat is a fundamental unit and a key concept in ecology. To preserve species, it is essential to conserve their habitats. But how can we define a habitat? Habitat is regularly mixed up with ecosystem, biotope or vegetal association (Hall et al. 1997), which leads to the attractive oversimplification of patch and matrix (Dennis, Shreeve & Van Dyck 2005) where the patch is a homogeneous and invariant entity and the matrix an empty space or a sea of non-habitat. Butterfly habitats in particular are often only based on host plant presence and distribution. However, although host plants are of primordial importance, they are not enough to define habitat in all species. The definition adopted here is the following: habitat is a delimited space made of union and intersection of the whole resources needed by the species (Dennis, Shreeve & Van Dyck 2003), individual movements assuring the link between the distinct and discontinuous units of habitat (Baguette & Mennechez 2004).

OBJECTIVES

(1) Definition based on resources

The resources required by a species can be distributed either in a unique spatial location or distributed widely in the landscape. As a consequence, biotope based definitions may overestimate or underestimate both the area and the amount of suitable habitat. This is why a resource-based definition of habitat is increasingly considered for butterfly conservation. Moreover, as a butterfly life cycle consists of several stages, the precise identification of essential resources for eggs, larvae, nymphs and adult stages is necessary. Here, our first aim is to describe and measure a wide array of such resources such as nectar resources, host plant abundance and distribution, resting, mating and laying sites and suitable microclimates for two butterfly species sharing the same larval food plant. We wish to determine whether or not both species exploit the same part of the biotope.

(2) Spatial and temporal variations of resources

Because there is a spatial combination of essential resources for the achievement of the species' life cycle, habitat can be spatially delimited. Inside habitat boundaries, four spatial arrangements of resources can be observed: superposed, inclusive, overlapping and disjoint distribution (Figure 1). Temporal variations of resources may also be divided in three categories: predictable variations, unpredictable variations and ephemeral resources, which determine the length of favourable and unfavourable periods (Southwood 1977). So, because of random environmental fluctuations, there is no single pattern of resources repartition in both space and time. Our second aim is to define these patterns for the two butterfly species under investigation.

(3) Resources complementation and supplementation

Critical resources that are spatially separated can be exploited by mobile animals. But the way resources are distributed through a landscape (*i.e.* biotope or landscape composition and physiognomy *sensu* Dunning et al. 1992) can constrain both foraging and dispersal movements. Therefore, what we are interesting in is first to quantify movements of the butterfly species between resources and secondly to define the spatial definition of habitat using butterfly movements as proxies.

METHODS

Field investigations were conducted during summer 2005 on two sympatric species using the same host plant: *Lycaena helle* and *Proclossiana eunomia*. Both species are peat bog specialists. *L.helle* is a univoltine lycaenid, flying in May and June, whereas *P.eunomia* is a univoltine nymphalid, flying only in June. Adult butterflies were first monitored using Mark-Release-Recapture (MRR), which allowed us to *(1)* estimate population sizes, *(2)* populations investigate the spatial structure of the two species, and *(3)* determine the distributions of distances moved between resources. We also tracked individual adult (males and females of the two species) to compare behaviour between species and to locate laying sites.

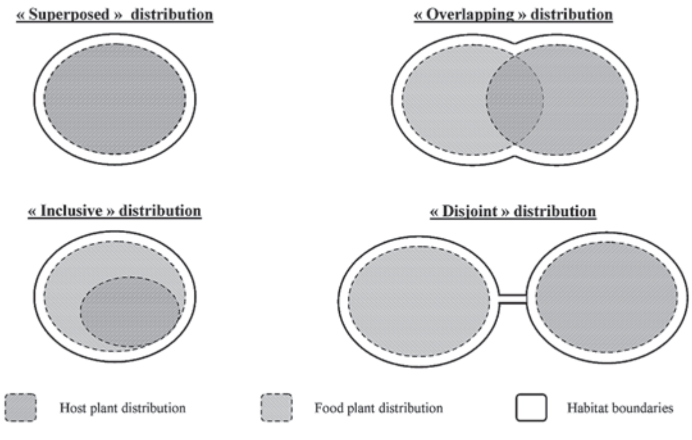

Fig. 1. Patterns of spatial arrangements of resources.

RESULTS

Results showed that:

(1) Even if the two species used the same host plant, females did not lay their eggs in the same conditions (host plant density and location). Moreover, if *Polygonum bistorta* was the only food plant used by both caterpillars and imagos of *P.eunomia*, adults of *L.helle* required other food plants. So, feeding resources were not the same for adults of the two species.

(2) Because the resources needed by the two species were not the same, habitat boundaries greatly differed: for *P.eunomia* resources are superposed, whereas for *L.helle*, resources distribution may be classified as inclusive. Furthermore, because nectar resources were ephemeral and because individuals of *L.helle* fed on several plants, habitat boundaries of this species may also vary in time.

(3) Finally, as distances moved by *P.eunomia* were larger and in different directions than those made by *L.helle*, and as the proportion of recaptures of the two species differed depending on their location, we conclude that there is a segregation of these species in space. We suggest that habitat quality and species interaction could influence the habitat selection and hence the spatial structure of the populations of both species.

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A comparative demographic study of two characteristic calcareous grassland butterfly species: *Cupido minimus* and *Lysandra coridon*

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Calcareous grasslands, like many other semi-natural habitats, are declining due to the abandonnement of traditional agro-pastoral techniques such as extensive grazing and mowing. The species typical of these habitats are consequently having to cope with decreased habitat area and increased isolation. The calcareous grasslands of the Viroin valley in southern Belgium are local biodiversity hot spots which have also suffered from increased urbanization and the intensification of agricultural practices. The population demography of two butterfly species (*Cupido minimus* and *Lysandra coridon*) was studied within this region using the Mark-Release-Recapture (MRR) method. Individual parameters, such as survival and catchability, and population features, such as population size, sex-ratio and recruitment rate, are estimated using constrained linear models. These parameters, and estimates of dispersal, were compared between species and correlated to landscape structure (patch area, patch isolation etc.). Suggestions for future conservation efforts are made.

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Transferability of predictive habitat models between areas: Butterfly models tested in three Flemish heathlands

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Models for predicting species absence/presence are increasingly used in nature conservation and have a broad range of conservation applications. Model outputs that are sufficiently accurate can be used for making conservation decisions, and, when they are spatially detailed, even for guiding reserve management or implementing species action plans. A very useful application for conservation is to extrapolate model predictions to areas for which information on a target species' distribution is lacking. However, the efficiency of this type of models is usually tested on the area for which it was developed. Although strongly recommended, predictive models are rarely validated on independent areas. The rare cases when this has been tested give contrasting results (Whittingham et al. 2003). Transferability and extrapolation of models was recently described as an 'unsolved problem in wildlife-habitat relationship modelling' (Seoane et al. 2005).

Most published models for predicting species' distributions explain absence/presence using combinations of relatively large-scale environmental and/or climatic variables. The relationships between these variables and the occurrence of the species are typically indirect, and may depend on the landscape characteristics of one specific area. As a result, models could be over-fitted to the area for which they were developed, thus explaining poor transferability. We argue that predictive models which are based on functional relationships between a species and its environment (essentially by adopting a resource-based habitat approach sensu Dennis et al. 2003) could capture better the actual habitat requirements of the species of interest resulting in higher levels of transferability across areas.

We tested these hypotheses for two Red List butterfly species (*Callophrys rubi* and *Hipparchia semele*) in three heathland areas in Flanders (N-Belgium). We built generalized linear models with species-specific essential resources mapped at a high resolution as variables. We found that a limited number of well-chosen resources can explain adult butterfly distributions very well. Not only were nectar sources and host-plants selected in the models, but also structural elements related to thermal requirements and territorial behaviour. The resulting maps allow managers to distinguish suitable habitat from unsuitable areas in the field and to identify zones of interest for restoration. These models not only worked well within the area for which they were developed, but most of them also gave accurate predictions when transferred to independent areas. Relations were not always reciprocal between areas and the quality of transferred models differed between the two study species. We conclude that in the case of the studied butterfly species, predictive models parameterised from one area could provide useful guidelines for conservation measures in other areas within the same ecoregion. Transferring model predictions from one area to another should be done, however, with considerable care. For example, it should be verified whether similar resources are used between study areas, and a small set of observations may be necessary to calculate reliable threshold values for distinguishing between absence and presence in the model output.

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Section 1.2.
Ecology of butterflies – Evolutionary biology

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Does voltinism in temperate insect herbivores depend on defences of their host plant?

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According to theories of plant antiherbivore defences, apparent plants utilise quantitative protective compounds, whose efficiency increases with ageing of foliage. In contrast, unapparent plants utilise qualitative chemicals, whose protective efficiency remains approximately constant during leaf age. It should follow that leaf-chewing insects feeding on apparent plants should synchronise hatching with appearance of fresh leaves. Since fresh leaves are typically available early in season in temperate environments, such insects, including butterfly larvae, should be constrained in annual numbers of generations. In contrast, no such constraint should apply to butterfly larvae feeding on unapparent, qualitatively protected plants. We tested the hypothesis using European butterflies, using both classical regressions and regressions controlled for phylogeny via independent contrasts.

If defined in a broad sense (woody plus gramineous plants), plant apparency performed as a strong predictor of low generation numbers; when controlled for phylogeny, even a narrower definition of apparency (woody plants) predicted low number of generations. Other significant predictors of low number of generations included living in arctic/alpine environments and having large bodies, but body size performed as a weaker predictor than host apparency.

The nature of host plant defences may contribute to our understanding of such patterns in phenology of temperate insects as scarcity of late-season monovoltines and a high numbers of generations in insects associated with ruderal plants. It also explains monovoltinism of some species, which are not limited by duration of vegetation season, suggesting that monovoltinism in temperate butterflies is an environmentally imposed constraint.

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Altitudinal life-history variation and temperature adaptations in copper butterflies

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Geographical variation in traits related to fitness is often the result of adaptive evolution. Particularly strong support for this notion comes from clinal variation, suggesting a contribution of directional selection to the differentiation among populations. Geographic gradients are of special interest for the study of climatic adaptation because the climate strongly varies with geographical variables. Although several environmental factors may impact on the physiology of individuals, temperature is thought to be one of the most important selective agents.

By comparing copper butterfly populations from low and high altitudes differing substantially in temperature, I demonstrate pronounced differences in life-history variables, which are presumably attributable to temperature adaptation. Low and high altitude populations were, for instance, found to differ in voltinism and concomitantly in the mode of diapause induction, in growth patterns and in body size. Here, however, I focus on variation in pupal melanization (which increases with increasing altitude) and its functional ecology, and on chill coma recovery time. The latter method has proven to be a rapid and sensitive index of climatic adaptation and acclimation, varying strongly across populations and groups being raised at different temperatures.

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Size-dependent, continuous response of larval growth rates to photoperiod in the satyrine Nymphalid *Coenonympha pamphilus* (L., 1758)

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Populations of widespread species living in temperate areas with a mild climate and a winter season are often expected to experience both, a plastic response of larval growth rates to photoperiod, and a comparatively low life-cycle synchronisation. This situation was investigated by analysing the responses of larval growth rates to photoperiod in a sub-montane Mediterranean population of the satyrine Nymphalid *Coenonympha pamphilus*. The insects originated from the locality of Manzanares el Real (province of Madrid, Spain, ca. 900 m above the sea level). The adults of this population are on the wing from April to September, and their frequency distribution seems to fit a broadly bivoltine pattern, probably with one part of the population going through one further generation in mild years.

Ripe females were collected in the field and transported to the laboratory, and the eggs were collected to assemble groups of 40-50 larvae from several females. The newly hatched larvae were placed in individual plastic jars with a commercial mixture of living grass, and immediately placed in the experimental day lengths (10h, 12h, 13h, 14h, 15h and 16h in 24h cycles, at constant 23ºC). They were regularly weighed, and kept in the same conditions until they pupated or died. These rearing experiments were complemented by an experiment designed to switch photoperiods (short to long, and long to short) to assess the effects of photoperiodic changes in the last instar. Since one group of the larvae experiencing the shortest day lengths remained in diapause after four months or more, and eventually died, most comparisons were made using relative growth rates instead of the total larval development times.

An important degree of individual variation in diapause induction below the critical threshold (between 14L:10D and 15L:9D) was onserved, suggesting that a part of the population retains the ability to develop directly in short photoperiods. Variation was also recorded in diapause intensity and size within the diapausing larval instar.

An apparently plastic response of growth rates to day length was detected in all larval instars. The relative growth rates were strongly size-dependent, suggesting an ontogenetically programmed response. However, the results only marginally conformed to the ‘time horizons’ hypothesis. This is attributed to the fact that, even when there is a dominating overwintering instar, reaching a fixed size or instar for winter diapause seems not to be crucial. However, the effect of ‘ambiguous’ photoperiodic signals (which is probably state-dependent) was only partially assessed.

It is suggested that day length-dependent growth rates are viewed as a part of the 'pre-diapause program', and that they may have an adaptive meaning in climates where conditions favouring larval feeding may predictably occur close (immediately before, and after) the winter season, although this is predicted to result in low synchronisation of adult emergence in the spring generation.

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Conservation Genetics and Phylogeography of *Parnassius mnemosyne*

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INTRODUCTION

Conservation of biodiversity involves preserving the objects and processes of life at scales ranging from genes to ecosystems. The European Habitats' Directive is indeed an important stage towards a conservation approach that takes account of the role of species in ecosystems. On the other hand, species are made up of populations which may substantially differ in their evolutionary heritage and ecological features.

A key issue of conservation genetics is, thus, understanding the structure and geographical distribution of genetic diversity within species along with the role of the historical and evolutionary processes which shaped it, that is phylogeography.

The present availability of efficient and relatively cheap molecular tools means that phylogeographical analysis can be a first step towards the identification of evolutionary significant units (ESUs).

This research is part of a study committed to assess relationships between spatial distribution of habitat and genetic variation in *Parnassius mnemosyne* L. (1758), a Papilionid butterfly widely distributed from Central Asia to Western Europe (Fig. 1) and included in annex IV of directive 92/43/CEE (Habitats' Directive).

P. mnemosyne is an oligophagous species, whose larvae feed on several species of *Corydalis* (Fumariaceae). It typically inhabits meadows and clearings in cool mesophile forests, though it also occurs in more arid mountain habitats in part of its middle-East range. Due to its ecological requirements, *P. mnemosyne* presently has a quite scattered distribution, restricted to relatively high elevations (500 to 2500m) in most of its range. Even in the northernmost regions (Scandinavia and North-Eastern Europe), where the species occurs at low altitude, populations are often isolated from each other.

Despite legal protection, the species has gone through a substantial decline, disappearing from many of its localities, particularly in Northern and Central Europe. Various human-induced alterations of habitats, such as the application of pesticides, successional changes, planting of conifers and overcollecting, along with global climate change, were suggested as the caus-

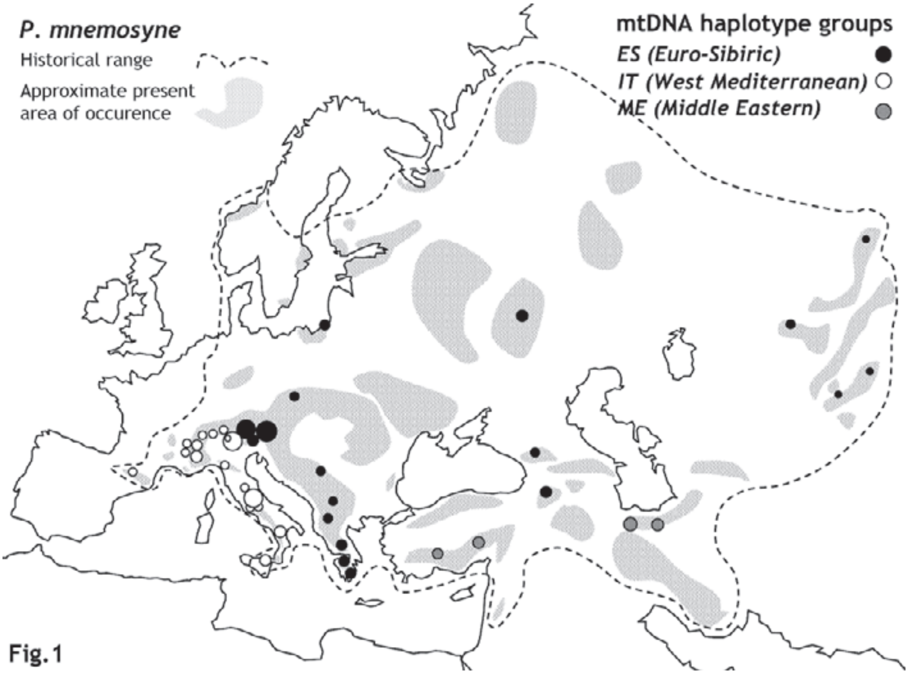


Fig.1

es of the species' decline. However, such suggestions are often anecdotal and the proximate causes of much local extinction remain unknown.

P. MNEMOSYNE PHYLOGEOGRAPHY

Phylogeographic analysis included a total of 148 *P. mnemosyne* individuals from 54 localities scattered over most of the species' range (Fig. 1). Our analysis also included 3 individuals of *P. ariadne*, which recent phylogenetic analyses showed to be *P. mnemosyne*'s sister taxon. GeneBank sequences of *P. phoebus* and *P. clodius* were employed as outgroups. Mitochondrial (COI) and nuclear (EF-1α, 6 microsatellite loci) genetic markers were employed in separate analyses.

A first analysis was conducted on a 950bp fragment of the mitochondrial COI gene and involved a subsample of 46 individuals (28 distinct haplotypes). Maximum Likelihood tree of COI haplotypes exhibits very deep phylogeographic structure, with three well supported (LRP bootstrap >90%) groups (Fig.2). One distinct Western European lineage (group IT) includes haplotypes from the Italian peninsula, Sicily, western Alps and the Pyrenees. A second group (group ME) comprises Middle Eastern specimens (Southern Turkey and Iran). Sequences from Central Asia, Caucasus and Norht-Eastern Europe (including Eastern Alps) form a third group (group ES).

Average p-distance between the main groups is between 0.028 and 0.043. If we assume that mutation rates for COI in *P. mnemosyne* are in the range of those reported in other insects (0.015-0.025/Myr), then our data support the hypothesis that divergence among main mtDNA lineages started 1-2 Myr before present. Thus, it is arguable that *P. mnemosyne* expanded in Europe during

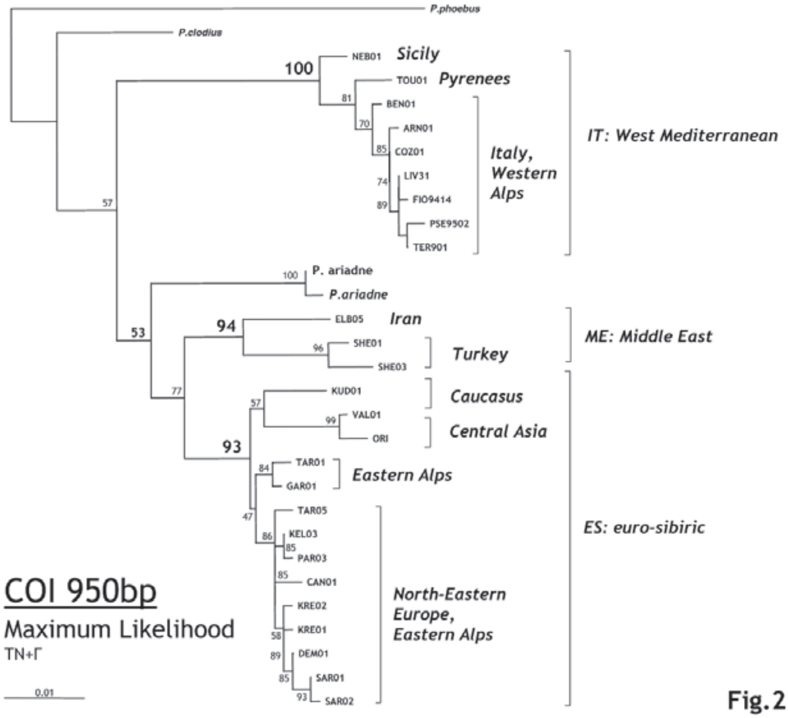
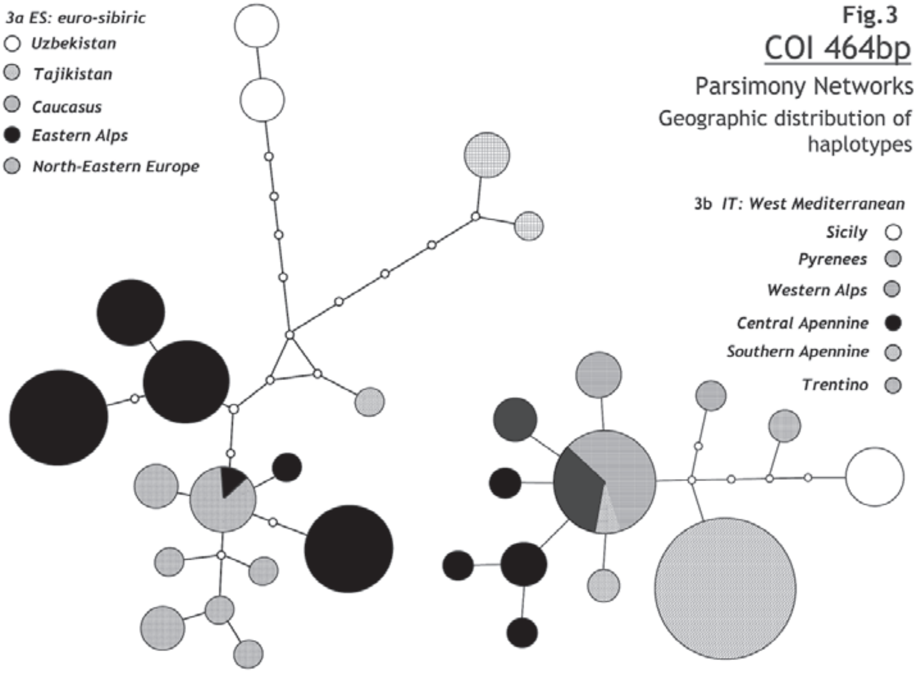

P.phoebus
P.clodius
100
NEB01 Sicily
TOU01 Pyrenees
81
BEN01
70
ARN01
85
COZ01
74
LIV31
89
FIO9414
PSE9502
TER901
Italy, Western Alps
IT: West Mediterranean
57
100
P. ariadne
P.ariadne
53
94
ELB05 Iran
96
SHE01
SHE03
Turkey
ME: Middle East
77
57
KUD01
Caucasus
99
VAL01
ORI
Central Asia
93
84
TAR01
GAR01
Eastern Alps
47
TAR05
86
KEL03
85
PAR03
85
CAN01
KRE02
58
KRE01
89
DEM01
85
SAR01
93
SAR02
North-Eastern Europe, Eastern Alps
ES: euro-sibiric
COI 950bp
Maximum Likelihood
TN+Γ
0.01

Fig.2

Fig.3


3a ES: euro-sibiric
○ Uzbekistan
● Tajikistan
● Caucasus
● Eastern Alps
● North-Eastern Europe
COI 464bp
Parsimony Networks
Geographic distribution of haplotypes
3b IT: West Mediterranean
Sicily ○
Pyrenees ●
Western Alps ●
Central Apennine ●
Southern Apennine ●
Trentino ●

the late Pliocene and the main lineages evolved in distinct refugia following early Pleistocene glacial periods. Highly differentiated haplotypes of the groups IT and ES nearly come in contact in Central-Eastern Alps, where it is likely that post-glacial colonisation routes met.

Interestingly, phylogenetic analysis did not support a strict monophyly of *P. mnemosyne*, since *P. ariadne* sequences come out as an ingroup, linked to groups ME and ES, though with low statistical support (53%, Fig. 2). Saturation of phylogenetic signal in COI sequences does not seem a reasonable explanation for the lack of support to *mnemosyne* monophyly, as both transitions and transversions grow linearly with genetic distance in our sample (not shown). Actually, the analysis of 550bp of the nuclear gene EF-1α, which has far lower substitution rates than COI, did not clearly resolve the position of *ariadne* (not shown). It is therefore arguable that isolation of this taxon from *mnemosyne* did not occur much earlier than partition of main *mnemosyne* lineages.

A subset of 464bp from the COI gene was sequenced in all of the 148 individuals (40 distinct haplotypes) and analysed by statistical parsimony networking (Fig. 3).

Applying a connection limit of 90%, separate networks had to be drawn for groups IT and ES, and for Turkish and Iranian haplotypes in the ME group. Networks can be interpreted to draw inferences about colonisation processes responsible for the present distribution of *P. mnemosyne* in Europe, where sampling density is sufficient for this kind of analysis.

In the ES network (Fig. 3a) four divergent lineages can be identified, relative to Eastern European, Caucasian and two different Central Asian samples. All the haplotypes from Balkans and Eastern Europe are connected in a single lineage, while the Eastern Alps harbour two distinct lineages, suggesting multiple colonisation events and/or ongoing gene flow from the Balkan populations.

Substantial divergence is found within the IT group (Fig. 3b), with Sicilian, Pyrenean, and Alpine-Italians haplotypes representing distinct lineages. The star-like network connecting haplotypes from the Apennines and Western Alps suggests a recent range expansion in this Area. All the individuals from Trentino (Central Alps) samples have the same, unique, haplotype. Low genetic diversity in this area is consistent with a very recent colonisation, though the basal location of this haplotype in the network would imply a relatively independent origin of these populations.

CONSERVATION REMARKS

Our results show that *P.mnemosyne* is a complex species with strong phylogeographic structure. Probably the most important finding from a conservation perspective is the existence in Europe of deeply distinct Western and Eastern lineages, which come in contact across the Central Alps.

Some reproductive isolation between Western and Eastern European lineages is suggested by the spatial distribution of mtDNA haplotypes, since no sample harbours both haplogroups. A few data gathered with nuclear markers (EF-1α sequences and microsatellites) did not demonstrate gene flow between populations exhibiting different mtDNA haplogroups, but cannot be considered definitive at the moment.

The question of whether these lineages constitute reproductively isolated populations acquires great conservation relevance since the available literature about the ecology, behaviour and management requirements of *P. mnemosyne* disproportionately relates to populations from Eastern and Northern Europe.

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Evolution meets conservation: Changing butterflies in changing landscapes

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Due to changes in land-use, landscapes have changed dramatically. Moreover, such alterations of the structure and composition of landscapes are an ongoing and accelerating process in many regions of Europe (and elsewhere). Although several studies provide correlative data on the patterns of impact of those changes on biodiversity, including on butterflies (e.g., declining species richness, increased extinction risks in sedentary habitat specialists), we still face important gaps in our knowledge on the mechanisms behind such patterns. Using several experimental studies in the field and in the laboratory on life-history-traits, behaviour and functional morphology of two common butterflies (mainly the speckled wood *Pararge aegeria* and to some extent the Orangetip *Anthocharis cardamines*), I explore the importance of landscape-related changes to a butterfly's life-style and success. Being flying heliotherms, I will particularly focus on aspects of their thermal ecology and mobility (including dispersal).

Using common garden experiments (in climate rooms and large outdoor cages) and reciprocal transplant experiments with *P. aegeria* originating from continuous woodland landscape *versus* fragmented agricultural landscape in central Belgium, we provide several lines of evidence of evolutionary changes in their behaviour (mate-location, dispersal), functional morphology and temperature-related oviposition capacity. We also show experimental evidence for increased larval mortality in fragmented landscapes compared to continuous landscapes. Additionally, I integrate the results of a manipulative field experiment on host plant use by *A. cardamines* at the landscape level, to discuss deferred search costs of dispersal in fragmented landscapes.

Finally, I make a synthesis of the more general meaning of these findings in terms of butterfly conservation of both rare and widespread species and briefly comment the future steps of research in this field.

SOME RELATED RECENT PUBLICATIONS

Karlsson B. & Van Dyck H. (2005) Does habitat fragmentation affect temperature-related life-history traits? A laboratory test with a woodland butterfly. *Proc. R. Soc. B* 272, 1257-1263.

Merckx T. & Van Dyck H. (2005) Mate location behaviour of the butterfly *Pararge aegeria* in woodland and fragmented landscapes. *Anim. Behav.* 70, 411-416.

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Section 1.3.
Ecology of butterflies – Distribution & Phenology

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From larval ecology to distribution pattern: a case study in three swallowtail butterflies

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The immature stages are the most vulnerable parts in the life cycle of a butterfly due to their low mobility (Porter 2002, Fartmann 2004). Hence, the larval ecology is often the key to the understanding of a species' distribution and abundance. We studied the larval habitat preferences of two east Asian swallowtail butterflies (*Papilio maackii* and *P. xuthus*) and the Eurasian *P. machaon* and their implications for distribution patterns.

The study area of about 7.5 km² is located in the Lazovsky State Nature Reserve in the southern Sikhote Alin mountains (Primorsky Krai, Russian Far East, 134°E/43°N) at an elevation between 500 to 700 m a.s.l. The region is affected by a monsoon climate with warm, humid summers and cold, dry winters (Chochrjakow & Schochrin 2002).

In summer 2003, during the flight period of *P. xuthus*, *P. machaon* und *P. maackii*, potential larval host plants on the gravel banks of the rivers Kyevka and Tchornaya were checked systematically for eggs and larvae. The following parameters were measured: total height and diameter of the focal plant, coverage of herbs, stones, gravel and open soil 50 cm around the host plant, as well as the average height of herbs around the focal plant (Anthes *et al.* 2003, Fartmann 2004). Additionally, we determined the oviposition height of the eggs and the residence height of the larvae, respectively, above ground. To describe the microclimate at the oviposition sites the potential insolation duration per day in August was measured with a horizontoscope according to Tonne (1954).

We found a total of 22 preimaginal stages of *P. xuthus*, 43 of *P. machaon* and 109 of *P. maackii,* respectively. All three study species use habitats with a high coverage of gravel (median = 40%) and stone (median = 49%) with only slight grass coverage (median = 10%). *Papilio xuthus* deposited its eggs on *Phellodendron amurense* (Rutaceae). Larvae of *P. machaon* were found on three species of Apiaceae. *Papilio maackii* used all four plant species. *Papilio xuthus* preferred prominent *Phellodendron amurense* plants, but eggs were laid a little bit below the height of the surrounding vegetation (Table 1). For oviposition *P. machaon* chose host plants with nearly the same height as the surrounding vegetation. Egg-laying took place on leaves below the height of adjacent plants.

The proportion of gravel and stone differed between the habitats of *P. xuthus* and *P. machaon*: The oviposition sites of *P. xuthus* offered more gravel than stone unlike those of *P. machaon* (Table 1). When *P. maackii* used *Phellodendron amurense* as host plant, the larval habitats resemble

Table 1. Habitat parameters (medians) of the egg-laying/larval habitats of the three swallowtail butterflies. "Collectiv" represents the combined medians of Apiaceae and *Phellodendron amurense*.

	Cover [%]				**Height [cm]**		**Plant Vitality [cm]**		**Insolation duration [h]**	
	Bare ground	Gravel	Stones	Herbs/ grasses	Turf	Oviposition	Height	Diameter		
Phellodendron amurense										
P. xuthus	0	50	40	10	25	24	34	32	8	n = 11
P. maackii	**0**	**50**	**45**	**10**	**25**	**22**	**30**	**23**	**10**	n = 56
Collectiv										
P. maackii	0	30	45	10	25	19	27	32	9	
Apiaceae										
P. maackii	**5**	**20**	**50**	**10**	**23**	**16**	**23**	**35**	**8**	n = 52
P. machaon	30	40	50	10	20	15	21	31	8	n = 28

those of *P. xuthus*. If Apiaceae were the host plants of *P. maackii*, the habitats were similar to those of *P. machaon*.

In the highly dynamic flood plains *P. maackii* has a strategic advantage over its congeners *P. xuthus* and *P. machaon*. Using various host plants of different plant families (Rutaceae, Apiaceae) and therefore colonising a wider array of habitats can be interpreted as a risk-spreading strategy. The choice of host plants involves different ecological, especially micro-climatic, conditions. With this strategy *P. maackii* obtained higher reproductive success showing higher abundances and a larger distribution on the landscape level compared to *P. machaon* and *P. xuthus*. The rarity of the other two species is probably the result of their host plant specialization on only one host plant family in combination with their narrower microclimatic preferences. *Papilio xuthus,* the one with the most specific ecological niche, was by far the rarest swallowtail butterfly in the study area.

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Latitude, longitude, and the evolution of Iberian butterfly faunistics (Lepidoptera). A preliminary test for shifts in distribution areas in the Western Mediterranean

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There is increasing evidence that human-induced climate change is playing a role in recent shifts in the geographic distribution of organisms, including butterflies. Tracing back distributional trends along the last two centuries requires a relatively exhaustive and unbiased faunistic documentation, and hence the kind of information that might not be available from all European countries. Further, it may prove difficult to 'dissect' any apparent historical patterns to discriminate between latitudinal trends, historical sampling biases, and direct effects of changing land use.

A relatively exhaustive database was recently compiled from collection and published data as a basis for the provisional distribution atlas of Iberian butterflies (that is, the Papilionoidea and Hesperiioidea of the continental territories of Spain and Portugal). This compilation contained ca. 285,000 records with reliable date and year data, or that were at least attributable to a precise decade. Each record refers to one or more individuals of any species associated to a different combination of site, date, and collector, from the last 210 years. All the data were geo-coded with reference to the UTM projection system, and the 10 km squares were used as operative geographic units. These data were explored in order to discover possible geographic trends in the distributions of the butterflies within the Iberian Peninsula.

This preliminary approach was based in standard regression techniques; these were applied to seek for any correlation between the recorded dates and the associated geographic location data (latitude and longitude), both within each species and in the whole data set. The basic procedure was to seek significant correlations between latitude or longitude and the year reported, using as much information as possible from the original data. The effect of the two geographic variables on the variable 'year' were tested simultaneously by means of multiple regression; this was necessary because, given the profile-shape of the study area, shifts in the average value of one of the two variables often imply a correlated change in the other. The species that occupy less than twenty 10 km squares were excluded from the analyses, as were all the skippers (family Hesperiidae) due to uncertainties about the reliability of the oldest records. However, all those data were retained for the global analyses where an estimate of the amount of data per square, and not the species, were required. Specific comparisons were feasible for 180 species.

Applying a simple multiple regression model yielded significant results for most species (155 out of 180 showed a significant correlation between year and either latitude, longitude, or both). This, however, was very obviously a consequence of a general trend towards a SW to NE shift in the centre of gravity of the faunistic efforts along the last two centuries: across the whole data set, both latitude and longitude were slightly (but highly significantly, $P<0.0001$) correlated to the year of observation (respectively $r= 0.08$ and $r= 0.17$), and the two geographic position variables were inter-correlated ($r= 0.37$, $P<0.0001$). Four methods were applied to statistically control these general effects. (a) First, the raw individual positional data were divided by the global year-specific mean latitude or longitude. (b) Second, the residuals (standardised residual values) from the regressions of latitude and longitude on year (calculated from the whole data set) were estimated for each record, and used as the input for new regressions at the species level. (c) Third, the General Lineal Models procedure was applied; two additional variables were introduced, i.e., 'period' (four different periods of time) and 'large region' (eight large subareal units intended to account for possible interregional biases). The residuals were retained for further analysis. (d) And last (and partly supported by the results of the former), a nested ANCOVA model with the variables described formerly, with 'period' nested within 'large region', and 'year' as a continuous predictor. Again, the residuals were saved.

The overall model results from the analyses (b-d) were able to explain important amounts of the variance. However, only the residual values from the two last treatments (c and d) demonstrated full temporal independence. In other words, the historic overall trends in the geographic position variables almost disappeared ($r= 0.00$ in GLM procedure, $r= 0.01$ in nested ANCOVA). The correlation between latitude and longitude decreased without completely disappearing in the last two analyses ($r= 0.13$, $P<0.0001$ in both). Based on the residuals from these two treatments, the species-specific correlations were more conservative than after the regressions done on the raw data, or on the residuals from procedures a and b. Even so, significant results still arose from the data of 104 species (with slight differences between the data from methods c and d).

The results certainly represent evidence for changes in the size and shape of the species' geographic distributions in Spain and Portugal. However, any interpretation must be cautious. It is evident that any potential latitudinal (and/or longitudinal) shift in the distribution of any of the Iberian species must have progressed along with the development of faunistic studies in the area; in fact, the last is still far from complete, at least in terms of the percentage of territory that has been thoroughly prospected. A vast majority of the records (67%) was made after 1976. Most of the oldest data are bibliographic and lack detailed specimen counts, which implies that the volume of effort carried out in past decades becomes progressively underestimated as the original material disappears. In addition, important changes in the patterns of land use have prevailed across most of the study area in relation with the process of industrial development along the XXth Century, and hence -probably- slightly predating the spread of the bulk of collection activities. Finally, the patterns of geographic distribution of faunistic efforts seem to have followed a roughly SW to NE orientation. This is partly attributable to an important development of extensive work in the northern part of Spain in the decade of 1980. Although in theory the residuals used in the calculations (methods c and d above) were free of geographic bias, more detailed analyses, together with a species-by-species intuitive reconsideration, are necessary to ensure that any patterns detected do not just reflect the rhythm of discovery of new sites (thus, the process of 'filling' the still imperfectly known geographic ranges) for the species involved.

To mention a few specific cases, we concentrate on those species for which a significant, and relatively high (r>0.3) partial correlation exists between the year of observation and latitude or longitude, and with similar results in the two approaches derived from methods c and d.

Trend (spreading towards)/ Species

N: *Clossiana eunomia*, *Erebia pronoe*, *Pseudochazara hyppolite*, *Minois dryas*, *Maculinea alcon*, *Agriades pyrenaicus*, *Plebejus hespericus.*

NE: *Erebia zapateri.*

E: *Colotis daira*, *Vanessa virginiensis*, *Tarucus teophrastus*, *Polyommatus nivescens.*

SE: *Satyrus ferula*, *Danaus chrysippus.*

S: *Brenthis ino.*

SW: *Erebia pandrose*, *Danaus plexippus.*

W: *Erebia palarica*, *Cacyreus marshalli.*

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Aspects of the distribution and habitat of the two *Leptidea* species in Ireland

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Both *Leptidea reali* and *L. sinapis* occur in Ireland. This contrasts with Britain where only *L. sinapis* has been found. In Ireland, *L. reali* is the common and widespread species found in many open biotopes. By contrast our results show that *L. sinapis* is a habitat specialist confined to areas of karst with hazel scrub in a restricted area of western Ireland. We present the results of our research into the distribution of the two species in which we demonstrate that they are totally separate in distribution and habitat use. Our findings concur with those elsewhere in northern and central Europe. Both species appear secure currently in Ireland and indeed at some monitored sites *L. reali* is increasing.

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Different phylogeographical patterns in butterflies and burnet moths of Mediterranean origin

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Many warm-loving butterfly and burnet moth species survived the last ice-age in the southern European peninsulas of the Mediterranean and expanded from these differentiation centres to Central and Northern Europe during the Postglacial. However, the Mediterranean Faunal element is not a uniform biogeographic group, but reflects a variety of different phylogeographical patterns. Therefore, I present five examples of butterfly and burnet moth species and species complexes representing four different phylogeographical types.

The species complexes of the Chalk-hill Blues *Polyommatus coridon/hispana* and the Marbled Whites *Melanargia galathea/lachesis* have one major genetic lineage in each of the three large European differentiation centres of the Mediterranean. In both cases, the Iberian Atlantic-Mediterranean lineage is strongly differentiated from the Adriatic- and the Pontic-Mediterranean lineages and represents an independent sibling species. Both of these Atlantic-Mediterranean taxa were not able to colonise Central Europe during the process of postglacial expansion, so that Central Europe was colonised by the respective Adriatic- and Pontic-Mediterranean lineages. Detailed genetic studies revealed three alternative Postglacial expansion corridors in Central Europe for the Adriatic-Mediterranean lineage of *P. coridon* and two for the Pontic-Mediterranean lineage. This Postglacial expansion is accompanied by the loss of genetic diversity towards Northern Europe.

In contrast with these two species complexes, the Meadow Brown *Maniola jurtina* had only two genetic lineages all over Europe and a relatively weak genetic differentiation between lineages: a western lineage is of Atlantic-Mediterranean origin extending from Morocco over Iberia and France to the UK. The second lineage is of Adriatic-Pontic-Mediterranean origin and is found all over the rest of Europe. The differentiation within these two lineages is rather weak and no northwards loss of genetic diversity was observed. This suggests a phalanx-like postglacial range expansion.

For the Common Blue *Polyommatus icarus*, no differentiation into different genetic lineages was observed all over a European study area, but a strong isolation by distance structure exists on this continental scale. The differentiation between populations was rather weak and the genetic diversity of the populations is higher than in most other analysed species. Therefore, this species was apparently distributed throughout the Mediterranean area during the last ice-age, without major disjunctions of the distribution area. For that reason, no distinct genetic lineages evolved and no major genetic bottlenecks occurred.

At the other extreme, the Atlantic-Mediterranean zygaenid moth *Aglaope infausta* has at least two strongly differentiated genetic lineages with the evolution of both probably having taken place in two allopatric sub-centres in Iberia, one in the south-western and the other one in the south-eastern part of this peninsula.

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Chorological analysis of alpine and arctic-alpine disjunctions: an overview based on western Palearctic Lepidoptera

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The search for repetitive patterns or "paradigms" in the distribution of biota is one of the basic tasks of biogeography. It was often pointed out that some kinds of "repetitions" (e.g. areas of endemism, vicariant patterns, disjunct ranges, types of post-glacial expansion) reflect the dramatic changes all over the Quaternary period. It was postulated that the postglacial recolonization of temperate latitudes has regularly started from distinct glacial refugia. Based on the area-analytic method, several refugial belts and their core areas have been identified in the Mediterranean region and in the eastern Palearctic. The application of genetic markers have confirmed and modulated many of the earlier findings, and also unraveled still unresolved questions. As a result, species with Mediterranean core areas are relatively well studied, and genetic approaches support many of the previously formulated hypotheses based on chorological analyses. Recently, the phylogeographic significance of several extra-mediterranean refuges was also pointed out. The polycentric area structure of several former "Siberian" species was repeatedly demonstrated as well.

The genesis of the arctic-alpine disjunct areas is less well understood than the ones described above. There is a general lack of a comprehensive characterisation of the different types of the alpine and arctic-alpine disjunctions in the western Palearctic. Since there are several, often convergent types of regressive area fragmentation also in the oreal and oreotundral fauna, we have the possibility to search for some repetitive patterns in these faunal types, too. As a model group, we use butterflies and moths whose distributions are well studied in the western Palearctic. The chorological description of the different types of disjunctions is completed with hypotheses on the glacial distribution patterns and possible impacts on the genetic structure.

The oreal fauna is a kind of continental insular fauna of orographically caused non-arboreal biomes. The members of this fauna are often "spot-like" endemics or have disjunct alpine or arctic-alpine distribution areas. Their core areas are detectable by the accumulated occurrence of endemic species and by high species-diversity of some typical genera. In general, the oreal fauna is subdivided into two types: (i) the *alpine* type represents the faunal type of humid high-mountains with prevailing glacial morphology and with strong connections to the *tundral* zonobiome, and (ii) the *xeromontane* type of arid high mountains with prevailing physical weathering and with manifold connections to the *eremic* zonobiome. The formation of the *alpine* faunal type is closely connected to the Quaternary glaciations and its history is characterised by repeated long-distance translocations and disjunctions, followed by differentiation processes.

The number of endemic species with narrow distributions is nearly equal in the western and eastern Alps. However, there is a strong subdivision according to (i) the substrate (silicious vs. calcareous) and (ii) position (central vs. marginal). The two main areas of endemism partly overlap with the two main types of survival, i.e. (i) survival on nunatakker and (ii) survival in lower, at least partly unglaciated "massifs de refuge" or peripheral refugia. Most species of the alpine endemics with broader distribution are not restricted to the highest levels, but they occur in a relatively broad vertical belt. The main areas of survival of these species during the last glaciations must have been similar as in most members of the former group. However, they had better chances to disperse postglacially and/or were present in a larger number of alpine and/or perialpine refugia. Such disjunct past distribution pattern might have resulted in considerable genetic differentiation.

Numerous species of the "*alpine archipelago*" show similar distributions within the Alps as the alpine endemics, but they have restricted occurrences in some few mountains either closely connected with some parts of the Alps or, in a few exceptional cases, more geographically distant, but strictly confined to alpine elevations. The main area of glacial survival of the species of the "*alpine archipelago*" must have been around the glaciated areas of the Alps and thus relatively similar to the ones of the alpine endemics. However, the distributions of the former might have been larger, so that postglacial retreat was not only possible into the ice-free high elevations of the Alps, but also in other adjoining mountain systems.

A large number of the European alpine species is more widely distributed than the members of the "alpine archipelago". They regularly exist in three to four or even more different European mountain regions. Thus, they occur in considerable distances from the Alps. The main centres of glacial survival of the alpine species with wide western Palearctic distribution might include the areas of survival of the alpine archipelago species around the glaciers of the Alps ***and*** at least one of the following areas (i) in or south of the Pyrenees, (ii) in central/southern Italy, (iii) south and/or east of the Carpathians, and (iv) in the western and/or eastern high mountains of the Balkans.

The glaciation of the sub-mediterranean mountains was relatively limited during the Quaternary glacial periods, so that they could serve as important refugia of the western Palearctic oro-Mediterranean fauna. The ranges of these species are subdivided by the formerly heavily glaciated Central Alps into a western and eastern "flank". Some oreal species show Ponto-Atlantomediterranean or Pontomediterranean-W- and E-alpine disjunctions. In some cases, the Balkan endemics have vicarious sibling species in the Alps. The southern summer-arid mountains of inner Iberia, southern Italy and the southern Balkans are characterised by Mediterranean coniferous forests and xeromorphic high mountain vegetation. As a consequence, they are not populated by alpine species, but they have the habitats of the xeromontane species at the high altitudes.

The ranges of arctic-alpine species are subdivided into a tundral, zonobiotic "*continental*" and into an orobiotic "*archipelago*" part, resulting in many possible combinations of disjunct ranges. The oreotundral disjunctions within Europe (without Eurasiatic range) are fairly well-known in European beetles with arctic-alpine range where the importance of the periglacial "bridge" between the Scandinavian mountains and the Alps (+ Carpathians) was shown in several cases. However, this general type of distribution is nearly unknown in Lepidoptera. The oreotundral disjunctions in Eurasia can be subdivided into three different types: (i) the oreal part is often a large, Eurasiatic one, consisting of several disjunct alpine areas as well as (ii) the oreal part is restricted either to Europe or, (iii) more often, to Asia. The most important concentration of the species with the latter type of disjunction is known in the mountain tundra areas of the southern and eastern Siberian high mountains.

In some other cases the alpine and the arctic parts of the area are populated by pairs of sister species. The southernmost distribution limit of such species in the Balkanic high mountains essentially co-incide with that of the alpine species. Many different distributional and ecological types of alpine and arctic-alpine species have to be distinguished. Many speculations about possible past distribution patterns and evolutionary scenarios are possible for the members of this group. However, most of these speculations were not sufficiently testable with the classical analytical tools as the analysis of distributions and the elaboration of their core areas or the analysis of fossil records. However, genetic analyses will allow testing many of these assumptions and answering the above mentioned hypotheses and questions.

The hypothesis of differentiation and survival on a single nunatakker area in the Alps is best proved by the actual distributions of narrow endemics of the highest altitudes as already done in many publications on insects as in lepidopterans with flightless females. These groups show also a high level of endemism, regularly connected with food-plant specialisation to some petro- or chasmophyta. Therefore, relative genetic uniformity of the individuals for these narrow endemics might support this hypothesis. In some cases both, the "nunatak" survival and southern perialpine refugia (*massifs de refuge*), could be accepted, based on the recent disjunct patterns. Some examples of higher plants indicate that these main possibilities of survival can be separated by molecular markers.

In contrast to the species of the alpine archipelago, the widespread species should have endemic genetic lineages in the peripheral mountains. A rather strong genetic structure should be found in the group of oro-Mediterranean species. The existence of extended alpine habitats on the Balkan peninsula during the young Pleistocene glaciations is clearly suggested by the presence of numerous typical alpine and arctic-alpine species in the highest and mostly extended massifs, as N-Albanian Alps, Korab and Shar-planina, in the western part and in the Rila-Pirin massif. In addition, some strictly localised neo-endemic peripheric isolates clearly demonstrate the evolutionary significance of these alpine refuges. The study of genetic differentiation would be especially fascinating in the case of the long-distance Alpine-Balkanic disjunctions.

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Vertical distribution of the alpine Lepidoptera in the Carpathians and in the Balkan peninsula in relation to the zonation of the vegetation

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We discuss the vertical distribution of Arctic-Alpine, Alpine and Balkanic oreal species. The definition of faunal types follows Varga (1977, 1996). The general rules of their distribution can be summarized as follows:

– Arctic-alpine species have mostly a Eurasian distribution and occur in the Arctic and in the alpine and subnival zones of the Central and Southern European high mountains with expressed glacial morphology and alpine vegetation.

– Alpine species are mostly European species and, like arctic-alpine species, are connected to the alpine and subnival zones of Central and South European high mountains. However, they are absent from the arctic tundra and from most Asian high mountains.

– Balkanic oreal species are mostly southeast European species which sometimes also occur locally in the less glaciated southern parts of the Alps and Carpathians. Their main area of distribution is in the high mountains of the Balkan Peninsula. In Asia Minor, they occur only in the north-west, in the more humid part of the Pontic Mts.

The highest number of alpine and arctic-alpine species occur in the mountains which have the most extended alpine and subnival belts, e.g. Central and Eastern Pyrenées, Central Alps, massifs of the Southwestern and Southern Alps, Southern Carpathians, highest mountains of the Balkan peninsula (Sar-planina, Korab, Rila, Pirin). The total number of species and the number of endemic species are only partly correlated.

The distribution of oreal species mostly depends on the elevation of the timberline. However, it is often influenced by meso- and micro-climatic conditions. Arctic-alpine and alpine species occur, for example, on the northern slopes of the Carpathians at relatively low altitudes because of a suppression of the timberline due to the unfavourable climatic conditions (e.g. Tatra Mts., Rodna and Retezat Mts.). The overall number of oreal species in the Carpathians is lower than that in the highest mountains of the Balkan peninsula, where the extent of the subalpine and alpine zones is larger. The vertical belts of the vegetation show at least four different major types in the European high mountains. The occurrence of the tundro-alpine and alpine species is usually connected with the Helvetic and Penninian type of vertical zonation. They need the presence of a "true" alpine elevation with adequate types of vegetation (alpine turfs: "*Matten*", cushion plants, dwarf scrubs of "*Spalier*"-vegetation, etc. They reach a southern boundary in the Balkan peninsula at the "*Adamovic-line*" due to the basic change of vertical zonation.

The vertical distribution of Balkanic oreal species shows several characteristic differences. Balkanic oreal species are most numerous at the timberline, preferred habitats being grasslands in the upper subalpine belts. Only some few species are connected to the (mostly lower!) alpine elevations (2000-2400 m), and they exceptionally also occur at lower altitudes near to the timberline (*Erebia orientalis, E. rhodopensis, Aplocera simpliciata*). Some other species display a transitional character: They occur predominantly in lower-alpine and sub-alpine elevations with a mosaic-like scrub and grassland vegetation (e.g. in the Pirin Mts: *Pinus mugo* and *Juniperus sibirica* scrubs, *Bruckenthalia spiculifolia* and *Daphne oleoides* dwarf scrubs and grassy vegetation predominated by *Festuca paniculata* and *Stipa* spp.), or in steppe-like grasslands with abundant tall-forbs. Typical of these species are: *Polyommatus eroides, Boloria graeca, Coenonympha rhodopensis, Erebia ottomana, Anaitis lithoxylata*, *Xestia ochreago*, while other species occur mostly in humid sub-alpine meadows and tall-forb habitats, e.g. *Lycaena candens*. Some Balkanic oreal species and also the xeromontane species *(x)* are confined to rocky habitats with scarce vegetation, e.g. *Agriades pyrenaicus (x)*, *Erebia melas*, *Pseudochazara graeca (x)*, *P. sintenisi (x)*, *P. geyeri (x)*, *Elophos certhiatus*, *Hadena clara (x)*, *H. drenovskyi (x)*, *Rhyacia nyctimerides stavroitiacus (x)*, *Epipsilia cervantes (x)*, *Chersotis laeta (x)*, *Euxoa decora (x)*, etc.

The vertical distribution of butterflies is generally influenced by substrate type and by the vertical belts of vegetation. The occurrence of some arctic-alpine species, e.g. *Melanarta melanopa rupestralis, Pyrgus andromedae* seem to be connected with tundra-like formations, as the polygonic soils. Many species prefer slopes that are covered by erratic blocks or gravel. The apparent petrophily of several alpine and tundro-alpine species correlates with their sheltering behaviour under unfavourable weather conditions, e.g. in day-active geometrid species, such as *Pygmaena fusca*, *Sciadia tenebraria* and several species of the genus *Glacies* or some *Titanio* species (Pyralidae). The food plants of arctic-alpine butterflies and moths are often cushion plants and low herbaceous plants such as species of *Androsace* (e.g. *Elophos* and *Glacies* spp.)*, Dianthus, Gentiana, Plantago* (e.g. *Euphydryas cynthia*)*, Silene* and *Viola* (e.g. *Boloria pales*), or grasses (e.g. *Erebia* spp. and *Apamea* spp.). Vegetation and surface type can also provide shelter from cold and rain. We have observed that *Boloria pales*, *Euphydryas cynthia*, *Erebia orientalis* and *E. rhodopensis* regularly overnight under dwarf scrubs of *Juniperus nana.* Other species, e.g. *Erebia gorge*, *E. melas*, *Entephria nobiliaria*, *Glacies coracina*, etc. shelter under stones.

The habitat preferences of alpine species are rather diverse. The more diverse vegetation of limestone mountains is usually home to a higher number of alpine species of Lepidoptera than that of the mountains consisting of acidic rocks. Examples include the calcareous Belanské Tatry *vs.* the granite-gneiss High Tatra: *Erebia pharte*, *Calostygia austriacaria* and *Glacies noricana* occur only in the calcareous Belanské Tatry. The calcareous conglomerate summits of the Bucegi Mts. are inhabited by more alpine species than the granite-gneiss Fagaras Mts. in the Southern Carpathians. *Zygaena exulans, Glacies coracina, G. noricana* and *Grammia quenselii* e.g. occur only in the Bucegi massif. Similarly, *Boloria pales, Entephria nobiliaria, E. cyanata* Hübner and *Glacies coracina* Esper occur only in the calcareous Vichren-Kutela group and are lacking in the granitic parts of the Pirin Mts. Some alpine species occur mainly in the humid sub-alpine, lower alpine grasslands near to the timberline, e.g.: *Erebia epiphron, E. manto, E. pharte, E. eriphyle, E. melampus, E. sudetica, E. albergana*, *Psodos quadrifarius*, etc. Outside the Alps, some of these species (*Erebia epiphron, E. manto, E. pharte*, *E. sudetica, Psodos quadrifarius*) also occur in similar habitats of the Carpathians. However, they rather sporadically occur in the Balkan high mountains, because of the lack of suitable habitats, with the exception of *E. epiphron* which seems to be fairly widespread in the W Balkans, and also has a sister species, *E. orientalis* (subdivided into three subspecies: *E. o. orientalis* in Rila, *E. orientalis infernalis* in the Pirin Mts. and *E. orientalis macrophthalma* in the central Stara Planina) in the eastern Balkan high mountains. *E. manto* occurs exclusively in the Dinarids of Bosnia, *E. albergana* at medium altitudes (1200-1800 m) near to the beech-forest timberline, on the Stara Planina. Many other alpine species are connected to the rocky-gravelly habitats with sparse vegetation, e.g. *E. gorge* (widespread in European high mountains)*, Erebia pluto* (Alps, Central Appenines)*, E. lefebvrei* (Pyrenées, Cantabrian Mts)*, E. melas* (Balkans, Slovenian Karst, Southern and Eastern Carpathians, Mti Apuseni); most species of the genera *Glacies*, *Elophos* and *Charissa* (Geometridae).

The vertical distribution of butterflies is influenced also by competition from closely related species. They often show different types of habitat partitioning. A humid *vs.* dry partitioning, combined with some vertical shifts, characterises the sibling species of the *Boloria pales*-species group (Fig. 1). A typical sward vs. gravel partitioning has been observed for example in *Erebia mnestra* (grasslands) and *E. gorge* (gravel) in the western Central Alps, in *E. rhodopensis* (grasslands) and *E. gorge* (gravel) in the Balkans (Fig. 2) The vertical distribution of the alpine species displays a characteristic trend. While they often occur in the Alps and Carpathians near (and not exclusively above) the timberline, their distribution is essentially higher in the Balkan mountains. They do not occur at the sub-alpine meadows, at the clearings of the uppermost coniferous zone or of the '*krummholz*' belt. These habitats are populated by the Balkanic oreal group of species. The Balkanic oreal butterfly species populate mostly the tall-grass dry grasslands near the timberline, e.g. *Boloria graeca, Erebia orienta-*

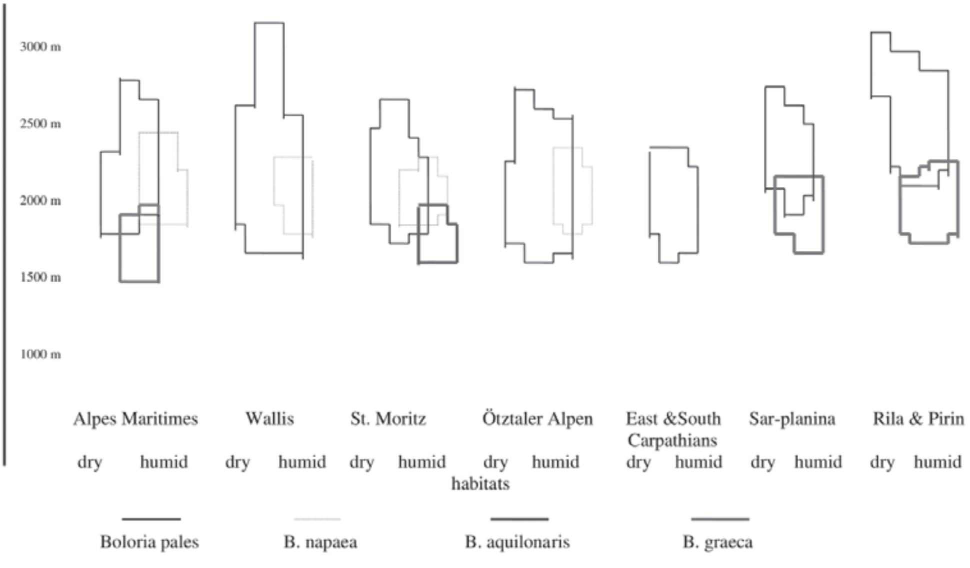

Fig. 1. Vertical distribution of the sibling species of the *Boloria pales* species-group in different European high mountains

lis, E. rhodopensis, E. ottomana as do numerous typical Balkanic Orthoptera species such as *Psorodonotus* spp. and *Anterastes serbicus*. The Balkanic endemic *Pinus* species, *P. peuce* and *P. heldreichii* form open stands and Balkanic oreal butterfly and grasshopper species regularly occur in the natural clearings of these forests near the timberline. At these elevations normally no arctic-alpine and alpine species occur.

Some other Balkan oreal species are connected to rocky habitats. The species of the genus *Erebia* display many interesting combinations of vertical and habitat type partitioning (swards vs. rocky habitats). In many areas of the Alps, Carpathians, Balkan high mountains more species occur sympatrically, but with restricted habitat overlaps. *E. cassioides neleus*, for example, has a relatively wide sub-alpine to alpine range (1550 m - 2100 m) in the Retezat Mts., where the Balkanic *E. ottomana* does not occur, while the Balkanic subspecies *E. neleus macedonica* seems to be restricted to the alpine zone (2200 m - 2600 m) in the Rila and Pirin Mts., where the sub-alpine zone is occupied by large populations of *E. ottomana*. The ecologically closely related Balkanic *E. melas* shows a nearly complete vertical exclusion with the taxonomically not closely related alpine *E. gorge* in many Balkanic high mountains. On the contrary, in the Olympus Mts., where no other *Erebia spp*. occur, *E. melas* occupies a wide range of rocky habitats, to the highest alpine levels (Fig. 2).

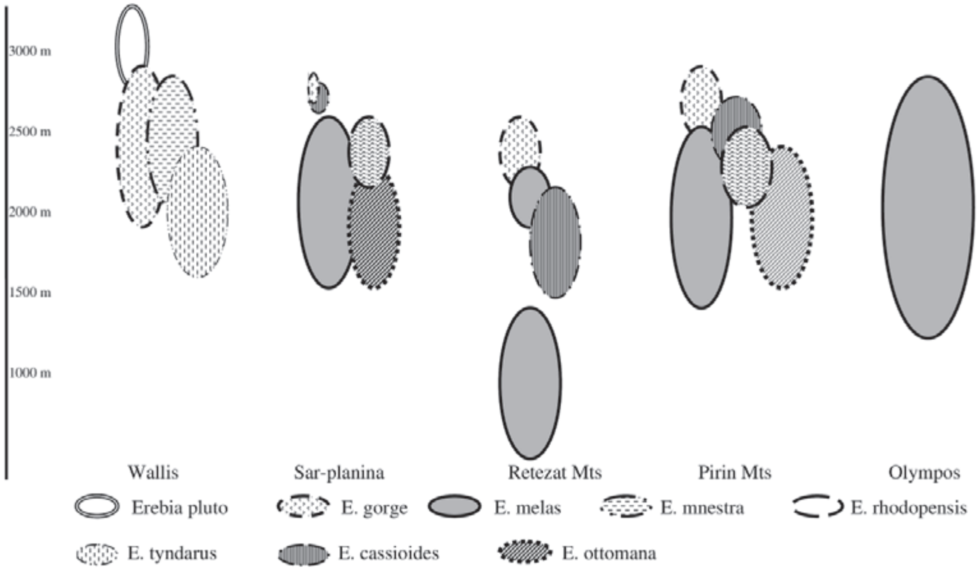

Fig. 2. Vertical distribution of the species of the *Erebia pluto* and *E. tyndarus* species-groups in different European high mountains

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Melitaea ogygia kovacsi Varga 1967 (Lepidoptera: Nymphalidae) in the Pannonian region: taxonomy, bionomy, conservation biology

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Melitaea punica Oberthur, 1876 or *Melitaea ogygia* Fruhstorfer, 1907?

Melitaea punica Oberthur, 1876 was described as "varietas" of the widely distributed polytypic species *M. phoebe* ([Denis & Schiffermüller], 1775) from Algeria (type locality: Lambessa). It is mentioned also in the best-known standard books (e.g. Higgins & Riley 1970, Higgins 1975, Forster 1971, Tolman & Lewington 1996) as subspecies of *M. phoebe*. However, its taxonomical status remained hitherto confused. Recently Hesselbarth et al. (1995) have demonstrated that *M. phoebe* and *M.* "*punica*" (as *M. punica ogygia*) frequently co-occur in Asia Minor. They pointed out that Varga (1967) has already demonstrated the occurrence of a "*second species*" in the Carpathian basin described as *M (phoebe) kovacsi*, recognising its connection with several described taxa from Italy, Balkan peninsula and Asia Minor. Several distinctive morphological characters (wing patterns, tips of antennae, palpi, fore legs, male genitalia) were described and depicted which were also confirmed by Hesselbarth et al. Several subspecific and infra-subspecific taxa described by Fruhstorfer (1907), Stauder (1914), Rebel (1917) und Verity (1919, 1938) were relegated as belonging to the "second species" (Table 1). Since the subspecies: "*ogygia*" (*M. phoebe ogygia* Fruhstorfer, 1907, Int. ent. Z. Guben I: 310, Typenfundort: Poros, Griechenland) and "*telona*" Fruhstorfer, 1907 (*M. phoebe telona* Fruhstorfer, 1907, Int. ent. Z. Guben I: 310, Typenfundort Jerusalem) were described in the same issue and on the same page of the journal Int. ent. Z. Guben, it is a matter for the revising author to decide which names should deserve the priority. Here we follow Bálint (1996), who has already used the name *M. ogygia* for the species occurring in the Carpathian basin, on the Balkan peninsula and in Asia Minor. The specific status of the eastern Mediterranean taxon was also confirmed by molecular data (Wahlberg & Zimmermann 2000), based on some specimens of Libanon identified as "*M. punica*". These data refer, however, to the Ponto-Mediterranean *M. ogygia* (= *M. telona*). Thus, the taxonomic status of *Melitaea punica* remained unclear.

Table 1. Synopsis of taxa relegated to *Melitaea ogygia* Fruhstorfer, 1907

Name + Auctor, Jahr	**Veröffentlichung**	**Typenfundort, Verbreitung**	**Bemerkung**
ogygia Fruhstorfer, 1907	Int. ent. Z. Guben I:310	Poros (Greece); FYR Makedonia, Greece, Bulgaria	
telona Fruhstorfer, 1907	Int. ent. Z. Guben I:310	Jerusalem; Syria, Jordania, Libanon	= dorae Graves, 1925
totila Stauder, 1914	Zschr. wiss. Ins. Biol. 10:373	Italia, Cocuzzo; Aspromonte	= phoebina Turati, 1920
amanica Rebel, 1917	Sitz.Ber. k. Akad. Wien 126: 252	Amanus-Mts.; Asia Minor, Transcaucasia	sec. Hesselbarth & al. synonym of ogygia
emipunica Verity, 1919	Ent. Rec. 31: 184	Sicilia, Palermo	= punicata Ragusa, 1920
nigrogygia Verity, 1938	Entomol. Record, Suppl. 20:17	Abbasia (= Opatija); FYR Makedonia,	? synonym of ogygia
kovacsi Varga, 1967	Acta biol. debrecina 5:117	Budakeszi (Buda hills); Hungary, Slovakia	sec. Hesselbarth & al. synonym of ogygia
capreola Varga, 1967	Acta biol. debrecina 5:117	Ucraina (Podolia)	

Morphological characters of *Melitaea ogygia*

Following Varga (1967) and Hesselbarth et al. (1995) the following characters can be used for the separation of *M. ogygia* (incl. *amanica* and *kovacsi*) and *M. phoebe*:

- Tip of antennae shorter, spatulate consisting of 29-34 segments (in *M. phoebe*: 35-37)
- shorter and more symmetric lateral arms of processus posterior of the valvae as in *M. phoebe*;
- Shorter and more rounded shape of fore wings;
- Wing pattern and colouration of the upperside:
  - Dull, yellowish reddish brown colouration, without expressed dichroism;
  - Blackish pattern more regular, network-like;
- Wing pattern and colouration of the underside:
  - On the fore wings the submarginal lunula are of triangular shape, the lunula between the veins m_1 and m_2 are not prominent;
  - On the hind wings the black marginal line is interrupted at the veins;
  - On the hind wings the reddish-brown filling of the submarginal lunules is more concolourous than in *M. phoebe*
  - The light spots and stripes of the hind wind are more whitish.

M. ogygia is known from the following areas: Israel, Jordan, Lebanon, Syria, Iraq, Iran, Transcaucasia, Turkey, Asia Minor, Bulgaria (Abadjiev 2000), Greece, FYR Makedonia, Kroatia N to Istrian peninsula, Hungary, S Slovakia, Romania (Varga & Rákosy 2002) and Ucraina (Podolia). The specimens of the northern populations show a darker reddish-brown colouration and blackish-brown reticular pattern than the southern ones.

Hesselbarth et al. (1995) have united all populations of the Near East and Southeastern Europe under *M. punica ogygia*. They have considered the external variations as modifications due to environmental influences. The populations of the Pannonian region have, however a rather uniform external appearance with a regular blackish pattern. In addition, they are geographically isolated from the Balkanic populations, they seem to be strictly monovoltinous and specialised to *Cirsium pannonicum* as larval food-plant. Based on these characters, we consider these populations as a single subspecies *M. ogygia kovacsi* (stat. revid.).

Bionomy and habitats of *M. ogygia kovacsi*

M. ogygia kovacsi is confined to meso-xerothermic habitats of the colline-submontane altitudes in the Hungarian Middle Range (see: map in Varga 1967). They are often clearings of white oak scrub forests (e.g. in the hills of Buda, type locality) or semi-dry tall-grass, tall-forb grasslands of the sub-Mediterranean white oak-turkey oak zone in the Bükk Mts and Aggtelek karst. Imagoes are on wing from mid-May or end of May to mid-June or early July, depending on weather conditions. Only a rather scarce second generation was observed, according to some museum specimens. Under laboratory conditions, however, no subitaneous development of larvae could be observed. The females lay the eggs in large piles (50-200 eggs) on the undersides of *Cirsium pannonicum* leaves near to the soil surface, where the young larvae weave nests and feed on the epidermis of leaves (Figs 1-3). From about mid-July they begin to continuously aestivate and hibernate. Hibernated larvae were observed from late March feeding on leaves of *Cirsium pannon-*

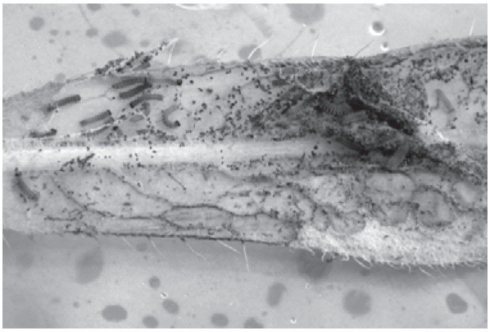

Fig. 1. Young larvae of *Melitaea ogygia kovacsi* feeding on *Cirsium pannonicum*

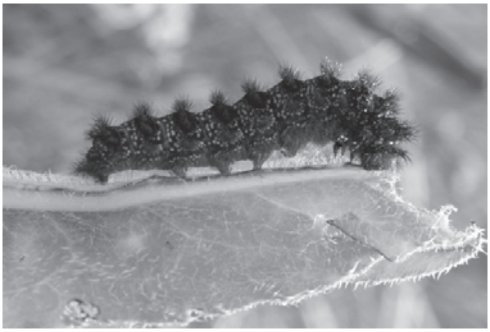

Fig. 2. Hibernated larva of *Melitaea ogygia kovacsi* feeding on *Cirsium pannonicum*

Fig. 3. Pupa of *Melitaea ogygia kovacsi*

Fig. 4. Female of *Melitaea ogygia kovacsi*

icum. They are different from larvae of *M. phoebe*: blackish-grey with whitish irroration and with reddish-brown head capsula (Fig. 4).

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Section 2.1.

Conservation of butterflies and global change – Monitoring butterflies across Europe

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Mapping the Italian Butterfly Diversity for Conservation

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The Italian Ministry for the Environment has recently published a preliminary distribution atlas for 10,000 animal species, on a 10x10 km UTM grid (Ruffo & Stoch 2005). Our team was involved in this project for the parts concerning the Papilionoidea and the Zygaenoidea (Balletto et al. 2005a,b). For the time being, data included in this database are mainly from literature and collections, even though a number of recent observations are also featured. Previously unpublished data represent about 50% of the total.

THE ITALIAN BUTTERFLY FAUNA

In Italy, 280 butterfly species are present (Balletto et al. 1995 and subsequent updates), assigned to 79 genera and 9 families or subfamilies. A number of these genera, which are represented by many species in the Palearctic, are present in Italy with just a few or only one species. This is the case, in particular, for the genus *Aporia* (1 species of 35, mainly Chinese currently known), *Oeneis* (1 of 35 Siberian, Central-Asiatic or North-American), and *Neptis* (2 species out of 53, mainly oriental or African). The Italian butterfly fauna represents 37% of the total Euro-Mediterranean fauna and is much richer than those occurring in any other European and Mediterranean Countries, with the exception of Turkey, where 357 butterfly species are present (Balletto 1996).

At a national level, butterfly biodiversity is higher in northern Italy, particularly in the Alps and pre-Alps, than in the Apennines and in the main Italian islands. This is a consequence of the peninsular effect (Tontini et al. 2003), which is only partially compensated by the presence of endemic species, mainly in the Apennines, in Sardinia and in Sicily. Butterflies are generally not characterised by a particularly high endemisation level. Strictly Italian endemics (i.e. restricted to the Italian political boundaries) are 18 and account for 7.5% of total. Some of them, such as *Pyrgus centralitaliae*, *P. picenus*, *Lycaena italica*, *Polyommatus virgilius*, *Hipparchia neapolitana*, *H. blachieri*, *Coenonympha elbana* and *Polyommatus gennargenti* may be subjectively considered subspecies of other more wide-ranging taxa. By following this point of view, the Italian endemisation rate would decrease to a mere 3.9% of the total butterfly fauna. On the other hand, it is also true that the number of endemic species occurring in Italy would increase to 48 (17.1% of total) if one considers species that are endemic to a small territory encompassing more than one Country, such as the Sardo-Corsican elements or as some restricted endemics of the Alps. The highest concentration of strictly Italian endemites occurs in the Apennines

(10 species), followed by Sardinia and Sicily (3 species each) and by the "xerothermic oases" of the western Alps (2 species).

Italian butterfly diversity varies considerably also along an altitudinal gradient. Beginning from the highest elevations, 47 species are only or mainly present above the timberline and are ecologically true alpine elements. Among the others, 97 species are typical of the montane vegetational level. About half of them are upper montane (mainly of the beech and fir horizon, more rarely of the Turkey oak's), while the remaining are lower montane (sessile oaks, or hills horizon). Only a few species, such as *Colias hyale*, *Maculinea alcon*, *M. teleius*, *Euphydryas aurinia*, *Coenonympha oedippus*, only inhabit the Padano-Venetian plains of northern Italy. *Lycaena dispar* and *Heteropterus morpheus* are also typical lowland dwellers, but partially penetrate into peninsula Italy as well. Only about a dozen species are truly Mediterranean and are limited to the maquis vegetational belt.

IMMIGRANT AND ALIEN SPECIES

Two butterfly species have come to belong to Italian fauna in recent times. *Danaus chrysippus* is a Pan-Paleotropical species and was first reported from Italy by Ochsenheimer (Torre del Greco Naples) in 1806-1807. This species, however, had soon become extinct in Italy, to reappear as a migrant in 1983 (unpublished data by W. Cameron-Curry). Perhaps as a consequence of recent climate changes, however, it soon became well established and a number of continuously breeding populations are currently known to exist, mainly in Sardinia and in the South of Italy. *Cacyreus marshalli*, in contrast, is originally a South African species, which reached the Mediterranean shores as a result of accidental introduction to the island of Mallorca in 1990, perhaps via the importation of some *Pelargonium*. Since then, however, it managed to spread to the whole W Mediterranean area. In Italy is was first observed in the EUR area of Rome in 1997 and became widespread soon after, behaving as an anthropophilous species. It is currently the commonest butterfly species in many Italian cities. However, as yet it has not become adapted to native geraniums.

CONSERVATION

Nine native Italian species are listed in Annexes 2 and 4 of the EU Habitats' Directive (338/97 CEE: HD). Seven additional species are included in Annex 4 only. Taking in consideration also the appendixes to the Bern Convention, the total number of Italian species considered by international agreements rises to 18, and shows a considerable concentration in the NW of the country (Tab. 1). Even though we are well aware that several other Italian species may be threatened across Europe (van Swaay et al. 1997), for the purposes of this paper we will mainly deal with these species, following a geographical-ecological scheme.

Endemic xerothermic elements of the Italian W Alps. The 9 species listed in the HD are known to be globally threatened, as well as *Polyommatus galloi* and *P. humedasae*, which were only included in the Appendix 2 of the Bern Convention in 1998, but are respectively listed as endangered and critical by IUCN. A third species, *P. exuberans*, will also be listed as endangered in the forthcoming Italian Red Data List, which is currently being compiled for the Ministry for the Environment by the Italian Zoological Union. All three are relic endemic species, having extremely small areas of occupancy (IUCN). *Polyommatus galloi* is restricted to the Mt Pollino and Orsomarso (La Mula) mountain ranges of southern Italy (3 10X10 km UTM quadrats). Even though both areas are Natural Parks, this species is endangered by natural afforestation. *Polyommatus humedasae* and *P. exuberans* are restricted to some very small xerothermic areas of the western Italian Alps. The former occurs at a single site straddling 2 quadrates, while the second is known to have become extinct at 2 of 4 quadrates where it used to thrive until the late 1950s (Balletto 2004). Both species, as well as *Papilio alexanor*, are threatened by the natural spread of the forest on previously grazed and/or cultivated areas. In this case, however, and despite being included in as many SCIs, overcollecting is an additional threat to their survival.

Mediterranean species. Since the early 1950s, Mediterranen butterfly species have suffered a generalised destruction of their original habitat along the seaside (Balletto & Casale 1991). *Melanargia arge,* is a well known Italian endemic of the central and southern Apennines, but even though it is listed in Annexes 2 and 4 of the HD it does not seem to be seriously threatened. Its status, however, requires careful re-evaluation. The same applies to another well known endemic flagspecies, *Papilio hospiton* and also to *Argynnis elisa*. Other Sardinian species, such as *Polyommatus gennargenti* and *Pseudophilotes barbagiae* will probably need to be considered for inclusion in HD Annexes in the near future, as well as two Sicilian species, *Melanargia pherusa* and *Melitaea aetherie*. Although a new site

Table 1. Italian butterfly species listed in the Annexes and Appendices of the Habitats' Directive and of the Bern Convention and their distribution in some Italian regions (columns).

	Piemonte	**Val d'Aosta**	**Liguria**	**Friuli**	**Calabria**	**Sardegna**
PAPILIONIDAE						
Papilio alexanor	X		X			
Papilio hospiton						X
Parnassius apollo	X	X	X	X	X	
Parnassius mnemosyne	X	X	X	X	X	
Zerynthia polyxena	X		X	X	X	
LYCAENIDAE						
Lycaena dispar	X			X		
Maculinea arion	X	X	X	X		
Maculinea teleius	X			X		
Polyommatus galloi					X	
Polyommatus humedasae		X				
NYMPHALINAE						
Argynnis (=*Fabriciana*) *elisa*						X
Euphydryas aurinia	X	X	(X)	X		
Euphydryas maturna	X					
SATYRINAE						
Coenonympha oedippus	X			X		
Erebia calcaria				X		
Erebia christi	X					
Lasiommata (=*Lopinga*) *achine*	X					
Melanargia arge					X	
TOTALS	**12**	**5**	**5(6)**	**9**	**5**	**2**

was recently discovered in Calabria (Scalercio 2002), the latter species is known to have become extinct at four of seven known Sicilian sites since the 1960s (Balletto 1992).

The Padano plains. From a more general point of view, endangered Italian butterflies are not necessarily restricted to endemics. Taken as a category, the most endangered Italian butterflies are hygrophilous species restricted to the plains of the Po river valley, in N Italy. In the Padano-Venetian Plains, a major problem is that they represent by far the most heavily industrialised and densely populated part of Italy. The few remaining semi-natural meadows and woodlands are under continuous pressure, not only from being increasingly reclaimed for building new factories, roads or railway lines, but perhaps even more importantly, from the ever increasing abstraction of water from the water table for human or industrial consumption. It is important to observe, in this connection, that at least one hygrophilous species, *Lycaena helle*, has apparently become extinct in Italy since 1798. At the regional level, *Melitaea britomartis*, which in Italy is interestingly also hygrophilous, became extinct throughout the NW of the country in the 1970s and only survives in the NE (Friuli). Of the remaining hygrophiles, the most endangered are *Maculinea alcon*, *M. teleius*, *Euphydryas aurinia*, *Coenonympha oedippus* and *Lycaena dispar*. Most of them occur in *Molinia caerulea* meadows, which are also listed in the Habitats' Directive (Annex 1). Of these butterfly species, *Coenonympha oedippus* is present with a limited number of generally isolated populations. Each population, however, remains in a relatively good conservation status (our unpublished data). This is not only a consequence of the relative abundance of its larval food plant (*Molinia caerulea*). *C. oedippus* is in fact a bivoltine species, which, whenever needed, can compensate for a bad early summer generation with a better second generation in September. *Lycaena dispar* is more hygrophilous and occurs primarily in the so-called *Magnocaricion*. The problem here is mainly a consequence of the progressive disappearance of its secondary habitat which, until the mid 1970s used to be in the rice paddies. With the introduction of more efficient cultural practices, including the massive use of highly selective herbicides and the subtraction of water from the paddy for the period of their application, this habitat became increasingly unsuitable for *L. dispar* (as well as for many amphibians), population sizes dwindled and in many cases populations connectivity disappeared. If Italian *L. dispar* are also bivoltine and tend to be almost as resilient as *Coenonympha oedippus*, *Maculinea* species are all monovoltine and the status of the hygrophilous species (*Maculinea alcon*, *M. teleius*) is alarming. It is very unfortunate, in this framework, that the biology of these species was neglected in Italy for a long time. Population studies only began in the last decade, as well as those on the ant species that support their larvae and pupae during the late phases of their cycle. One can observe, however, that Italian populations are virtually never connected to form meta populations and survive as more or less dense but single populations, each experiencing population crashes after one or more bad years. In at least two cases, this led to population extinctions, but the recent summer droughts experienced in N Italy caused a general declining trend that may or may not have been arrested in 2005. Since 2003, the progressively sinking water table caused a delay in the blooming of *Gentiana pneumonanthe* (food plant of *M. alcon*) and even the growth of *Sanguisorba officinalis* (food plant of *M. teleius*) was negatively impacted. The consequence was that the trophic resources available for these two species were strongly reduced and populations declined. Since the remaining populations of these species exist only on very small areas, ensuring their long-term survival on Italian soil requires site-by-site management programmes to be urgently approved and implemented. *Euphydryas aurinia* is probably better seen as a complex of bio-species, represented in Italy by *E. aurinia* (s. str.), *E. provincialis* and *E. glaciegenita*. Only the first of these is threatened and has a restricted range in the Padano-Venetian Plains, where about 40 generally isolated populations are known to occur. These populations are normally small and suffer many of the negative factors influencing the other hygrophilous species. Also in this case, implementing well planned management practices will be necessary. *Lasiommata* (=*Lopinga*) *achine* is in Italy a species of the native woodlands bordering the southern slopes of the Alps, on the margins of the plains of the Po river valley. It is still a rather widespread element in the north-eastern parts of its Italian range, but is known to have become extinct at several sites, particularly in Piedmont. The most important threat for this species is habitat destruction and should be dealt with on a case by case basis.

Montane elements. To come to the montane vegetational level, even though *Euphydryas maturna* was first reported from the western Italian Alps as early as in 1798 by the Italian entomologist Leonardo de Prunner, it was only rediscovered by Gallo & Gianti in 2003 at a single and highly isolated location in the same general area. Population size and other biological data are currently accumulating. The species' life cycle at this particular site involves *Fraxinus excelsior* as the larval food source before overwintering, while the second food plant is still unknown. Biological data are of course necessary before a correct management plan can be started for the conservation of this species, which is not yet protected in a SIC, as a consequence of its late discovery. The main threat for its survival is apparently overcollecting. Other montane species, such as *Parnassius apollo* (fig. 1), *P. mnemosyne* and *Zerynthia polyxena*, are not apparently globally

Fig. 1. The Italian distribution of *Parnassius apollo*

threatened on an Italian perspective, but a number of populations and/or 'subspecies' certainly are. Their conservation should be dealt with case by case, on a regional level.

Alpine elements. Butterflies living above the tree-line in the Italian Alps are generally not seriously threatened, but in some cases their biology remains almost completely unknown. This is certainly the case for the two alpine species listed in the HD, i. e. *Erebia christi*, and *E. calcaria*. Biological data are particularly scarce for *E. christi*, a restricted endemic of the CW Italian and Swiss Alps. Its larval food plant in nature is still unknown, as well as the reasons that make it so rare at its only Italian site, within the boundaries of the «Alpe Veglia e Devero» Natural Park. During a 2 years survey that we conducted with a field effort of 5 people, only 52 specimens were observed. Drawing a conservation plan for this species will certainly require more effort. In the meantime, no efforts should be spared to preventing any habitat subtraction and unauthorised collection of this species.

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Butterflies in Czech Reserves: a comprehensive survey of 140 local assemblages

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The Czech reserve system recognises two major categories of small-sized reserves, National (Nat. Nature Reserve and Nat. Nature Monument) and Regional (Nature Reserve and Nature Monument). The former category includes 206, the latter several thousand reserves. In 2004 and 2005, the Czech Agency of Nature Conservation funded a comprehensive survey of butterflies and burnets in most of the National category reserves. All were surveyed using an identical method (five visits per season, duration of visits scaled by reserve size), providing one of the data sets on composition of local butterfly assemblages available to date from Central Europe. We will present preliminary analyses of the data, focusing on patterns related to reserve size, altitude, biotope type and richness, as well as on main gradients structuring local butterfly assemblages. We will show that although many of the reserves host considerable butterfly diversity and provide refuges for declining and threatened species, some of the most threatened butterflies are not represented. Additionally, the original purposes for reserve establishment had little in common with their recent butterfly fauna: some reserves originally established to preserve geological or palaeontological phenomena are as important for butterflies as those established for fauna and flora.

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Assessing Conservation Status of Butterflies at the Regional Scale: Analysing Data from the Biodiversity Observatory of Latium, Italy

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Lazio region is located at the center of the Italian peninsula, on the western side of the Apennine chain; the surface is about 19,000 km^2 and the altitude ranging from sea level to 2.458 m a.s.l. (Fig.1).

In the database of Papilionoidea and Hesperoidea, a section of the Biodiversity Observatory of Latium, more than 15,000 records including 155 species (55.5% of the Italian fauna) have been stored so far. One of the Latium species (*Hipparchia sbordonii*) is endemic to the Pontinian archipelago and a second one (*Melanargia arge*) is endemic to central and southern Italy.

Data obtained from literature, collections and field observations, ranging from 1847 to August 2005, were entered in the database only after a careful check. Each record contains the

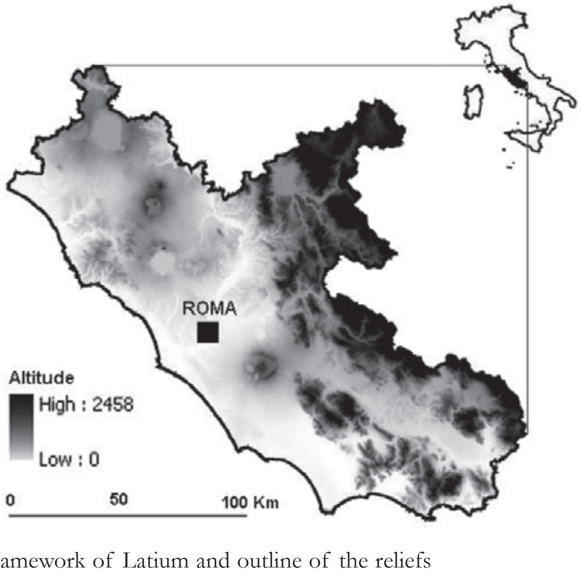

Fig. 1. Geographic framework of Latium and outline of the reliefs

species name, locality, date and type of source. Starting from 1980, additional attributes, such as abundance, estimation of sampled area and a sampling effort index, have been included. All the records labelled by a locality have been geo-referenced both as point (by coordinate of locality) and as area (a circle centered on the point locality for recent data or Thiessen polygon for the historical data); old records labelled by generic, wide areas, were not geo-referenced and were only used for broad comparisons between geographical districts inside the region. Recent field observations have strongly increased the number of records, however these data were gathered without any clear cut sampling design or monitoring scheme at the regional scale, because of the low number of local recorders, and the need for detailed data in some protected areas under study.

An attempt for an objective "a priori" categorisation of the butterflies based on the habitat association was carried out by the use of the recent data and the land cover of the region. The outcome shows that species were mainly distributed along an altitudinal gradient and no species group could be clearly delimited on the basis of the variables considered. Results of time analysis showed several interesting features, useful for planning conservation actions and for the design of future monitoring.

No extinction of species could be assessed in Latium after 1980; only 1 species (found only once) out of 150 reported before 1980, was still not confirmed, 2 species have been found for the last time more than 5 years ago, and 147 species were confirmed in the last 5 years. In our opinion this good trend can be interpreted in the light of the great heterogeneity of landascapes, where plains and low altitude areas with intense human activities lie close to hills, valleys and mountains in which numerous sites suitable for butterflies can still be found.

A comparison was made between historical and recent records, with the aim of detecting any spatio-temporal changes that have occurred during the last 25 years. Significant efforts were made to minimize the bias due to sampling heterogeneity, which is a recurring trouble when attempting to infer changes in insect abundance and distribution, starting from old collection data.

By the use of a GIS, a grid 10x10 km was overlaid to the region and, as a first step, only the quadrats in which butterflies were sampled before and after 1980 were selected. Then a second selection was performed to ensure a balanced sampling effort in each quadrat; accordingly we set the threshold:

Nspecies POST-80 $\geq$ 0.95 Nspecies PRE-80

As a result of these selections only 63 quadrats out of the 182 quadrats initially considered, were maintained for subsequent analysis. However, the geographical distribution of these quadrats still includes a representative sampling of the region. The mean value of the ratio Nspecies POST-80/ Nspecies PRE-80 in these quadrats is 7.84 (S.D.= 11.07).

The occurrences of each species in these quadrats was then compared between PRE-80 and POST-80, taking into account species phenology, i.e.: checking for appropriate sampling dates.

A large number of species, especially the common ones, show a very remarkable increase in presence, which can be interpreted as the joint result of the under-representation of the common species in collections, and the disproportionate high level of recent sampling efforts (Tab.1).

However in spite of the sampling effort, ten species showed a decline in the number of quadrats. Three of these species (*Zerynthia polyxena*, *Melanargia arge* and *Parnassius mnemosyne*) are included in annexes II and/or IV of the Habitats' Directive 92/43 EEC.

Unfortunately our data cannot be directly used according to the present IUCN criteria for Red lists species, hence we have followed a double criterion method, similar to the one proposed for the butterflies of Czech Republic (Konvička & Beneš, 2002), to higlight the threatened species.

1. A species is regarded as threatened when it was found in no more than three localities among all POST80 localities, both if the localities were inside or outside of the 63 selected quadrats (Tab.3).

Table 1. Increase of occurences for some of the commonest species, based on 63 selected quadrats

SPECIES	PRE	POST	POST-PRE
Iphiclides podalirius	5	56	+51
Pieris brassicae	13	57	+44
Vanessa atalanta	6	48	+42
Celastrina argiolus	12	49	+37
Gonepteryx rhamni	9	45	+36
Polygonia c-album	9	37	+28
Kanetisa circe	7	32	+25
Hipparchia hermione	5	24	+19
Thymelicus lineolus	3	15	+12
Limenitis camilla	1	10	+9

Table 2. Species decreasing in quadrat occurences, based on 63 selected quadrats

SPECIES	PRE	POST	POST-PRE
Zerynthia polyxena	19	13	-6
Melanargia arge	12	9	-3
Polyommatus escheri	4	1	-3
Satyrium acaciae	11	9	-2
Pyronia cecilia	9	7	-2
Boloria dia	7	5	-2
Boloria pales	3	1	-2
Parnassius mnemosyne	11	10	-1
Brenthis hecate	2	1	-1

Table 3. Species threatened in Latium because of the low number of occurrences in the database

SPECIES	N. localities
Coenonympha dorus	1
Erebia pluto	1
Gegenes nostrodamus	2
Lasiommata petropolitana	2
Brenthis hecate	3
Erebia euryale	3
Erebia meolans	3

2. The conservation status of the species has been assessed on the base of the formula: $\Delta N = (1 - Nr/Nt)*100$ where **Nr** = Number of recently (POST80) occupied quadrats; **Nt** = Total number of occupied quadrats, and according to the following classification:

	$\Delta N > 66.7$	Strong decrease (SD)
66.7>	$\Delta N > 33.3$	In decrease (D)
33.3 >	$\Delta N > 0$	Light decrease (LR)

Species with less than 3 records in the 63 selected quadrats have been 'Not Evaluated'; only strongly decreasing and decreasing species are listed in Tab. 4

In conclusion, 24 out of 155 species reported for Latium could be considered threatened because of the high localization of their populations (8 species) or because of the reduction of their ranges (16 species). Out of five species included in annexes II and/or IV of the Habitats' Directive 92/43 EEC, two are in decline (*Zerynthia polyxena* and *Melanargia arge*) and three (*Parnassius mnemosyne, Parnassius apollo* and *Maculinea arion*) could be considered as being in light decline (ΔN is between 29% and 21%).

The evaluation of the causes of the loss of the area for these species, particularly the manifold consequences of human impact on the country, are under investigation.

Table 4. Species of Latium threatened because of the reduction of the spreading area

SPECIES	Nt	Nr	ΔN	Status
Polyommatus escheri	4	1	75%	SD
Boloria pales	3	1	66%	D
Boloria dia	11	5	55%	D
Hyponephele lupina	4	2	50%	D
Pyronia cecilia	14	7	50%	D
Erebia meolans	6	3	50%	D
Zerynthia polyxena	24	13	46%	D
Lycaena thersamon	11	6	45%	D
Satyrium w-album	9	5	44%	D
Hamearis lucina	14	8	43%	D
Satyrium acaciae	15	9	40%	D
Melanargia arge	15	9	40%	D
Melitaea cinxia	24	15	38%	D
Pyrgus sidae	8	5	38%	D
Cupido alcetas	19	12	37%	D
Euchloe ausonia	26	17	35%	D

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Butterfly Monitoring in Germany

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In 2005 a nationwide butterfly monitoring scheme was started in Germany. As in other long-term schemes e.g. in the UK [1] and the Netherlands [2], the recordings are based on weekly transect walks. In the long-term, the new monitoring scheme should provide a central element for the analysis of biodiversity within Germany as well as for Europe. Therefore, this scheme is also integrated into the activities of BCE (Butterfly Conservation Europe; <http://www. europeanbutterflies.net>).

The project is hosted at the Centre for Environmental Research Leipzig-Halle (Umweltforschungszentrum Leipzig-Halle, UFZ) and its start was an integral part of the PR activity called "Abenteuer Schmetterling" ("butterfly adventure"), which included ZDF (a public German television channel), BUND (a NGO) and UFZ. By 2006, it is envisaged to get the support of a large number of volunteers throughout the country in order to produce the data necessary for a profound analysis. By then, an input mask will be designed which allows the online entry and processing of the data. Further on, the involvement of other web services will be tested (e.g. determination help forums like <http://www.lepiforum.de>).

Monitoring activities in Germany started earlier in 2001 with a project limited to the federal state of Northrhine-Westphalia [3]. Experiences from this study are useful for the new nationwide scheme.

The structure of the scheme as well as experiences of the first year are presented. A constructive discussion might contribute to further improve the scheme and to make it known to an even broader audience. Further information is available at <http://www. tagfalter-monitoring.de>

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How many counts are needed? Effect of sampling effort on observed species numbers of butterflies and moths in transect counts

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Transect counting has become a standard method in monitoring and ecological studies on butterflies (Pollard & Yates 1993). In order to get a representative sample of the whole species pool of a location, several counts per transect are needed during the season. When the number of counts is increased, however, fewer new species become included in the sample. At some point, the cost of extra effort is likely to exceed the gain from further counts.

We studied the effect of increasing sampling effort on the number of observed species in transect counts. Our data is from the Butterfly Monitoring Scheme in Finnish Agricultural Landscapes, started in 1999 (Kuussaari *et al.* 2000). From transects with at least 16 counts per season, we first randomly selected one count, and then added observations of each consecutive, randomly selected count to the sample until all 16 counts were included. We calculated the mean number of species and individuals for each number of counts in the sample.

The mean number of observed butterfly species per transect was 10.5 in a single count and 35.6 in all 16 counts per season (Fig. 1). The number of observed butterfly species rose considerably with the first few additional counts in the sample, up to an average of 23.9 species in a pool of four randomly selected counts. At a sample size of 7-9 counts, over 80% of the species observed in all 16 counts were already included in the sample. With a larger number of counts the cumulative curve of the observed number of species started to level off, and increasing the number of counts from 12 to 16 brought only a 6% increase in the mean species number.

In addition to random selection of counts, another set of 7 counts with regular two week intervals was picked from the same dataset. When compared to a random sample of 7 counts the mean species number of butterflies rose now from 29.5 to 31.7 (Fig. 1). This means that on average 89% of the species observed in all the 16 counts were already included in this sub-sample.

In the Finnish monitoring scheme moths have also been recorded on some of the transects, and the same approach was used for them. The mean number of moth species per transect was 6.6 in a single count and 42.4 in all 16 counts per season (Fig. 1). In contrast to butterflies, the number of all moth species increased almost linearly up to 16 counts, as further counts were added in the sample. The reason for this is that most moth species are night-active and are only occasionally observed in transect counts. The overall number of moth species is also much

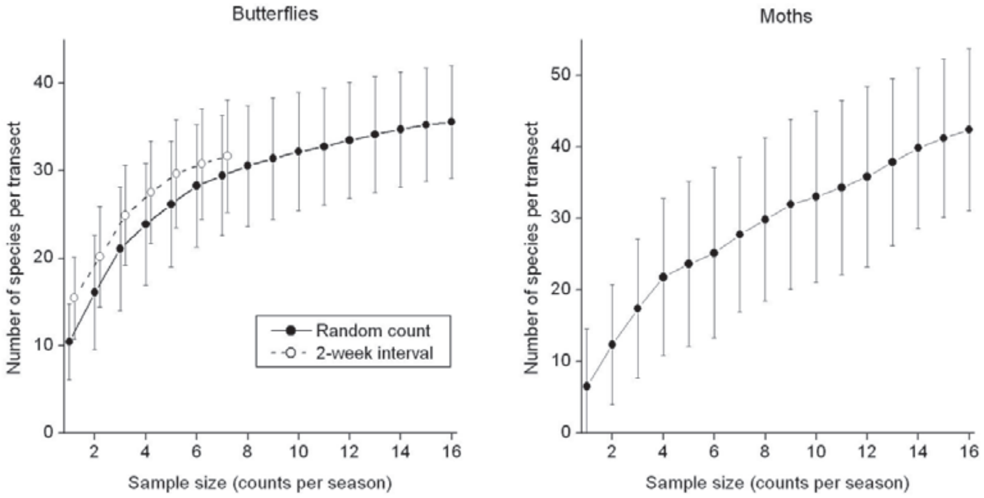

Fig. 1. Mean number of species in samples of 1-16 random counts per transect, for butterflies (left) and moths (right). For butterflies the graph also includes the mean species numbers for samples of 1-7 counts, when the counts for each transect were selected with ca. 2 week intervals. The results are based on 55 replicates from 19 separate transects in butterflies and on 21 replicates from 7 transects in moths.

higher than the number of butterfly species. Nevertheless, within the dataset a group of approx. 30-40 relatively common moth species were identified that are primarily day-active and regularly observed in larger numbers in transect counts.

We conclude that when resources are limited, 7-9 counts with regular time intervals is enough to give a reasonably good sample of the local butterfly species pool. Interestingly, the commonly observed pool of both butterfly and moth species in Finnish transect counts is roughly the same, approx. 30-40 species. This group of day-active moth species can be quite reliably monitored with transect counts in Finland.

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Two national initiatives for Butterfly Monitoring in France

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Butterfly monitoring is exemplified as one of the powerful sources of data to document large-scale trends in biodiversity. Monitoring schemes are now running in many European countries, but not yet in France. Most existing Butterfly Monitoring Schemes (BMS) are derived from the Pollard and Yates' method (1993), i.e. weekly transects from April to September. The required fieldwork effort is easily achieved for countries with important numbers of volunteers (e.g. U.K., Netherlands), but it seems too intensive for France where public involvement in naturalist schemes is low.

To compensate for this lack of monitoring data on butterflies in France, three complementary initiatives are presented: (1) a reduced effort BMS at national scale, (2) a citizen science project on garden butterflies, and (3) a standard BMS run at 10 national nature reserves, with the aim of quantifying the impact of openland management (e.g. grazing, cutting) on butterfly populations (communication of D. Langlois).

Resampling analyses of the UK BMS data (D. Roy and P. Rothery, unpublished results) helped us to find a reduced effort BMS that would optimally distribute fieldwork effort among the number of visits per sites and the number of sites monitored. The proposed protocol is: 5 visits from April to September, to 10 250-m transects, with homogenous habitat per transect. Two procedures will be possible to choose the site where to set up transects: (1) randomly chosen 2-by-2-km square within 10 km from a locality provided by declared volunteers, and (2) free choice. Whatever the protocol, weather conditions have to be favourable for butterfly activity (*cf.* UK BMS) and are recorded. A preliminary version of this protocol was tested in Ile-de-France (Paris' region) in 2005 at 27 sites. Some results on diversity and abundance indexes will be presented.

The French Garden Butterfly Monitoring will be based on citizen participation, in collaboration with a major national firm of gardening (Gamm vert®). Basics of the protocol are: to record the maximum number of individuals observed simultaneously, at any one time per month, from March to October, for a closed list of common garden species (i.e., highly mobile generalists). Basic garden characteristics (size, composition) are also provided.

We hope to receive constructive feedback from the discussion to optimize these protocols.

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Motivating observers and recorders – web based community tools for the German butterfly monitoring

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In 2002 a team of lepidopterologists and programmers started to build up a web-based application to manage sightings and field recordings of butterflies. Experiences based on the development of the DOS-Application "Florifauna" – used for keyboarding and managing of data as well as producing printable maps and diagrams for the fauna of Baden-Württemberg – and the existing community of active observers of migrating butterflies in the DFZS (Deutsche Forschungszentrale für Schmetterlingswanderungen – German research centre for the migration of butterflies and moths) have been combined, and in 2003 the first version was launched (www.science4you.org).

Besides the scientific requirements regarding the data handling and data quality, it was very important to motivate the observers to use the system and therefore we incorporated mechanisms to encourage exchanges of experiences and information between the users. Examples include discussion boards, observation comments, and picture uploads for each record and in all discussion boards. Communication facilities between the site managers and the users are also important, and an online content management system is available to maintain editorials, FAQs, link lists and news. Rapid feedback is important to the user, and therefore we try to match place names automatically to show the observation on the map immediately. Another component consists of flexible species fact sheets, maintained by the content management system. These fact sheets can be edited online and ambitious users can receive author-status and access to these functions.

To ensure data quality, active recorders must register into the system. At the end of October 2005, 750 registered users had entered 41000 observation records by keyboard.

As the application is based on modules, components and services, it is very easy to implement in new project areas. We have now started projects for longhorn beetles, birds, orchids, and dragonflies. And we are working on an enlarged Lepidoptera-site covering all European butterflies and moths. Other scientific projects based on our system are GloBIS – the Global Butterfly Information system (www.lepidat.org), wrappers for Species2000 and GBIF and glossaries for ENBI.

Therefore it was a natural choice for us to offer our experience and services to the German Butterfly monitoring project (see Feldmann et al., this volume). We have adapted our system to the requirements of the project and the first prototype is now available for testing by users. To support the direct communication between the recorders and the local supervisors, we have implemented local sub-projects managed entirely by the local supervisors. The first subproject available (www.s2you.com/platform/lex/nrwfalter/) covers NRW (North-Rhine-Westphalia) and others will follow soon. In addition to input masks for transect data recording, all sightings beyond the transect can be entered too. It is possible to upload pictures of the transect parts and as evidence of a sighting. The location of the transect and the transect parts can be viewed on satellite maps using the Google map service. Each observer has full control over its data by online lists and download function.

In 2006 we will improve the system based on the practical experiences in all our projects and we will implement - in close cooperation with the UFZ Leipzig-Halle - sophisticated data analysing and data visualizing tools.

Technology: we are using 5 dedicated servers working under Linux and Solaris. The main application is written in JAVA using the STRUTS-framework (http://struts.apache.org/), sitemesh (http://www.opensymphony.com/sitemesh/), Tomcat servlet engine (http://tomcat.apache.org/), the database is Oracle (www.oracle.com) and some image-processing uses PYTHON (http://www.python.org) with the PIL library. The map server uses the JAVA open source product degree (http://deegree.sourceforge.net).

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Descend towards unimodality: butterfly loss in Czechia changes a major macroecological pattern

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Eleven percent of formerly 160 Czech butterflies went extinct during the last century, and half of the 143 surviving species are threatened. To make the matters worse, ongoing distribution mapping and species-focused studies indicate that the losses are accelerating, often as a consequence of policies primarily intended to help the environment. Examples include *Colias myrmidone*, a Habitats' Directive species recently lost from most of its Czech range as a consequence of inappropriate management of reserves. Survival of another Habitats' Directive species, *Euphydryas aurinia*, is recently being impeded as a side effect of implementation of EU Agro-Environmental schemes. Good intentions have dreadful consequences in this case, as the responsible authorities refuse to co-operate with conservationists while preparing scheme guidelines. *Hipparchia semele*, once a widespread butterfly of lower altitudes, is loosing its last refuges as a result of reclamation of post-industrial brownlands. A particular case is the fate of military training ranges, which had been for decades maintained in early successional state by intensive training of Warsaw pact troops. The much welcomed reduction of military activities now paradoxically threatens such species as *Pseudophilotes baton* and *Maculinea arion*.

Losses of rarities are accompanied by declines of more common butterflies. We document this by comparing frequency distributions of species occupancy patterns in past versus present. Whereas the past distribution was clearly bimodal (rare and common species were represented relatively evenly), it has shifted towards an unimodal pattern in present (more species became rare, few species remain widely distributed). Such a shift is characteristic for enlarging the sampling units, which includes more rare species in samples. Because our analysis refers to equally-sized grid cells, the shift of the pattern confirms severe losses of formerly widespread species, and thus the restructuring of the entire fauna.

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Developing indicators for monitoring biodiversity in agricultural landscapes: differing status of butterflies associated with semi-natural grasslands, field margins and forest edges

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INTRODUCTION

There is much need for useful indicators in monitoring the effects of land use changes on biodiversity. Butterflies are a particularly useful indicator group in open habitats, and have thus been selected as one of those taxa that are actively monitored in agricultural landscapes of Finland. Approx. 70% (74 species) of Finnish butterflies live in agricultural landscapes. These species have been classified into three ecological groups of species according to their habitat preference (Pitkänen et al. 2001): species of (1) field margins and farmyards (“arable”), (2) semi-natural grasslands (“grassland”) and (3) forest verges and clearings (“forest”).

We studied how the observed long-term population trends in Finland differ between these three ecological species groups. The study had three specific aims:

(1) to study distributional changes of the 74 species of butterflies in agricultural landscapes during the last approx. 50 years in Finland
(2) to classify the species into four indicator groups: declining, stable, increasing and fluctuating species
(3) to study whether the observed population trends differ among the three ecological species groups

MATERIAL AND METHODS

We used all available butterfly atlas data for the 74 focal butterfly species gathered in Finland before the year 2004 (a total of 212.460 species records from ca 2.500 10 x 10 km^2 squares) and divided these data into four time periods: <1960 (8% of all records), 1960-1990 (38%), 1991-1998 (27%) and 1999-2003 (26%). Records before 1991 were collected by the Finnish Museum of Natural History from many kinds of sources and published in the Atlas of Finnish Macrolepidoptera by Huldén et al. (2000). The records from the last two time periods 1991-2003 have been collected in the National Butterfly Recording Scheme in Finland (NAFI; Saarinen et al. 2003). The main qualitative difference between the datasets from <1991 and 1991-2003 is the over-representation of rare species in the old data collected before 1991. The records of the last 13 years reflect better the real occurrence of common and rare species in Finland, because in NAFI the emphasis is on collecting data from all species present in a 10 x 10 km^2 square.

In order to minimize the over-representation of rare species in the data, we focused on only the best studied 10 x 10 km^2 squares in the analyses of population trends. We included in the analyses all the squares with a minimum of 40 records during the first time period (n = 90) and all the equally well studied replicates from the same study squares during the three subsequent time periods (resulting in a total of 229 replicates from the 90 squares). In addition, we included all the squares which were sufficiently well-studied (≥40 records) in each of the three last time periods (n = 51 study squares) to equalise the number of studied squares for each time period to 90-100 replicates. This selection procedure resulted in a total of 141 study squares with a total of 382 replicates during the four time periods.

For each species the trend in the occupancy of the studied 10 km squares during the four time periods was analysed using generalized linear mixed models (GLMM) with the study square as a categorical random factor. In addition to the examination of linear trends, the significance of the non-linear second and third order terms was also tested in the model building. The results of the GLMM models as well as plots of the fitted GLMM models with their 95% confidence limits were used in the classification of species into the four trend categories. To solve borderline cases in the classification we checked the trends in the much larger set of unselected original data as well as the trends in the well studied squares of the last two time periods (210 squares with ≥40 records during both of the last time periods).

RESULTS

There were clear differences in the population trends among the species groups preferring different habitats, with predominantly declining trends in grassland species and mostly increasing trends in arable and forest species (Fig. 1).

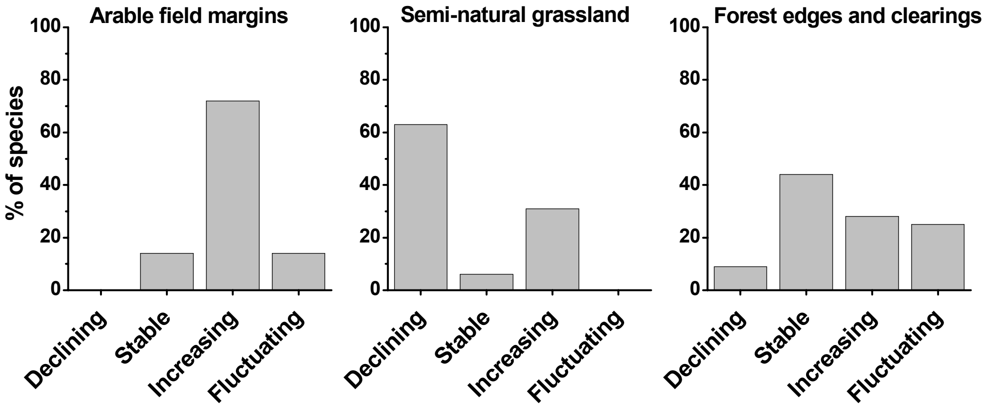

Fig. 1. Summary of long-term butterfly population trends in Finnish agricultural landscapes separately in the arable (n = 7), grassland (n = 35) and forest (n = 32) species.

In 63% of grassland species the occupancy of the 10 x 10 km^2 squares had decreased, and in 31% of these species it had increased during the four time periods. For example *Hesperia comma*, *Lycaena helle* and *Melitaea diamina* had disappeared from >80% of their previously occupied squares during the last ca 50 years. Common grassland species such as *Pyrgus malvae* and *Coenonympha pamphilus* had declined by >20%. The increasing grassland species showed a long-term increasing trend with typically no clear increase during the recent years. These included species of abandoned grasslands such as *Thymelicus lineola*, *Polyommatus amandus*, *Brenthis ino* and *Aphantopus hyperantus*.

Only 9% of forest species had declined, whereas 28% had increased during the four time periods. *Boloria titania*, which had lost >90% of its former distribution area, was the only forest species that had severely declined. Increasing species included several common species such as *Gonepteryx rhamni*, *Callophrys rubi*, *Nymphalis antiopa* and *Lasiommata maera*. *Araschnia levana* showed a remarkable expansion from an occupancy of 0 to 22% within the well-studied squares. As much as 25% of forest species showed fluctuating trends in the level of occupancy with a clear recent increase following an earlier period of decline. Large-scale fluctuations of the distribution area were observed in *Aporia crataegi*, *Limenitis populi* and *Argynnis paphia*. Summing the long-term and recent increase, >50% of the forest species showed evidence of increasing trends.

All except one arable species (*Pieris brassicae*) showed long-term (5 species) or recent (*Pieris rapae*) increase in occupancy of 10 x 10 km^2 squares. The long-term increasing species included four nettle-feeding nymphalids and *Pieris napi*. *Nymphalis io* showed the largest increase from an occupancy of 36% to 93% in the well-studied squares.

DISCUSSION AND CONCLUSIONS

Large-scale changes in the distributional patterns were observed in each of the three ecological groups of butterflies. Changes in land use are likely to be the most important drivers of the observed changes in occupancy. Severe decline of the area of semi-natural grasslands and the ceasing of cattle grazing in semi-natural pastures and the subsequent overgrowth have presumably caused the decline of the many grassland specialists. On the other hand, modern forestry with its clear-cutting practices has produced suitable forest edge habitats for many forest butterflies for already many decades. This a likely explanation for the observed increase in the occupancy of several forest species.

The fluctuating trends, which were observed in nine species, are likely to be associated with climatic factors. The expansion of several forest species during the climatically favourable years of the last decade has been possible because of the good availability of suitable forest edges and clearings produced by forestry. The lack of observed recent expansion in grassland species in spite of favourable weather conditions is in agreement with the current poor availability of semi-natural grasslands. This results from a long-period of habitat loss caused by agricultural intensification and deteriorating quality of remaining grasslands after the ceasing of cattle grazing.

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Butterfly monitoring in 10 National Nature Reserves in France

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In 2001 butterfly monitoring was started in order to better understand the impact of management practices (grazing, cutting, etc) on open land (grassland, moor, etc) in 10 National Nature Reserves (NNR). We present details of this initiative and welcome comments on how to improve it.

METHODS : AN APPROPRIATED BUTTERFLY MONITORING SCHEME (BMS)

The methods used for this monitoring are found in a Réserves Naturelles de France’ publication (« Proposition de mise en place d’une méthode de suivi des milieux ouverts par les rhopalocères

et Zygaenidae dans les Réserves naturelles » – D. DEMERGES, 2002). We have adapted the methods used in the C.E.H. Butterfly Monitoring system:

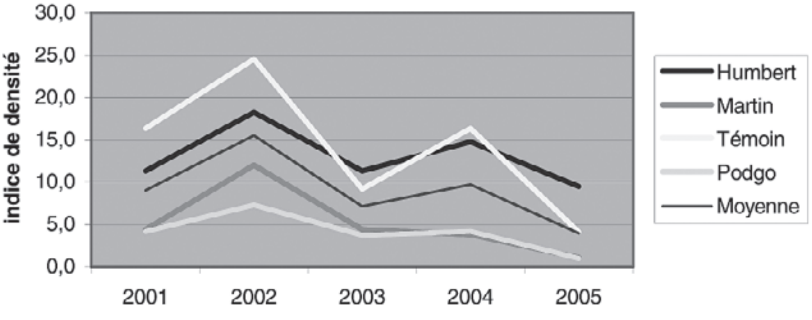
- **Species**: We have added some Zygaenidae and some NNRs record the Ascalaphidae. In accordance with the diffulties with identifying some species in the field, we have created some species complexes (for instance "*Colias* 1" = "*C. hyale* + *C. alfacariensis*"). To analyse the results we will only work with the species living in openlands. However, on the transect we count all the butterflies, even the migrant and the forest ones which could be analysed in a future national/European BMS.
- **Transect**: First, we differentiate the habitats. For each habitat, we do several sections, in accordance with the managment and our questions about its impact.
- **Weather conditions** have to be consistent throughout each habitat (sun on ground and light wind) to be able to compare the impact of the managment.
- **Period**: we begin in April and finish in September, but each NNR chooses its own period in accordance with its climate. The transect is recorded every week. We try not to leave more than 9 days between 2 transects. This point is the most complicated in this method and we would like to simplify it.

FIRST RESULTS

The trends of all the species will be calculated and analysed this winter 2005-2006 for the 10 NNRs. Some results will be presented.

For instance, here is a first result on Ravin de Valbois NNR (Franche-Comté), for a species which seems to be decreasing in France but whose population is still large in the NNR. Figure 1 shows the trend in a meso-xerophile grassland.

The results fluctuate every year, but do not seem to be linked to the managment. However, we find the biggest population when the grassland is not grazed in spring and summer. This result



Humbert = high grazed every 2 winters (donkeys)
Martin = high grazed every year, June to October (cows)
Podgo = low grazed every year, June to October (cows)
Témoin = not grazed
Indice de densité = number of M. dryas on the transect along the year, by 100 meters.

Fig. 1. Evolution de la population de *Minois dryas* sur les pelouses de corniche

shows that we have to imagine a managment which leaves some places not grazed for long periods.

Our monitoring is new and will be perfected by calculating better indices (with TRIM for instance) and by monitoring over several years to take into account unusual years (2002 was good for M. dryas and 2005 was perhaps bad).

WIDENING

Our data can be used for a French and/or European Butterfly Monitoring Scheme. In the NNRs we need French and European trends too, to be able to think about our managment. The new transects which will be set up in Europe could be used to observe European trends and at the same time to provide answers to managment questions.

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Aspects of Butterfly Conservation in Serbia

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As the central state in the Balkan peninsula, Serbia occupies 0.8% of European territory. In that area, 192 butterfly species exist, making 43% of European fauna in this group. Such an abundance of fauna results from the history of living world formation and decomposition of ecological factors, as can be seen by existence of 7 biomes.

In Serbia, as in other European countries, biodiversity has been degraded, primarily by anthropogenic activities. This paper specially highlights factors endangering the butterfly fauna of Serbia. I emphasize the consequences of these threats. They manifest themselves in decreases of population sizes, in impoverishment of communities, in areal decrease for certain species, and in species extinction.

The development of an understanding for the need to protect the butterflies of Serbia is described. Through the activities of the Ministry of Science and Environment Protection, the Directorate for the Environmental Protection and the Institute for nature conservation of Serbia, institutional activities in biodiversity protection are achieved. The basis for such activities is the legislature, set out by the Law on Environmental Protection (Off. Gazette R.S., No. 135-04), and the bylaws.

This paper also assesses the results achieved to date in the protection of butterflies of Serbia. Old bylaw protected 7 butterfly species, while the new one includes significantly more species. The Red Data list comprises 131 species, while the Red Data book includes 57 butterfly species in Serbia. In addition to this direct legal protection, species are protected indirectly, in situ, through the conservation of certain territories in Serbia. The Law protects a total of 378 natural units of different categories, including 5 national parks. Apart from that, 12 Prime Butterfly Areas are singled out.

I indicate the current activities and future plans for butterfly protection in Serbia. The focus of activity is to become increasingly integrated with European and regional trends concerning biodiversity protection in general, and butterfly protection in particular. The selection of indicator species was chosen as a first focus, and it should be concerted with European initiatives for indicators and monitoring. Following the opinion of expert groups (Species group, Area group), criteria were defined, and 7 indicator species were chosen. That selection was performed through a national project titled “The Indicators of Sustainable Development in Serbia”. Priority among selected species was given to the species *Maculinea arion*, having in mind integration into the

European project of monitoring this species (Recommendation No. 65 of the Standing Committee (1998) on the conservation of *Maculinea* butterflies).

It is emphasized that many preconditions are necessary for the success of butterfly protection in Serbia: concrete support from official state institutions, the formation of a network of local assistants, the development of a NGO sector, inclusion into European integration course and support from European institutions.

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Monitoring Butterflies in Vienna and surroundings

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In 2003 the University of Natural Resources and Applied Life Sciences in Vienna, "the eco-councelling" of Vienna and other local NGO's started a project for monitoring butterflies and moths in urban areas. The project title is "Volkszählung für Schmetterlinge", (conform to "census of butterfly population") and points out the target group. Gardeners and all people interested in nature are invited to record butterflies and moths. The aims of the project are:

- Raising public awareness for butterfly protection
- Installing, motivating and attending of a permanent monitoring group
- Analysis of recorded data regarding plausibility and quality
- Statistical analysis regarding species abundance and number of flowers in gardens
- GIS analysis regarding species diversity and green space situation on site

There are several schemes in Vienna and surroundings for monitoring the butterflies and moths:

- **Permanent recording** or **Site recording:** The focus is to collect data where people live regularly, preferred in their own garden, over a season. A form for this kind of recording can be downloaded in pdf format and is suitable for watching species on *Buddleja davidii*.
- **Casual recording:** People are also welcome to send in records of any sightings outside their gardens. There is no doubt that the regular monitoring of butterflies at key sites across the urban area is of great importance.

Annual reports on how the butterflies have developed across the country were published on the homepage of "the eco-councelling" Vienna (www.umweltberatung.at/schmetterlinge) as figures 1 and 2 shows.

Further the poster will show rare recorded species, medial attendance, number of volunteers and the first statistical results can be expected as well. The final paper is supposed to be finished in April/May 2006.

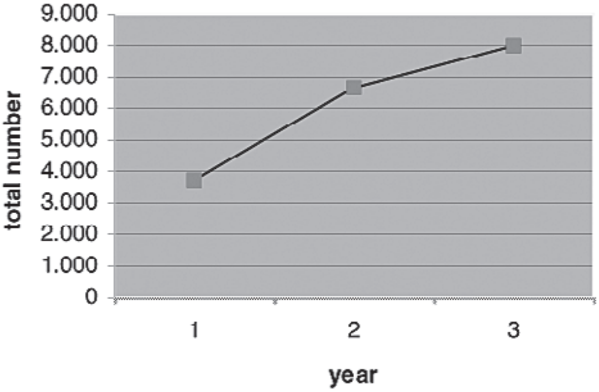

Fig. 1. Number of recorded butterflies and moths expected 2005.

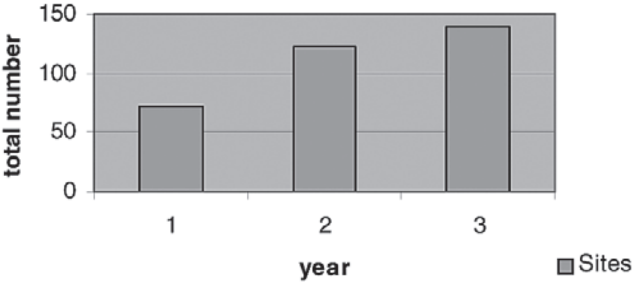

Fig. 2. Expected number of sites records 2005.

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Developing a method for monitoring butterflies in the wider countryside 2005 pilot studies in Dorset, 2005

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The objective of this research is to carry out pilot field studies to investigate a range of issues related to developing a suitable method for monitoring common/widespread butterfly species occurring at low density in ordinary lowland farmland habitats such as cereal field margins, hedgerows and improved pastures. This *Wider Countryside Monitoring* method will seek to be simpler and less labour intensive than butterfly transects, which will be retained (‘*Special Sites Monitoring*’) to monitor rare butterflies in semi-natural habitats.

The *Wider Countryside Monitoring* method involved surveys of random 1km^2 of the National Grid across the UK, following the approach developed by the BTO for the BTO/JNCC/RSPB Breeding Birds Survey (BBS). In this, a series of visits are made to a 1km square and birds are counted along two evenly spaced, linear transects of 1km length, in different distance bands, from which abundance indices can be generated.

In July and August of 2005, pilot studies were carried out following the basic approach of the BBS, but adjusting the recording bands to account for the different spatial scale at which butterflies occur compared to birds. Fieldwork was carried out in six separate 1 km^2 of the National Grid on the Lulworth Estate, Dorset. More extensive field trials will be carried out in 2006 and 2007 in other parts of the UK, including in the Uplands.

For each square an habitat survey was completed, including the number and variety of butterflies in the square, by surveying (BMS criteria) along each linear feature (ditch, hedge, woodland ride, etc), and sampling systematically across open grass/ heath/ scrub/ woodland clearings using a structured (zigzag) walk. Then, two 1km long transect sections were established in each square, following BBS survey methodology guidelines. Butterfly surveys were carried out twice in succession, in the same weather conditions. On the first one, butterflies were counted in different distance bands: 0-1.25m either side of the transect line, 2.5-5m either side, 5-25m either side, 25-100m either side. On the second one, other insects were counted, including hoverflies, orthoptera, dragonflies (hawkers, damselflies), but in this case butterfly counts were not grouped into distance bands.

The 2005 field studies have investigated a range of issues, related to how repeatable and representative the methodology being tested is. The number and variety of butterflies recorded along both of the 1km transects was compared with the number and variety of butterflies present from a more complete survey of the square, obtaining a total of 954 butterflies seen when the transect was walked three times versus the 1028 specimens that we found in the six 1 km squares. In terms of length, a total of 64.64 km was walked covering the six squares and 36.27 km when the transects, three times walked, were taking into account (12.09 each one). The number of butterflies seen while a transect was walked for a second or third time (always considering a band of 0-2.5 m at either side of the transect line) was not very variable, about 359, 370 and 225 specimens respectively. On average we found 318 ± 46.6 butterflies on each transect walked. When the transect was walked only once, almost every species of butterfly existing in the whole square was found, and almost all of the remaining butterflies were recorded when the transect was walked a second or third time.

When the surveys of the whole square and the three times walked transect were complete, the most frequent species of butterfly found was Large White (*Pieris brassicae*), followed by Meadow Brown (*Maniola jurtina*). The square that showed the greatest number of butterflies seen the three times that the transect was walked was at OS grid SY8181, with 134, 130 and 94 specimens respectively, with the Large White again the most abundant.

When frequency was plotted against the number of butterflies seen in a transect, and this was repeated three times, we obtained a high correlation (R^2 = 0.9789, R^2 = 0.9393, R^2 = 0.9433), showing that there is a negligeable difference between counting the presence-absence of butterflies and the number of butterflies that were really to be seen.

In every square, the whole square survey was compared with the results obtained on the transect in which we also surveyed other insects, and we found that the transect method represented 36.5% of the total number of butterflies seen in the whole square. We found 732 specimens of other insects in this transect, consisting of 24 different species. The most abundant species was Meadow Grasshopper, followed by Field Grasshopper.

During the surveys we recorded a total of ten different types of habitat in the six. Those with the largest number of butterflies and species were Hedgerows (455 butterflies seen, 18 species), Field Margin Grass (171 butterflies seen, 11 species) and Field Boundary with Margin Grass (129 butterflies seen, 11 species). When we analysed the quantity and density of butterflies per habitat, the most abundant species was the Large White, followed by Meadow Brown and Wall Brown (*Lasiommata megera*) in the case of Hedgerows; Meadow Brown and Small White (*Pieris rapae*) in Field Margin Grass, and Small White and Wall Brown in Field Boundary with Margin Grass.

Although the transects did not cover all habitats (i.e., Arable Field, Scrub and Unimproved Grassland), the transect method collected the same number of butterfly species that were found in the whole square and 30.6 % of its specimens when the 6 squares were considered.

The analysis of the data yielded the conclusion that this method was good enough for monitoring widespread common species like Large White, Meadow Brown and Wall Brown among others, but not for monitoring species like e.g. Small Copper (*Lycaena phlaeas*), Lulworth Skipper (*Thymelicus acteon*) or Small Skipper (*Thymelicus sylvestris*).

Recent analysis of distribution data has shown that butterflies are declining more rapidly than either birds or plants in Britain, and other research has shown that the two most important impacts on butterfly populations in recent decades have been land use change and climate warming. So, this method is part of an overall project to monitor butterfly abundance with the objective of producing composite and individual species abundance indices.

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The design of a systematic survey scheme to monitor butterflies in the United Kingdom

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BACKGROUND

Effective monitoring of butterfly populations is essential if they are to be managed and conserved effectively. However, resources (both financial and time effort) for monitoring schemes are limited and need to be carefully targeted.

Twelve butterfly monitoring schemes have been established across Europe, and the number of new schemes continues to grow. The results of these schemes have contributed greatly to our understanding of the causes of change to biodiversity, particularly the impacts of climate change and habitat management (Thomas, 2005). However, in all schemes where volunteers are used for recording, there is no systematic sampling of sites; schemes operating in Switzerland and Finland apply systematic or stratified-random sampling using professionals for recording. Schemes are therefore not necessarily representative of the underlying national or regional population. This knowledge gap is important because recent research indicates that many wider countryside species underwent substantial declines in local and regional abundance in the UK during the 20th century; declines that were largely undetected by current monitoring and mapping schemes (e.g. Cowley *et al.*, 1999).

All butterfly monitoring schemes relying on volunteer recorders use a methodology developed by Pollard (see Pollard & Yates, 1993 for details). Briefly, the method consists of a fixed transect route that is walked weekly through the main butterfly season (26 weeks in the UK). The weekly counts (with missing data filled in by interpolation) are summed for each species to provide an index of abundance; the total represents an estimate of the area under the flight period curve. To encourage the inception of new monitoring programmes for butterflies across Europe, and to enhance existing schemes there is a need to develop less intensive sampling regimes. These are necessary if volunteer recorders are to be recruited to monitor remote areas and to habitats that do not generally support a rich butterfly fauna. This paper uses existing transect data from the UK to evaluate the performance of potential schemes.

APPROACH

Transect data from the UK for the period 1995-2004 have been used to test the efficiency of butterfly monitoring schemes based on a reduced number of visits. The analysis is restricted to *wider countryside* species that are suited to a stratified-random sampling approach for monitoring on a national basis. More restricted, *habitat specialist*, species may require more targeted monitoring.

The reduced-effort schemes are chosen to account for the seasonal pattern in butterfly flight periods. In the UK the highest numbers of butterflies are counted in July and August (around 70% of the flight period on average) but for multivoltine and some univoltine species an important proportion of the annual flight period also occurs earlier in the season (e.g. May). Two main schemes were evaluated:

- 3 visits in July and August
- 4 visits: 1 visit in May plus 3 visits in July/August

To assess the trade-off between the intensity of sampling at each site versus number of sites that need to be sampled, we assessed these reduced schemes in terms of bias and precision of indices using the full 26-week scheme as the ‘gold standard’. In particular, we address the question of *how many ‘reduced-scheme’ sites needed to achieve similar efficiency to existing scheme?*

Existing indices of change in the UK are based on the total of the 26 weekly counts; an estimate of the area under the flight period curve. For reduced schemes a direct estimate of this area is not available as the schemes do not span the whole season. Estimates of indices of change must therefore allow for the seasonal pattern in the counts. In this analysis we use a loglinear model (Poisson regression) with effects for year, site and week. The year effect from this model is of primary interest for assessing trends over time.

This change index model is applied to data from:

- Full 26-week scheme
- 3-visit scheme: 3 counts in July/August
- 4-visit scheme: 3 counts in July/August, 1 count in May

The precision (average standard error of index) of each scheme is estimated and used to calculate the number of additional sites needed in reduced schemes for the same precision as a full scheme. An absolute estimate of the power of these schemes for detecting declines in butterfly populations is also calculated. This power calculation assesses:

- decreases which can be detected with 80% power (5% level) over 10 years;
- the number of sites required to achieve 80% power for detecting decreases of 15%, 25% and 50% over 10 years.

RESULTS

On average, a scheme with 3 weekly counts in July-August would require about twice as many sites to achieve the same precision as the 26-week scheme (Table 1). A scheme with an additional count in the third week of May allows *Anthocharis cardamines* (Orange tip) to be sampled as well as leading to a worthwhile gain for species with a pronounced spring peak in their flight period, e.g. *Gonepteryx rhamni* (Brimstone) and *Celastrina argiolus* (Holly blue).

Table 1. Summary of efficacy of reduced schemes relative to scheme with 26 weekly counts using the ratio of average bootstrap standard errors of annual indices from loglinear model. Results for 3 weekly counts in July-August are an average over three different schemes using weeks (15,18,21), (16,19,22) and (17,20,23). Relative number of sites required for same precision as 26-week scheme is calculated as the square of the ratio of standard errors.

[a] For Orange tip the flight period is April-June so that no analysis is possible for July-August counts.

Species	**Mean se (26 weeks)**	**Jul-Aug (3 weeks)**	**May (1 week) Jul-Aug (3 weeks)**
Gonepteryx rhamni (Brimstone)	0.043	2.30 (5.3)	1.85 (3.4)
Aricia agestis (Brown argus)	0.111	1.30 (1.7)	1.22 (1.5)
Polygonia c-album (Comma)	0.071	1.25 (1.6)	1.22 (1.5)
Polyommatus icarus (Common blue)	0.06	1.35 (1.8)	1.32 (1.7)
Pieris napi (Green-veined white)	0.046	1.34 (1.8)	1.20 (1.4)
Pyronia tithonus (Hedge brown)	0.041	1.17 (1.4)	1.17 (1.4)
Celastrina argiolus (Holly blue)	0.128	1.29 (1.7)	1.11 (1.2)
Ochlodes venata (Large skipper)	0.049	1.47 (2.2)	1.47 (2.1)
Pieris brassicae (Large white)	0.056	1.27 (1.6)	1.23 (1.5)
Melanargia galathea (Marbled white)	0.072	1.10 (1.2)	1.10 (1.2)
Maniola jurtina (Meadow brown)	0.037	1.12 (1.3)	1.12 (1.2)
Anthocharis cardamines (Orange tip) [a]	0.052	-	2.30 (5.3)
Inachis io (Peacock)	0.048	1.89 (3.6)	1.71 (2.9)
Aphantopus hyperantus (Ringlet)	0.043	1.23 (1.5)	1.23 (1.5)
Lycaena phlaeas (Small copper)	0.07	1.19 (1.4)	1.17 (1.4)
Coenonympha pamphilus (Small heath)	0.053	1.36 (1.8)	1.13 (1.3)
Aglais urticae (Small tortoiseshell)	0.066	1.47 (2.2)	1.39 (1.9)
Pieris rapae (Small white)	0.074	1.18 (1.4)	1.17 (1.4)
Pararge aegeria (Speckled wood)	0.037	1.43 (2.0)	1.35 (1.8)
Lasiommata megera (Wall brown)	0.066	1.60 (2.6)	1.46 (2.1)
Mean		1.39 (1.9)	1.35 (1.8)

The statistical power of the the 26-week BMS scheme varies between species depending on their variability in annual fluctuations between sites (Table 2). Relatively high power is achieved for species such as marbled white, orange tip and ringlet where population fluctuations are synchronous between sites. Species such as brown argus and meadow brown have less power.

CONCLUSIONS

The two reduced-effort sampling schemes perform well when compared to the existing method based on weekly visits. This evaluation uses a model that allows for the seasonal pattern in butterfly numbers. On average, twice as many 'reduced-effort' sites achieve equivalent efficiency as a 26-week scheme and around 150 (range 75-350) 'reduced-effort' sites will achieve 80% power for detecting a 50% decline over 10 years. This approach gives great potential for expanding the UK Butterfly Monitoring Scheme and potentially elsewhere in Europe.

Table 2 Number of sites in reduced schemes to achieve 80% power for detecting decreases in butterfly indices.

Species	**Number of sites in 10-year scheme to achieve 80% power for detecting 25% & 50% decreases over 10 years**			
	July-August (3 weeks)		**May (1 week) July-August (3 weeks)**	
	25%	**50%**	**25%**	**50%**
Gonepteryx rhamni (Brimstone)	828	344	535	222
Aricia agestis (Brown argus)	592	246	522	217
Polygonia c-album (Comma)	312	129	297	123
Polyommatus icarus (Common blue)	344	143	329	137
Pieris napi (Green-veined white)	269	111	216	90
Pyronia tithonus (Hedge brown)	221	92	223	93
Celastrina argiolus (Holly blue)	453	188	338	140
Ochlodes venata (Large skipper)	399	166	396	165
Pieris brassicae (Large white)	248	103	231	96
Melanargia galathea (Marbled white)	144	60	145	60
Maniola jurtina (Meadow brown)	494	205	489	203
Anthocharis cardamines (Orange tip) [a]	-	-	716	312
Inachis io (Peacock)	742	308	608	253
Aphantopus hyperantus (Ringlet)	187	77	187	77
Lycaena phlaeas (Small copper)	235	98	227	94
Coenonympha pamphilus (Small heath)	284	118	196	82
Aglais urticae (Small tortoiseshell)	458	190	406	168
Pieris rapae (Small white)	267	111	265	111
Pararge aegeria (Speckled wood)	311	129	277	115
Lasiommata megera (Wall brown)	584	242	486	202
Mean	388	162	355	147

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Using butterfly monitoring data to develop a European grassland butterfly indicator

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INTRODUCTION

Recent years have seen political agreements on halting or significantly reducing the current rate of loss of biodiversity by 2010 (the 2010 target). This is accompanied by a growing consensus on the need for structured European coordination of biodiversity monitoring, indicators, assessment and reporting efforts, with a long-term perspective and sound funding basis.

To test the possibilities to use butterfly monitoring data for a European Butterfly Indicator, a grassland-butterfly indicator has been developed, containing seven widespread grassland species and ten grassland-specialists.

METHOD

The field method is based on the British Butterfly Monitoring Scheme (Pollard & Yates, 1993), where it has been used since 1976. The main objective of the monitoring schemes is to assess changes in abundance at national and regional levels of butterflies, including species of the Habitat Directive.

Seven widespread grassland species have been selected (*Ochlodes venata, Anthocharis cardamines, Lycaena plaeas, Polyommatus icarus, Lasiommata megera, Coenonympha pamphilus, Maniola jurtina*) and ten grassland-specialists (*Erynnis tages, Thymelicus acteon, Spialia sertorius, Cupido minimus, Maculinea arion, Maculinea nausithous, Polyommatus bellargus, Polyommatus semiargus, Polyommatus coridon, Euphydryas aurinia*).

Data from nine countries has been collected:
Ukraine (Transcarpathia only) since 1983 (only for *Erynnis tages*)
Pfalz region (Germany) since 1989 (only for *Maculinea nausithous*)
The Netherlands since 1990
Flanders (Belgium) since 1991
Catalunya (Spain) since 1994
Aargau (Switzerland) since 1998

Finland since 1999
Nordrhein Westfalen (Germany) since 2001
Doubs and Dordogne (France) since 2001

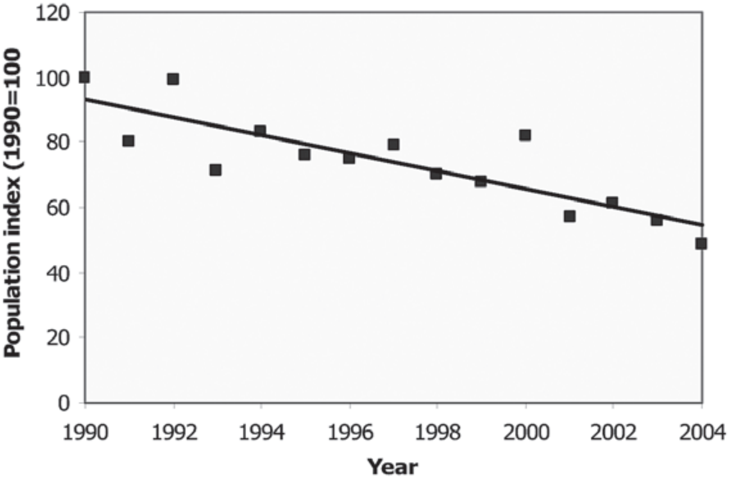
In 2004 a butterfly monitoring scheme was started in Jersey (Channel Islands), in 2005 a large new monitoring scheme was set up in Germany. These data could not be used in this assessment.

A European index and trend is produced for each species by combining national results for that species. The individual European species indices are combined (averaged) to create multi-species supranational indicators. This method is based on the one for bird indicators (Gregory *et al.*, 2005):

1. National level. The indices for each species are produced for each country, using TRIM (Pannekoek & Van Strien, 2003). TRIM is a programme to analyse time-series of counts with missing observations using Poisson regression.
2. Supranational level. To generate European trends, the difference in national population size of each species in each country has to be taken into account. This weighting allows for the fact that different countries hold different proportions of a species' European population (Van Strien *et al.*, 2001). A weighting factor is established as the proportion of the country (or region) in the European distribution (Van Swaay & Warren, 1999). The missing year totals are estimated by TRIM in a way equivalent to imputing missing counts for particular sites within countries (Van Strien *et al.*, 2001).
3. Multi-species level. For each species the geometric mean of the supranational indices is calculated.

RESULTS & DISCUSSION

The graph shows the European Butterfly Indicator for grassland butterflies since 1990. The decline appears to be enormous, resulting in a reduction of grassland butterfly abundance by almost 50%. Gregory *et al.* (2005) indicate a 12-year population decline of 12% for farmland birds (1990-2002), so much smaller than the butterfly decline. The same pattern has been de-



scribed for British birds and butterflies (Thomas *et al.*, 2004), where butterflies experienced the greatest net losses, as well as in the Netherlands. Thomas (2005) makes clear that in the UK the butterfly trend maybe well representative for other insects as well. Insects are by far the most species rich taxon, thus representing the highest biodiversity. The method is also highly useful to monitor European wide trends for protected species, e.g. of the Habitats Directive

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Section 2.2.

Conservation of butterflies and global change – Population biology and land use

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Landscape scale conservation, theory into practice

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Ecological theory, from island biogeogragy to metapopulations, have encouraged conservationists to think beyond single site safeguard to operating at a landscape scale. Here we describe how recent advances in metapopulation theory have influenced the work of Butterfly Conservation.

In 2001 a re-orientation in conservation priorities was recommended by Thomas et al as their results demonstrated that habitat quality and spatial effects operated at different hierarchical levels within the same metapopulation process.

These authors highlighted that habitat quality and metapopulation effects are the main hypotheses that currently explain the disproportionate decline of insects in cultivated Holarctic landscapes. The first assumes a degradation in habitat quality for insects within surviving ecosystems; the second that too few, small or isolated islands of ecosystem remain in landscapes for populations to persist. These hypotheses are often wrongly treated as alternatives, and can lead to serious conflict in the interpretations of conservationists.

This work demonstrated that within-site variation in habitat quality explained which patches supported a species' populations 2-3 times better than site isolation and the authors concluded that the preservation of nearby groups of many sites while being highly desirable, small size or isolation were not *a priori* reasons for rejecting a site so long as the habitat quality within it is high. Thus while metapopulation theory had usefully re-orientated conservation priorities to the landscape scale (Harrison 1994; Hanski 1999), it should not be employed as a substitute for within-site habitat management (Harrison & Bruna 1999). The study suggested that it is at least as important to maintain high habitat quality through targeted management for valued types of community and species within individual sites as it is to maintain as many contiguous populations as possible in a landscape.

Here we present case studies to demonstrate how both approaches can come together to conserve wildlife. Butterfly Conservation staff are involved in 44 'landscape scale' projects, which for the purpose of this paper can be defined as 'the coordinated conservation and management of habitats for a range of species across a large natural area, often made up of a network of sites'.

The first case study involves the Heath Fritillary, *Mellicta athalia*, which principally occurs across two distinct landscapes in the UK, moorland edge habitats in the west and active 'coppice' woodland in the east of the country. In both cases recent declines have been high but targeted conservation effort across the landscapes has begun to yield positive results. A second case study will be two new projects undertaken by Butterfly Conservation with our conservation partners to conserve the Marsh Fritillary, *Euphydryas aurinia* in the south west of Britain, the 'Two Moors threatened butterflies project' and the 'Re-connecting the Culm Project'.

Lessons learned are of relevance across the other highly intensified agricultural landscapes of Europe.

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Initial results on the impact of parasitism on the demography of the bog fritillary

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Understanding population fluctuations is a major topic in population ecology. Several factors, including parasitism, can be responsible for the population fluctuations observed in many species.

This study examines some results obtained from data gathered on the parasitism rate of a particular butterfly species: the bog fritillary (*Proclossiana eunomia*). Variation in population size is not rare in this species. For example, during the two year study, total population size of *P. eunomia* dropped by more than half. Although it's too early to draw any serious conclusions (long term data being necessary to see an eventual relation between demography and parasitism), it can be noted that this drop was accompanied by a parasitism rate of 64 percent.

P. eunomia caterpillars are infested by one particular parasitoid species. The spatial distribution of the parasite is analysed and compared to the spatial distribution of *P. eunomia* larvae. The effects of local environmental factors (including vegetation type, exact location in relation to habitat boundary and microclimatic conditions) on parasitism rates are also tested.

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Decline and extinction of *Parnassius apollo* populations in France – continued

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The Apollo swallowtail, *P. apollo* L., a mountain butterfly, has undergone a general decline of its populations in all European mountain massifs during the XXth century. A survey of the status of its populations in France has been published in 1995 by HD. We present here data which show that its decline has continued and try to precise the causes of this decline. These data include a detailed survey of the populations of *P. apollo* since the pre-1950 years in the Puy-de Dôme department in French Massif Central, a less detailed but more extensive survey of the populations of the Provence-Alpes-Côte d'Azur region and more scattered observations all over French territory. Otherwise, the results of extensive breeding experiments and those of reintroduction trials are used to highlight the distributional observations.

As for extinction, the most noteworthy event is the blunt extinction of the "abyssal" but flourishing populations of the Vaucluse massif at the end of the 1990s. The meteorological scenario which led to this catastrophic extinction is strikingly parallel to that which produced the previous wave of disappearing at the end of the eighties (in particular on Causse du Larzac in southern Massif Central): a "false spring" in winter, followed by a return of cold.

In Puy-de-Dôme, the average elevation of the colonies has risen from 1200 m in the pre-1950 years to 1500 m at the present time; the lower limit of the flight zone has risen from below 600 m to above 1250 m during the same period.

All over its distribution, *P. apollo* displays the same trend, and even in the higher mountains as the Alps and the Pyrenees. It also displays a phenological shift towards earlier dates, in particular in the region of Briançon (Hautes-Alpes), where the flight period takes place at present in the beginning of July at 1900 m in place of the end of this month during the sixties.

Breeding observations show that the L1 larvae, which hibernate inside of the egg shell, hatch suddenly and massively as soon as the temperature rises above 20°C; but they are at that time also very sensitive to cold, dry periods, where they cannot feed and promptly dehydrate and die. On the contrary, at the end of their growth period, too warm temperatures render them quite sensitive to opportunistic diseases. Moreover, the presence of tender growing foodplants is also very important for their good health and the synchronisation of the life cycle of the phytophagous insect with that of its foodplant is easily disturbed.

All these data strongly suggest that climate warming has a strong impact on the viability of at least the lower populations of *P. apollo*. A simple, mechanistic interpretation is that the lower limit of the species' habitat, which is ecophysiologically determined, is raising in proportion of the observed increase of temperature. However, in the Puy-de-Dôme department, the latter is insufficient to explain the enormous rise of the lower limit of the species' range.

Another factor of disappearance is the closure by shrub and forest vegetation of the spaces available to the species. This factor, obvious or covert, is likely to be present in all mountain or subalpine vegetation zones. It is not exclusive with the previous factor and both could combine.

It is hard to propose management provisions to counteract this disastrous trend. Reintroduction has generally led to frank and massive chess, with a significant exception: the populations of the Puy de Dôme Mountain had been wiped out by the construction of a road, but the elevation of this summit was still sufficient (1400 m), and the reintroduction was a success. Obviously, the closure of open habitats can be counteracted at a feasible extent by simple actions; but global warming is a phenomenon which is produced by man but which cannot be counteracted at a suitable extent by him.

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Climate and butterfly distribution changes

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Climate is important in limiting the distributions of butterflies and there is now considerable evidence that over the past three decades some species have shifted their ranges to keep track of current climate warming. Here, we review the factors which determine whether or not species have responded to warming and the degree to which species' distributions have changed, and may change in the future. We focus on those species that currently are responding to climate and expanding at their northern (cool) range margins, and we investigate the importance of evolutionary changes in dispersal and larval host plant choice on the patterns and rates of range expansion. We discuss how differences among species in their response to climate warming will affect the distribution of diversity in the future.

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Predicting butterfly occurrence and establishing management guidelines through predictive model selection in the calcareous grasslands of the Viroin Valley (Belgium)

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Since the beginning of the last century, calcareous grasslands are no longer being maintained with traditional agro-pastoral methods, resulting in forest recolonization. Isolation and fragmentation of the remaining calcareous grasslands should be considered as a major threat (van Swaay 2002) since the metapopulation structure of many specialist butterfly populations requires networks of habitat patches (Bourn & Thomas 2002; Hanski 1999). Butterflies are considered as good indicators because they are sensitive to the modifications of their environment (Erhardt & Thomas 1991; Bourn & Thomas 2002). Consequently, a large decrease in butterfly populations can be explained by rapid changes in the vegetation of their habitat (Thomas 1991).

We analyse the composition and the structure of butterfly communities persisting in the largest remaining calcareous grassland network in Belgium (Viroin Valley). We focus on the identification of the factors influencing both community structure and composition, with the aim of determining the relative importance of landscape effects and habitat quality to produce some conservation guidelines and some predictive models of butterfly occupancy for the others remnants of calcalreous grasslands in this region.

Important factors such as fragment surface or host-plant diversity are selected by multiple regression models. In this way, for example, we can establish that a minimum area of approximatively one hectare is sufficient to accommodate the maximum butterfly diversity. Predictive models for butterfly diversity do not seem to vary from one year to another whereas abundance models do vary, suggesting that diversity predicitive models are the most pertinant for the conservation of the studied calcareous grasslands. This difference can be explained by a covariable such as the climate.

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Community Development and Nature Conservation Policy in Scotland: Environmental Democracy on the Isle of Rum National Nature Reserve

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In Scotland, statutory and voluntary nature conservation agencies manage land for its wilderness qualities and associated biodiversity. Usually this management is ostensibly based on 'impartial' and 'value-free' science. However, the demands that this science-based conservation practice places on the land often conflicts with the more culturally-based management practices of rural communities who live and work on this land.

Under recent post-devolution reforms in Scotland, the reconciliation of conservationists' values and locals' concerns has been given a high priority. Its prioritisation has led to the gradual development of legislation that aims to resolve conflicts, legislation that involves novel participatory mechanisms to enhance public involvement in science-based nature conservation policies. Yet, it remains to be seen whether or not these 'inclusive' and 'co-operative' mechanisms can work in practice.

The aim of this paper is to stimulate debate on the development of new participatory mechanisms like these that are ostensibly orientated towards the practical reconciliation of wild land conservation and community interests. This will be done by describing and analysing these mechanisms and evaluating their success in achieving environmental democracy in Scotland. Illustrating this, the Isle of Rum, a world-renowned 'wild area' with a community development plan in preparation, will be used as a case study.

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The Population Biology and Genetics of the Marsh Fritillary, *Euphydryas aurinia*, in Northern Ireland, a new research project

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The Marsh fritillary, *Euphydryas aurinia*, is a threatened species across Europe and protected under Annex II of the Bern Convention. *Euphydryas aurinia* has undergone significant decline in Northern Ireland (Nelson, 2000). Currently there are eight known breeding sites for this species. These sites are distributed mainly across the eastern side of the province, in a highly fragmented agricultural landscape. *E. aurinia* also occurs in one isolated western part of the province. As part of my PhD, larval web counts were undertaken in autumn 2005 and larval samples were collected under licence. This information will be used to understand the current biological genetic and historical relationships both within and between the known sites of occurrence. The five main aims of my project are to: 1). investigate the genetic structure and variability of the marsh fritillary in Counties Down and Armagh (east) and define distinct metapopulations. 2) Establish the biology of these metapopulations to explain recent population bottlenecks. 3) Measure the genetic differentiation of the marsh fritillary across Northern Ireland, including the known site in Co. Fermanagh (west) and any additional sites identified during this research project. 4) Investigate the role of parasitic wasps (*Cotesia*) on *E. aurinia* population biology in Northern Ireland. 5) Investigate habitat characteristics including the availability of *Succisa pratensis,* (the sole food plant of the marsh fritillary butterfly in Northern Ireland), both within sites and between sites to help explain habitat patch occupancy and the variability of population sizes.

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First results of a study on *Coenonympha oedippus* in Hungary

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The False Ringlet (Coenonympha oedippus) is one of the most endangered butterfly species in Europe. According to the Habitats' Directive (92/43/EEC), the conservation of this species requires the designation of special areas of conservation where it needs special protection. It is distributed in the Palaearctic Region. In Europe most of its populations are extinct and the remaining ones are very isolated from each other. Its former habitats in Hungary were destroyed by drainage, which drastically decreased the water table level in marshy areas. In Hungary, only one population remained in the marshlands of Central Hungary (Ócsa Landscape Protection Area, Duna-Ipoly National Park).

Our aim was to map the habitat patches of *C. oedippus*, to estimate the abundance of populations, sex ratio, and to detect movement patterns within habitat patches and survey of vegetation characteristics.

A long-term ecological genetic study, together with, mass breeding was started in 2005 in order to develop an ecologically-based programme for conservation management and re-introduction. Former conservation management plans were not based on detailed ecological studies, however an urgent change in habitat management was required because a decline of population has been noticed.

The present study was carried out in two distant (8 km), well-separated sampling areas in the same region. One area is 0.65 ha (Site1), the other 0.75 ha (Site2). Mark-release-recapture (MRR) method and transect samplings were used during the flight period from middle June untill early July in 2005. Site1 was divided into 10 × 10 m squares in order to detect the movement pattern of the butterflies. Eight transects covered Site1, each of them were as long as 20 m and 10 m wide. The sampling period lasted 17 days for MRR and 9 days for transect counts. Site 2 was sampled every second day for MRR and 10 transects were used to cover the area. Calibration of transect method by MRR data was carried out in order to provide a simple but reliable system for monitoring in the entire territory of Ócsa Landscape Protection Area in the future. We used MARK program package to analyse the MRR data.

The number of marked animals was 136 at Site1 and 201 at Site2. Recapture probability of males (0.43) was higher than that of females (0.24), while the survival rate was 85% for both sexes. Specimens were rather sedentary although patch fidelity decreased at the end of the flight period.

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Do agri-environment schemes help butterflies?: experience from the UK

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Farmland is a crucial habitat for butterflies across Europe and more than 90% of UK species utilise it over all or part of their range (Brereton, 2004). However, over the last 50 years there have been major changes in farming practice and agricultural intensification, leading to large scale loss of semi-natural habitats where most species breed. This has led to steep declines in butterflies and other wildlife. Overall 60 of the UK's resident species have become extinct and 70% are declining, with losses far outstripping those for birds or plants (Thomas et al, 2004).

The UK has a complex system of habitat protection, ranging from nature reserves to designated Sites of Special Interest (SSSI) that now cover over 12% of the land surface. However, habitat specialist butterflies have continued to decline on such "protected" land (e.g. Warren, 1993) and conservationists have sought ways of influencing land management on a wider scale. Since their introduction in 1987, agri-environment schemes have become a key mechanism to halt the loss of biodiversity on farmland in the UK and many other European countries. The schemes are voluntary and farmers entering receive extra payments to meet various wildlife, landscape, and archaeological conservation objectives. In England, there are two main schemes: Environmentally Sensitive Areas (covering 22 landscape areas) and Countryside Stewardship, which is targeted at habitats, mostly semi-natural grasslands.

By 2003, over 1.2 million ha had been entered into schemes with an annual budget of over £130 million, more than all the UK nature conservation agencies put together. A key question is whether this investment of resources in these schemes is helping to slow or reverse the decline of biodiversity. Unfortunately there is little biological data available to assess the impact on schemes apart from birds, which are covered by a detailed monitoring programme (e.g. Gregory *et al.*, 2005).

A project was therefore started in 1999 to bring together all the butterfly transect data in England and Wales, to see whether this could provide evidence on the impact of agri-environment schemes on butterfly populations. The project was funded by the Department for Environment, Food and Rural Affairs as part of their biodiversity research programme. Over the six years of the project, data have been gathered from 820 sites, of which 371 (45%) were entered into schemes. Trends were obtained for 40 species and analysed for the ten-year period from 1994-2003, comparing sites that had been entered into schemes with those that had not.

The overall results show that there has been a significant decline in mean species abundance of -30% over the 10 last years, with the majority of species having declined significantly. The declines have been across the board, including at scheme and non-scheme sites and in the wider countryside highlighting the acute problems butterflies face in the UK landscape.

There was no significant difference between trends at scheme and non-scheme sites, either for all species combined and habitat specialist butterflies, showing that schemes had not slowed the general loss of butterfly species over the last decade. However, schemes do seem to have significantly slowed the overall decline of 8 Priority Species that have been listed within the UK Biodiversity Action Plan (BAP). Six of these species had improved trends at scheme sites compared to non scheme sites, including significant improvements for some of our most threatened species: *Polyommatus bellargus, Argynnis adippe, Mellicta athalia*, and *Plebeius argus*. This improvement seems to be attributable to the extra, targeted measures that are now being taken for such species on a large number of sites, often following advice from experts at Butterfly Conservation.

Looking at individual species performance, some species do seem to be benefiting most from schemes, mainly those associated short and medium turf conditions, such as *Hesperia comma* and *Polyommatus bellargus.* Species least benefiting from schemes included those associated with ranker grass, variable turf and scrub edge/mosaics, including *Thymelicus sylvestris, T. acteon, Cupido minimus*, and *Hamearis lucina*. It is strongly suspected that the habitat heterogeneity required by the latter species is not being provided in the drive to restore generic ('favourable') habitat conditions as defined by homogenous vegetation communities.

The study found that overall butterfly populations fared no better on sites that had been protected as SSSIs, which represent the best semi-natural habitats in the UK. Designation also appeared to make no difference in mean trend of eight Priority Species, although four species had improved trends at SSSIs. However, the mean decline of Priority Species on SSSIs that had been entered into agri-environment schemes was significantly lower compared to non-scheme sites (-31% vs -68%), and 7 out of the 8 species seemed to have benefited. These data indicate that schemes are a key mechanism helping to halt the decline of BAP Priority species on SSSIs, but not other species. Once again, species requiring mosaic habitats fared worse on SSSIs, while short turf species seemed to benefit most.

The study concluded that agri-environment schemes are helping to significantly slow and in some cases reverse the declines of BAP Priority butterflies, and some short/medium turf species, but not the majority of other species. This suggests that very targeted measures are beginning to work on some sites but that the broad management prescriptions aimed at conserving wildlife in general have not been sufficient to halt most butterfly declines. The failure of schemes to halt the decline of many widespread butterflies may also be because only 2.5% of the CAP budget goes towards agri-environment schemes and they still only cover 7% of the England's agricultural land. Many organisations, including Butterfly Conservation, are now pressing for an even greater shift in resources to support environmentally sensitive farming as a matter of urgency.

Another important conclusion of the study is that for some species types, schemes may have exacerbated declines, notably those requiring habitat mosaics and scrub edges that are not catered for within standard prescriptions. This is of wider concern, as scrub and habitat mosaics are critically important for threatened insects (e.g. 352 UK Red List and BAP Priority Species; Mortimer *et al.*, 2000).

On the positive side, examples of successful management were found for all species, proving it is technically possible to manage effectively for even the most threatened and specialised butterfly species. Also, a great deal has been learnt from the development and implementation of agri-environment schemes over the last decade. Many of the concerns highlighted in this study have been addressed in the new Environmental Stewardship (ES) scheme that was introduced in 2005 to replace all previous schemes. The challenge now is to ensure that the specific lessons learnt from this study are translated into better practice in the future, otherwise butterflies and many other insects will continue to decline. The study also shows the enormous power of butterflies to evaluate land use policy and their value as biological indicators to complement indicators being developed for birds (Gregory, 2005).

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