Changes in ranges of hoverflies in the Netherlands in the 20th century (Diptera: Syrphidae)

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Abstract
In July 2001 the database of the Netherlands Syrphidae Recording Scheme contained approximately 200 000 records of Syrphidae. This database was used to examine changes in the hoverfly fauna of the Netherlands during the 20th century. The dataset was divided into two parts, before and since 1988, containing equal numbers of records. This revealed that there is a significant increase in the distribution of hoverfly species with saproxylic larvae. Probably this is a consequence of the changes in woodland management that have taken place in the past 20 years. Another result of the trend analysis is the conclusion that there is a high proportion of southern species among the increased species. A likely explanation for this is the change in climate in the past 20 years.
Of a total number of 317 species, 29% increased, 40% remained stable and 31% has decreased. Eight species have increased strongly and 22 species show a strong decline. The causes of the strong trends are often unclear, but seem to be very different from species to species.

Key words: Syrphidae, trends, Netherlands, saproxylic species, climate change.

Introduction
The Netherlands Syrphidae Recording Scheme has built up a database of approximately 200 000 records of Syrphidae (July 2001). These records cover all parts of the country and the oldest date back to the 19th century. This extensive database offers the possibility to acquire more knowledge of the changes in distribution and abundance of hoverfly-species in the Netherlands. Which species have decreased and which have increased? Is there a detectable general trend among different ecological species groups?
The construction of the database started in the 1980s. Aat Barendregt gathered all records of *Anasimyia* Schiner, 1864, *Helophilus* Meigen, 1822 and *Parhelophilus* Girschner, 1897 present in Dutch collections. In the 1980's and early 1990's *Brachyopa* Meigen, 1822, *Epistrophe* Walker, 1852, *Melangyna* Verrall, 1901 and *Platycheirus* Lepeletier & Serville, 1828 followed. In 1998 the Nederlandse Jeugdbond voor Natuurstudie, European Invertebrate Survey – The Netherlands and the Nederlandse Entomologische Vereniging started the Netherlands Syrphidae Recording Scheme. All digitally available records of private collectors were added to the database. This resulted in the publication of a provisional atlas of the Dutch Syrphidae, which was based on approximately 100 000 records (NJN 1998).
In July 2001 all the records in the Zoological Museum Amsterdam (ZMAN) and most of the smaller public collections were included in the database. Besides, many more records of private collectors were included (both collection and field data). The collection of the National Museum of Natural History Leiden (RMNH) had not yet been included in the database at that time. The contents of the database of July 2001 is summarized in table 1.

Methods

Calculation of trends
The data are divided into two periods: before 1988 and 1988-2000. Both the number of records and the number of investigated 5 km squares is approximately equal in both periods. Therefore it is not necessary to compensate for differences in recording intensity. Figure 1 shows that the spatial distribution of the records is similar in both periods.

Table 1
Summary of the contents of the Dutch Syrphidae database of July 2001.

	total	**before 1988**	**1988-2000**
number of records	194 942	93 505	101 437
number of investigated 5 km squares	1437	1239	1136
number of species	317	303	292

For each species, we calculated the relative abundance (RA) in both periods as follows:

$$RA = \frac{\text{(number of squares in which a species is recorded)}}{\text{number of investigated squares}} \times 100\ \%$$

The number of investigated squares is defined as the number of 5 km squares in which at least one hoverfly species is recorded.
The advantage of using the number of squares (instead of the number of records) is that this method is less sensitive for differences in the collecting behaviour of entomologists, for some of them collect almost every specimen they encounter, while others only take one or two. Besides, there is the effect of the considerably larger proportion of field observations in recent years, which results in a larger number of records of common species. This effect is very much reduced by basing the analysis on 5 km squares. According to their relative abundances, we assigned the species to 10 categories of abundance, both in the first and in the second period (table 2). The trend of each species was determined by assessing the shifts in categories between the periods (table 3).

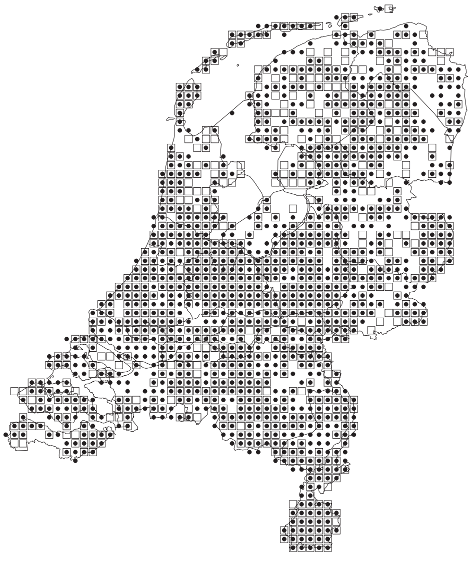

Figure 1
Distribution of records of Syrphidae in the Netherlands before 1988 (squares) and in 1988-2000 (dots).

Statistics
The χ^2-tests were conducted by the computer program Microsoft Excel 97.

Ecological groups
The species are divided into four ecological groups: predatory species (Pr, n = 147), phytophagous species (Ph, n = 50), saprophagous species associated with wood (saproxylic species) (Sx, n = 55) and (semi-)aquatic saprophagous species (Aq, n = 61). This division is based on information in Rotheray (1993).

Northern and southern species
For each species, we determined the distributional borders in Europe. We did this by considering distributional data from the Netherlands and all surrounding countries (Ball & Morris 2000, NJN 1998, Speight 2001, Torp 1994, Verlinden 1991). Southern species are defined as species of which the northern limit of their range runs through the Netherlands. We calculated the proportion of northern and southern species among the increased species of all four ecological groups.

Results

Of a total number of 317 species, 29% increased, 40% remained stable and 31% has decreased, as shown in figure 2. The trends within the four recognized ecological groups are shown in figure 3a-d. To test whether the differences in the

Table 2
Categories of abundance (COA), indicating the percentage of investigated 5x5 km squares in which a species has been found.

COA	maximum percentage of investigated 5x5 km squares
0	0 %
1	0.39 %
2	0.78 %
3	1.56 %
4	3.13 %
5	6.25 %
6	12.5 %
7	25 %
8	50 %
9	100 %

Table 3
Explanation of trend categories, based on the shift in categories of abundance between the two considered periods.

trend category	shift in category of abundance
strong decrease	- 2 or more COA
decrease	- 1 COA
stable	no shift in COA
increase	+ 1 COA
strong increase	+ 2 or more COA

proportions of trend categories between these groups are statistically significant, χ^2-tests have been conducted (table 4). This revealed that only the observed increase of saproxylic species can not be attributed to coincidence ($p < 0.05$). The proportions of the trend categories within the other three ecological groups do not differ from the proportion among the total species group.

Several examples can be given of species belonging to the saproxylic species group that in recent years have appeared in regions where they had never been seen before, despite long term recording: *Brachyopa pilosa* Collin, 1939, *Brachypalpus laphriformis* Macquart, 1834, *Criorhina floccosa* (Meigen, 1822), *C. pachymera* Egger, 1858, *Temnostoma bombylans* (Fabricius, 1805), *T. vespiforme* (Linnaeus, 1758) and *Xylota sylvarum* (Linnaeus, 1758). Most of these are large, easily detectable and identifiable species, which must have been as conspicuous before 1988 as they are now. Besides, their forest habitat has always attracted hoverfly recorders, so a strong effect of differences in recording intensity seems improbable.

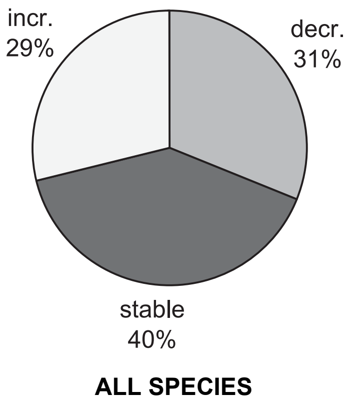

Figure 2
Proportions of trend categories among 317 species of Syrphidae.

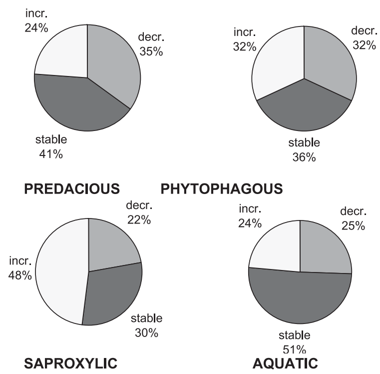

Figure 3
Proportions of trend categories among the four ecological groups of Syrphidae: predacious species (n = 146); phytophagous species (n = 50); saproxylic species (n = 54); (semi-)aquatic species (n = 59).

Table 4
Results of χ^2-tests of the observed proportions of trend categories within the four recognized ecological groups of hoverfly species (obs. = observed number, exp. = expected number). The only significant p-value ($p < 0,05$) is printed in bold.

	all n=317	predacious species n=146			phytophagous species n=50			saproxylic species n=54			(semi)aquatic species n=59		
		obs.	**exp.**	**p**	**obs.**	**exp.**	**p**	**obs.**	**exp.**	**p**	**obs.**	**exp.**	**p**
Increased species compared with stable and decreased species													
increased	92	35	42.4	0.179	16	14.5	0.643	26	15.7	**0.002**	14	17.1	0.370
stable / decreased	225	111	103.6		34	35.5		28	38.3		45	41.9	
Decreased species compared with stable and increased species													
decreased	99	51	45.6	0.335	16	15.6	0.907	12	16.9	0.153	15	18.4	0.336
stable / increased	218	95	100.4		34	34.4		42	37.1		44	40.6	
Stable species compared with decreased and increased species													
stable	126	60	58.0	0.739	18	19.9	0.588	16	21.5	0.129	30	23.5	0.081
decreased / increased	191	86	88.0		32	30.1		38	32.5		29	35.5	

Strongly increased species

A few species show a strong increase of two or more categories of abundance. These species are listed in table 5. This group of species is ecologically very heterogeneous. There seems to be no general factor which explains the increase of all species together. For some of them, the 'increase' might be explained by differences in recording effort. This could be true for *Sphegina verecunda*, a species with a specific habitat preference which is easily overlooked. In other species however, this is certainly no satisfactory explanation. *Cheilosia caerulescens*, for instance, is a species with phytophagous larvae which was first recorded in the Netherlands in 1986. Since then there have been numerous records, almost all of them from gardens. The increase of this easily identifiable species is probably caused by the increase in the use of its host plant, *Sempervivum*, in rooftop gardens in the Netherlands (Stuke 2000).

Strongly decreased species

A total number of 22 species has strongly decreased in the Netherlands (table 6), three of which have disappeared from the Netherlands. (Please note that there are several other species which have only been recorded before 1988 and probably have disappeared. However, these species are not considered as 'strongly decreased', because their number of records is too low.)

Among these strongly decreased species some interesting groups of species which share certain ecological features can be recognized.

1. Coastal species (species which in the Netherlands seem to depend on areas with brackish water): *Lejops vittata*, *Platycheirus immarginatus*. The amount of suitable habitat has strongly declined in the Netherlands, especially since the former 'Zuiderzee' (now called 'IJsselmeer') was dammed in 1932. Another species belonging to this ecological group, *Eristalinus aeneus*, has remained stable in the Netherlands.
2. Bog species: *Anasimyia lunulata*, *Eristalis anthophorina*, *Parhelophilus consimilis*.
3. Fungus feeding species: *Cheilosia longula*, *C. scutellata*. These species presumably have decreased because the fungi in which they breed have decreased as well. In recent years both the fungi as the *Cheilosia*-species seem to recover from their decline.

Northern and southern species

Only three hoverfly species have been identified as 'northern species': *Eristalis anthophorina* (Fallén, 1817), *Eupeodes lundbecki* (Soot-Ryen, 1946) and *Neocnemodon verrucula* (Collin, 1931). All three species have decreased in the Netherlands.

The group of 'southern species' contains 58 species. A comparison with the non-southern species

Table 5
Strongly increased species.

species	relative abundance before 1988	relative abundance 1988-2000	remarks
Brachyopa pilosa Collin, 1939	2.3 %	7.0 %	this species now occurs in western parts of the Netherlands, where it has not been found before, despite many records of other *Brachyopa*-species
Cheilosia caerulescens (Meigen, 1822)	0.1 %	1.8 %	apparently this species rapidly colonized the gardens in which the host plant *Sempervivum* is growing (Stuke 2000)
Cheilosia illustrata (Harris, 1780)	2.6 %	10.2 %	cause of increase unclear
Epistrophe melanostoma (Zetterstedt, 1843)	2.7 %	8.9 %	southern species that benefits from climate change?
Eristalis picea (Fallén, 1817)	1.3 %	4.7 %	this is probably no real increase, but the result of specific recording efforts
Pipizella annulata (Macquart, 1829)	0.3 %	1.1 %	southern species that benefits from climate change?
Sphegina sibirica Stackelberg, 1953	0.0 %	1.4 %	increase all over Europe (Van der Ent & Jansen 1988)
Sphegina verecunda Collin, 1937	0.1 %	1.2 %	this is probably no real increase, but the result of specific recording efforts

(table 7) shows that the increase among southern species is 6 % larger than among non-southern species ($p = 0.04$).

Table 8 gives the proportion of southern species among the increased species of all four different ecological groups. None of these proportions is significantly different from the proportion of southern species in the total group of increased species. This suggests that climate change is not a more important factor in the increase of one ecological group than it is in the others.

Discussion

Conclusions

Two of the calculated results proved to be significant when tested with a χ^2–test. These results support the following conclusions:

- Hoverfly species with saproxylic larvae have become more widespread in the Netherlands after 1988.
- There is a relatively large group of southern species among the hoverflies that have increased after 1988.

The increase of saproxylic species

The most likely explanation for the increase of many saproxylic species is the change in woodland management in combination with the increased age of the Dutch forests. This has been suggested earlier by Barendregt (1992) and Reemer et al. (2000). In the management of

Table 6
Strongly declined species.

species	relative abundance before 1988	relative abundance 1988-2000	disappeared
Anasimyia lunulata (Meigen, 1822)	1.5 %	0.2 %	
Cheilosia longula (Zetterstedt, 1838)	3.8 %	1.3 %	
Cheilosia scutellata (Fallén, 1817)	7.1 %	2.9 %	
Chrysotoxum octomaculatum Curtis, 1837	3.4 %	0.4 %	
Dasysyrphus friuliensis (van der Goot, 1960)	1.6 %	0.3 %	
Eristalis anthophorina (Fallén, 1817)	4.3 %	1.1 %	
Eumerus flavitarsis Zetterstedt, 1843	0.9 %	0.1 %	
Eumerus sabulonum (Fallén, 1817)	1.1 %	0.1 %	
Leucozona glaucia (Linnaeus, 1758)	4.6 %	1.0 %	
Lejops vittata (Meigen, 1822)	1.7 %	0.2 %	
Mallota fuciformis (Fabricius, 1794)	1.1 %	0.0 %	yes
Melangyna barbifrons (Fallén, 1817)	1.5 %	0.2 %	
Neocnemodon verrucula (Collin, 1931)	1.0 %	0.2 %	
Parhelophilus consimilis (Malm, 1863)	1.7 %	0.7 %	
Paragus tibialis (Fallén, 1817)	0.8 %	0.0 %	yes
Parasyrphus vittiger (Zetterstedt, 1843)	6.5 %	1.9 %	
Platycheirus immarginatus (Staeger in Zett., 1849)	4.0 %	0.9 %	
Platycheirus parmatus Rondani, 1857	1.1 %	0.4 %	
Psarus abdominalis (Fabricius, 1794)	1.1 %	0.0 %	yes
Sphaerophoria fatarum Goeldlin de Tiefenau, 1974	3.2 %	0.9 %	
Sphaerophoria philanthus (Meigen, 1822)	3.2 %	1.0 %	
Sphaerophoria taeniata (Meigen, 1822)	3.8 %	1.1 %	

Table 7
Proportions of trend categories within the groups of southern and non-southern species.

	number of stable / decreased species	number of increased species	expected number of increased species	p
southern species	38 (18 %)	20 (24 %)	15.1	
non-southern species	173 (82 %)	64 (76 %)	52.5	
total	211	84		
				0.04

Table 8
The proportion of southern species among the increased species of the four ecological groups of hoverflies.

	total number	number and proportion of southern species	expected number of southern species	p
increased total	92	20 (22 %)		
increased predacious (Pr)	36	11 (31 %)	7.8	0.2
increased phytophagous (Ph)	16	4 (25 %)	3.5	0.8
increased saproxylic (Sx)	26	4 (15 %)	5.7	0.4
increased aquatic (Aq)	14	1 (7 %)	3.0	0.2

forests, the tendency to remove all dead wood and ill trees gave way for the recent policy (since 1973) of leaving it in the forests. Besides, an important part of the Dutch forests is no longer in use for forestry. This is of great benefit to saproxylic insects.
Another explanation for the increase of saproxylic hoverflies could be a larger proportion of southern species among them in comparison with the other ecological groups. However, the results in table 8 show that this is probably not the case.

The increase of southern species
Probably the warmer climate during the last 20 years is responsible for the high proportion of southern species among the increased species. Another indication for this is the recent addition of several southern species to the list of Dutch hoverflies, like *Cheilosia soror* (Zetterstedt, 1843), *Chrysotoxum intermedium* Meigen, 1822, *Paragus quadrifasciatus* Meigen, 1822 and *Scaeva dignota* (Rondani, 1857) (Lucas 1992, NJN 1998, Smit et al. 2001a, b).

Trend calculation
We have used categories of abundance to get a better overview of the changes in distribution. However, the use of categories has some disadvantages. The most important disadvantage is that it makes a big difference whether the relative abundance of a species lies on one side of the category border or on the other. For instance, a species with a pre-1988 distribution of 1.6 % (COA 4) and a post-1988 distribution of 6.0 % (COA 5) has 'increased', whereas a species with a pre-1988 distribution of 3.1 % (COA 4) and a post-1988 distribution of 6.3 % (COA 6) has 'strongly increased' (for explanations of these categories see table 2 and 3).
For future research on the changes in the Dutch syrphid fauna, it would be better to use a trend calculation which is not based on categories but on an assessment of the relative change. A good alternative would be the method that has been used for the calculations in several red lists in the Netherlands (Odé 1999, Wasscher 1999). In these reports, the trend is calculated as follows (RA= relative abundance):

$$\text{trend} = \frac{(\text{RA in recent period} - \text{RA in historical period})}{\text{relative abundance historical period}} \times 100\ \%$$

Because this paper is a comprehensive version of our lectures on the international colloquium of EIS, we decided not to use another method in this paper but to stick to the calculations we made for the lectures. In the atlas of the Dutch hoverflies (in prep.) we will publish new results of trend calculations.

Future analyses
The data in the database of the Netherlands Syrphid recording scheme have not been collected by a systematic, standardized method. This makes it hard to analyse and interprete the data. Because of this and because of the discussed disadvantages of the methods we used, the analysis in this paper should be regarded as a first attempt to present a view on the changes in ranges and abundances of the syrphid fauna in the Netherlands. Within a couple of years, the database will contain much more data and the methods we will use for the analysis will be more refined. We hope to present the results of the next trend analysis in the atlas of the Syrphidae of the Netherlands which will appear within a couple of years.
It would be interesting to compare the changes in the Netherlands with the changes in other northwestern European countries. At present several people in different countries are working on distributional databases. In the near future a better analysis of distributional changes of European Syrphidae will be possible.

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