Butterfly densities on line transects in The Netherlands from 1990-2001

The Dutch Butterfly Monitoring Scheme started in 1990. Today more than 300 sites are recorded yearly, most of them by volunteers. Counts are made weekly on a fixed transect. The results offer the possibility to calculate mean butterfly numbers in different habitats. The highest densities are found on semi-natural grasslands. Heathlands have a typical butterfly fauna; a few species reach high densities here. In woodlands butterflies are mostly found at paths and rides. In the rest of the Dutch countryside, butterflies are almost completely restricted to road and railway verges. Urban areas are becoming more and more important for butterflies, but the density is still much lower than in semi-natural grasslands or in woodland.

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C.A.M. van Swaay

De Vlinderstichting
P.O. Box 506
6700 AM Wageningen
The Netherlands
chris.vanswaay@vlinderstichting.nl

Introduction

Over the last century, many butterflies in The Netherlands have declined in range and abundance. Out of 70 native Dutch butterfly species, seventeen have disappeared and 30 are considered threatened on the Red List (Van Ommering *et al.* 1995, Maes & Van Swaay 1997). Only 23 species are considered as 'safe and/or low risk'. Almost all threatened butterflies are nowadays restricted to nature reserves.

In order to preserve the remaining butterfly populations, management of nature reserves should focus on maintaining sustainable populations. To achieve this more information should be gathered on the population characteristics of the various species. These characteristics can be described by a number of parameters, like dispersal capacity, fluctuation in numbers between years and between sites, and population size. Population size is determined by density and patch size. Recent studies of metapopulation dynamics focus on dispersal, patch quality, patch size and isolation (*e.g.* Hanski 1999). There is little information available on patch size and butterfly density. In this paper we focus on the calculation of butterfly densities by using data from butterfly monitoring transects in The Netherlands.

Method

The field method is based on the British Butterfly Monitoring Scheme (Pollard & Yates 1993), which is used since 1976. In 1990, De Vlinderstichting (Dutch Butterfly Conservation Foundation) and CBS (Statistics Netherlands) started a Butterfly Monitoring Scheme (Van Swaay *et al.* 1997, Van Swaay 2000) as a part of the Dutch Network of Ecological Monitoring (NEM). The main objective of the monitoring scheme is to assess changes in abundance at national and regional levels of butterflies, including species of the Habitat Directive. Since 1990 the number of transects has grown from 93 to 366 in 2001 (figure 1). The number and general coverage over the country is good (figure 2), although extra sites would be welcome on the Frisian Islands in the north and parts of Zeeland in the south-west.

Counts are made on a line transect divided into sections with a length of 50 m and a width of 5 m. A transect must have a homogeneous vegetation and vegetation structure. The length of a transect can be up to 1 km (*i.e.* 20 sections), but may be shorter. From April to September all butterflies 2.5 m to the left and right, and 5 m in front and above of the recorder should be counted weekly under standardized weather conditions. The method is described in detail in Van Swaay (2000). Most sites are recorded by volunteers. All recorders have each been visited by the co-ordinator of Dutch Butterfly Conservation; they have a good knowledge of the butterfly fauna at their transect. All data are checked by butterfly experts. After this the quality of the data is controlled by specialists of Statistics Netherlands (CBS).

Each section is assigned to one of the following habitat types:

- dry heathland: habitat dominated by heather and grasses with patches of bare ground on dry, sandy soils, both inland and in the coastal dune area;
- wet heathland: like dry heathland, but on moist to wet, sandy soils;

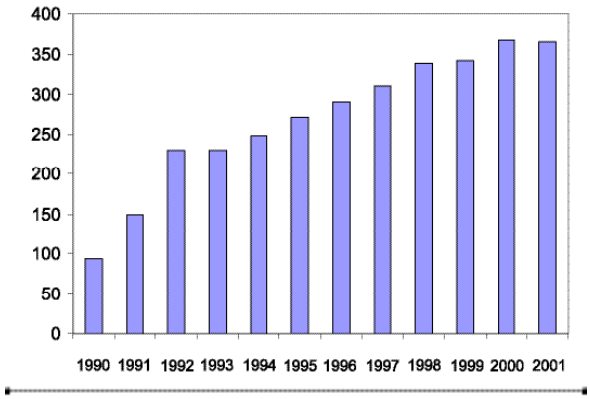

Figure 1. Number of butterfly transects in the Dutch Butterfly Monitoring Scheme in 1990-2001 as used for this assessment.
Aantal getelde transecten in de jaren 1990-2001 in het Landelijk Dagvlinder Project die gebruikt zijn voor de berekeningen in dit artikel.

- dry semi-natural grassland: habitat dominated by grasses and herbs with low management intensity, such as extensive grazing or mowing once or twice a year. These grasslands include dry grassland in the coastal dunes and calcareous grassland in the south of the province of Limburg;
- wet semi-natural grassland: formerly widely distributed over the country, nowadays small and almost completely restricted to nature reserves;
- road and railway verges: in the intensely-farmed Dutch landscape almost the only refuge for butterflies outside nature reserves;
- woodland: habitat dominated by trees, where most butterflies are restricted to the edges or are found along paths, rides and glades where warm, sheltered and sunny conditions and a varied structure provide suitable habitat;
- urban areas: parks, gardens, industrial areas, derelict land;
- open coastal dunes: sandy soils along the western and northern North Sea coast, but excluding heathlands, semi-natural grassland, verges, woodland or urban areas, which are assigned to one of the above habitat types.

Over the flight period of a particular species, a series of counts is obtained for each transect (see example in figure 3). The number of butterfly individuals rises and falls during the season due to the emergence of butterflies from pupae or by immigration, followed by death or emigration. Density calculations per species and per transect were made using the numbers in the peaks of the flight seasons (in the example in figure 3: 56 butterflies on 28 July 1999).

For each group of sections with the same habitat type on a transect the peak number in every year is transformed to a standard transect length of 1000 m (*i.e.* 5000 m^2 or 0.5 hectares). After that the average number of butterflies per transect per year is calculated for all species-habitat combinations with ten or more transects.

Results

Table 1 shows the average number of butterflies in the peak of the flight period per transect of 1000 x 5 m over the period 1990-2001.

Dry heathland

Dry heathlands can be very rich in butterflies, especially in late summer when *Calluna vulgaris* is flowering. This plant can attract ubiquists from large distances. Characteristic species of this habitat type reaching high densities are *Hesperia comma**, *Hipparchia semele*, *Lycaena tityrus* and *Plebeius argus*. *Coenonympha pamphilus* is a widespread species that has its highest density on dry heathland. *Neozephyrus quercus* is a typical woodland butterfly, that can have very high concentrations on solitary *Rhamnus frangula* trees on dry heathland close to neighbouring oak forest.

Wet heathland

The butterfly fauna of Dutch wet heathlands is often dominated by *Plebeius argus* (figure 4). In the transition zone to neighbouring forest some characteristic woodland butterflies can reach high densities, like *Callophrys rubi* and *Pararge aegeria*. Many Dutch heathlands are nowadays being invaded by grasses. As a result of this, typical grassland butterflies like *Maniola jurtina*, *Pyronia tithonus* and *Thymelicus lineola*, can be found in high densities as well.

Dry semi-natural grassland

These grasslands can be very rich in butterflies, both in numbers and in species. Characteristic species for this habitat type reaching high densities are *Plebeius agestis*, *Polyommatus icarus*, *Papilio machaon* (only in the south) and *Issoria lathonia* (mainly on dry grassland in the coastal dune area). Some of the common and widespread species reach

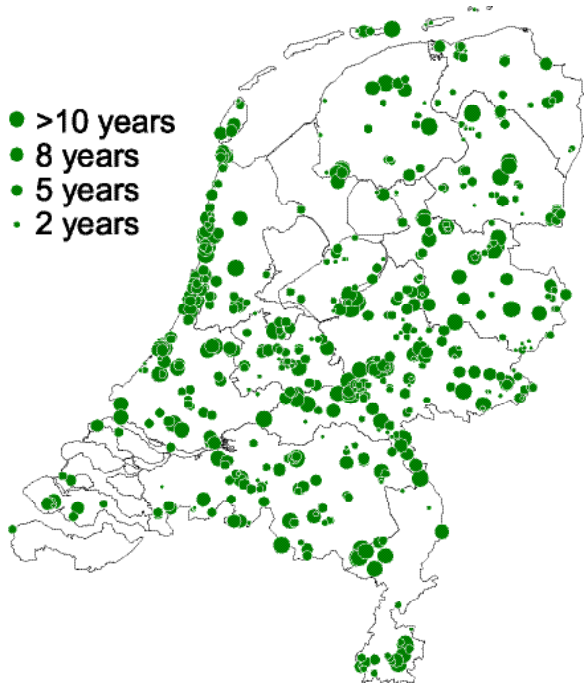

Figure 2. Distribution of the transects over The Netherlands. Dot size indicates the number of years a transect has been counted between 1990-2001.
Ligging van de transecten in Nederland. De stipgrootte is een maat voor het aantal jaren dat een transect geteld is tussen 1990 en 2001.

* author's names are given in table 2

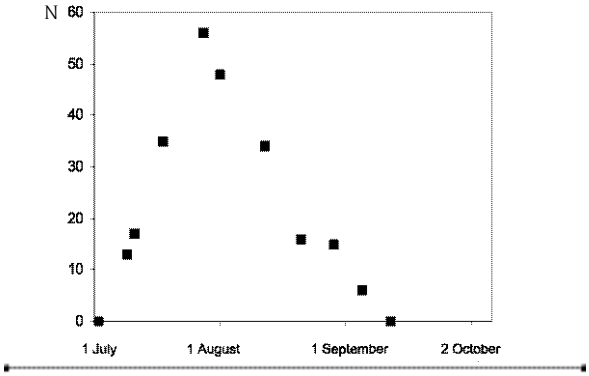

Figure 3. Example of the data in the Dutch Butterfly Monitoring Scheme: individual counts of *Hipparchia semele* in 1999 on a transect in Berkheide, open coastal dune area near Leiden, province of Zuid-Holland.

*Voorbeeld van gegevens uit het Landelijk Meetnet Dagvlinders: tellingen van de heivlinder (*Hipparchia semele*) in 1999 op het transect Berkheide, een open duingebied bij Leiden, Zuid-Holland.*

their highest abundance in this habitat, like *Maniola jurtina*, *Aglais urticae*, *Inachis io*, *Pieris brassicae*, *P. rapae*, *Polygonia c-album* and *Vanessa atalanta*.

Wet semi-natural grassland

Wet semi-natural grasslands were once widespread and common in The Netherlands. Nowadays the remnants are restricted to often small and isolated nature reserves, suffering from drainage from the surrounding agricultural land. Some of the characteristic species of this habitat type have gone extinct in the last century, like *Euphydryas aurinia* and *Lycaena hippothoe*, others like *Boloria selene* have become very rare. Nevertheless many species still have their highest density in this habitat type, like *Anthocharis cardamines*, *Aphantopus hyperantus*, *Boloria selene* and *Pyrgus malvae*.

Road and railway verges

Although their total area is relatively small, verges are an important habitat in the Dutch agricultural countryside. Almost all butterflies here are restricted to this part of the landscape, since the agricultural fields, meadows and pastures are completely sterile as an effect from the extremely intensive Dutch agricultural practice. *Pyronia tithonus* and *Ochlodes faunus* can be very abundant in these verges, especially in the eastern and southern part of the country.

Woodland

In The Netherlands woodland is mainly found in the eastern part of the country and in the coastal dune area. Butterflies are often restricted to paths and glides. Characteristic species are *Araschnia levana*, *Carterocephalus palaemon*, *Limenitis camilla*, *Gonepteryx rhamni* and *Satyrium ilicis*.

Urban areas

The densities of butterflies in urban areas are relatively low and not a single species has its highest density in this habitat type. Most abundant species are *Maniola jurtina*, *Pieris rapae*, *Thymelicus lineola*, *Pyronia tithonus*, *Polyommatus icarus* and *Inachis io*.

Open coastal dunes

Open coastal dunes have relatively few butterflies. Most species in this part of the country are attracted to flower-rich road verges or grasslands, and have therefore been excluded from the numbers in true open coastal dunes. The highest densities of *Argynnis niobe*, a characteristic species for this habitat, are found here.

Discussion

The densities as calculated in this paper cannot always be straightforward compared with densities in other publications for two reasons. First, the presented densities are calculated for the number of butterflies at the peak of the flight period. The actual population size is always larger than this peak number. As a rule of thumb, total adult population sizes are roughly three times the population size at the peak of the flight period (Thomas 1983). Second, the presented densities are calculated for a line transect. In some habitat types (*e.g.* heathlands) the densities on the transect can be regarded as a sample of the whole area, but in others this will not be the case. For example, in woodlands the transects and the butterflies will tend to aggregate along paths (Warren & Fuller 1990). Butterflies are scarce in the true dark forest in between the lanes and paths.

Table 2 compares the densities from this study to the densities given by Bink (1992). For 21 species out of 37 (57%) the densities on the line transects fall within the range given by Bink (1992). For one species (*Lycaena tityrus*) the density on transects is lower, for all other species (41%) the densities on the line transects are higher. It is not clear if this is a result of the second reason above (a methodological reason), or means that the actual densities have changed since the period that Bink did his research, mainly before 1990. A true comparison is also difficult since Bink (1992) does not give a detailed description of his method of density establishment.

Butterfly densities vary largely per habitat type. The highest number of butterflies in The Netherlands is found on semi-natural grasslands. These grasslands were once widespread in the country, but nowadays they are restricted to small relicts in nature reserves. They suffer strongly from isolation, drainage and nutrient enrichment by the surrounding agricultural countryside. Nevertheless the local density of butterflies can still be very high, resulting in large populations if sufficient area or connectivity is available. This is especially the case for some of the characteristic grassland butterflies, like *Maniola jurtina* and *Aphantopus hyperantus*.

Heathlands have a typical butterfly fauna, in which a few species reach high densities. Typical examples are *Hipparchia semele* and *Hesperia comma* (figure 5) on dry heathlands. *Plebeius argus* can be found on dry and wet heathlands in the same densities, but is much more widespread on wet heathlands. Heathlands can be very rich in nectar sources (mainly *Calluna vulgaris* on dry heathlands and *Erica tetralix* on wet heathlands), attracting species from adjacent areas. Also the flowering small trees of *Rhamnus frangula*, found at the edge of heathlands, can attract typical woodland butterflies like *Neozephyrus quercus*. Nutrient enrichment of heathlands has caused grasses to become more and more dominant. As a result of this, typical grassland butterflies, like *Maniola jurtina*, *Pyronia tithonus* and *Thymelicus*

Table 1. Average number of butterflies over twelve years per line transect of 1000 x 5 m per habitat type at the peak of the flight period. Only species-habitat type combinations with ten or more transects have been evaluated. The highest density for each species is given in red. Species names are according to Kuchlein & De Vos (1999).

Gemiddeld aantal vlinders over twaalf jaar per transect van 1000 x 5 m per begroeiingstype tijdens de piek van de vliegtijd. Alleen soort-begroeiingstype-combinaties met tien of meer transecten zijn gebruikt. The hoogste dichtheden per soort zijn in rood weergegeven. Soortnamen volgen Kuchlein & De Vos (1999).

	dry heath-land	wet heath-land	dry semi--natural grass land	wet semi-natural grass land	road and railway verges	wood-land	urban areas	open coastal dunes
number of transects:	49	36	87	86	96	151	115	76
Aglais urticae	8	17	18	14	17	17	14	6
Anthocharis cardamines		11	14	33	6	21	8	7
Aphantopus hyperantus	21	34	58	148	57	93	15	23
Araschnia levana	10	18	22	14	14	25	8	5
Argynnis niobe						4		8
Boloria selene				74				
Callophrys rubi	13	24	5	5		19		
Carterocephalus palaemon						20		
Celastrina argiolus	6	14	7	6	6	10	5	3
Coenonympha pamphilus	38	8	24	18	9	20	7	19
Gonepteryx rhamni	8	13	11	11	11	20	7	3
Hesperia comma	8							6
Hipparchia semele	42		16		7	15	6	13
Inachis io	7	8	39	13	18	26	15	6
Issoria lathonia			27			15	5	12
Lasiommata megera		19	23	16	15	18	8	6
Limenitis camilla						11		
Lycaena phlaeas	16	18	15	13	10	11	7	16
Lycaena tityrus	16			12		14		
Maniola jurtina	36	100	163	144	78	116	31	115
Neozephyrus quercus	48	22	9	14	14	13	6	7
Ochlodes faunus	20	51	29	24	58	55	8	12
Papilio machaon			3					
Pararge aegeria	11	29	11	17	24	25	14	
Pieris brassicae	6	10	12	9	9	12	8	3
Pieris napi	16	33	63	67	47	45	19	8
Pieris rapae	8	33	38	30	30	31	28	9
Plebeius agestis			45		9	30	7	7
Plebeius argus	94	94		59		25		
Polygonia c-album	4	5	10	5	4	7	4	4
Polyommatus icarus	33	16	62	12	15	28	17	16
Pyrgus malvae	10			33				4
Pyronia tithonus		85	55	48	140	65	22	
Satyrium ilicis						11		9
Thymelicus lineola	30	86	78	43	79	77	25	52
Vanessa atalanta	6	10	17	9	11	14	8	5
Vanessa cardui	6	10	18	27	12	10	9	7

Figure 4. *Plebeius argus* is a characteristic species of heathlands. Photo: Henkjan Kievit, De Vlinderstichting.

*Het heideblauwtje (*Plebeius argus*) is een kenmerkende vlinder van heideterreinen.*

Table 2. Comparison of average butterfly density at the flight peak on transects in the Dutch Butterfly Monitoring Scheme compared with the density according to Bink (1992) for NW-Europe. Colours indicate differences: black = density on transects larger; green = density more or less similar; red = density on transects lower. Both average (first column) and NW-European density (second column) are presented as number of butterflies/hectare. *Vergelijking tussen de gemiddelde dichtheid van vlinders in de piek van de vliegtijd op transecten in het Landelijk Meetnet Dagvlinders (eerste kolom) en volgens Bink (1992) voor Noordwest-Europa (tweede kolom). Kleuren geven de verschillen aan: zwart = dichtheid op transecten is hoger; groen = dichtheden zijn min of meer gelijk; rood = dichtheid op de transecten is lager.*

species	average density on transects of Dutch Butterfly Monitoring Scheme	density according to Bink (1992)
Aglais urticae (Linnaeus, 1758)	12-36	0.06-4
Anthocharis cardamines (Linnaeus, 1758)	14-66	1-16
Aphantopus hyperantus (Linnaeus, 1758)	30-296	16-260
Araschnia levana (Linnaeus, 1758)	10-50	0.25-4
Argynnis niobe (Linnaeus, 1758)	8-16	4
Boloria selene (Denis & Schiffermüller, 1775)	148	4-260
Callophrys rubi (Linnaeus, 1758)	10-48	4-64
Carterocephalus palaemon (Palls, 1771)	40	16
Celastrina argiolus (Linnaeus, 1758)	6-28	0.25-16
Coenonympha pamphilus (Linnaeus, 1758)	14-76	4-64
Gonepteryx rhamni (Linnaeus, 1758)	6-40	0.06-16
Hesperia comma (Linnaeus, 1758)	12-16	16
Hipparchia semele (Linnaeus, 1758)	12-84	16
Inachis io (Linnaeus, 1758)	12-78	0.02-4
Issoria lathonia (Linnaeus, 1758)	10-54	0.25-64
Lasiommata megera (Linnaeus, 1767)	12-46	1-16
Limenitis camilla (Linnaeus, 1764)	22	16
Lycaena phlaeas (Linnaeus, 1758)	14-36	4-64
Lycaena tityrus (Poda, 1761)	24-32	64
Maniola jurtina (Linnaeus, 1758)	62-326	16-1000
Neozephyrus quercus (Linnaeus, 1758)	12-96	16-260
Ochlodes faunus (Bremer & grey, 1852)	16-116	16
Papilio machaon Linnaeus, 1758	6	0.25
Pararge aegeria (Linnaeus, 1758)	22-58	16
Pieris brassicae (Linnaeus, 1758)	6-24	0.25
Pieris napi (Linnaeus, 1758)	16-134	4-64
Pieris rapae (Linnaeus, 1758)	16-76	1-260
Plebeius agestis (Denis & Schiffermüller, 1775)	14-90	4-260
Plebeius argus (Linnaeus, 1758)	50-188	16-1000
Polygonia c-album (Linnaeus, 1758)	8-20	0.06-1
Polyommatus icarus (Rottemburg, 1775)	24-124	4-260
Pyrgus malvae (Linnaeus, 1758)	8-66	16
Pyronia tithonus (Linnaeus, 1771)	44-280	64
Satyrium ilicis (Esper, 1779)	18-22	16
Thymelicus lineola (Ochsenheimer, 1808)	60-172	16-1000
Vanessa atalanta (Linnaeus, 1758)	10-34	0.02-1
Vanessa cardui (Linnaeus, 1758)	12-54	0.02-0.25

Figure 5. In The Netherlands *Hesperia comma* is restricted to dry heathland and open coastal dunes. Photo: Kars Veling, De Vlinderstichting. I*n Nederland wordt de kommavlinder (*Hesperia comma*) uitsluitend gevonden op droge heidevelden en in de open kustduinen.*

lineola can nowadays occur in high densities on heathlands.

The paths and rides where most butterfly transects in woodlands are located, are also the main habitat for woodland butterflies (Warren & Fuller 1990). Next to the characteristic species of this habitat, many other species visit the sheltered sites for nectar sources.

Intensive farming of agricultural grasslands leaves no room for butterflies. As a result of this, butterflies in the rest of the Dutch countryside are almost completely restricted to road and railway verges. If well managed these verges represent the last places where butterflies can survive. Two grassland butterflies, *Pyronia tithonus* and *Ochlodes faunus*, even reach higher densities on these verges than on semi-natural grasslands. Nevertheless these verges are dangerous habitats, since the spraying of nearby crops with insecticides, a common practice in modern Dutch agriculture, is often lethal for the larvae (Groenendijk *et al*. 2002).

Figure 6. Densities of *Maniola jurtina* in this urban area in Naarden were very high. Photo: Inge van Halder, De Vlinderstichting.
*De dichtheden van het bruin zandoogje (*Maniola jurtina*) op de wallen van Naarden waren bijzonder hoog.*

In a highly urbanized country like The Netherlands, urban areas are becoming more and more important for butterflies and other animals. The results show that the density of butterflies in these areas is still much lower than in semi-natural grasslandsor woodland. The main reason for this is, presumably, that management in urban areas still mainly focuses on gardening, including intensive mowing of grasslands (in that case called lawns) and the use of insecticides in flowerbeds. More and more cities and villages are changing their management to a more ecological form, allowing wild and semi-wild plants to flower (figure 6). The mowing frequency is reduced to once or twice per year, thus resulting in a semi-natural vegetation offering better opportunities for butterflies.

The data presented here can also be used to compare the butterfly densities on a certain transect with the overall average density. Next to the comparison of the local trends to the national trends this provides information to wardens and managers of nature reserves about developments in their butterfly fauna, making it possible to detect changes on time so there is still an opportunity to take appropriate action.

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Samenvatting
Dagvlinderdichtheden op Nederlandse transecten van 1990-2001

In het Landelijk Meetnet Dagvlinders, dat is gestart in 1990, wordt momenteel op meer dan 300 plekken in Nederlands dagvlinders geteld, meestal door vrijwilligers.Wekelijks worden de vlinders geteld op een vast transect. De resultaten bieden de mogelijkheid om de gemiddelde vlinderdichtheid in verschillende begroeiingstypen te berekenen. De hoogste vlinderdichtheden worden gevonden op halfnatuurlijke graslanden. Heidevelden hebben meestal een karakteristieke vlinderfauna, waarbinnen een paar soorten in hoge dichtheden voorkomen. Bosvlinders worden meestal aangetroffen op paden en langs de randen. In de rest van het Nederlandse platteland zijn vlinders vrijwel geheel beperkt tot bermen. Stedelijk gebied wordt steeds belangrijker voor vlinders, maar de resultaten laten zien dat de dichtheid hier nog lager is dan in halfnatuurlijke graslanden en bossen.