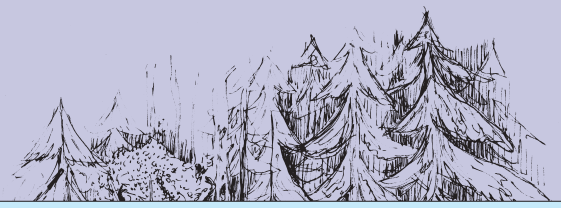

Eberhard Karls Universität Tübingen

Ringlets (*Erebia*, Satyrinae, Lepidoptera) as indicators for climate and land use change in the southwest of Germany

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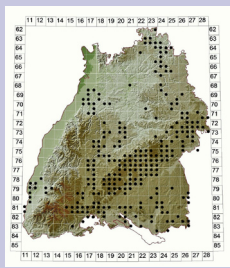
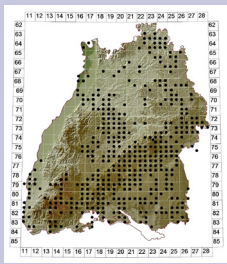
Introduction

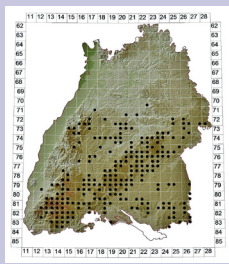
The ringlet species *Erebia medusa, E. aethiops* and *E. ligea* were once widespread in the southwest of Germany (Baden-Württemberg). Since about 1980 populations of these species are strongly declining especially in warm and atlantically influenced lowland regions (compare Ebert & Rennwald 1991). Due to the boreo-mountainous to arctic-alpine distribution of the genus *Erebia* in general and the preference of mountainously toned regions of indigenous species, those may function as ideal indicators for climate change. The main question pointing out is: Which reasons are responsible for the decline of ringlet species? Does climate change have an influence on this decline or is it just conditioned by habitat loss and fragmentation? In which way does climate warming affect these species? Furthermore, this work attempts to get better knowledge about larval host plants and microhabitats which are barely identified up to now (Hermann 1999).



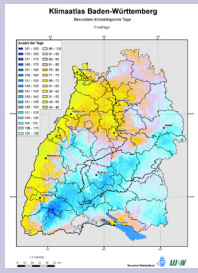
Distribution of *E. aethiops* in Baden-Württemberg historical (above) and current (below). n = 852.



Distribution of *E. medusa* in Baden-Württemberg historical (above) and current (below). n = 1351.

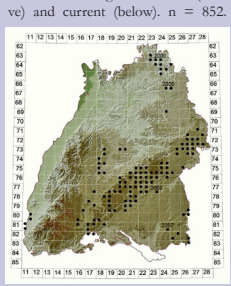


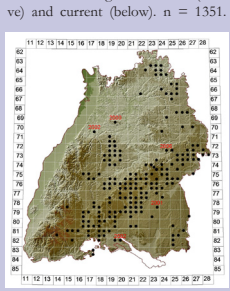
Distribution of *E. ligea* in Baden-Württemberg historical (above) and current (below). n = 531.

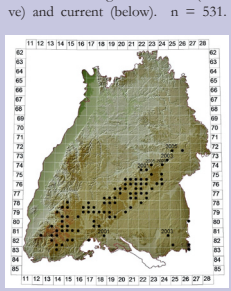


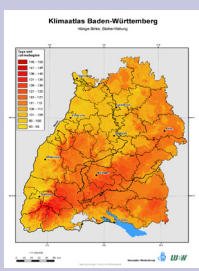
Number of frost days (above) and time to leaf evolvement since beginning of a year (below), © LUBW.

Female of *E. ligea* in the prealpine area of Adelegg (above) and young larval stage of *E. medusa* raised out of egg from the Swabian Alb (below).









Habitat of *E. medusa* in the foreland of the Swabian Alb. The species occupies here fallow, semi-dry grassland. The microhabitat is characterised by dominant litter layers and *Festuca ovina*.

Habitat of *E. aethiops* in the Schönbuch. It is the last occupied patch in the formerly area-wide populated woodland. This open forest system only exists due to military utilisation.

Habitat of *E. ligea* in the prealpine mountains of Adelegg. The species colonises here deeply carved valley cuttings, so-called ravines. As hostplants function most likely species of the Genus *Luzula*.

Larval habitat of *E. medusa* in the northeast of Baden-Württemberg (Tauberland). *Festuca ovina* is dominant in this litter-rich, planar fallow land next to steeply sloping semi-dry grassland.

Larval habitat of *E. aethiops* on the Swabian Alb. This poor and litter-rich edge of the forest with dominant populations of *Brachypodium pinnatum* provides optimal conditions for the larval stages.

Larval habitat of *E. ligea* in the Black Forest. Oviposition was observed in dominant populations of *Luzula sylvatica* on the edge of the forest. On the Swabian Alb the species feeds as well on *Brachypodium pinnatum*.

Material & Methods

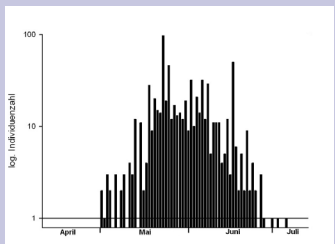
Between 2009 and 2011 formerly as occupied known and suitable habitats in the southwest of Germany (Baden-Württemberg) were controlled in regard to occurrence of *Erebia* species. At every patch several geographic, abiotic, and biotic parameters were collected (according to Eichel & Fartmann 2008) in order to be able to describe requirements of larval stages and adults exactly (Tab. 1). Climate chamber experiments were conducted during the winter periods using larval stages of *E. medusa* and *E. aethiops*. Different hibernal weather patterns were tested under standardised conditions. Collected parameters were mixed with different climate variables to determine coherences between decline and climate warming. Discriminant analysis, both logistic and multiple linear regressions, and tests on statistical significance helped to detect requirements of *Erebia* species and reasons for their decline.

Tab. 1: Geographic, abiotic, and biotic parameters collected in the studied patches and the number of records per patch.

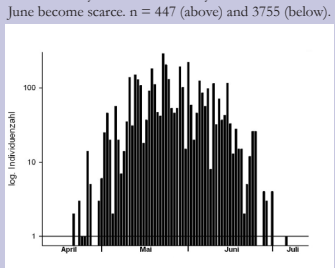
Parameter [unit]	Records/patch
Altitude [m NN]	1
Patch size [ha]	1
Connectivity [km]	1
Exposition [°]	1
Inclination [°]	1
Type of habitat [categorial]	1
Type of agricultural use [categorial]	1
Number of *Erebia* individuals [categorial]	1
Height of vegetation layers [cm]	3
Dominance of vegetation layers [%]	3
Amount and quality of larval hostplants [%]	3
Duration of sun exposure in June (h)	3

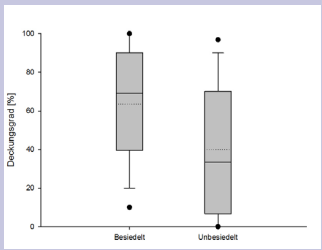
Results

Erebia species respond to climate warming in different intensity. Declines of *E. aethiops* are more linked to habitat deterioration induced by high forest usage attended by darkening of woodland. In contrast, decreases of *E. medusa* are highly associated with climate warming. Populations of this most widespread species in south-western Germany are disappearing in warm and atlantically influenced lowland regions even though suitable habitats in adequate size and connectivity abound. Populations occupying lowland regions are only able to survive if a dominant litter layer is abundant which protects the larval stages against extreme temperatures during hibernation and during development in summer. At last *E. ligea* is the species reacting the most strongly to climate warming. During the last decades it has given up every single lowland population and is currently restricted to high altitude areas. This is due to the long development time of the larval stages (nearly two years) and the larval habitats which provide only small degrees of litter layer. For the first time in Baden-Württemberg larval host plants of *E. ligea* have been detected. In the Black Forest and in the mountains of Adelegg it uses *Luzula* ssp., mainly *Luzula sylvatica*. In contrast to that, on the Swabian Alb oviposition was observed in dominant populations of *B. pinnatum*.

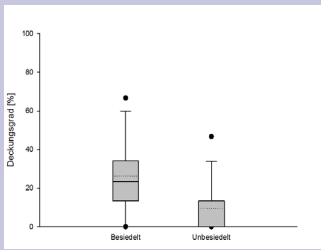


Flight period of *E. medusa* until 1989 (above) and from 1990 until today (below). The beginning of the flight period has shifted about two weeks earlier and the maximum is already reached in mid-May. Observations in late June become scarce. n = 447 (above) and 3755 (below).

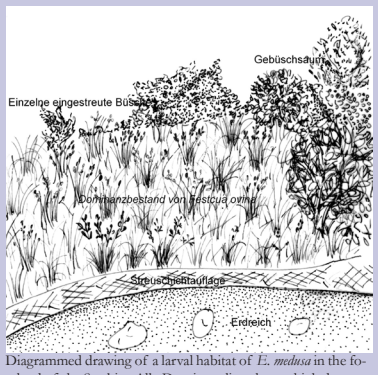




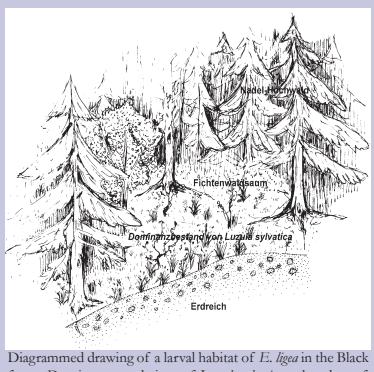
Degree of coverage of litter layer [%] of occupied (left box plot) and available (right box plot) habitats of *E. medusa*. The difference is highly significant ($p < 0{,}001$). Solid line: median; dotted line: mean value. Outliers: 5th/95th percentiles. Occupied: n = 146, available: n = 277.



Degree of coverage of *Brachypodium pinnatum* [%] of occupied (left box plot) and available (right box plot) habitats of *E. aethiops*. The difference is highly significant ($p < 0{,}001$). Solid line: median; dotted line: mean value. Outliers: 5th/95th percentiles. Occupied: n = 77, available: n = 396.



Diagrammed drawing of a larval habitat of *E. medusa* in the foreland of the Swabian Alb. Dominant litter layers, high degrees of coverage of *Fectuca ovina*, several interspersed bushes and margins of shruberry indicate the fallow character of the habitat.



Diagrammed drawing of a larval habitat of *E. ligea* in the Black forest. Dominant populations of *Luzula sylvatica* at the edges of spruce forest serve as larval habitat. A dominant litter layer is absent. The drawing shows the equivalent to the larval habitat photo.

Discussion

A few still existing relictic populations of *Erebia* species in lowland areas prove that survival would regionally be possible if sufficient habitat of high quality, size, and connectivity was available. High forest usage, afforestation and intensification of open landscape lead to isolation and habitat fragmentation, which accelerate and enhance declines due to climate warming, and finally lead to extinction on a large scale. *E. medusa* depends on semi-dry, partially fallow grassland (compare Fartmann (2004)) which is regionally (e.g. on the Swabian Alb) still present. *E. aethiops* and *E. ligea* are reliant on more (*E. aethiops*) or less (*E. ligea*) open and highly structured woodland, woodland - open land ecotones and bushy semi-dry grasslands on the border to open pine forests. These habitat types are more and more declining and need to be enhanced by forest ecosystem management. Furthermore traditional forms of forest use as coppice-with-standards or wood pasture should regionally be re-established (Treiber 2003). Additionally prohibition of clear cuttings affects chances of re-extension and forming of metapopulation structures negatively.

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