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Species richness and abundance of butterflies in natural and drained mires in Finland

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Introduction

Approximately half of Finnish peatlands have been drained for forestry. However, there is considerable variation regionally, and in particular in southern half of Finland ca 80-90 % of the original mire area has been ditched. Drainage was most intensive in 1960s and 1970s, but ditching has gradually decreased since that. Drainage has extensive effects on flora and fauna of mire habitats (Laine & al. 1995b, Aapala & Lappalainen 1998a, Aapala & Lappalainen 1998b, Vasander 1998, Heikkilä & al. 2002). Restoration of drained mires has began relatively recently and the research based knowledge of the ecological effects of the restoration are still forthcoming. Nevertheless, in order for the restoration to be effective, the ecological effects of restoration must be known. Therefore, the monitoring of the effects of restoration should be planned and carried out carefully in experimental setups with appropriate controls.

There is a distinctive butterfly fauna associated with mire habitats and the highest butterfly species richness is found in pine mires with stunted and patchily distributed pines (Mikkola & Spitzer 1983, Marttila & al. 1990, Väisänen 1992). In Finland, drainage has been heavily concentrated on these mire types (Eurola et al. 1991), and it is suggestive that it is the mire butterflies associated in these habitats that have clearly declined (Pöyry 2001, Marttila 2005). Interestingly, the extensive drainages have been carried out 30-40 years ago, but the declining of mire butterfly populations have been observed only during the last 10-20 years. The reason may be that there are no empirical studies carried out before. However, this phenomenon may also reflect the fact that species seem to persist in an area some time after the area has already become unsuitable; this phenomenon is known as extinction debt (Tilman & al. 1994, Hanski & Ovaskainen 2002).

Many mire butterfly larvae feed on rather common mire plants, e.g. *Rubus chamaemorus*, *Vaccinium uliginosum* or *V. oxycoccos*, many of which grow on hummocks. Dwarf shrubs and hummock plants usually decline less or even increase after the drainage. They start to decline only when the forest becomes too dense and shady, which may take decades (Laine & al. 1995a).

Other factors, such as physical characteristics of the habitat and the microclimate, may be more important for mire butterflies than the mere plant species composition (Väisänen 1992, Marttila 2005). Indeed it seems that most effects on butterfly adult and larvae populations are caused by changes in mire microclimate (Laine & al. 1995b, Pöyry 2001). Mire species that have been suggested to be most vulnerable to habitat changes are e.g. *Pyrgus centaureae*, *Clossiana freija*, *Clossiana frigga* and *Erebia embla* (Pöyry 2001).

The aim of the research presented here was two fold: i) to determine the effects of drainage on total abundance of the mire and generalist butterflies, on species richness of mire and generalist butterflies and on the abundance of each individual species and ii) to establish a replicated experimental setup to allow effective monitoring of the effect of restoration on the butterflies and to collect before restoration treatment data on the variables listed above. A section of each of the study areas was due for restoration after the study (Figure 1) and the restoration was completed during the winters 2003-2004 and 2004-2005.

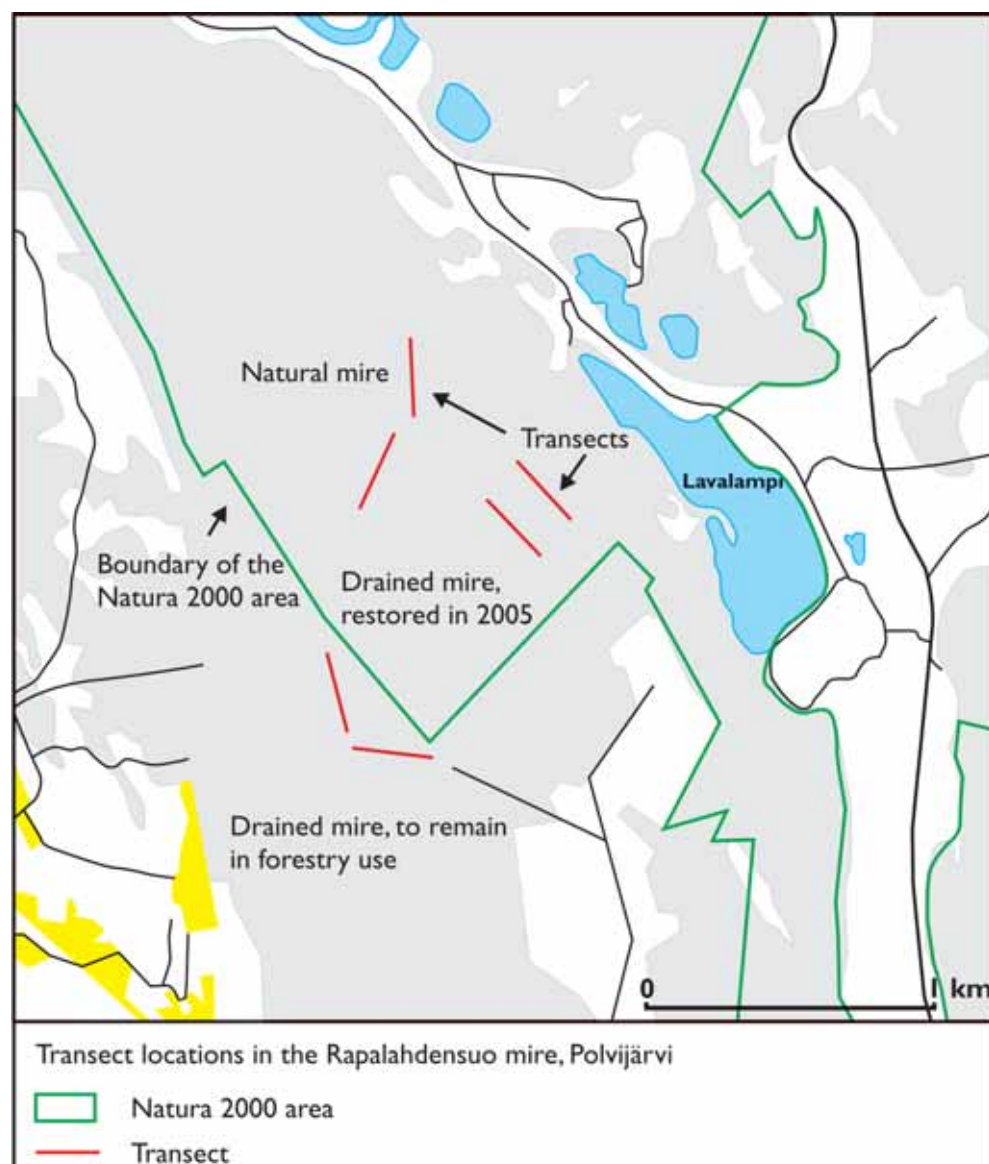


Figure 1. Transect locations in the mire Rapalahdensuo, Polvijärvi.

Materials and methods

Study areas

The study was conducted at nine mires in southern Finland (Table 1, Figure 2). Four study areas were located in Central Finland province and five areas in North Carelia province in eastern Finland. Study areas were located in the mire complexes which included both drained and natural mire habitats. We chose the study areas in the mires where mire habitat type would have been as uniform as possible if the mires had not been drained in the past. It may be expected that level of ground water has been affected also in the “natural” parts of the study mires. In this study we call the unditched mires as natural.

Natural habitats i.e. the undrained parts of the mires are included in the Natura 2000 network. Some areas are included also in the Finnish mire conservation programme. Two mires in Kulhanvuori are part of the Kulhanvuori Natura area. Parts of the mires in Kulhanvuori were drained in the end of 1960s or in the beginning of 1970s. Some of the ditches were cleaned in 1980s (Kuosmanen, pers. comm. 5.11.2004). Väljänneva and Kiemanneva are included in the Seläntauksen suot Natura area. Also parts of these mires were drained in the end of 1960s or in the beginning of 1970s (Kuosmanen, pers. comm. 5.11.2004).

Juurikkasuo, Heinäsuo and Ristisuo are included in the Koitajoki Natura area. Parts of Heinäsuo mire were drained in 1977 and Juurikkasuo mire in 1967. Juurikkasuo mire was fertilised in 1968 and the ditches were cleaned in 1987. The drainage plan of Ristisuo was made in 1977 and the mire was drained probably shortly after the plan was finished (Similä, pers. comm. 5.11.2004). Both Rapalahdensuo mire and Tiaissuo mire are included in Viklinrimpi Natura area. Both mires were drained between 1965-1975, probably in the end of 1960s (Kondelin, pers. comm. 5.11.2004).

The most common natural mire habitat type in the study areas was pine mire. The most common pine mire types were ordinary dwarf-shrub pine bog, *Eriophorum vaginatum* pine bog, *Empetrum-Fuscum* bog and *Calluna-Fuscum* bog. The study areas contained also fens and combination site types. All the combination site types were combinations of fen and pine mire. The field and bottom layer vegetation and the tree stand structure in drained parts of the study mires resembled forest structure.

Table 1. The location of the study areas, main natural mires types and the date of drainage.

Study area	Municipality	Coordinates	Main natural mire type	Date of drainage
Kulhanvuori, Iso-Musta	Multia, Saarijärvi	62°34' N, 24°57' E	Pine mire	The end of 1960s or the beginning of 1970s
Kulhanvuori, Iso Sarasuo	Saarijärvi	62°35' N, 24°58' E	Combination type	The end of 1960s or the beginning of 1970s
Väljänneva	Pihtipudas, Kinnula	63°19' N, 25°18' E	Combination type	The end of 1960s or the beginning of 1970s
Kiemanneva	Pihtipudas	63°23' N, 25°16' E	Pine mire	The end of 1960s or the beginning of 1970s
Ristisuo	Ilomantsi	62°56' N, 31°21' E	Pine mire	The end of 1970s
Juurikkasuo	Ilomantsi	62°57' N, 31°26' E	Pine mire	1967; fertilised 1968; ditches cleaned 1987
Heinäsuo	Ilomantsi	62°54' N, 31°28' E	Pine mire	1977
Rapalahdensuo	Polvijärvi	62°54' N, 29°30' E	Combination type	Between 1965-1975
Tiaissuo	Polvijärvi	62°56' N, 29°24' E	Pine mire	Between 1965-1975



Figure 2. Study area locations

Our experimental design was such that we chose three different study sites (treatments) in each of the nine study areas: i) natural mire habitat, ii) drained mire habitat to be restored after the study and iii) drained mire habitat remaining in forestry use in the future. In each of the treatments we established two 250 m long transects for butterfly monitoring resulting in six transects per study area (Figure 1). The study included 54 transects in all. To determine the effects of drainage on butterflies, we combined the treatments ii) and iii) in the analyses. This is possible because the restoration of drained mires were not made until after our study.

Transect method

In the study we used a transect method developed by Pollard (1977; see also Somerma & Väisänen 1990). The method has proved to be effective in studies on habitat preferences of butterflies and on the species diversity of various habitats. Butterfly counting was conducted in transects which were marked permanently by wood sticks or tape in the field.

Field studies were carried out during the summer 2003. Counts started in the second week of May and they were carried out weekly through the summer. The last counts were made on the third week of August. Total number of counts was 15 in Central Finland and 12 in North Carelia.

During the butterfly monitoring, the recorder walked slowly and at the steady pace along the transect and recorded all butterflies seen within 5 × 5 m square in front of the recorder (5 m forward and 2.5 m left and right from the recorder). If the recorder was not able to identify the species in flight, the individual was caught with a butterfly net. The count was stopped until identification of this individual was made and restarted

from the point where the recording was interrupted. The butterfly individual was released after identification. Each butterfly individual was counted only once. The result of every count was marked on the field observation sheet. On the sheet was also marked the study area, the treatment, the date, the name of a recorder, starting time, sun condition (sunny, half shadow, shadow), temperature and strength of the wind using the Beaufort scale (Somerma & Väisänen 1990).

The weather conditions were taken into account on the transect counts. Counts were not made when the temperature was below 13°C. If temperature was between 13–17°C counts were carried out only in sunny conditions (minimum 60 % sunshine). Above 17°C weather conditions might be cloudy but not rainy. Temperature was measured 1.5 m above ground. Counts were made mainly between 11 a.m. and 4 p.m. The time limits were not strictly followed when the conditions were otherwise good (Somerma & Väisänen 1990). In the study we observed superfamilies Hesperioidea and Papilionoidea. Butterflies were identified to species level. The nomenclature follows Marttila & al. (2001).

We categorized butterflies into mire butterflies and generalist butterflies. Mire butterflies that were recorded in the study were *Boloria aquilonaris*, *Clossiana freija*, *Clossiana frigga*, *Colias palaeno*, *Coenonympha tullia*, *Erebia embla*, *Procllossiana eunomia* and *Pyrgus centaureae*. These species feed as larvae and reproduce mainly on mire habitats. Some of these species may fly also in other habitats, e.g. on shores (*B. aquilonaris*, *C. tullia*). *C. freija*, *C. frigga*, *E. embla*, *P. eunomia* and *P. centaureae* feed and reproduce only in mire habitats. Generalist butterflies refer to species that fly and reproduce also in other habitats than in mires (Marttila & al. 1990, Pöyry 2001). In this article, we use the names mire butterflies and generalist butterflies to refer to these butterfly categories.

Statistical analyses

Differences of butterfly total abundance and species richness between study areas and the treatments were analysed with analysis of variance (ANOVA). As the study was completed in two geographically distant provinces (Figure 2), the province was initially included in the analyses. As expected not one of the results were dependent on the province and thus it was excluded from the final analyses. In the analyses we included the treatment, the study area and the interaction between the two. However, not one of the interactions were significant, and they were excluded from the final analysis. Abundance data was (ln+1)-transformed before the analyses. Statistical analyses were performed with SPSS version 14.

Results

The total sample comprised of 1909 individual observations from 21 butterfly species. Eight species were classified as mire species and 13 as generalist species.

Total abundance and the species richness of mire butterflies were significantly higher in natural mire habitats than in drained habitats (Table 2, 3, Figure 3, 4). However, when we analysed the generalist species the pattern was different: there were no difference in the total abundance or in the species richness between natural and drained habitats (Table 4, 5, Figure 5, 6).

When we analysed the effect of drainage on the abundance of each species we found that five of the mire butterflies and two of the generalist butterflies were significantly

Table 2. Total abundance of mire butterflies

Source	SS	df	MS	F	P
Area	17.99	8	2.25	4.18	0.001
Drainage	16.87	1	16.87	31.34	< 0.001
Error	23.68	44	0.54		

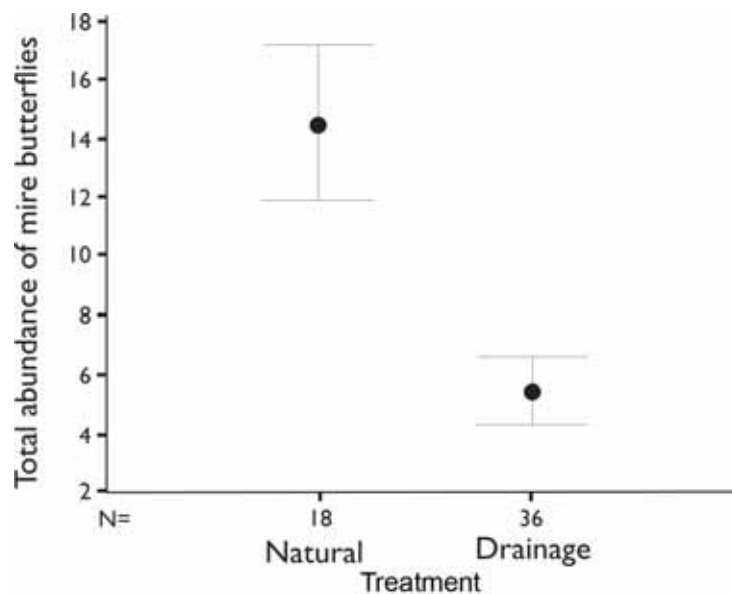


Figure 3. Total abundance of mire butterflies

Table 3. Species richness of mire butterflies

Source	SS	df	MS	F	P
Area	27.26	8	3.41	2.42	0.029
Drainage	45.37	1	45.37	32.22	< 0.001
Error	61.96	44	1.41		

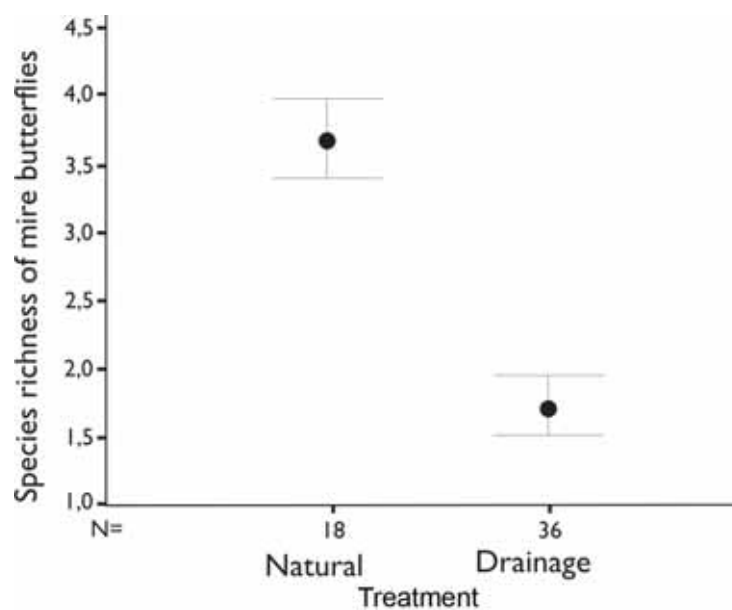


Figure 4. Species richness of mire butterflies

Table 4. Total abundance of generalist butterflies

Source	SS	df	MS	F	P
Area	23.65	8	2.96	4.54	< 0.001
Drainage	0.40	1	0.40	0.61	0.438
Error	28.66	44	0.65		

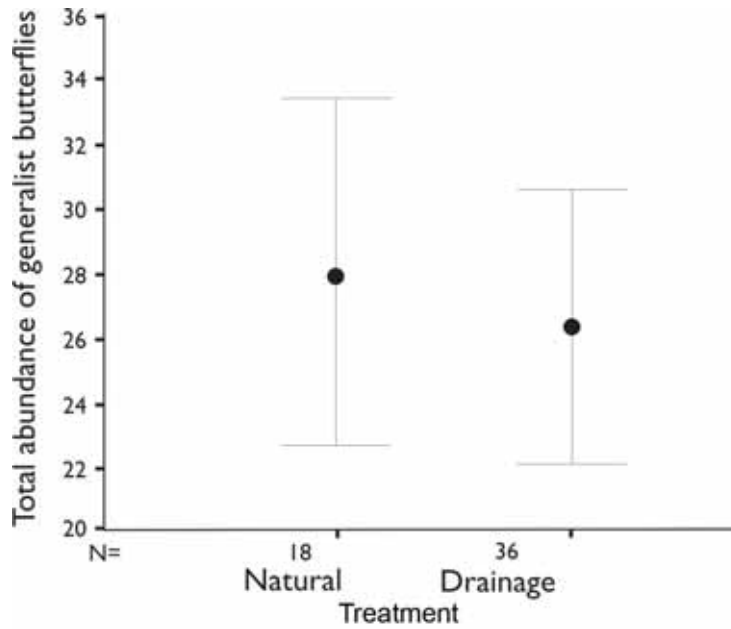


Figure 5. Total abundance of generalist butterflies

Table 5. Species richness of generalist butterflies

Source	SS	df	MS	F	P
Area	42.00	8	5.25	3.55	0.003
Drainage	0.33	1	0.33	0.23	0.638
Error	65.17	44	1.49		

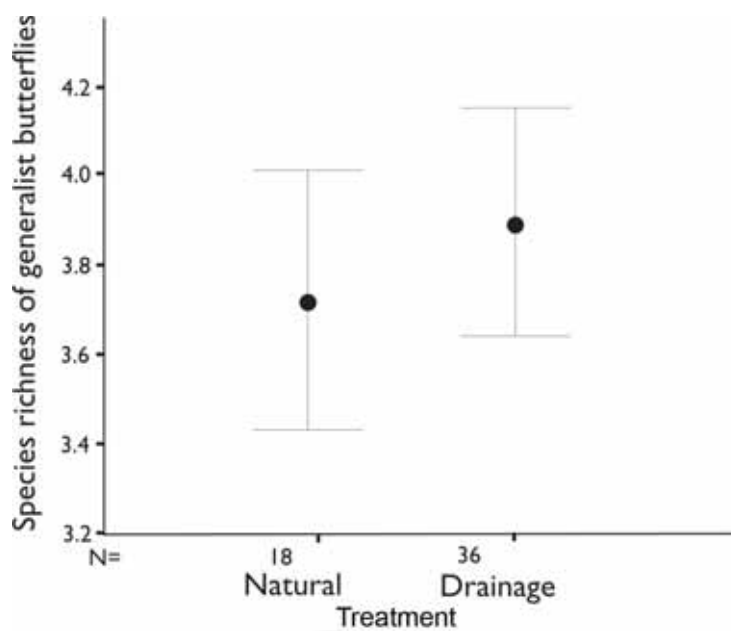


Figure 6. Species richness of generalist butterflies

Table 6. The effect of drainage on the abundance of each species. Species marked with * are classified as mire butterfly. + = drainage has positive effect on species abundance; - = drainage has negative effect on species abundance. When +/- is in brackets the difference is not significant. Species that were observed less than seven times are not included in the analyses.

Species	Abundance	Area		Drainage		
		F	P	F	P	+/-
<i>Boloria aquilonaris</i> *	32	1.07	0.403	10.15	0.003	-
<i>Brenthis ino</i>	64	2.81	0.013	0.67	0.419	(+)
<i>Callophrys rubi</i>	123	0.76	0.643	1.18	0.284	(+)
<i>Clossiana euphrosyne</i>	171	5.86	< 0.001	3.95	0.053	(+)
<i>Clossiana freija</i> *	14	3.44	0.004	7.80	0.008	-
<i>Clossiana frigga</i> *	17	1.61	0.150	13.21	0.001	-
<i>Coenonympha tullia</i> *	58	1.41	0.219	39.56	< 0.001	-
<i>Colias palaeno</i> *	198	6.51	< 0.001	5.00	0.030	-
<i>Erebia embla</i> *	7	2.19	0.046	0.85	0.362	(-)
<i>Erebia ligea</i>	22	2.07	0.060	10.21	0.003	+
<i>Gonepteryx rhamni</i>	7	6.05	< 0.001	4.40	0.042	+
<i>Plebejus argus</i>	911	5.26	< 0.001	5.04	0.030	-
<i>Procllossiana eunomia</i> *	123	2.98	0.009	2.97	0.092	(-)
<i>Pyrgus centaureae</i> *	10	0.86	0.560	2.28	0.138	(-)
<i>Vacciniina optilete</i>	138	3.96	0.001	6.74	0.013	-

more abundant in natural mire habitats than in drained mire habitats (Table 6). The remaining three mire butterflies were also more abundant in natural mire habitats than in drained mire habitats but the difference was not significant (Table 6). Only two species, both generalist butterflies, were significantly more abundant on the drained mires than in the natural mire habitats (Table 6).

Discussion

Mire drainage and species diversity

In the drained mire habitats both abundance and species richness of the mire butterflies were lower than in natural mires. Similar results have been found also in other studies (Rintala & al. 2000, Hiltula & al. 2005). Some mire butterfly species have been observed to disappear shortly after drainage, and Pöyry (2001) suggested that species most vulnerable to habitat changes are *Pyrgus centaureae*, *Clossiana freija*, *Clossiana frigga* and *Erebia embla*. Our results are partly in line with this suggestion as the effect of drainage was most pronounced on *C. freija* and *C. frigga*. However, the effect of drainage on the abundance of *P. centaureae* and *E. embla* seemed to be less pronounced although it still tended to be negative. The lack of significant effect on the last two species may be due to the fact that we had only 10 and 7 observations of these two species respectively and thus the power of the analysis is weak. In a study conducted in SW Finland, *Procllossiana eunomia* was observed to be very tolerant to the effects of mire drainage (Pöyry 2001). This appears to be consistent with the marginally significant effect of drainage in this study.

Dwarf shrubs and hummock plant species have been observed to benefit from drainage at first, but later they decline due to forest canopy closure and increased shading

(Laine & al. 1995a). Mire butterflies that declined after drainage feed mostly on hummock plants as larvae. For example, *Rubus chamaemorus* is the food plant of monophagous *Clossiana frigga* and *Pyrgus centaureae*. *Clossiana freija* feeds on two species, *R. chamaemorus* and *Vaccinium uliginosum*. *V. uliginosum* is also the food plant of very mobile *Colias palaeno*. *Vaccinium oxycoccus* and *Andromeda polifolia* are food plants of *Boloria aquilonaris* (Marttila & al. 1990, 2001). As the food plants of the species seem to tolerate the effects of drainage rather well or may even benefit from it, we must search other reasons for the decline of mire butterflies. These changes may be related to the changes in microclimate (Väisänen 1992, Marttila 2005). On the other hand, *Coenonympha tullia* is the only mire species found in this study that feeds on sedges as larvae. Sedge species growing on wet habitats are among the first species that disappear after mire drainage (Eurola & al. 1995, Laine & al. 1995a). This is reflected also in our data as the drainage had the strongest negative effect on *C. tullia* (Table 6).

Methodological considerations

Transect method has been proved to be efficient in studying species diversity of day-active butterflies (Väisänen 1992, Pöyry & al. 2004). Butterflies are also mostly rather easy to spot and recognise in the field. However, in transect method a few practical issues must be considered. Since butterflies are sensitive to weather conditions and some species have rather short flying period, even few week long bad weather conditions may skew the results. Also flexible working circumstances may be required to be able to make butterfly counting during the best weather conditions.

Some butterfly species have two years life cycle and they are in flight in every other year only, e.g. a pine mire species *Oeneis jutta* is in flight only in even years and rare *Erebia embla* mostly in odd years in southern Finland. The flying pattern might vary in different parts of the country however (Marttila & al. 2001). These life cycle patterns should be taken into account when planning a monitoring program.

Conclusion

Our study found a clear effect of drainage on both the abundance and species richness of mire butterflies. However, such effects were not evident on the generalist species which may even benefit from disturbances such as drainage. Unlike the mire specialists, generalists species have not strict habitat requirements related to microclimate prevailing in natural mires (Marttila & al. 1990, Pöyry 2001).

This study provided data that will be used as a reference to which to compare the results of the future monitoring. In the present study we had nine study areas in two provinces. We acknowledge that this is not a large sample size and suggest that it should be taken into consideration to include more areas into the monitoring network especially in southern Finland. That would greatly improve the reliability of the monitoring program.

Butterflies are a useful species group to use in restoration monitoring for several reasons: i) there are several specialist species that are restricted to mire habitats, ii) some of these mire butterfly species are very sensitive to changes in their environment and can be used as indicators and iii) there are efficient and reliable monitoring methods available. In the future, butterfly monitoring sites will form an important part of the network for monitoring biodiversity effects of mire restoration in Finland (see Aapala et al. this volume).

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