Butterflies and insecticides: a review and risk analysis of modern Dutch practice

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Results of the Dutch Butterfly Monitoring Scheme during 1990-1998 showed that about twenty butterfly species listed as 'safe/low risk' at the National Red List significantly decreased. The reason for this decrease is largely unknown and the possibility of insecticides playing a role is reviewed in this study. Larvae of common butterflies in the Netherlands proved to be extreme sensitive to insecticides currently used in Dutch agricultural systems. A risk analysis shows that larvae of butterflies in field margins would not survive a spray on nearby crop. This preliminary risk analysis is based on the use of insecticides in the Netherlands and on toxicity data of *Pieris brassicae*. It is concluded that the current use of insecticides in the Netherlands is of potential risk for butterflies common in field margins.

Keywords: butterflies, insecticides, risk analysis, field margins

In the Netherlands butterflies are counted systematically since 1990 in the Dutch Butterfly Monitoring Scheme. On more than 300 butterfly transects distributed all over the country, butterflies are counted every week from April to September using a standardised method (Van Swaay 2000). The main results from the Dutch Butterfly Monitoring Scheme are national trends per species, which are a useful tool for conservation at different levels. Many butterfly species display a significant decrease and only a few species increased during 1990-1998 (Van Swaay 2000). For many butterfly species a strong negative correlation is observed for environmental factors like acidification and eutrophication, resulting in the absence of sufficient habitat of adequate quality. Simultaneously, habitat loss and fragmentation are also regarded as main reasons for the decrease of these butterfly species. For some species the reasons are well known and the current distribution of many butterfly species is only a minor proportion of the earlier distribution. All those species are listed on the National Red List (Van Ommering *et al.* 1995) in different categories ranging from 'extinct' to 'safe/low risk'. Many threatened or endangered butterfly species still show a strong decline during 1990-1998. Most surprisingly, for about twenty species listed at the National Red List in the category 'safe/low risk', a significant decrease was also detected (Van Swaay 2000).

It is however, not exactly known what the reason for the decrease of these common butterfly species is. All butterfly species in the category 'safe/low risk' of the National Red List are species known for their broad ecological habitat choice and are abundant all over the country. Therefore, it is tentatively put forward that other factors than habitat loss, fragmentation and overall decrease of habitat quality could play an additional role. The agricultural use of insecticides was regarded as one of the possibilities. Because of the lack of knowledge of effects of insecticides on butterflies, the Dutch Butterfly Conservation asked the Science Shop Biology of Utrecht University to review the effects for butterflies of insecticides currently used in Dutch agricultural systems and to analyse the risk for butterfly larvae in field margins nearby sprayed crop. The present paper summarises the main results from this literature study and preliminary risk analysis.

MATERIAL AND METHODS

Most pesticides are used in agricultural areas and sprayed on standing crop to prevent from damage by pest organisms. Due to drift of the sprayed pesticides, non-target organisms will get in contact with the used pesticides and effects of drift can be harmful for butterflies (Sinha *et al.* 1990; Davis *et al.* 1991a). This study focused on the effects of insecticides only, although direct and indirect effects of herbicides can be harmful for butterflies too. To evaluate the effects of insecticides on non-target organisms, a selection of butterfly species abound in Dutch field margins was made. In addition, the selected butterflies were grouped using ecological criteria, based on the number of generations each year and the way larvae hibernate (Table 1). This study is mainly a literature review on the effects of insecticides and a preliminary risk analysis for the selected butterfly species. Results were analysed using three different levels. At first the known effects of insecticides for the selected butterfly species were described. Second, the use of insecticides in the Netherlands in relation to the presence of larvae of butterflies was investigated. Third, a risk analysis for butterfly larvae present in field margins was made. The results of these three steps are summarised below. More detailed information is presented in Van Mannekes (2001).

RESULTS

Review of effects on butterflies

Analysing the direct effects of insecticides on larvae of the selected butterfly species (*cf*. Table 1), it was shown that insecticides in general are extremely toxic for caterpillars (Fig. 1). The majority (>75%) of the reported LD_{50} values (dosage of insecticide compound which is lethal to 50% of the tested larvae) were below 0.05 µg insect^{-1}, indicating that larvae of butterflies are in general very sensitive for insecticides. However, not all butterfly species listed in Table 1 were used in toxicity tests. Most toxicity experiments were carried out on larvae of *Pieris brassicae*. In addition, toxicity values were reported on *Pieris napi*, *Polyommatus icarus* and *Pyronia tithonus*. Values for ten different insecticides were used for the compilation of Fig. 1 and all data are from Sinha *et al.* (1990) and Davis *et al.* (1991a, 1993). It should be noted that the broad ranges of the two groups of insecticides is caused by differences in sensitiveness among butterfly species and by differences between compounds. All LD_{50} values for each butterfly species and insecticide compound used for the compilation of Fig. 1 are given in Table 2.

Table 1. Selected butterfly species on which effects of insecticides were reviewed in this study. The criteria used for this selection included: A) the species is a common inhabitant of Dutch field margins and B) the larvae of the species is feeding on plant species commonly occurring in Dutch field margins (for more details consult Van Mannekes 2001 and Van Mannekes & Groenendijk 2001). The selected butterflies were grouped in three different ecological groups: group 1) hibernating as a larvae and only one life cycle each year; group 2) larvae present during the summer months and normally more than one life cycle each year; group 3) hibernating as a larvae and normally more than one life cycle each year.

Group 1:
Essex Skipper, *Thymelicus lineola* (Ochsenheimer, 1808)
Small Skipper, *Thymelicus sylvestris* (Poda, 1761)
Large Skipper, *Ochlodes faunus* (Turati, 1905)
Meadow Brown, *Maniola jurtina* (Linnaeus, 1758)
Ringlet, *Aphantopus hyperantus* (Linnaeus, 1758)
Gatekeeper, *Pyronia tithonus* (Linnaeus, 1771)
Group 2:
Large White, *Pieris brassicae* (Linnaeus, 1758)
Small White, *Pieris rapae* (Linnaeus, 1758)
Green-veined White, *Pieris napi* (Linnaeus, 1758)
Peacock, *Inachis io* (Linnaeus, 1758)
Small Tortoiseshell, *Aglais urticae* (Linnaeus, 1758)
Group 3:
Small Copper, *Lycaena phlaes* (Linnaeus, 1761)
Common Blue, *Polyommatus icarus* (Rottemburg, 1775)
Wall Brown, *Lasiommata megera* (Linnaeus, 1758)
Small Heath, *Coenonympha pamphilus* (Linnaeus, 1758)

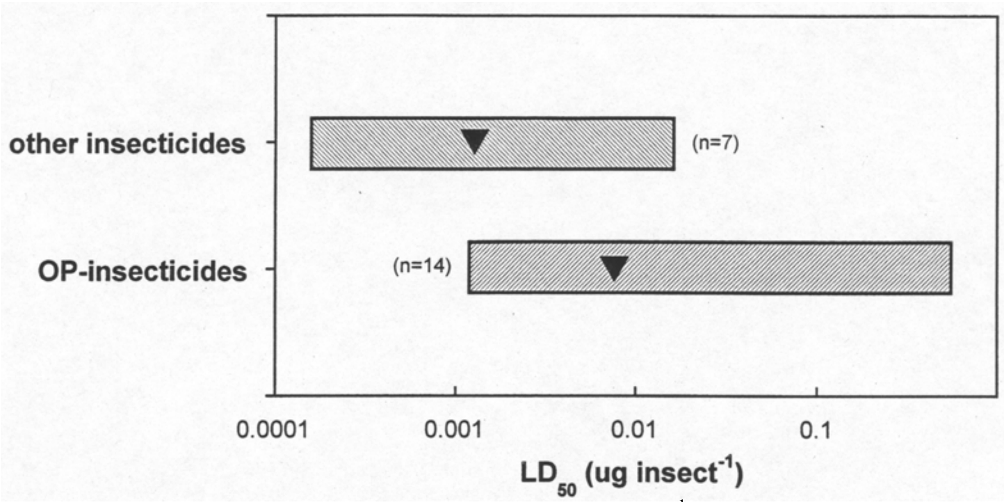

Figure 1. Range of short term (24-48 h) LD_{50} values (µg insect^{-1}) reported for larvae (2-13 days old) for some (n=4) of the selected butterfly species (*cf.* Table 1) for organophosphorous insecticides (n=14) and other insecticides, including pyrethroids (n=3), ureum compounds (n=2), carbamates (n=1) and chlorated carbohydrates (n=1). The median value for both groups is indicated with a black triangle. Data from Sinha *et al.* (1990) and Davis *et al.* (1991a, 1993).

Table 2. Short term (24-48 h) LD_{50} values (µg insect^{-1}) of ten different insecticides reported for larvae (2-13 days old) for four species of butterfly (*cf.* Fig. 1). Data from Sinha *et al.* (1990) and Davis *et al.* (1991a, 1993).

Insecticide	Butterfly species	LD_{50} (µg insect^{-1})
Organophosphorous insecticides		
triazofos	*Pieris brassicae*	0.0011
triazofos	*Pieris brassicae*	0.0026
triazofos	*Pieris brassicae*	0.0045
pirimifos-methyl	*Pieris brassicae*	0.0028
fenitrothion	*Pieris brassicae*	0.0030
fenitrothion	*Pyronia tithonus*	0.0051
fenitrothion	*Pieris napi*	0.0077
fenitrothion	*Polyommatus icarus*	0.024
phosalone	*Pieris brassicae*	0.027
phosalone	*Pyronia tithonus*	0.027
phosalone	*Pieris napi*	0.069
dimethoaat	*Pieris brassicae*	0.521
dimethoaat	*Pieris brassicae*	0.439
dimethoaat	*Pieris napi*	0.834
Pyrethroids		
cypermethrin	*Pieris brassicae*	0.00016
fenvalerate	*Pieris brassicae*	0.00125
Ureum compounds		
diflubenzuron	*Pieris brassicae*	0.00075
diflubenzuron	*Pieris brassicae*	0.00061
diflubenzuron	*Pieris napi*	0.0013
Carbamates		
pirimicarb	*Pieris brassicae*	0.395
Chlorated carbohydrates		
endosulfan	*Pieris brassicae*	0.016

The use of insecticides in relation to the presence of larvae

More than 65% of all pesticides in the Netherlands is used during May to August (Fig. 2). Because butterflies are most likely to be affected by pesticides during the larval phase, it was investigated when larvae of the different selected butterflies are present as larvae in field margins. Fig. 2 shows for each of the different ecological groups (*cf.* Table 1) of butterflies the expected presence of larvae in the field. In addition, the use of pesticides in the Netherlands is shown for each month or quarter of a year. Clearly, the use of pesticides is peaking at times that larvae of the selected butterfly species are to be expected in field margins. This is especially true for those butterfly species from group 2 and 3 (Fig. 2).

Table 3. Estimated ingestion (µg) by two-day old larvae of *Pieris brassicae* and factors exceeding the LD_{50} (µg $insect^{-1}$) at drift rates of 1% and 10% for four different model insecticides. Information on dosage and toxicity comes from Davis *et al.* (1993) and Sinha *et al.* (1990). More detailed information on calculations and underlying assumptions is given in Van Mannekes (2001).

insecticide	Dosage	estimated ingestion by larvae (µg)		LD_{50}	factor exceeding LD_{50}	
	(g ha^{-1})	at 1% drift	at 10% drift	(µg $insect^{-1}$)	at 1% drift	at 10% drift
phosalone	700	0.2265	2.27	0.0272	8	83
pirimicarb	250	0.0809	0.81	0.3948	0.20	2.1
fenvalerate	30	0.0097	0.10	0.0013	7	74
diflubenzuron	100	0.0324	0.32	0.0006	54	540

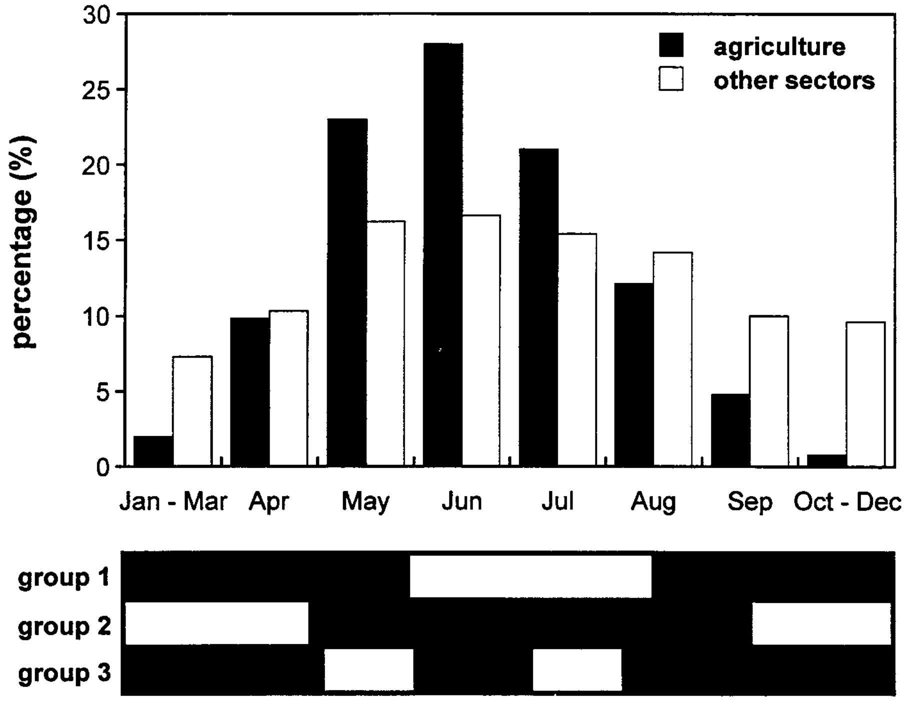

Figure 2. Use of pesticides during the year (split to use in agriculture (black bars) and other sectors (white bars) in the Netherlands. Percentages are average values for a period of three years. The expected presence of larvae of butterflies from the three different ecological groups (*cf.* Table 1) is indicated in black below the graph.

Risk analysis

The main observations from the first two parts of this study were: 1) insecticides are highly toxic for larvae of butterfly species common in Dutch field margins and 2) the use of insecticides in the Netherlands occurs commonly in periods that larvae of butterfly species are present in field margins. To estimate the actual risk for Dutch butterflies therefore, a risk analysis was carried out. This preliminary risk analysis was based on the percentage drift allowed by the Dutch government since March 2000. However, this drift percentage of 1% is based on the amount of pesticides which are allowed to enter the aquatic phase in ditches close to the sprayed field. According the current practice in the Netherlands, it is much more realistic to consider a drift percentage of circa

10% at a distance of 1 metre from the sprayed crop (P.J.M. van Vliet, personal communication). For both percentages of drift, an estimation of the factor exceeding the short term LD_{50} value for *Pieris brassicae* larvae is presented in Table 3. More detailed information on calculations and underlying assumptions for this preliminary risk analysis is offered in Van Mannekes (2001). The estimated amount of intake of the four model insecticides is exceeding the short term LD_{50} value for two-day old larvae of *Pieris brassicae* in most cases. The factor exceeding the short term LD_{50} value at drift rates of 10% are ranging from circa 2 to over 540. Even at drift rates of 1% the estimated factors exceeding the short term LD_{50} value indicate a potential risk (especially for diflubenzuron) for young instars of *Pieris brassicae*. Only for pirimicarb the estimated amount of intake is lower than the short term LD_{50} value (Table 3).

DISCUSSION

Clearly, under normal field conditions two-day old larvae of *Pieris brassicae* inhabiting field margins in Dutch agricultural systems, are at a potential risk during or shortly after a insecticide spray on nearby crop. This important observation, resulting directly from the preliminary risk analysis is based on short term (24-48 h) toxicity values for mortality. In fact, the potential risk of insecticides for butterfly larvae is most likely underestimated. Chronic toxicity values for instance, based on growth, pupation, or amount of offspring are for most insects much lower compared with acute lethal toxicity values. Furthermore, a risk analysis is normally based on No Effect Concentrations (NECs), which are however unknown for the tested insecticide compounds and tested butterflies. The present study used the ratio between the Predicted Environmental Concentration (PEC) and the short term LD_{50} value to estimate the actual risk for larvae of butterflies in field margins. Thus, the presented values are most likely lower compared with values deriving from a risk analysis based on NEC values (*cf.* Van Straalen & Verkleij 1991) and the actual risk for butterflies is therefore, likely to be higher than presented here. This indicates that the estimated risk for larvae of *Pieris brassicae* in the present study is an important indication that butterfly communities inhabiting field margins in agricultural systems will encounter serious threats during periods of insecticide use.

It was shown that pesticide spraying in the Netherlands is peaking between May and August (Fig. 2). There are examples of insect species which just miss the strongest impact of insecticide spraying events by the timing of their life cycle (Takamura 1996). Indeed, when reviewing the ecological groups presented in Table 1, butterfly species belonging to ecological group 1 have a fair chance of missing an insecticide spraying event during the summer months. Because they are winged adults during summer (June-August) they are able to avoid sprayed field margins actively. However, even in this ecological group larvae may encounter the negative effects of insecticide spraying. From early August first instar larvae will be present on food plants in the vegetation of field margins and these early stages are amongst the most sensitive. An insecticide spray at this moment therefore, may have also a strong impact on butterfly species from ecological group 1. Butterfly species from group 2 and 3 are during the whole season susceptible for spraying events since (young) larvae are to be expected in field margins during all summer months. In conclusion, insecticides are used during periods in which larvae form all three different ecological groups are present in the field and negative effects on butterfly communities in field margins are therefore likely to be encountered. Indications for implications on population level are offered in a few field studies describing drift effects of insecticides on butterflies. Davis *et al.* (1991b) for instance mentioned nearly 25% mortality on larvae of *Pieris brassicae* at a distance of 24 metres downwind from the sprayed area at wind velocities of 2.5 m s^{-1}. This wind velocity is a factor two lower than allowed by the Dutch government for spraying insecticides for agricultural use. In addition, effects of diflubenzuron on *Pieris brassicae* larvae were measured downwind the sprayed area at wind velocities of 3.5 m s^{-1}. Furthermore, at concentrations of only 0.16% of the used dosage on the crop, mortality effects on larvae could be detected (De Jong & Van der Nagel 1994). It is therefore concluded that all butterfly species common in Dutch field margins, especially those belonging to ecological group 2 and 3, could be negatively affected by insecticides at critical periods of their life cycle.

However, the actual exposure of insecticides to butterfly larvae is difficult to estimate precisely and is depending on many factors. It is argued that the extent of insecticide deposition and consequent bio-availability of insecticide residues on butterfly host plants for both adult and larval stages depends upon their location within the field boundary, their architectural structure, the extent of surrounding vegetation, the width of the boundary and the chemical properties of their foliage (Longley & Sotherton 1997). Furthermore, the direct and indirect effects of herbicides may be an additional risk for both butterfly larvae and winged imagoes. Although many uncertainties may be addressed, the results from the literature review and preliminary risk analysis strongly suggest 1) that butterflies are amongst the most sensitive organisms for insecticides; 2) that butterflies could be negatively affected as non-target organisms during every moment of the insecticide spraying season and 3) that butterflies are at a potential risk during or shortly after a insecticide spray on nearby crop. Thus, butterfly communities inhabiting field margins in agricultural systems, will encounter serious threats during periods of insecticide use and we propose therefore, that butterflies will be incorporated as non-target organisms in research on effects of insecticides. A more sophisticated risk analysis using actual exposure levels of insecticides on butterfly larvae of different species incorporating results from field experiments is currently needed.

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