Nature Conservation 6: 31–48 (2013)
doi: 10.3897/natureconservation.6.5205
http://www.pensoft.net/natureconservation

APPLIED ECOLOGY

A peer-reviewed open-access journal
Nature Conservation
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Land-use changes, farm management and the decline of butterflies associated with semi-natural grasslands in southern Sweden

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Academic editor: *L. Penev* | Received 26 March 2013 | Accepted 30 October 2013 | Published 18 November 2013

Citation: Nilsson SG, Franzén M, Pettersson LB (2013) Land-use changes, farm management and the decline of butterflies associated with semi-natural grasslands in southern Sweden. Nature Conservation 18: 31–48. doi: 10.3897/natureconservation.6.5205

Abstract

Currently, we are experiencing biodiversity loss on different spatial scales. One of the best studied taxonomic groups in decline is the butterflies. Here, we review evidence for such declines using five systematic studies from southern Sweden that compare old butterfly surveys with the current situation. Additionally, we provide data on butterfly and burnet moth extinctions in the region's counties. In some local areas, half of the butterfly fauna has been lost during the last 60–100 years. In terms of extinctions, counties have lost 2-10 butterfly and burnet moth species. Land use has changed markedly with key butterfly habitats such as hay meadows disappearing at alarming rates. Grazed, mixed open woodlands have been transformed into dense coniferous forests and clear-cuts, and domestic grazers have been relocated from woodlands to arable fields and semi-natural grasslands. Ley has increased rapidly and is used for bale silage repeatedly during the season. Overall, the changed and intensified land use has markedly reduced the availability of nectar resources in the landscape. Species that decline in Sweden are strongly decreasing or already extinct in other parts of Europe. Many typical grassland species that were numerous in former times have declined severely; among those *Hesperia comma*, *Lycaena virgaureae*, *Lycaena hippothoe*, *Argynnis adippe*, and *Polyommatus semiargus.* Also, species associated with open woodlands and wetlands such as, *Colias palaeno*, *Boloria euphrosyne* and the glade-inhabiting *Leptidea sinapis* have all decreased markedly. Current management practise and EU Common Agricultural Policy rules favour intensive grazing on the remaining semi-natural grasslands, with strong negative effects on butterfly diversity. Abandoned grasslands are very common in less productive areas of southern Sweden and these habitats may soon become forests. There is an urgent need for immediate action to preserve unfertilized, mown and lightly grazed grasslands. It is also crucial to

encourage that management of abandoned grasslands resumes before it is too late. In order to mitigate risks of further species loss and to work towards recovery of threatened butterfly populations using best known practises, we recommend twelve types of management measures favourable for many butterflies.

Keywords
Land management, conservation, agroecology, semi-natural grasslands, management recommendations, butterflies, Sweden

Introduction

During the last 100 years, agriculture has experienced profound changes in Europe. In particular, it has become increasingly mechanized because of the pressure for higher yields and the rising price of labour (Dahlström et al. 2008; Tscharntke et al. 2005). As a consequence, considerable areas of traditionally managed grasslands that once were unfertilized, mowed late in summer and then grazed have become intensively used land or abandoned (Dahlström et al. 2008; Eriksson et al. 2002; van Swaay et al. 2013). Intensification includes applying inorganic fertilizer, draining and often increasing the grazing pressure. In Sweden and many other parts of Europe, grasslands on low productive soils have been transformed into forests either by being planted with coniferous trees or by being abandoned. This changed management has had a substantial negative effect on flora and fauna, and many species are declining and are on the verge of regional extinction (Mace et al. 2008). Indeed, the declining European semi-natural grasslands are associated with a unique set of species that since long has been adapted to these habitats (Hoekstra et al. 2005). Traditionally, conservation efforts in these habitats have mainly focused on plants, but during the last 30 years, butterflies have gained more attention (Erhardt 1985; Thomas 1984), and the knowledge about butterflies is today relatively good with well-established monitoring programs in many European countries (van Swaay et al. 2013). Most studies report declines and a vanishing butterfly fauna (van Dyck et al. 2009) as a consequence of habitat destruction (Warren et al. 2001), unsuitable management and lack of interest to preserve key sites and declining populations (Dover et al. 2011; Konvicka et al. 2008). However, there are also a few studies reporting positive results from conservation actions and recovering butterfly populations (Thomas et al. 2009). Here we highlight a number of local studies from southern Sweden that cover land use changes and associated consequences for butterflies and burnet moths during the last 100 years. Using Red List data for Swedish counties (Gärdenfors 2010), we also compare these effects of land use in Sweden with regional extinction rates in a number of Swedish counties.

Focus area

Most of southern Sweden is characterised by a forest-dominated landscape, with small-scaled farmland covering about 5 % (Anon. 2012; SNA 1996). Fertile plains cover

10 % of the area and are dominated by intensive agriculture with large fields. In the forest-dominated parts of the landscape, small to mid-sized villages are sparsely scattered throughout the landscape with small fields around them. Soils are typically oligotrophic with low calcium content and lakes and mires are abundant. Fields are often bordered by deciduous trees or mixed forest stands, but coniferous forest plantations dominate the landscape. The area has experienced drastic changes in landscape composition during the last two centuries, with changes accelerating since the 1950s (Nilsson and Franzén 2009; Nilsson et al. 2008). Traditional semi-natural meadows, of which nearly all once were hay meadows, have been transformed to intensively grazed pasture or forest. Likewise, many pastures and previously grazed woodlands in the area have been abandoned and planted with coniferous forests (Nilsson 2006). Open, arable farmland is mainly found near hamlets and is used for crop and ley. Ley has increased and ley fields are today harvested for bale silage repeatedly during the season, often beginning as early as in May (Nilsson and Franzén 2009). These new harvesting methods have also had major effects on the availability of nectar resources in the landscape as the onset of the harvest cycle in May or early June commonly takes place before flowering peaks in summer (Dahlström et al. 2008; Nilsson et al. 2008). Most ley fields and other arable fields are fertilized and most of the regions' semi-improved grasslands are intensively grazed for animal production. The floral and host plant diversity of these parts of southern Sweden is also affected in more subtle ways as the region is exposed

Figure 1. Open habitats associated with a rich butterfly fauna in southern Sweden: **A** Taxås nature reserve in Kronoberg County, Småland, a pasture with one part experiencing late grazing **B** An abandoned pasture in Blekinge **C** A recently abandoned meadow in Småland. *Photos: Markus Franzén*.

to considerable nitrogen deposition from the atmosphere (wet deposition: 10–12 kg ha-1 year-1; Öckinger et al. 2006b) causing a decrease in floral and butterfly diversity (Bobbink et al. 1998; Öckinger et al. 2006b). Nevertheless, despite decreases in semi-natural grasslands, changed harvesting regimes and continuing atmospheric nitrogen deposition, the small-scaled nature of many parts of the landscape still harbours some of the most diverse and attractive pastoral landscapes of Sweden (Figure 1). Small-scale farms still occur with their cattle grazing the landscape's pastures and the butterfly fauna still remains richer than in most other parts of Sweden.

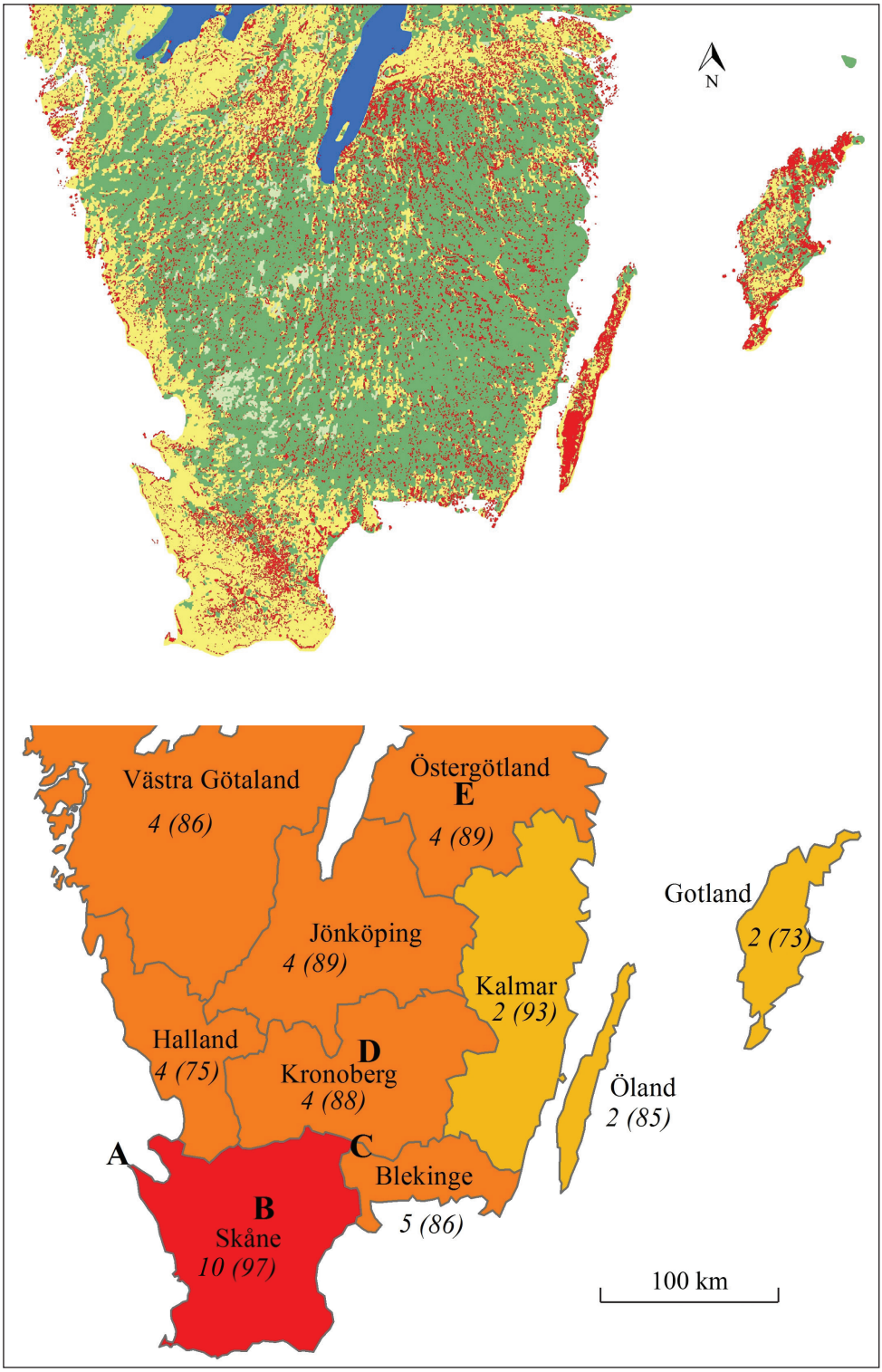
Main grassland types in the area

Administratively, the studied area is split into nine counties (Figure 2) which, together with the Baltic island Öland, form the basis for our analysis of extinction events (cf. Gärdenfors 2010). The study area contains a wide variety of grasslands, ranging from fertilized and managed swards still being traditionally managed by farmers and local enthusiasts in late summer (Franzén and Nilsson 2008; Franzén and Ranius 2004a; Nilsson et al. 2008). Extensively grazed woodlands or tree-rich pastures are not uncommon in the area and mirror some of the 19th century grazing commons, although many of today's tree-rich pastures are formerly open ones that have become more closed over time (Nilsson et al. 2008; Öckinger et al. 2006b). Overall, semi-natural grasslands that are intensively grazed and that have sometimes been fertilized earlier are the dominating grassland habitat. Cattle and horse grazing dominate, but sheep grazing has increased in the area.

Extent of habitat types in the area

The proportion of the landscape that consists of pastures and hay meadows in this area is approximately 5% (Data from the Swedish Board of Agriculture; Anon. 2008). In terms of area, the amount of pasture in some of the counties covered range from

Figure 2. Upper map: Main habitats in southern Sweden (dark green= forest; light green = wetlands; yellow = arable fields; blue = water; red = semi natural grasslands; data from (SNA 1996) and the Swedish national survey of semi-natural meadows and pastures (TUVA database, https://etjanst.sjv.se/tuvaut/site/index.htm [Access date 2013-03-25]). **Lower map**: Delimitations of the nine counties and the province (Öland, which forms a separate province but administratively belongs to the county of Kalmar) in south Sweden that were studied. The number of extinct butterfly and burnet moth species in each region (Gärdenfors 2010) are given together with the total number of observed butterfly and burnet moth species in region (in brackets; data from Catalogus Lepidopterorum Suecicae, http://www2.nrm.se/catalogus.html [Access date 2013-03-25]). A redder colour indicates a higher number of extinct species. Thus, the county of Skåne has 10 extinct butterflies and burnet moths out of a total of 97 observed species. The capital letters denote the areas where the five different local studies was performed; **A** (Franzén and Johannesson 2007) **B** (Andersson 2002) **C** (Öckinger et al. 2006b) **D** (Nilsson et al. 2008) **E** (Douwes 2004). Study C was performed in Skåne, Blekinge and Kronoberg. Only Swedish territory is shown on the map.


N
Västra Götaland
4 (86)
Östergötland
E
4 (89)
Jönköping
4 (89)
Kalmar
2 (93)
Gotland
2 (73)
Halland
4 (75)
D
Kronoberg
4 (88)
Öland
2 (85)
A
C
Blekinge
5 (86)
B
Skåne
10 (97)
100 km

21,000 hectares in the county of Kronoberg (part of the Swedish province Småland), to 77,000 hectares in the county of Kalmar (covers eastern parts of Småland as well as the island Öland). On average, these southern Swedish counties each contain about 43,000 hectares of pasture (Data from the Swedish Board of Agriculture; Anon. 2012). The extent of hay meadows with traditional late harvest is very low, and is about 7,800 hectares for Sweden as a whole (Anon. 2012). Furthermore, about 35% of these 7,800 hectares come from farms smaller than 2 hectares (Anon. 2008), demonstrating that much of the traditional hay harvest is done by local enthusiasts rather than being part of regular farm economy. The area used as hay meadows is also highly variable between counties as demonstrated by its range of 75 hectares in Blekinge to 1,998 hectares in Skåne (Anon. 2012). On average, the area is 566 hectares per county but heavily influenced by the large area in Skåne. In contrast, the area used for short- and long-term ley ranges from 16,000 to 123,000 hectares, with 38,000 in the focal area (Anon. 2012). The extent of these habitat types within Natura 2000 in the focal area of Småland, Kronoberg County, is 928 hectares pasture (4.4% of the total pasture area) and 70 hectares hay meadows (35% of the total hay meadow area) according to the latest (2012) data from the Swedish Board of Agriculture.

Butterfly and burnet moth trends in the area

Five studies during the last decade have documented distinct decreases in butterfly and burnet moth species richness in southern Sweden (Table 1, Figure 2). It should be noted that burnet moths are generally included in butterfly surveys in Sweden because of the two groups' similar habitat requirements and ecology and we follow this tradition here (Franzén and Ranius 2004a, b; Nilsson and Franzén 2009; Pettersson et al. 2012). In Skåne and Östergötland, two early studies documented declines in butterfly species richness, from around 70 butterfly species in the Ringsjö area of Skåne in the 1870s to half as many in the 1990s (Andersson 2002). In the Östergötland study Douwes (2004) found a decrease of the butterfly fauna but the area still harboured a high number of butterfly species.

After these two pioneering papers, long term declines in countryside butterfly diversity have been documented in detailed studies from the focal area of the present report (Table 1). From Kullaberg in north-western Skåne, a 45% loss from the initial 50 butterfly species has been documented between 1953 and 2005 within a 1000 hectare area of mixed forest and agricultural land (Franzén and Johannesson 2007). In the village Nöbbele, Småland, a 450 hectare area in a typical forest dominated agricultural landscape, 44% of the 48 butterfly species present in 1910 were extinct in 2003 (Nilsson et al. 2008). Similarly, a survey investigating changes in the butterfly and burnet moth fauna in a set of 13 pasture-dominated plots in Skåne, Blekinge and Småland between 1981 and 2002 found that an average 35% of the original 30 species found in pastures of this study (with a combined area of 328 hectare area) had gone extinct (Öckinger et al. 2006b). Considerably fewer species had colonised the three areas sur-

Table 1. Butterfly and burnet moth species that have disappeared (*Extinct*), decreased in numbers (*Decrease*), increased (*Increase*) or remained relatively unchanged (*Unchanged*) in abundance in three systematic resurveys in southern Sweden at Kullaberg (*Kullaberg*; Franzén and Johannesson 2007), Nöbbele (*Nöbbele*; Nilsson et al. 2008) and in 13 pasture areas (*Pastures*; Öckinger et al. 2006b), as well as their main habitat (*Grassland, Wetland, Forest;* cf. Eliasson et al. 2005), and the main larval food plants of each species in these areas. Burnet moths are indicated with asterisks (*). Species not present in a study are indicated with dashes (-). Only species that had decreased or increased in at least two of these three studies are included in the table. Species not reproducing in Sweden are excluded. Positions of the studies are indicated with capital letters in Figure 2.

Species	Grassland, Wetland or Forest	Kullaberg	Nöbbele	Pastures	Major larval food plants
*Adscita statices**	G	Unchanged	Decrease	Decrease	*Rumex acetosella* *Rumex acetosa*
Anthocharis cardamines	G	Unchanged	Decrease	Decrease	Brassicaceae
Aporia crataegi	G	Extinct	Extinct	Extinct	*Sorbus aucuparia* *Crataegus*
Araschnia levana	G	Increase	-	Increase	*Urtica dioica*
Argynnis adippe	G	Extinct	Extinct	Decrease	*Viola* spp.
Argynnis aglaja	G	Extinct	Unchanged	Decrease	*Viol*a spp.
Boloria euphrosyne	W	Extinct	Decrease	Decrease	*Vaccinium uliginosum*
Boloria selene	G	Extinct	Unchanged	Decrease	*Viola*, especially *Viola palustris*
Coenonympha pamphilus	G	Unchanged	Decrease	Decrease	Poaceae
Colias palaeno	W	Extinct	Extinct	-	*Vaccinium uliginosum*
Cupido minimus	G	Extinct	Extinct	-	*Anthyllis vulneraria*
Erynnis tages	G	Extinct	-	Extinct	*Lotus corniculatus*
Favonius quercus	G	Unchanged	Decrease	Decrease	*Quercus*
Hesperia comma	G	Extinct	Extinct	Decrease	*Festuca ovina* *Festuca rubra* *Agrostis vinealis*
Lasiommata maera	G	Extinct	Decrease	Decrease	Poaceae
Leptidea sinapis	G	-	Extinct	Extinct	*Lathyrus linifolius*
Limenitis populi	F	Extinct	Extinct	-	*Populus tremula*
Lycaena hippothoe	G	Extinct	Extinct	Decrease	*Rumex acetosa* *Rumex acetosella*
Lycaena virgaureae	G	Extinct	Extinct	Decrease	*Rumex acetosa*
Maculinea arion	G	-	Extinct	Extinct	*Thymus* *Origanum vulgare*
Melitaea athalia	G	Extinct	Decrease	Decrease	*Melampyrum*
Melitaea cinxia	G	Extinct	-	Extinct	*Veronica spicata* *Plantago lanceolata*
Nymphalis polychloros	F	Extinct	Extinct	-	*Ulmus*, *Salix*
Papilio machaon	G	Extinct	Extinct	Extinct	*Peucedanum palustre* *Pimpinella saxifraga*
Plebejus optilete	W	Extinct	Decrease	Unchanged	*Andromeda polifolia* *Vaccinium oxycoccos* *Vaccinium uliginosum*

Species	Grassland, Wetland or Forest	Kullaberg	Nöbbele	Pastures	Major larval food plants
Polyommatus semiargus	G	Extinct	Extinct	Decrease	*Trifolium pratense*
Pyrgus malvae	G	Unchanged	Decrease	Decrease	*Fragaria vesca* *Potentilla*
Satyrium pruni	G	Extinct	-	Decrease	*Prunus spinosa*
Thecla betulae	G	Extinct	-	Extinct	*Prunus spinosa* *Prunus padus*
*Zygaena filipendulae**	G	Unchanged	Extinct	Decrease	*Lotus corniculatus*
*Zygaena lonicerae**	G	Extinct	Extinct	Decrease	*Trifolium medium*
*Zygaena viciae**	G	Extinct	Unchanged	Decrease	*Lathyrus linifolius* *Vicia cracca*

veyed, 4% were new at Kullaberg in 2005, 6% were new at Nöbbele in 2003 and on average 18% were new in the 2002 survey of pasture-dominated landscapes.

It is worth noticing that most historical Swedish butterfly information on trends is based on presence/absence data as relatively few quantitative analyses have been carried out over time (Eliasson et al. 2005). However, there is now a nationwide butterfly monitoring scheme in Sweden with about 25% of its 271 monitored sites at least partially covering agricultural land on a yearly basis (Pettersson et al. 2012). This new Swedish data is included in the 2012 revision of the European Butterfly Indicator for Grassland species (van Swaay et al. 2013).

In total, 130 butterflies and burnet moths have been recorded in Sweden; 117 of these are resident and another 13 species occur sporadically. While no species have become extinct from Sweden during the last four decades, 40 butterfly and burnet moth species are included in the latest Red List (Gärdenfors 2010). In the counties which we cover in this review, an average of 4.3 species has become regionally extinct, with the southernmost county Skåne suffering the greatest loss with 10 extinct species (Figure 2, Table 2). The majority of the Red Listed butterfly species in Sweden are closely associated to species-rich unfertilized grasslands (cf. Eliasson et al. 2005; Gärdenfors 2010).

Trends in European Butterfly Indicator species in the area

In Sweden, we presently have 12 of the 17 different grassland species included in the European Butterfly Indicator for Grassland species (Pettersson et al. 2012; van Swaay et al. 2013). These include Dingy Skipper (*Erynnis tages*), Large Skipper (*Ochlodes sylvanus*), Orange Tip (*Anthocharis cardamines*), Small Copper (*Lycaena phlaeas*), Little Blue (*Cupido minimus*), Large Blue (*Maculinea arion*), Mazarine Blue (*Polyommatus semiargus*; Figure 3), Common Blue (*Polyommatus icarus*), Marsh Fritillary (*Euphydryas aurinia*), Wall Brown (*Lasiommata megera*), Small Heath (*Coenonympha pamphilus*), and Meadow Brown (*Maniola jurtina*) (Pettersson et al. 2012). Several of these are characteristic of many types of grassland in southern Sweden. Five of them, Dingy Skipper, Orange

Table 2. Butterfly and burnet moth species listed in the Swedish Red List as extinct from the studied counties in southern Sweden (Gärdenfors 2010). Extinctions are indicated with the sign †.

Species	Skåne	Blekinge	Gotland	Öland	Kalmar	Kronoberg	Jönköping	Halland	Västergötland	Östergötland
Argynnis niobe						†	†			
Coenonympha hero	†					†				
Euphydryas aurinia	†						†			†
Euphydryas maturna	†	†								
Hamearis lucina	†	†								
Limenitis camilla	†									
Lopinga achine	†									
Lycaena hippothoe			†							
Maculinea arion						†	†	†		†
Melitaea britomartis							†			†
Melitaea cinxia								†		
Melitaea diamina									†	
Parnassius apollo	†	†				†	†	†	†	
Parnassius mnemosyne	†		†	†	†					†
Polyommatus dorylas		†			†					
Pyrgus alveus	†	†		†						
Satyrium ilicis								†	†	
Zygaena osterodensis	†								†	
Total	10	5	2	2	2	4	5	4	4	4

Tip, Large Blue, Mazarine Blue, and Small Heath have all been disappearing or strongly decreasing in two or three of the detailed studies covering Kullaberg, Nöbbele, and the 13 pasture-dominated landscapes in Skåne, Blekinge and Småland (Franzén and Johannesson 2007; Nilsson et al. 2008; Öckinger et al. 2006b) causing concern for the future. Surprisingly, many species that were numerous just a few decades ago have more or less disappeared from the surveyed areas; among those Silver-spotted Skipper (*Hesperia comma*), Scarce Copper (*Lycaena virgaureae*; Figure 3), Purple-edged Copper (*Lycaena hippothoe*; Figure 3), High Brown Fritillary (*Argynnis adippe*), and Mazarine Blue.

Among species associated with forest glades and wetlands, Moorland Clouded Yellow (*Colias palaeno*), Pearl-Bordered Fritillary (*Boloria euphrosyne*) and the glade-inhabiting Wood White (*Leptidea sinapis*) have all decreased markedly (Nilsson and Franzén 2009). The Moorland Clouded Yellow and the Pearl-Bordered Fritillary both utilize Bog Bilberry (*Vaccinium uliginosum*) which is a low nitrogen specialist that may suffer from the ongoing nitrogen deposition. The three spectacular species Black-veined White (*Aporia crategi*), Poplar Admiral (*Limenitis populi*), and Swallowtail (*Papilio machaon*) have all disappeared from the areas investigated in the three detailed studies

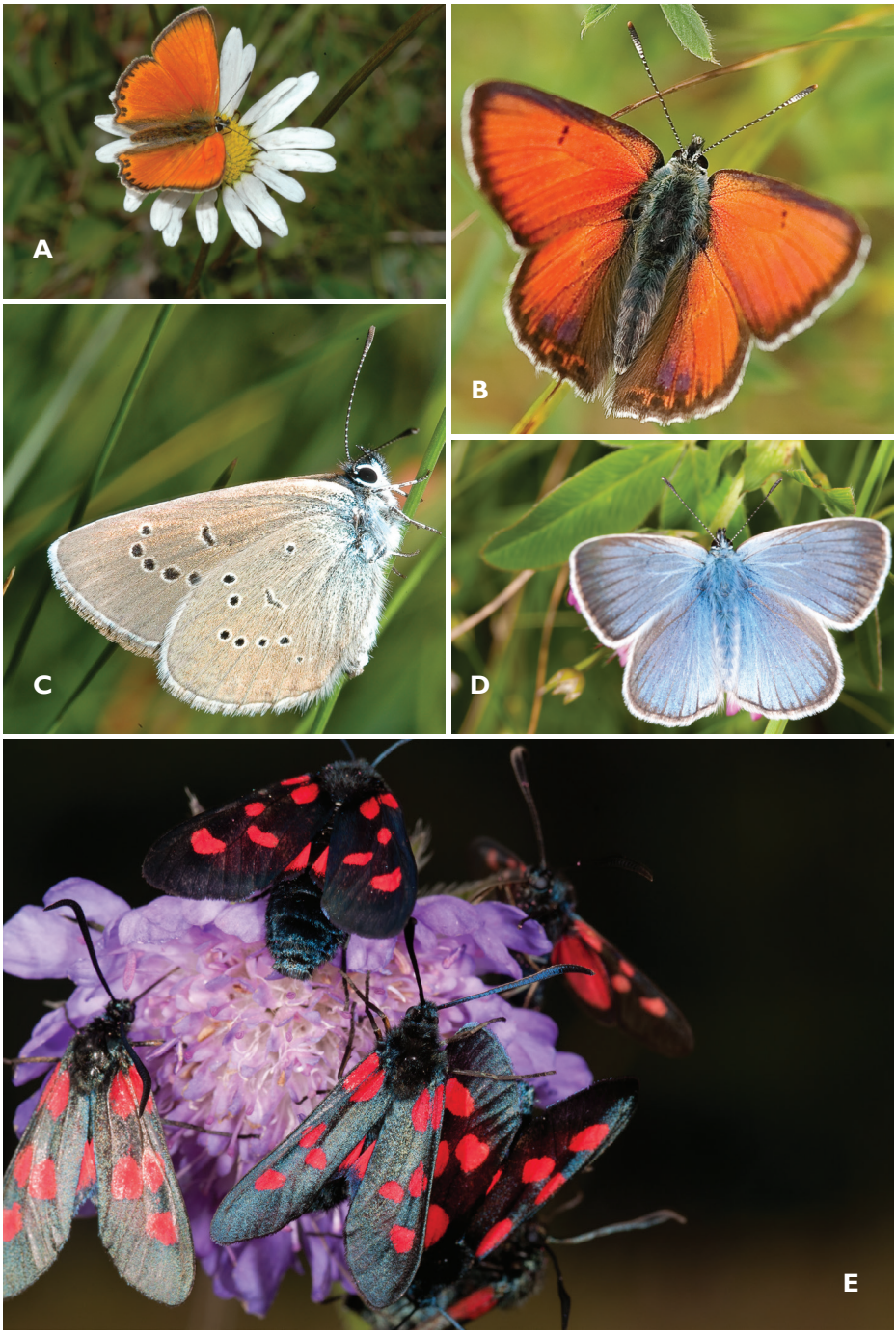


Figure 3. Butterflies and burnet moths associated with semi-natural grasslands in the area: **A** Scarce Copper (*Lycaena virgaureae*) **B** Purple-edged Copper (*Lycaena hippothoe*) **C** Mazarine Blue (*Polyommatus semiargus*) **D** Amanda's Blue (*Polyommatus amandus*) **E** New Forest Burnet (*Zygaena viciae*) and Narrow-bordered Five-spot Burnet (*Zygaena lonicerae*). *Photos: Markus Franzén.*

(Franzén and Johannesson 2007; Nilsson et al. 2008; Öckinger et al. 2006b). While these negative trends in grasslands and other habitats represent considerable losses in diversity, there are also species expanding their ranges. Two species with nitrogen-favoured larval host plants are currently highly successful and are rapidly expanding to the north through southern Sweden: the Map Butterfly (*Araschnia levana*) and the Purple Emperor (*Apatura iris*) (Betzholtz et al. 2013; Pettersson et al. 2012).

Trends in land use and farming systems affecting the habitat types

The land use in the focal area has changed dramatically over the last decades. Before Sweden joined the European Union in the early 1990s, there was a period when large farmland areas were used as set-asides in order to reduce subsidised production of wheat and other crops. The set-asides of these areas had a major positive impact on the population sizes of several bird species (Wretenberg et al. 2007). The effect on butterflies remains little studied in Sweden but data from Finland and the UK indicate positive effects on butterflies, moths and bumblebees (Alanen et al. 2011; Merckx et al. 2009). Soon after Sweden joined the European Union, these large set-asides were taken back into production. At the same time, grazing of pastures intensified for a number of reasons. Partly, authorities encouraged the use of high grazing pressure to increase floral diversity, which had been high during historical periods of intensive grazing. Intensive grazing is also easily quantifiable as the sward is kept to a measurable height, and this may also have contributed to the implementation of sward height regulations for farmers to qualify for agricultural subsidies. The movement towards more intensive grazing also led to larger areas being grazed by sheep (Figure 4). Sheep grazing is generally more negative for butterflies and burnet moths than cattle and horse grazing (Öckinger et al. 2006a). New results suggest that careful management and timing of sheep grazing can reduce negative effects substantially (van Noordwijk et al. 2012) but these approaches have not yet been widely adopted. Altogether, changes in land use and grazing pressure beginning in the early 1990s led to a marked decline in flower availability in summer in the southern Swedish agricultural landscape (Franzén and Nilsson 2008; Nilsson and Franzén 2009). Cattle farmers and horse owners were recommended to let their animals graze intensively, and sheep selectively grazed herbs. This heavy grazing regime, often applied early in the season and homogenously within whole pastures, has had clear negative impacts on many butterflies and disastrous impacts on burnet moths (Nilsson and Franzén 2009; Öckinger et al. 2006a; Öckinger et al. 2006b).

Another trend in recent years has been to harvest hay earlier and earlier, moving the onset of hay harvest back from around Midsummer to early June, and now often to late May (Franzén and Nilsson 2008; Nilsson et al. 2008). Much of the hay harvest has now been replaced by repeated bale silage which commonly starts as early as May and then continues 2-3 times throughout the summer (Figure 4). Although much of the bale silage is based on ley harvest from former arable fields, it is also being practised

Figure 4. Three examples of sites less suited for butterflies: **A** Intensified hay cutting of ley fields has a strong negative effect on the butterfly fauna. Here is a storage place for bale silage close to a former Clouded Apollo, *Parnassius mnemosyne,* site in Blekinge **B** Succession of former semi-natural grasslands due to abandonment and **C** Intensive grazing early in the season as here by sheep can be devastating for many butterflies, their eggs, larvae and pupae as well as for nectar resources. *Photos: Markus Franzén.*

in former hay fields (Nilsson et al. 2008). Bale silage is increasing rapidly throughout Sweden and the deployment is already nearly 100% in many areas. Woodland grazing was common 50-100 years ago, but is unfortunately used much less today. This type of management is important for maintaining sparsely vegetated and semi-open woodlands with glades that constitute important butterfly habitats (Nilsson and Franzén 2009; Nilsson et al. 2008). Grazed woodlands in Sweden do not qualify for the same subsidies from EU as semi-natural pastures do, a problem which has received much attention lately but still remains unresolved (Anon. 2010). Small scale farming is not an economically attractive profession today and this has led to a dramatic decrease in the number of farmers as well as an increase in the number of livestock per farm remaining. The disappearance of small to medium-sized farms initiates vegetation succession in semi-natural grasslands and gradually transforms these grasslands into forests (Figure 4). This is especially prominent in the forest dominated regions with low produc-

tive soils, where traditional management survived until recently. On the productive plains, small to medium-sized farms were merged into larger units and converted to intensively used arable fields several decades ago.

Wetlands in the agricultural landscape have been drained in many places, and the butterflies of these areas were often seeking nectar on the surrounding meadows and pastures. Thus, because of the interactive effect of wetland draining and flower-rich pastures and meadows disappearing, species associated with wetlands have declined in the area during the last 50 years (Nilsson and Franzén 2009).

Comparisons with other regions

The present results from southern Sweden show an interesting parallel to studies elsewhere in Europe (Kuussaari et al. 2007; van Swaay et al. 2011; van Swaay et al. 2006; Wenzel et al. 2006). It seems that species that are severely decreasing in southern Sweden already have gone extinct from the UK, the Netherlands, and Denmark or are also declining rapidly there. On the other hand, expanding species in Sweden seem to be increasing also in other countries (Betzholtz et al. 2013; Fox et al. 2011). Interestingly, butterfly distribution changes and population trends in southern Sweden show striking similarities with corresponding processes in Finland (Kuussaari et al. 2007; Pöyry et al. 2009). The general trends appear to be pronounced decreases of butterfly species and a shift in species composition from species associated with flower rich grasslands and dry grasslands, such as the Large Blue (*Maculinea arion*), towards a fauna dominated by species associated with nitrogen rich habitats, which can tolerate intensive agriculture as well as successional habitats with less suitable colder microclimatic conditions, such as the Map Butterfly and the Large Skipper *Ochlodes sylvanus* (Dennis 2010; van Swaay et al. 2013).

Grassland management

Current management and the European Union Common Agricultural Policy (CAP) regulations as applied in Sweden and elsewhere (Batary et al. 2011; Kleijn et al. 2006; Kleijn and Sutherland 2003) favour intensive grazing on the remaining semi-natural grasslands, with strong negative effects on butterfly diversity (Dover et al. 2011; Franzén and Nilsson 2008; Konvicka et al. 2008; Pöyry et al. 2004). The presumed effects on plant diversity have not been unequivocally verified, compared to the relatively lower and more varied grazing pressure before 1995 in Sweden (Söderström et al. 2001; Vessby et al. 2002). Instead, domestic animals have been concentrated on a smaller area; while much semi-natural grassland on small patches and low fertility land has been abandoned. As an example, the threatened butterfly Clouded Apollo, *Parnassius mnemosyne,* disappeared from most of its few remaining sites in Blekinge when subsidies where applied to manage grasslands (Franzén and Imby 2008) and a similar decline can be expected for other species as intense and early grazing is detrimental for

many butterfly species and, in particular, burnet moths (Franzén and Nilsson 2008; Franzén and Ranius 2004a, b; Figure 4). Today, abandoned grasslands are very common in less productive areas and might in a near future become transformed into forests. There is an urgent need for immediate action to preserve the most endangered types of grassland vegetation such as unfertilized, mown and lightly grazed areas, as well as to manage the abandoned grasslands before it is too late (Skorka et al. 2007).

Based on the examples above, on conservation practitioners experience (cf. Kleijn and Sutherland 2003; Sutherland et al. 2004) and recent literature (Dahlström et al. 2008; Dover et al. 2011; Franzén and Nilsson 2008; Konvicka et al. 2008; Nilsson et al. 2008; Öckinger et al. 2006a; Pöyry et al. 2004; van Noordwijk et al. 2012; van Swaay et al. 2012), we believe the following measures are likely to be highly valuable for the butterfly and burnet moth fauna if implemented in the remaining grasslands of Sweden and similar parts of Europe.

- Later grazing, and grazing in segmented/split parcels so that some parts of pastures can grow taller and keep nectar resources longer in summer.
- Reduced grazing pressure in spring and early summer on herb-rich sites.
- Rotational grazing with some semi-natural grassland grazed only in late summer in some years.
- Hay cutting later in summer, preferably in late July, and once per season, followed by grazing of cattle in September–October.
- Herb rich grasslands should preferably be grazed by cattle or horses rather than sheep.
- If sheep are used, grazing needs careful management and timing to minimize negative effects on nectar resources.
- Implementation of policy measures that reduce in the overall nitrogen deposition from the atmosphere.
- Burning grasslands when the vegetation is dry in early spring, before the middle of April.
- Soil disturbance measures where fertilized top soil is removed, particularly at sun-exposed, sandy sites.
- Young invading trees (bushes), expanding shrubs, invading brackens and other expanding plant species should be removed.
- Spruce and pine plantations must cease on low fertility, semi-natural grassland sites.
- Implementation of compensation action from activities with negative impacts on butterfly habitats.

Acknowledgement

Markus Franzén was supported by the STEP-project (grant 244090–STEP–CP–FP; Potts et al. 2011). Lars B. Pettersson was funded by Lund University and the Swedish Environmental Protection Agency. We thank Alrun Siebenkäs for proofreading of an earlier draft. The research presented in this paper is part of the strategic research area Biodiversity and Ecosystems in a Changing Climate, BECC.

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