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Biology and conservation of *Pseudophilotes baton* in Finland (Lepidoptera, Lycaenidae)

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In Finland, *Pseudophilotes baton schiffermuelleri* is an endangered blue butterfly associated with open and dry esker habitats. During this century *P. baton* has been recorded from about twenty sites, but only one population is known to have survived, at Säkylä, SW Finland. Forest fires and from 1963 onwards the military rifle and grenade shooting ranges have kept the southwestern slopes of the sandy esker open and suitable for the butterfly. The population size and movements of *P. baton* were investigated by mark-recapture method and its habitat preferences were studied. The total adult population size was estimated in 1990 at about 850 individuals. The number of males increased as the tree cover of the habitat decreased. The proportion of bare mineral soil and the coverage of the host plant *Thymus serpyllum* also contributed to the habitat preferences of the butterfly. Individuals flew on average more than 100 m, and females flew longer distances than males. A conservation programme is proposed for *P. baton*, including active habitat management and a reintroduction plan.

1. Introduction

The boreal zone does not include only forests and mires but also open or semi-open habitats on mineral land, some of which are associated with glaciofluvial landscapes (e.g. Aartolahti 1972, Tikkanen 1981, Kontturi 1990). The characteristic fauna and flora of these usually small open habitat patches on eskers contributes to the biodiversity of the boreal areas (e.g. Jalas 1950, Väisänen et al. 1991). From a conservation point of view these open areas are especially interesting, since they received at least part of their species early after the Ice Age before continuous coniferous forest covered most of the area. A drastic decline in early successional open habitats on dry esker slopes is mainly due to efficient fire-prevention practices during the last 50 years (Zackrisson 1977, Heliövaara & Väisänen 1984, Wikars 1992, Parviainen 1993). In northern Sweden, intervals of 40–50 years have been reported as the highest fire frequencies in natural pine-lichen forests without human interference (Zackrisson 1977, Engelmark 1987). Fires were most frequent on continuous uplands, on steep slopes and at

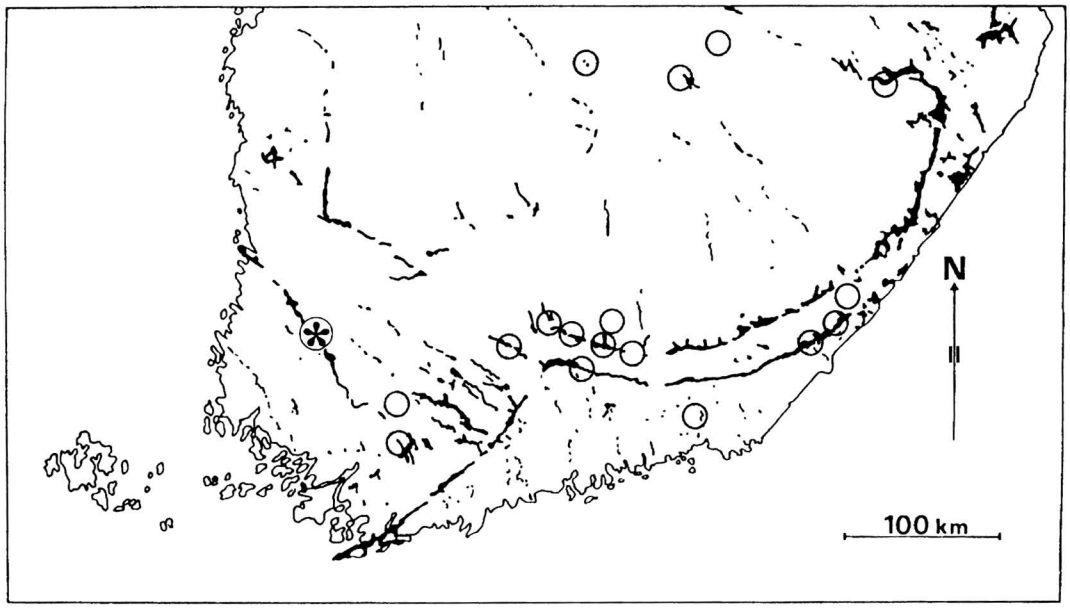

Fig. 1. Distribution of *P. baton* in Finland. Study area at Säkylä is indicated by a star, other localities by open circles. Main esker areas are black.

low elevations (Engelmark 1987). In moister forests the average time-lapse between fires in central Finland was about 120 years (Haapanen & Siitonen 1978). The preservation of fauna living in open esker habitats of a temporary nature now requires intensive management which takes landscape dynamics into account.

Pseudophilotes baton (Bergsträsser, 1779) is a small blue butterfly (Lycaenidae) living on sunny, sandy meadows on eskers and the Salpausselkä ridges in Finland. It has been recorded from about twenty Finnish localities, but only one viable population has remained until the present day, at Säkylänharju, southwestern Finland. The species is considered endangered in Finland and is protected by the Nature Conservation Act of 1989 (Rassi et al. 1986, 1992). It is classified by the Finnish government as a species in need of special protection (Väisänen 1992).

In order to investigate its population size and adult movements, and to define its habitat preference and the exact distribution area of this butterfly population, we studied the population at Säkylänharju in 1990 by mark-recapture methods. We also discuss here the history and decline of *P. baton* populations in Finland.

2. Distribution and natural history of *Pseudophilotes baton*

The distribution of *Pseudophilotes baton* extends from western Europe through central and eastern Europe to Asia Minor, Iran, Afghanistan and the Himalayas (Hemming 1929, Higgins & Riley 1973). In northern Europe the butterfly occurs in southern Finland (Kaisila & Peltonen 1955, Marttila ym. 1990) and Estonia (Thomson 1967, Kesküla 1992), but has not been recorded from Sweden, Norway or Denmark (Nordström et al. 1955). In adjacent Russia, *P. baton* has been recorded from Vitele, Pyhäjärvi and Valkjärvi (Kaisila & Peltonen 1955), and it still occurs on the island of Bolshoy Tuters (Tytärsaari) (L. Luukkonen, pers. comm.).

The larvae of *P. baton* (and associated taxa) live on *Thymus* spp., though at least occasionally on other plants (Koch 1956, Higgins 1982, Nel 1982, 1983, 1986, de Prins & van der Poorten 1982). Some remarks on the biology of the species complex have been published along with biogeographical information (Mattoni 1980, Nel 1982, 1983, 1986, Pierrat 1986), but population ecological investigations have not been carried out.

P. baton was found in Finland only in 1899 (Reuter 1900). Since then it has been recorded on eskers of southern Finland, especially at the Salpausselkä ridges (Kaisila & Peltonen 1955, Marttila et al. 1990), from about twenty sites (see Table 1, Fig. 1), but only one population has survived at *St*: Säkylä, Säkylänharju. Unlike most other blue butterflies in Finland, *P. baton* flies in early summer from late May to early July (Valle 1935, Marttila et al. 1990, own observations).

Table 1. Records of *Pseudophilotes baton* from Finland.

Province, locality	Years	Remarks
Ab: Kiikala	1958	One individual (Järventausta et al. 1988).
Ka: Kymi, Tavastila		Old record (O. Sotavalta, unpubl.).
Valkeala, Vekaranjärvi	1959	Military target area (H. Erola, pers. comm.).
St: Säkylä and Oripää	1940, 1945–	In addition to Säkylänharju, *P. baton* was still abundant in some clearings on Porsaanharju and Virttaankangas eskers about 3 km to the southeast in the 1970s and early 1980s, but after that most of the site have become overgrown (several persons, unpubl.)
Ta: Asikkala, Vääksy	1928	(Kaisila & Peltonen 1955, von Bonsdorff 1985).
Asikkala, Vesivehmaa	1948, 1970s	(von Bonsdorff 1985, H. Erola, pers. comm.).
Heinola, Vierumäki	1899–1902	Military area and eskers (Reuter 1900, Kaisila & Peltonen 1955, von Bonsdorff 1985)
Heinolan mlk.	1966	(A. Järvelä, pers. comm.).
Nastola, Uusikylä	1899	(Kaisila & Peltonen 1955).
Jaala, Hartola	1945–1959	Frequently seen on a sandy meadow and roadsides in the 1950s, but disappeared possibly in association with aerial pesticide spraying against diprionids and road construction in 1960 (Kaisila & Peltonen 1955, O. Peltonen pers. comm.).
Lammi, Kataloinen		(O. Sotavalta, unpubl.).
Somero	1962	One individual (Järventausta et al. 1988).
Sa: Ruokolahti	1970s–1984	Still abundant in the early 1980s, but disappeared due to habitat deterioration (Marttila et al. 1990, O. Marttila, pers comm.). Reintroduction planned (see text).
Joutseno	1933, 1940, 1947, 1951	(Kaisila & Peltonen 1955, O. Sotavalta, unpubl.).
Imatra	1932	(Kaisila & Peltonen 1955).
Tb: Sumiainen		Uncertain record (Nordström et al. 1955).
Sb: Suonenjoki	1953, 1959–1972	Abundant on the 1960s on an old airport, but disappeared apparently due to habitat deterioration (Hublin & Savolainen 1985, O. Sotavalta, unpubl.).
Kuopio	1953, 1958, 1959	(O. Sotavalta, unpubl.).
Kb: Liperi	1945–1974, 1985?	Last verified record dates back to 1974 (O. Sotavalta, unpubl.), but uncertain records from a gravel pit 10 km apart from the earlier sites in 1985 (M. Pajari, pers. comm.).

In Finland, *P. baton* lives on *Thymus serpyllum* L. on warm and dry, open or semi-open slopes of eskers and sheltered sandy meadows. The female *P. baton* oviposits on *Thymus* one egg at a time. According to Bergmann (1952), the female oviposits on the underside of a *Thymus* leaf. Ebert & Rennwald (1991) report egg-laying on the flower buds of *T. pulegioides*, whereas Lepidopterologen-Arbeitsgruppe (1987) states that in Switzerland the eggs are laid all over a *Thymus* plant. The larva feeds especially on *Thymus* flowers but also on the leaves (Forster & Wohlfart 1955). In addition to *Thymus* spp., larvae have been recorded to feed on *Coronilla varia* L. in Germany (Vorbrodt & Müller-Rutz 1911, Koch 1956: *P. baton* s.l.), on *Thymus* and *Mentha* spp. in France (Nel 1982, 1983, 1986: *P. baton* s. str.) and on *Satureia thymbra* L. in Greece (Coutsis 1979: *P. baton shiffermuelleri*).

In Finland and at high elevations in central Europe the larva hatches from the egg at the end of June or at the beginning of July (Bergmann 1952, Kaisila & Peltonen 1955). The immature larva hibernates (Koch 1956, Seppänen 1970). Representative studies on lycaenids suggest that nearly all species of the blue butterflies have a relationship with ants during their larval or pupal stages (Thomas et al. 1989). Unfortunately, nothing seems to be known about the association of *P. baton* with ants. Forster & Wohlfahrt (1955) state that the western *P. baton baton* is myrmecophilous.

3. Material and methods

3.1. Survey of distribution of *Pseudophilotes baton* in Finland

We collected all records on *P. baton* in Finland from the literature and from Finnish amateur lepidopterists in order to obtain a picture of the species' distribution in the past and present. We investigated also the collections of the Zoological Museum at the University of Helsinki (about 50 specimens).

We carried out a population study at *St*: Säkylä, Säkylänharju (Finnish uniform grid coordinates 6776–7:258–9) on the eastern side of Lake Pyhäjärvi in southwestern Finland (Fig. 1, Table 1) in 1990. The population was also surveyed on 14–16 June 1992 (by J. Kullberg) during a short visit. Suitable habitat patches in the surroundings of Säkylänharju were examined especially in 1992.

3.2. Mark-recapture methods

We investigated the population biology of *P. baton* at Säkylänharju in 1990 using mark-recapture methods. Säkylänharju lies by the side of an ancient trade route and it has been used as campsite. A forest fire raged in the area in 1949, burning down several square kilometres including the whole esker. The steep southwestern slope of the esker has been used as military target area for shooting annually since the establishment of the Huovinrinne garrison of the Pori Brigades in 1963.

The study area of 200 × 2500 m of southern slope and top of the esker was divided first into 50 × 50 m quadrats, and the quadrats occupied by the butterflies further into 10 × 10 m quadrats. The steep ridges of the upper slopes are of coarser material than these of the more gentle lower slopes (Glückert 1971, Aartolahti 1972).

The whole study area was investigated (by M. K. & M. N.) daily, by criss-crossing it thoroughly on foot. All butterflies captured were individually marked on the underside of the hind wing using a fine-point pen (Pilot SC-UF, permanent) and released immediately at the capture spot. The 10 × 10 m quadrat of each capture and behaviour at the moment of encounter were recorded. Handling of small butterflies can result in additional mortality (Murphy 1988; no additional mortality was observed in the present case), but mark-recapture techniques also provide essential information on adult mobility and interpatch dispersal, which is needed when habitat management is planned.

Daily male population size was estimated using Jolly-Seber (Jolly 1965, Southwood 1978, Krebs 1989) and Lincoln (Southwood 1978) methods. Since the study population appeared to be split into two distinct local populations, we obtained separate estimates for each. Female population-size estimates could not be calculated due to the small number of recaptures.

The total number of butterflies in the Säkylänharju esker was estimated using the method

described by Watt et al. (1977). With this method total population size is obtained by multiplying the sum of daily population estimates for the whole flight season by the average daily loss-rate. For the calculation we used daily Jolly-estimates of the combined male mark-recapture data. The (low) numbers of butterflies before and after the study period were extrapolated. Daily average loss-rate was obtained from a recapture-duration-decay plot (e.g. Watt et al. 1977, Gall 1984). This means plotting the natural logarithm of the number of marked butterflies known to be alive in the population against the time since their first capture. The slope of this regression is the natural logarithm of residence rate (= the probability of staying alive in the same population on the next day). The total male population size was then multiplied by two in order to determine total population size in 1990 (assuming the sex ratio 1:1).

The positions of all butterfly captures and recaptures were plotted on a map in order to measure the movement lengths of every individual. The following adult mobility parameters were then calculated separately for males and females (see Scott 1975, Warren 1987a):

- d_i minimum straight-line movement in metres between capture i and (i+1);
- t_i time in days between capture i and (i+1);
- D sum of d_is for each individual (minimum distance moved);
- D_{max} maximum D recorded in the population;
- T sum of t_is for each individual (number of days between first and last capture);
- R distance in metres between two furthest capture points for each individual
- R_{max} maximum range recorded within each population
- v_i d_i/t_i, minimum speed
- V D/T, minimum overall speed

The sample size of d_i and t_i is the total number of recaptures, and the sample size of D, T and R is the number of individuals recaptured.

We calculated mean observed residence times for both sexes in both local populations by dividing the total observed age of all butterflies by the number of individuals. These results, however, underestimate the real residence times. A more realistic expectation for the average residence time was obtained as suggested by Cook et al. (1967):

$$\text{residence time} = -1 / \ln (\text{residence rate}).$$

This calculation could be done only for the combined male population.

3.3. Vegetation and faunistic investigations

The environmental variables measured included the coverage (%) of trees, treeless areas, bare ground (usually sand) and *Thymus serpyllum,* as well as the mean height of field layer vegetation. The vegetation was analysed in detail in five of the most densely populated 10 × 10 m quadrats using 16 small, randomly placed quadrats of 25 × 25 cm per each 10 × 10 m quadrat. Ant nests were counted (10 ants sampled from each nest) in these quadrats, since it is possible that *P. baton* spends its larval period partly in ant nests, or the larva is otherwise closely associated with ants like other blue butterfly species are (e.g. Fiedler 1989, Pierce 1989). For the present paper, only *Myrmica* species were identified. The butterfly and diurnal moth species observed were recorded daily. Nocturnal moths were investigated using light traps and sugar-bait traps. A list of the Lepidoptera species recorded at Säkylänharju is available from the authors on request.

4. Results

4.1. The former occurrence of *Pseudophilotes baton* in Finland

All Finnish localities of *Pseudophilotes baton* are listed in Table 1 (see also Fig. 1). *P. baton* was found as a new species to the Finnish fauna at Vierumäki on an exercise field of the local garrison in 1899 (Reuter 1900, von Bonsdorff 1985a, b). Later the species was recorded at several sites on the eskers of Vierumäki, Nastola and Jaala until the 1950s (Kaisila & Peltonen 1955, Marttila et al. 1990). The last *P. baton* records from South Häme (*Ta*) are from the early 1970s. The population at the old airport at Suonenjoki disappeared at the same time (Hublin

& Savolainen 1985). *P. baton* was still abundant at one locality at Ruokolahti on the shore of Lake Saimaa during the late 1970s and early 1980s (Marttila et al. 1990). This population went extinct when the pine forest reached maturity and covered the whole southern slope of the esker. The locality was visited repeatedly in the 1980s and 1990s, but the last individual was observed in 1984 (O. Marttila, pers. comm.). In the 1960s *P. baton* occurred at Liperi in the same esker area, where the large blue *Maculinea arion* L. still has its northernmost known population in Europe. Since 1974 this locality has been investigated several times, and a population study of *M. arion* has been carried out at the locality in the 1990s without any further *P. baton* records (M. Pajari, pers. comm.). Five unlabeled *P. baton* specimens were discovered in 1993 in the collection of a young amateur lepidopterist, who had apparently collected the material at Liperi (about 10 km distance from the old locality) in 1985.

4.2. Population size and structure at Säkylänharju

There were two distinct local populations at Säkylänharju about 1 km apart, separated by pine forest, but connected by a dirt road at the top of the esker. The smaller but denser local population occurred on the rifle shooting range and the larger and sparser subpopulation on the grenade shooting range, both located on the southern slope of the Säkylänharju esker.

In the smaller local population, we captured 49 males and 17 females. This comprises 22% of the total number of 294 marked individuals in 1990. The butterflies concentrated in a 20 × 50 m area where the slope flattens out relatively abruptly (Fig. 2). The daily estimates for males were about 30 individuals on several days. The number of marked females was less than half that of the males.

For the larger local population, the suitable open habitat is divided by pine woods into a mosaic of smaller units. Altogether 164 males and 67 females were marked there in 1990. The daily estimates for the male population in the larger shooting range were 110 individuals at the highest. The largest continuous area of suitable habitat was a treeless slope about 200 m wide, where wind easily disturbed the flight of *P. ba-*

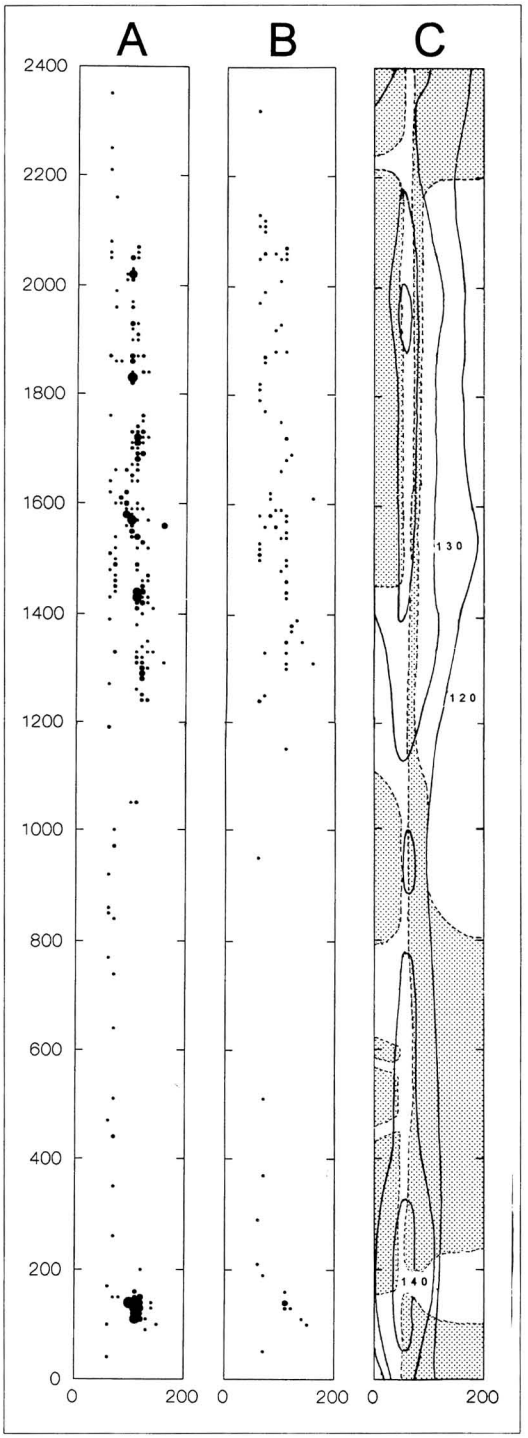

Fig. 2. Distribution of *P. baton* males (A) and females (B) at Säkylänharju (SE at the top). Pine forest is indicated by grey shading in study area map (C) (see also Väisänen et al. 1991: fig 4).

ton and cooled the ground-level temperatures. The population was much sparser in that area than in the smaller more sheltered clearings. The patches most frequently occupied by the males were small spots of ground made bare by grenade explosions, where *Antennaria dioica* (L.) Gaertner flowers were abundant.

The total male population size at Säkylänharju in 1990 was estimated to be (0.24 × 1787) = 431. Assuming the sex ratio as 1:1 gave us a population-size estimate of 861 *P. baton* adults for the whole season. It is probable that the much lower number of females observed than of males was only a result of the dark colouration and less active behaviour of the females.

There was a clear difference in observed residence times between sexes. Average residence times were 1.9 and 0.6 for males and for females in the smaller local population and 1.6 and 0.3 in the larger local population. The highest observed individual residence times were 8 and 18 days for females and for males. Expectation of the average residence time for males, based on recapture duration decay plot, was 3.6 days.

4.3. The habitat preferences of *Pseudophilotes baton*

At Säkylänharju the habitat is an open south-west-facing slope, with low, sparse and discontinuous vegetation. *Thymus* is a pioneer species which can quickly colonize open ground but becomes excluded as a poor competitor during the succession and closing of vegetation. The mean coverage of *Thymus* was 1–9% in the five habitat quadrats most frequently visited by *P. baton* adults. In addition to *Thymus*, the field layer of the suitable habitat was dominated by *Calluna vulgaris* (L.) Hull (mean coverage 11%), *Arctostaphylus uva-ursi* (L.) Sprengel (7%), *Convallaria majalis* L. (5%), *Antennaria dioica* (4%) and *Vaccinium vitis-idaea* L. (4%), as well as lichens (19%) and mosses (6%). Sand and gravel was visible in many places (12%), and the coverage of litter was high (41%). The flight of *P. baton* was concentrated on open treeless or semiopen spots which can be found in several places along the esker slope. The tree layer was dominated by Scots pine (*Pinus sylvestris* L.), with a mixture of many small aspens (*Populus tremula* L.) and some birches (*Betula* sp.). Altogether 30 ant samples were taken from the quadrats preferred by *P. baton* adults. Three of these quadrats contained *Myrmica* ants, which all belonged to *M. sabuleti* (Bondroit).

Some significant relationships appeared between the occurrence of *P. baton* males and females and different environmental variables in 50 × 50 m and 10 × 10 m quadrats. Firstly, in the 50 × 50 m quadrats both male and female abundance decreased as the tree coverage increased (for females, tree coverage was significant only when 'tree coverage × bare ground' was omitted), but the amount of bare ground did not have a significant effect (Table 2). Secondly, in 10 × 10 m quadrats

Table 2. Relationships between number of *Pseudophilotes baton* adults observed and environmental variables in 50 × 50 m and 10 × 10 m quadrats (multiple regressions for 50 × 50 m quadrats, $n = 81$; stepwise regressions with forward selection for 10 × 10 m quadrats, $n = 233$). Bare ground = proportion of bare ground, and *Thymus* = coverage of *Thymus* in quadrat.

Variable	Coefficient	*t*	*P*
50 × 50 m, males			
Constant	15.807	4.54	0.000
Tree coverage (T)	–0.182	–3.58	0.001
Bare ground (B)	–0.291	–0.68	0.496
T × B	0.009	1.16	0.251
Whole model: $R^2 = 0.20$, $F = 6.48$, $P = 0.001$			
50 × 50 m, females			
Constant	1.663	2.34	0.022
Tree coverage (T)	–0.009	–0.85	0.400
Bare ground (B)	0.110	1.26	0.210
T × B	–0.001	–0.81	0.421
Whole model: $R^2 = 0.09$, $F = 6.48$, $P = 0.060$			
10 × 10 m, males			
Constant	2.226	12.13	0.000
Tree coverage (T)	–0.049	–4.71	0.000
T × *Thymus*	0.007	3.50	0.001
Whole model: $R^2 = 0.09$, $F = 11.13$, $P = 0.000$			
10 × 10 m, females			
Constant	0.414	7.63	0.000
T × B	–0.000	–2.50	0.013
Thymus × B	0.002	1.98	0.049
Whole model: $R^2 = 0.03$, $F = 3.54$, $P = 0.031$			

different environmental factors were significant for the occurrence of males and females. Male abundance was associated with tree coverage and the combined variable 'tree coverage × *Thymus*'. Female abundance was associated with the combined variables including the proportion of bare ground and either the coverage of trees or *Thymus*.

There were more females in the quadrats with no males than in those with 1–5 males (paired samples *t*-test, $t = -22.44$, $df = 222$, $P < 0.001$). However, the most densely populated male quadrats also revealed more females than an average quadrat (1–5 males vs. 6 or more males; $t = -20.09$, $df = 180$, $P < 0.001$).

4.4. Behaviour

There were distinct behavioural differences between sexes. Males were territorial, defending their territories against other males. They used *Antennaria dioica* frequently as perching places and as nectar sources, since other flowering plants were scarce in the area during the study. Females were more difficult to observe due to their darker coloration and their habit of staying on the ground or among the vegetation. They were also less alert than males and less easily disturbed into flight. There were proportionally more females seen on the top of the esker (38% of 90 individuals) than on the slope (15% of 420) where males defended their territories.

Although fewer females were seen on flight than males, females flew on an average longer distances than males (Table 3). The flight distances of males were longer in the larger local population of the grenade target area than in the smaller, areally very restricted local population of the rifle target area. The movement distances remained very short in the smaller local population which was largely surrounded by unsuitable habitats, while the larger local population lived in a habitat that more gradually turned less favourable. In the grenade target area individuals commonly moved between clearings separated by less suitable semi-open areas and small pine-forest patches. Movements of several hundred metres were common in the larger local population (mean *R*: males 176 m, females 276 m).

5. Discussion

5.1. Decline of *Pseudophilotes baton* in Finland

P. baton has been rare in Finland in the twentieth century. During the early 1900s the most well-known localities were situated near Vierumäki, Nastola and Jaala, but later *P. baton* has been found over a wide area of the southern Finnish eskers. Due to the rarity of *P. baton* it is difficult to obtain a full picture of its decline. However, the number of records has decreased in spite of

Table 3. Adult *Pseudophilotes baton* movement data at Säkylänharju. Note small number of recaptured females in the smaller local population.

Movement parameter	Whole population		Larger local population		Smaller local population	
	Males	Females	Males	Females	Males	Females
Individuals marked	211	83	164	67	49	17
Individuals recaptured	114	13	89	12	26	2
Total of recaptures	211	20	162	17	59	4
Mean T (days)	2.7	1.6	2.6	1.4	3.2	5.0
Mean t_i (days)	1.5	1.1	1.4	1.0	1.6	2.5
Mean R (m)	146.6	319.2	176.1	276.1	41.9	719.0
R_{max} (m)	1493	1422	1493	811	338	1422
Mean D (m)	168.4	329.6	202.3	287.5	47.3	719.0
D_{max} (m)	1493	1422	1493	811	338	1422
Mean d_i (m)	91.0	214.3	111.2	202.9	24.6	359.5
Mean V (m/day)	83.6	182.0	100.1	198.7	21.1	92.9
Mean v_i (m/day)	77.6	163.2	95.5	188.2	16.1	102.4

the steadily increasing number of active lepidopterists. In the 1970s, *P. baton* populations were still known at three localities in different parts of Finland: *Kb*: Liperi, *Sa*: Ruokolahti and *St*: Säkylä. The last verified records from Liperi are from 1974 and those from Ruokolahti from 1984. Since then, *P. baton* has been recorded only at Säkylä. Most individuals have been observed at the target areas of the Säkylä garrison on the Säkylänharju esker. A few individuals have also been seen at Virttaankangas a few kilometres to the southeast.

The survival of *P. baton* at Säkylänharju is not just by chance. Apparently forest fires have played a key role in the ecosystem dynamics of the esker, allowing the existence of several small populations or a metapopulation (see Hanski 1991, Hanski & Gilpin 1991). A dark layer of ashes with black-burned stubs in some dunes (or ancient beach ridges) is an evidence of a fire which destroyed the pine forest on the esker complex 100–150 years ago (Glückert 1971). The whole Säkylänharju area burnt again in 1949 providing large open areas. Pine forest covered most of the esker slopes in the 1970s. Since then it is apparent that *P. baton* has survived at Säkylänharju due to shooting which has kept the vegetation treeless and has opened bare ground for *Thymus* colonization. The topography and especially the warm and sheltered microclimate at the foot of the esker may have contributed to the success of *P. baton* in the area.

Suitable habitats for *P. baton* have been destroyed elsewhere by sand and gravel pits, afforestation and natural succession (e.g. Kontturi 1990). Previously dry and sunny pine forests of eskers are burnt relatively often (cf. Engelmark 1987, Wikars 1992, Parviainen 1993). Forest fires opened vegetation and created suitable habitats for *P. baton*. Nowadays fire-prevention is efficient and new habitats have seldom been formed.

5.2. Population ecology

The population-size of butterflies fluctuates from year to year and in the long run (e.g. in a century) a population of 800 individuals may relatively easily disappear even due to stochastic variation in the population size. For example, two populations of the checkerspot butterfly *Euphydryas editha* have been monitored in California during 27 years. The male population size of one population has fluctuated from 18 to 2000 and that of the other from 40 to 7227 individuals, although no changes in the quality or quantity of the suitable habitat have been noticed (Harrison et al. 1991). Both populations have been close to extinction, although in between they have been much larger than the *P. baton* population at Säkylänharju. The Säkylänharju population is prone to extinction unless the amount of suitable habitat and the population size of the butterfly both increase.

Turnover (extinctions and colonizations) in patch occupancy within metapopulations of another small blue butterfly, *Plebejus argus* L., was relatively high in small patches (Thomas & Harrison 1992). Similarly, the small local population of *P. baton* at the rifle shooting range would hardly have survived any longer period without the larger local population nearby. The rescue effect (Brown & Kodric-Brown 1977) by the females from the larger local population can compensate even for poor years of reproduction in the smaller local population. There was an exchange of at least three individuals (2 males, 1 female) between the local populations in 1990.

5.3. Behaviour and habitat preferences

Observations on the behaviour of *P. baton* males suggest that the males were perching and waiting for hatching females at the high quality spots, whereas *P. baton* females seemed to avoid males after copulation and tried to find suitable oviposition sites. Females flew longer distances than males, which has also been discovered for several other butterflies, e.g. *Melitaea cinxia* (L.) in Finland (Hanski et al.1994). It is possible that females lay a part of their egg load near their hatching site and later switch to long-distance flights in order to find new habitats (e.g. Gall 1984). The long-distance flight of males may be associated with the search for free territories.

In the 50×50 m quadrats the number of both males and females decreased as the tree-coverage increased. The butterfly clearly avoided closed forest. In the 10×10 m quadrats the association of number of butterflies with environ-

mental variables was complex, with regression models explaining only a small proportion of the variation. The number of males was associated with tree coverage and the combined effect of the coverage of *Thymus* and trees. Males were commonly found in open glades containing the host plant, but not in dense pine forest even though the coverage of *Thymus* was sometimes high there. The number of females was associated with two factors, e.g. tree coverage and the coverage of the host plant, each combined with the proportion of bare ground. This may be explained by the relatively high proportion of females at forest edges and on the road boarded by dense pine forest at the top of the esker. Females were also found to prefer quadrats with high host-plant coverage combined with patches of bare mineral soil. In another lycaenid species, *Plebejus argus* L., eggs are laid along margins between vegetation and bare ground (Thomas 1985). Edges may be favoured due to their allowing enhanced survival of immature stages or to the higher palatability of plants growing in such positions.

The association of *P. baton* with ants remains obscure, though the presence of *Myrmica sabuleti* in the preferred spots may be indicative. *M. sabuleti* is the host species of *Maculinea arion* (L.) (Thomas et al. 1989). Saaristo (1991) also recorded *M. schrencki* Emery, *M. sulcinodis* and *Formica cinerea* Mayr from Säkylänharju.

5.4. Conservation

The succession of pine forest is obviously the greatest threat to the survival of *P. baton* in Finland, since the species is dependent on the continual creation of specific and relatively short-lived types of habitat. Thus, safeguarding the remaining Finnish population of *P. baton* requires active habitat management, including removal of tree saplings from its habitat (cf. Warren 1987b). The main conservation efforts will be concentrated on Säkylänharju (and nearby Virttaankangas), where favourable habitat mosaics for *P. baton* will be created by clearing small glades (50×50 m) in the pine forest providing open but sheltered habitat patches for the butterflies. The aim is to create a strong and only slightly subdivided population. The field layer vegetation will be managed in two different manners in similar patches of cleared area on the southwestern slope of Säkylänharju esker. Half of the patches will be left untouched after clear-cutting. Another half will be managed by routine military practice creating open ground and suitable habitats for colonizing *Thymus*. The whole area needs continuous monitoring and management, since several other rare or endangered species occur there (Väisänen et al. 1991, unpublished).

Reintroduction of *P. baton* to Ruokolahti would essentially diminish the probability of extinction of the Finnish *P. baton*. The population at Säkylänharju is apparently large enough to serve as a source for the establishment of a new population. The ultimate objective is to create a metapopulation system at Ruokolahti where several suitable habitat spots have been located on the eskers in addition to the managed site. Few environmental catastrophes occur on a scale that would include both Säkylä and Ruokolahti (more than 300 km apart), although such environmental factors (e.g. exceptional weather conditions, large forest fires) could result in the extinction of a single metapopulation (see Harrison & Quinn 1989).

Recent studies on conservation of other butterflies often emphasize the relevance of information on larval biology (e.g. Thomas et al. 1989, Thomas 1991, Elmes & Thomas 1992). The larva of *P. baton* lives on *Thymys serpyllum* for at least part of its life, but the association of larvae with ants clearly needs further research. This information may prove essential when planning the details of habitat management and reintroduction.

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