Butterflies on organic farmland: association to uncropped small biotopes and their nectar sources
(Lepidoptera: Papilionoidea and Hesperioidea)

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In the summer of 1996, butterfly transect countings were conducted at two organically managed farms near Varde, Denmark. The transects included linear small biotopes (hedgerows, woodland edges and ditches/ embankments) as well as non-linear small biotopes (meadows/fens). All potential nectar sources present in the transects were counted during the season. Additionally, midfield transect countings of butterflies were carried out. Furthermore, the relative value of different types of small biotopes for the butterfly fauna was investigated.

22 species of butterflies were observed in this study, 12 immobile and 10 mobile species, and a total of 2631 individuals were counted. The five most frequently observed species were the ringlet (*Aphantopus hyperanthus*), the Essex skipper (*Thymelicus lineola*), the green-veined white (*Pieris napi*), the meadow brown (*Maniola jurtina*) and the small skipper (*Thymelicus sylvestris*), together contributing 80% of the total number of butterflies observed.

Analysis revealed a highly significant association of butterflies to small biotopes compared to midfield areas; this result underlines the importance of small biotopes in farmland. Correlations between butterfly numbers and nectar sources indicated that "thistle-like flowers" are an important nectar source, to which immobile butterfly species are strongly associated. In one of the two non-linear biotopes, the Tange meadow, the number of butterflies observed was extremely high, and neither the nectar source species individually nor together could account for this. The high degree of shelter and undisturbed conditions is suggested as an explanation.

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Introduction

Over the last four decades, agricultural intensification has reduced abundance and species richness of wildlife in NW-European farmland due to intensive use of chemical fertilizers, synthetic pesticides and cultivation of uncropped, semi-natural habitats such as hedges, woodland and wetlands. Concerning butterflies (Papilionoidea and Hesperioidea), this is particularly well documented; many species have suffered from drastic declines and local, regional or even national extinctions (Thomas, 1984; Kaaber & Nielsen, 1988; Stoltze, 1996). In Denmark, farmland occupies about 70% of the country and most of it is managed conventionally. In 1997, about 2% consists of organic farmland, where pesticide spraying and application of chemical fertilizers are not allowed. Currently, the number of farmers converting to organic agriculture is increasing, as a result of increasing political and public enviromental concern and the increasing demand for healthier foods.

The consequences of this conversion on wildlife -both flora and fauna- are still poorly investigated, although the general opinion is that organic farming benefits wildlife. Two major studies show an overall positive effect of organic farming on wild plants, insects and birds compared to conventional farming (Christensen *et al.,* 1996; Hald & Reddersen, 1990). Concerning butterflies, comparative studies of sprayed versus unsprayed cereal field margins has been performed in England (Rands & Sotherton, 1986: Dover *et al.*, 1990), where significantly more butterflies were recorded in unsprayed field margins, and in Denmark (Hald *et al.*, 1994), where more Lepidoptera larvae were caught in unsprayed field margins. According to Feber *et al.* (1996), the adult abundance of most butterfly species is more closely associated with the abundance of nectar sources than with the abundance of larval food plants. Dover (1996) showed that "thistle-like flowers" (*Cirsium* spp., *Arctium minus, Centaurea nemoralis* and *Knautia arvensis*) is one important factor affecting positively the distribution of common satyrine butterflies, along with other non-floral factors like shelter and insolation.

In this study, we examine the distribution of adult butterflies in organic fields and uncropped small biotopes: the butterfly transect counting method is applied to Danish organic farmland, and the species composition along with counts per 100 m are presented. The following problems are examined and discussed: do butterflies prefer the small biotopes to the midfield in organic fields? Do different small biotope types in organic farmland exhibit systematic variation in their butterfly faunas? Is there a correlation between species diversity of butterflies and plants in the small biotopes? Are the mobile and immobile butterfly species asssociated with various groups of nectar sources in the small biotopes?

Methods and materials

Study areas

The study was conducted at two organically managed farms, named Tistrup and Tange. Both are located NE of Varde in SW Jutland, Denmark, 10 km apart, adjoining Varde river and the associated riverbanks and permanent moist grasslands. Both farms converted from conventional to organic farming in 1991. Crops were entirely spring barley (often undersown with clover) or white clover/grass fields. The barley was either harvested early for silage or later for grain, and the clover/grass fields were either harvested for silage or fenced for cattle grazing. The soils are sandy and relatively uniform within a larger area including both farms. Both had a high proportion of hedgerows as typical for the region.

On each of the two farms, nine semi-natural small biotopes were selected. Small biotopes are defined as being uncropped areas, permanently covered by vegetation or water, situated within agricultural areas. Linear small biotopes are between 0.1-10 m wide and more than 10 m long. Non-linear small biotopes are between 10 and 20.000 m^2 in area, and are too wide to fit the definitions of linear small biotopes (Agger *et al.*, 1986). Transects were placed either along the entire length in the eight linear small biotopes or passing through most of the area in the non-linear small biotopes. The linear small biotopes consisted of nine hedges, five woodland edges and two dry ditches/embankments, while the non-linear small biotopes consisted of one fen partly overgrown with willows (Tistrup) and one ungrazed moist meadow (Tange).

Butterflies

Butterflies (Papilionoidea and Hesperioidea) were recorded using the transect counting technique developed by Pollard *et al.* (1975) and Pollard (1977), widely used in national butterfly monitoring programmes in Great Britain (Hall, 1981; cit. by Dover *et al.*, 1990); in Denmark (Nielsen, 1992). Recordings were performed weekly from 5 June – 23 Sept. totalling 16 occasions. Within each week, the specific day was selected among those conforming to the set of minimum weather conditions described by Pollard *et al.* (1975) and Pollard (1977), viz.: a) temperature at least 13°C (if between 13-17°C, count only if sunny; if higher than 17°C, count at any cloud cover), b) no rain, c) wind speed less than 5-6 m/s and d) between 10:30 a.m. and 4:00 p.m. (summer time).

At a few June-July censuses, recordings were extended to 5:00 p.m. when the weather allowed it, and there was no apparent decline in butterfly activity. Walking at a steady pace, all butterflies within a rectangle 5 m ahead of the observer and 2 m to each side were recorded by the same person throughout the study. For linear small biotopes, this implies that butterflies were recorded in the small biotope as well as in the adjacent field margin, while for non-linear small biotopes, only butterflies in the small biotope itself were recorded. Sometimes proper identification necessitated a halt or even capture, and in those cases recording was not resumed before the observer was back on the track.

Butterfly species were divided into two groups, according to their relative migrational powers, viz. mobile and immobile species, in the literature often refered to as having open and closed populations, respectively (Thomas, 1984). By definition, immobile species only occur close to their larval host plant, while mobile species have the potential of spending much of their adult lifetime at considerable distances from their larval hostplant (Schwerdtfeger, 1975; cit. by Erhardt, 1985), resulting in extensive long-distance dispersal by some species, e.g. *Cynthia cardui* (the painted lady).

In addition to the standard weekly census programme, 21 cases of butterfly midfield transect counting were conducted at a number of dates from 16 June to 4 Aug., when harvest started. Midfield censusing followed the same procedure as described above. All midfield transect countings were initiated at least 10 m away from the field margin and the associated small biotope transect, which was used for paired comparison. The selected midfields included both spring barley and white clover/grass fields.

Nectar sources

Nectar sources were recorded in the same transects and on most of the dates of butterfly censusing, totalling 10 occasions. Nectar source abundance was estimated over 140 m (which was the length of the shortest small biotope) in each small biotope transect. Biotopes longer than 140 m were split into 7 intervals of 20 m evenly distributed over the length of the biotope. Number of all potential nectar sources present within 1 m to each side of the observer were estimated for each small biotope, including only open but not yet withering flowers.

Censusing nectar source abundance, a 'flower' was estimated as a 'unit', defined as "what a butterfly is expected to percieve as a unit" (Rabjerg, 1993): a flower head of Asteraceae and an umbel of Apiaceae flowers was counted as one unit, and similarly for other plant groups: a dense group of small flowers, as the inflorescences of *Trifolium* spp., *Medicago* spp. and *Vicia cracca*, was defined as one unit. Nectar source abundance was recorded as number of 'active flower units' per 140 m transect, estimated to one of the following intervals: 0, 1-10, 11-100, 101-1000, 1001-10.000 and >10.000, subsequently assigned to abundance scores 0-5. For each butterfly species, the nectar sources prefered were given a preference score from 1 to 5 according to Herrmann *et al.* (1991): nectar sources scoring 1-3 are of minor importance, while 4 and 5 represents the most important nectar sources for a given species.

Identification

All butterflies were identified to species, except for two species pairs; *Thymelicus lineola/sylvestris* and *Pieris rapae/napi* due to difficulties in identifying flying individuals. Since as much as 58% of the *Thymelicus* spp. and 79% of the *Pieris rapae/napi* were identified to species, the unidentified species were assigned to the underlying species according to the relative frequencies within species pairs among the identified individuals. Nomenclature follows Stoltze (1996), Box 1: Scientific, English and Danish names of all butterfly species observed during the study period.

Box 1: Latinske, engelske og danske navne på alle sommerfuglearter, der indgår i undersøgelsen.

Scientific names	**English names**	**Danish names**
Thymelicus lineola (Ochs.)	Essex skipper	Stregbredpande
Thymelicus sylvestris (Poda)	Small skipper	Skråstregbredpande
Ochlodes venata (Br. & Gr.)	Large skipper	Stor bredpande
Pieris brassicae (L.)	Large white	Stor kålsommerfugl
Pieris napi (L.)	Green-veined white	Grønåret kålsommerfugl
Pieris rapae (L.)	Small white	Lille kålsommerfugl
Anthocaris cardamines (L.)	Orange tip	Aurora
Gonepteryx rhamni (L.)	Brimstone	Citronsommerfugl
Inachis io (L.)	Peacock	Dagpåfugleøje
Vanessa atalanta (L.)	Red admiral	Admiral
Cynthia cardui (L.)	Painted lady	Tidselsommerfugl
Aglais urticae (L.)	Small tortoiseshell	Nældens takvinge
Issoria lathonia (L.)	Queen of Spain fritillary	Storplettet perlemorsommerfugl
Maniola jurtina (L.)	Meadow brown	Græsrandøje
Aphantopus hyperanthus (L.)	Ringlet	Engrandøje
Coenonympha pamphilus (L.)	Small heath	Okkergul randøje
Quercusia quercus (L.)	Purple hairstreak	Blåhale
Satyrium w-album (Knoch)	White-letter hairstreak	Det hvide W
Lycaena phlaeas (L.)	Small copper	Lille ildfugl
Lycaena virgaureae (L.)	Scarce copper	Dukatsommerfugl
Polyommatus icarus (Rott.)	Common blue	Almindelig blåfugl
Polyommatus amanda (Schn.)	Amanda's blue	Isblåfugl

and a list of scientific, English and Danish names is shown in **Box 1**. All nectar species were identified to species, excluding *Taraxacum* spp. The following species were grouped as thistle-like nectar sources (sensu Dover): *Cirsium arvense, Cirsium palustre, Cirsium vulgare, Knautia arvensis* and *Jasione montana.*

Data manipulation and statistical analysis

For nectar sources, scores from each small biotope were summed across all censusing dates, while for butterflies, total seasonal counts were transformed to "no. of individuals per 100 m small biotope" to allow comparison between biotopes of different length.

Sign tests (Berry & Lindgren, 1990) were used to test the association of each of the observed butterfly species to the field margin, and a sign test was also performed on field margin versus midfield data on total butterfly numbers per 140 m transect for each date separately. Linear regression analysis on abundance and diversity were used to examine the correlation between butterflies and their nectar sources, expressed by Pearsons r-value.

Results

Butterfly species and abundances

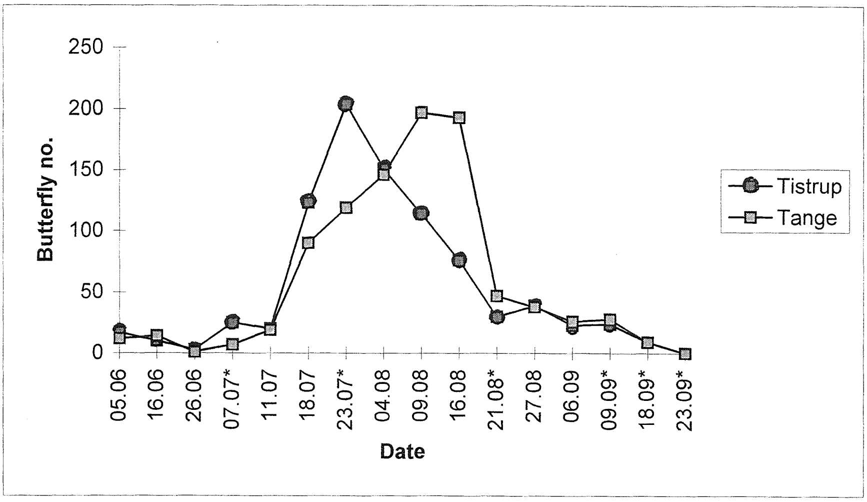
A total of 22 species and 2591 individuals of butterflies (excluding midfield counts) were recorded at the main transect routes (**tab.1**); 12 species could be classified as immobile and 10 as mobile. Five species were very frequently seen and contributed 80% of the total individual number: *A. hyperanthus* (24%), *T. lineola* (17%), *P. napi* (16%), *M. jurtina* (15%) and *T. sylvestris* (7%). In the midfield transect censuses, a total of 48 individuals were observed. More butterfly individuals were recorded in the non-linear

Table 1: Species and number of individuals recorded per 100 m, by locality and biotope (Linear (L), non-linear (N) and midfield (M)). The period of recording is indicated either by "Full" (6 June - 23 Sept) or "Red." (reduced, viz. 16 June - 4 Aug). Asterisks (*) indicate immobile species, while unmarked species are mobile. [1]*Anthocaris cardamines* was observed in the area, but not during transect counting.

Tabel 1: Arter og antal registrerede individer pr. 100 m, fordelt på lokalitet og biotop (lineær småbiotop (L), udbredt småbiotop (N), og midtmarkstransekt (M)). Optællingsperioden er vist som enten "Full" (6. Juni - 23 Sept.) eller "Red." (reduceret, dvs. 16 Juni - 4. aug). Stjerner (*) markerer immobile arter, mens umærkede arter er mobile. [1]Anthocaris cardamines blev observeret i området, men ikke i linietakseringerne.

Site	Tistrup/100 m			Tange/100 m			Both in total	
Biotope	L	N	M	L	N	M	L+N	M
Transect no.	8	1	4	8	1	5	18	9
Transect length (total)	1718	258	1820	2120	228	1120	4324	2940
Recording period	Full	Full	Red.	Full	Full	Red.	Full	Red.
Species								
Hesperiidae:								
Thymelicus lineola (Ochs.) *	4.7	16.0	0.1	7.6	85.9	0.2	444	3
Thymelicus sylvestris (Poda) *	1.7	5.7		2.7	30.8	0.1	173	1
Ochlodes venata (Br. & Gr.)*	0.1	1.2		0.1	2.6	0.1	14	1
Pieridae:								
Pieris brassicae (L.)	0.6	0.8		1.2	16.7		76	
Pieris napi (L.)	9.0	7.4	0.7	5.8	43.8	0.3	394	17
Pieris rapae (L.)	2.2	1.9	0.2	1.4	11	0.1	99	4
Anthocaris cardamines (L.)[1]								
Gonepteryx rhamni (L.)	0.4	0.4		0.7	2.2		27	
Nymphalidae:								
Inachis io (L.)	0.3			0.4	8.8		34	
Vanessa atalanta (L.)	1.5	0.4		0.8	0.9		47	
Cynthia cardui (L.)	1.0	2.3		1.0	9.6		67	
Aglais urticae (L.)	3.6	1.2	0.1	1.2	2.2	0.1	95	2
Issoria lathonia (L.)	0.9			0.4			24	
Maniola jurtina (L.)*	9.9	5.8	0.3	7.1	20.2	0.2	383	7
Aphantopus hyperanthus (L.)*	12.2	23.6		8.9	78.1	0.4	637	5
Coenonympha pamphilus (L.)*				0.2			4	
Lycaenidae:								
Quercusia quercus (L.)*					0.4		2	
Satyrium w-album (Knoch)*				0.1			3	
Lycaena phlaeas (L.)*	0.1			0.3			7	
Lycaena virgaureae (L.)*				0.3			7	
Polyommatus icarus (Rott.)*	2.1			0.8	0.9		54	
Polyommatus amanda (Schn.)*	0.1						1	
All/100 m.	49.9	65.5	1.3	40.7	307.5	1.5	59.9	1.4
Total	858	169	23	863	701	17	2591	40

small biotopes (meadow/fen) than in the linear ones, especially in Tange, where 307.5 indiv. per 100 m were counted. For comparison, the mean number counted in linear small biotopes in Tange was 40.7 indiv. per 100 m (**tab. 1**). Total butterfly counts and total nectar source scores through the recording period, showing thistle-like flowers seperately, are shown in **fig 1**. Analysis of biotope types and nectar source relationships a)



b)

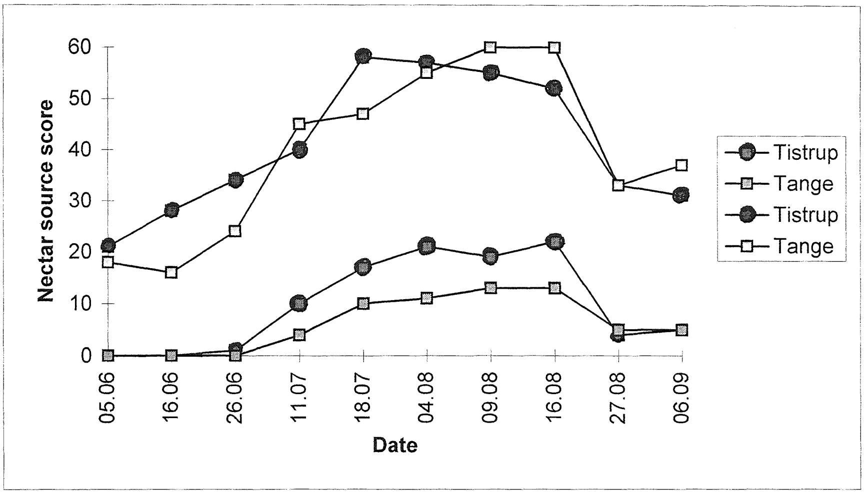


Fig. 1. a) Flight period of butterflies (Papilionoidea and Hesperioidea) in the linear small biotopes at the two sites Tistrup and Tange. Asterisks (*) indicate dates, where nectar source recording was omitted. b) Total abundance score of important nectar sources (upper curves) and of thistle-like nectar sources (lower curves) in the linear small biotopes at the sites Tistrup and Tange.

Fig. 1. a) Flyveperiode for dagsommerfuglene (Papilionoidea og Hesperioidea) i hhv. Tistrup og Tanges lineære småbiotoper. Stjerner (*) markerer datoer, hvor registrering af nektarkilder ikke blev foretaget. b) Totalscoren af vigtige nektarkilder (øverste kurver) samt af tidsel-lignende nektarkilder (nederste kurver) i Tistrups og Tanges lineære småbiotoper.

(below) were conducted across farms as butterfly numbers were similar in the linear small biotopes.

Nectar source species and abundances

117 species of potential nectar sources were recorded in Tistrup and Tange, out of these 23 could be classified as important nectar sources (**tab. 2**). Of these, 21 were biennials or perennials. In the linear small biotopes, flower units of the following five species were observed most frequently: *Achillea millefolium, Trifolium repens, Cirsium arvense, Epilobium angustifolium* and *Taraxacum* sp. A

Table 2: Mean score per 140 m of the nectar sources prefered by the butterflies observed, by site and biotope (linear (L) and non-linear (N)). Lifetime for the plants are indicated: Perennials (P), biennials (2) and annuals (1). Listed in alphabetical order.

Tabel 2: De observerede dagsommerfugles foretrukne nektarplanters gennemsnitlige score pr. 140 m, opdelt på brug og småbiotop (Lineære (L) og udbredte (N)). Planternes levetid er angivet: Flerårige (P), 2-årige (2) samt 1-årige (1). I alfabetisk rækkefølge.

Site		Tistrup		Tange	
Biotope type		L	N	L	N
Biotope no.		8	1	8	1
Species	Lifetime				
Achillea millefolium	P	8.3		7.8	
Ajuga reptans	P	1.3			
Angelica sylvatica	P			1.9	14.0
Cardamine pratense	P	0.8			5.0
Cirsium arvense	P	7.0	3.0	4.8	
Cirsium palustre	2		19.0		21.0
Cirsium vulgare	2	1.5		0.9	
Epilobium angustifolium	P	4.4	10.0	6.4	
Epilobium palustre	2	0.1			7.0
Geum urbanum	P			0.5	
Jasione montana	2	0.1		0.1	
Knautia arvensis	P	2.4		2.0	
Lamium purpureum	1	0.1		0.4	
Leontodon autumnalis	P	2.1		0.1	
Lotus corniculatus	P	1.3		6.4	
Medicago lupulina	1-2	0.3			
Prunella vulgaris	P			0.5	
Salix caprea	P			1.4	
Taraxacum spp.	P	7.0		3.5	
Trifolium pratense	P	0.9		0.8	
Trifolium repens	P	4.9		8.3	
Valeriana procurrens	P			1.5	18.0
Vicia cracca	P	5.0		0.8	
Total		47.5	32.0	48.1	65.0

pronounced difference between nectar species available in linear compared to non-linear small biotopes was evident; the latter were dominated by few but very abundant species; *Cirsium palustre, Valeria procurrens, Angelica sylvatica* and a few others, all caracterizing moist growing conditions, while generally, the nectar species mentioned above in linear small biotopes are common in agricultural areas.

Midfield transect censusing

The results of the midfield transect countings are shown in **tab. 1** and **tab. 3**: out of the 22 species observed in the study area, only six species were encountered in the midfield transects (**tab. 1**). Also, significant more butterfly individuals were recorded in the corresponding small biotope transects than in the midfield transects (N(margin):N(midfield) = 4.8:1). All single species observed frequently enough for sign testing were more abundant in the small biotopes (**tab. 3**). A strong preference of the butterflies for the uncropped small biotopes is evident, especially for the immobile species: *A. hyperanthus* was most strongly restricted to the small biotopes (14.2:1) while *P. ra-*

Table 3: Total numbers of each species observed in midfield/small biotope transect pairs, total length 2940 m and 5363 m, respectively. Sign testing shows, that all species abundant enough for testing are associated strongly with the linear small biotopes. *** = p<0.001, ** = p<0.01, * = p<0.05, nt = not tested.

*Tabel 3: Total antal individider for hver art observeret i midtmarks- og småbiotop transektparrene, total længde hhv. 2940 m og 5363 m. Fortegnstests viser en stærk tilknytning til småbiotoperne for alle arter, der er hyppige nok til at teste. *** = p<0.001, ** = p<0.01, * = p<0.05, nt = ikke testet.*

Species	Total number of individuals		Sign test results	
	Field	Biotope	P-value	p-value
Thym. spp.	4	69	0.0005	***
O. venata	1	3	nt	
P. rapae/napi	22	75	0.0384	*
A. hyperanthus	6	155	0.0012	**
M. jurtina	13	96	0.0038	**
A. urticae	2	19	0.0269	*
P. icarus	0	1	nt	
L. phlaeas	0	1	nt	
L. virgaureae	0	2	nt	
S. w-album	0	3	nt	
Totals	48	424		

pae/napi was least strongly restricted (1.6:1).

Butterfly abundance in relation to nectar source abundance

Significant correlations between butterfly abundance and the accumulated score of nectar sources appeared in three out of six cases, and all combinations resulted in positive Pearson´s r-values (**tab. 4**). All species combined seemed to be significantly correlated to the thistle-like flowers but not to all nectar sources. However, when split into immobile and mobile butterflies, only the immobile butterflies maintained significant correlations; the strongest of these concerned thistle-like nectar sources (**tab. 4**). Both non-linear small biotopes were omitted from this analysis due to outlier values, caused by the extreme abundance of butterflies at one of the two. Including these in the tests generally lowered Pearson´s r.

Table 4: Correlations between butterfly count/100 m linear small biotop trancect and the estimates of the important nectar sources, analysed by linear regression. Showing variables analysed, Pearson's r, p-values and test results. ** = p<0.01; * = p<0.05; NS = non-significant.

*Tabel 4: Korrelation mellem sommerfugleantal pr. 100 m lineær småbiotop og estimaterne af de vigtige nektarkilder, analyseret ved hjælp af linear regression. Tabellen viser de analyserede variable, Pearson's r , p-værdierne og testresultaterne; ** = p<0.01; * = p<0.05; NS = ikke signifikant.*

Butterfly count/100 m	Nectar source score	Pearson's r	Test (P)	Test result
All species	All nectar sources	0.42	0.110	NS
All species	Thistle-like flowers	0.72	0.002	**
Immobile species	All nectar sources	0.56	0.025	*
Immobile species	Thistle-like flowers	0.71	0.002	**
Mobile species	All nectar sources	0.20	0.455	NS
Mobile species	Thistle-like flowers	0.20	0.458	NS

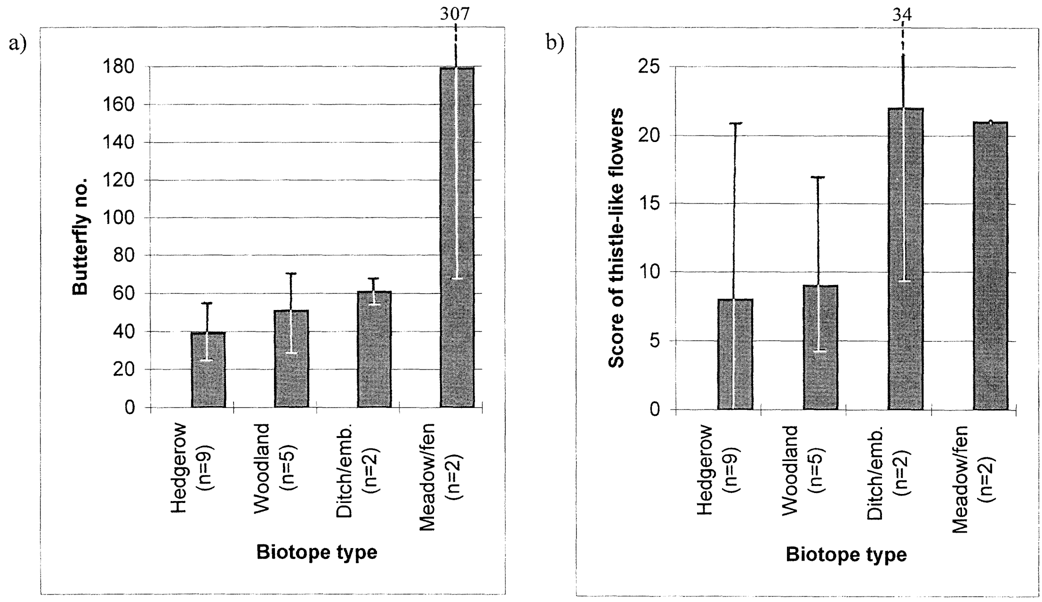


Fig. 2. a) Mean butterfly number and b) mean score of thistle-like nectar flowers observed in the four biotope types. The associated ranges of values are shown.

Fig. 2. a) Det gennemsnitlige antal dagsommerfugle og b) scoren af tidsellignende nektarplanter observeret i de fire biotoptyper. Max.-min. intervallet omkring gennemsnittet er vist.

Butterfly abundance in different small biotope types

Among the 18 small biotopes, categorized as hedgerow, woodland edge, ditch/embankment or meadow/fen, the lowest mean butterfly numbers were found in the hedgerows and the highest in the meadow/fen (**fig. 2a**). Additionally, the mean abundance of thistle-like flowers in the small biotope types is shown (**fig. 2b**); this largely follows the abundance of butterflies, except for the meadow/fen, where the butterfly number is extremely large compared to the number of nectar sources present. Lack of transect replication in the ditch/embankment and in the meadow/fen biotope types makes proper statistical analysis impossible. Based on the ranges shown, the variation in total butterfly counts is remarkably small except for the one outlier (meadow/fen-value), while the variation in nectar source scores are much larger.

Butterfly species diversity in relation to nectar source species diversity

Regression analysis revealed no apparent correlation between any measure of butterfly species richness and any measure of plant species richness across the 16 linear small biotopes (non-linear biotopes omitted from analysis). Only one out of six relationships appeared weakly significant (number of immobile species versus number of all plant species, Pearson´s $r=0.547$; $p<0.05$). The remaining Pearson´s r-values were negative or close to zero.

Discussion

Applying identical methods in unsprayed cereal field margins within conventional farmland (conservation headlands), Dover *et al.* (1990) reported on butterfly species richness and total abundances similar to ours: they observed a total of 13-21 species per year during the study periods in 1984-87 (transect length 2068-4005 m). This is comparable to the 20 species recorded in our study in the linear small biotope transects (transect length 3838 m). Our total butterfly abundance of 45 indiv./100 m (including only linear small biotope transects) is higher than the mean abundance of 30.2 indiv./100 m recorded by Dover *et al.* (1990) in unsprayed field margins, but within the ranges of 22-47 indiv./100 m recorded during their study period 1984-87. Only 13.7 indiv./100 m were recorded by Dover *et al.* (1990) in sprayed field margins. Thus, unsprayed field margins are considerably better than sprayed ones, and strictly organic field margins and small biotopes may improve the butterfly environment even further. We found no comparable literature on butterflies on organic farmland and assume our study to be the first one published.

Twelve out of the 22 species observed were immobile and four of the immobile species contributed 63% of all individuals observed (*A. hyperanthus, Thymelicus* spp., *Maniola jurtina*). According to Feber & Smith (1995), immobile species are generally less common in agricultural areas; this forms a contrast to our results as well as the results obtained by Dover *et al.* (1990). One reason may be the absence of pesticides in conservation headlands and organic farmland, while the low abundance of immobile butterflies mentioned by Feber & Smith (1995) refers to ordinary conventional areas.

Our results concerning butterfly preference for small biotopes compared to midfields are in accordance with preliminary results reported by Dover (1989a), studying butterflies in conservation headlands. This association to the small biotopes at field margins is most likely explained by higher degree of shelter, warmer microclima and the presence of perennial nectar sources, which butterflies prefer to annual nectar sources (Fussel & Corbet, 1991,1992; cit. by Feber & Smith, 1995), but possibly also behavioral preference towards vertical structures (Gary Fry, pers. comm.). However, Dover (1989a) observed a midfield:field margin ratio of 1:50 comparing a sprayed midfield with surrounding unsprayed field margin. Although still strongly significant, we observed a more moderat field margin association, viz. a midfield:field margin ratio of 1:4,5. We suggest two important factors influencing the strength of field margin association: Firstly, it strongly depends on butterfly species composition as our data showed mobile species like the whites to be less strongly associated to field margins, while the immobile species, e.g. the skippers, practically never moves into midfield areas. Secondly, it may depend on the quality of the midfield crop environment, which may be more favourable under organic management conditions with higher abundances of flowering dicot weeds (Hald & Reddersen, 1990). Reddersen (1998, in press) similarly found a less steep decline in arthropod abundance from field margin to midfield in organic cereal fields compared to conventional ones.

Feber *et al.* (1996) and Dover (1996) both reports on abundance of nectar sources, especially thistle-like flowers (Dover, 1996), as factors affecting adult butterfly distribution strongly. Several studies reports on the importance of nectar abundance on butterfly longevity, fecundity and thus abundance (Murphy, 1983; Murphy *et al.*, 1983; Stern & Smith, 1960; Watt *et al.*, 1974; Wiklund & Karlsson, 1984; all cit. by Dover, 1989b). Positive correlations between butterfly abundance and the score of nectar sources were therefore expected in this study. The strong correlation of immobile species to abundance of thistle-like flowers in particular support the results of Feber *et al.* (1996) and Dover (1996), while the mobile species seem much less correlated with local conditions such as distribution of nectar sources or thistle-like flowers. Other factors may act stronger in distributing these species. The important message for future studies on this subject is that immobile and mobile species behave differently and should be analysed separately.

Correlations between plant and butterfly diversity was found by Erhardt (1985) in a study on butterfly populations in grasslands in the Swiss Alps. As a corollary, we expected a similar correlation across the 18 small biotopes investigated, but no such correlation was found. This may be due to the exclusion of grasses and other herbs not producing nectar in our study; these plants are important as larval food plants for many of the frequent butterfly species observed in our study, such as *Thymelicus* spp., *A. hyperanthus* and *M. jurtina.* On the other hand, our results indicate that species diversity of nectar sources is of minor significance for butterflies, while the pooled abundance of nectar sources seems important.

Our comparisons of different small biotope types such as hedgerow, woodland edge, ditch/ embankment and meadow/ fen showed tendency towards butterflies being least abundant in hedgerows and woodland edges and most abundant in dry ditches/embankments and meadows/fens. This is in accordance with results obtained by Rands & Sotherton (1986) studying conservation headlands in connection with linear small biotopes, in which low butterfly numbers were found in transects along hedgerows and woodland edges, while considerably more butterlies were recorded along railway embankments. The high number of butterflies obtained in the meadow/fen in our study could not simply be explained by nectar source abundance. We assume that the high degree of shelter, which by Dover (1996) is reported to be an important butterfly-distributing factor, and maybe the lack of agricultural disturbance, resulted in the multitude of butterflies, either by aggregation of adult butterflies and/or by higher reproduction. If the pattern described above is general, conservation of non-linear biotopes like meadows and undisturbed grassland may be of major importance compared to linear small biotopes for butterflies, even in organic farmland. Since farmland covers most of Denmark as in most other NW-European countries, further investigation on this subject is important for future butterfly conservation.

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Litterature

Agger, P., J. Brandt, E. Byrnak, S.M. Jensen & M. Ursin, 1986. Udviklingen i agerlandets småbiotoper i Østdanmark. – *Forskningsrapport no. 48.* – Publikationer fra Institut for Geografi, Samfundsanalyse og Datalogi, Roskilde.

Berry, D.A. & B.W. Lindgren, 1990. *Statistics, Theory and Methods.* – Brooks/Cole Publishing Co., Pacific Grove. 763 pp.

Christensen, K.D., E.M. Jacobsen & H. Nielsen, 1996. A comparative study of bird faunas in conventionally and organically farmed areas. – *Dansk Ornitologisk Forenings Tidsskrift* 90: 21-28.

Dover, J.W., 1989a. Butterflies and wildlife corridors. – *Annual Review of the Game Conservancy for 1989* **21**: 62-64.

Dover, J.W., 1989b. The use of flowers by butterflies foraging in cereal field margins. – *Entomologist´s Gazette* **40**: 283-291.

Dover, J.W., 1996. Factors affecting the distribution of satyrid butterflies on arable farmland. - *Journal of Applied Ecology* **33**: 723-734.

Dover, J.W., N.W. Sotherton & K. Gobbett, 1990. Reduced pesticide inputs on cereal field margins: the effects on butterfly abundance. – *Ecological Entomology* **15**: 17-24.

Erhardt, A., 1985. Diurnal Lepidoptera: sensitive indicators of cultivated and abandoned grassland. -*Journal of Applied Ecology* **22**: 849-861.

Feber, R.E. & H. Smith, 1995. Butterfly conservation on arable farmland. – *Ecology and Conservation of Butterflies.* (Ed. Pullin, A.S.) Chapman & Hall, London.

Feber, R.E., H. Smith & D.W. Macdonald, 1996. The effects on butterfly abundance of the management of uncropped edges of arable fields. – *Journal of Applied Ecology* **33**: 1191-1205.

Hald, A.B., & J. Reddersen, 1990. Fugleføde i kornmarker – insekter og vilde planter.

Miljøprojekt 125. Miljøstyrelsen, København. 112 pp.

Hald, A.B., H. Pontoppidan, J. Reddersen & H. Elbek-Pedersen, 1994. Sprøjtefri randzoner i sædskiftemarker. Plante- og insektliv samt udbytter: Landsforsøg 1987-92. – *Bekæmpelsesmiddelforskning fra Miljøstyrelsen,* nr. 6. Miljøstyrelsen, København.

Herrmann, R., N. Hirneisen, I. Nikusch, A. Steiner & K. Treffinger, 1991. Band 1: Tagfalter I. In G. Ebert & E. Rennwald (eds.): *Die Schmetterlinge Baden-Württembergs.* Verlag Eugen Ulmer, Stuttgart.

Kaaber, S. & O.F. Nielsen, 1988. 30 års forandring i Ry-egnens dagsommerfuglefauna. – *Flora og Fauna* **94**: 95-110.

Nielsen, P.S., 1992. *Linjetaksering af sommerfugle.* Xeroxed report. Entomologisk Fredningsudvalg maj 1992. 15 pp.

Pollard, E., 1977. A method for assessing changes in the abundance of butterflies. – *Biological Conservation* **12**: 115-134.

Pollard, E., D.O. Elias, M.J. Skelton & J.A. Thomas, 1975. A method of assessing the abundance of butterflies in Monks Wood National Nature Reserve in 1973. – *Entomologist's Gazette* **26**: 79-88.

Rabjerg, S., 1993. Undersøgelse af en dagsommerfuglelokalitet. – Unpubl. Master´s Thesis, Dep. of Zoology, University of Aarhus, Aarhus. 177 pp.

Rands, M.R.W. & N.W. Sotherton, 1986. Pesticide Use on Cereal Crops and Changes in the Abundance of Butterflies on Arable Farmland in England. – *Biological Conservation* **36**: 71-82.

Reddersen, J., 1998 (in press). The arthropod fauna on organic versus conventional cereal fields in Denmark. – *Biological Agriculture and Horticulture.*

Stoltze, M., 1996. – *Danske Dagsommerfugle.* Gyldendal, Copenhagen. 383 pp.

Thomas, J.A., 1984. The conservation of butterflies in temperate countries: past efforts and lessons for the future. In R.I. Vane-Wright & P.R. Ackery (eds.) *The Biology of Butterflies,* Academic Press, London. Pp. 333-353.