2.4 DISCUSSION

2.4.1 Development of bioassay techniques for assessment of herbicide drift applied from the air

The combined results from these five experiments show that it is possible to detect the damage caused by herbicide drift downwind using a combination of bioassay plants and drift collectors. The basic technique worked well in four out of five experiments, and in the exception there was a suggestion that absolute amounts of herbicide applied was lower than usual, and the effectiveness of the asulam spray was suspect (Experiment 3).

The main reason for concentrating on the use of bioassay plants was to demonstrate that any herbicide drift was having a biological effect. Measurements of herbicide deposition (including the use of tracers) on their own only demonstrate that some of the spray should have arrived at the target site. In order to measure herbicide drift directly chemical analysis of the herbicide is need, and this process is extremely costly.

The techniques developed in this study, using both bioassay plants and simple drift collectors, appear to provide a useful inexpensive way of assessing and monitoring aerial drift of asulam. For simple field work it may be possibly simply to use water sensitive papers. Experience suggests (Experiment 5 and generally) that where drift was detected on the papers then biological damage occurred. Water sensitive papers are relatively easy to use, and could be used routinely by field staff monitoring aerial applications of asulam. Only simple precautions are required:

- Throughout - do not handle unless wearing rubber gloves.
- Do not use if it is raining - spraying should not be done anyway.
- Do not set out papers until immediately before the spraying operation.
- Set papers out on canes using staples or nails, keep away from overhanging vegetation.
- Retrieve and place in envelopes as soon as the spraying is done.
- Photocopy as soon as practicable afterwards in case quantitative results using an image analysis machine are required.

Attempts were made in 1992 to get English Nature field staff to evaluate this method for practical use in the field without success.

2.4.2 Problems with the bioassay approach

There are three main problems associated with this methodology, (a) choice of bioassay species, (b) ecological relevance of the damage caused, and (c) relationship with drift deposition.

(a) **Choice of bioassay species**
Results could be critically dependent on the choice of bioassay species. To tackle the effect of spray drift on native ferns it is neither possible nor desirable to collect or propagate native species. It was essential to choose species that could be easily obtained in large number, were easily propagated and sensitive to asulam. Our choice of *Rumex acetosa* and *Adiantum pubescens* was to some extent based on practicalities. *Rumex* could be propagated in very large numbers, is susceptible to asulam, but is not related to the ferns. *Adiantum* is a fern, but of sub-tropical origin; it was available in limited numbers so was not ideal for large scale bioassay assessments. Moreover, ferns are sometime more difficult to maintain in good condition as damage can often occur through other adverse factors (eg. frost, temperature and moisture).

The main difficulty is whether the bioassay plants are more or less susceptible to the herbicide drift than the native fern of conservation value. As far as drift is concerned damage can be caused through two interacting processes - drift capture (gravitational fallout and inertial impaction, the ratio between the two depending on the droplet size spectrum of the spray; Williams *et al.*, 1987) and the toxicological response of the plant to the herbicide. In out studies we used two contrasting leaf morphologies to cover a range of deposition types, *Rumex* with larger leaves should have intercepted the larger droplets, and the more finely divided leaves of *Adiantum* should have intercepted finer droplets by inertial impaction. However, the relative toxicities of the bioassay species relative to native ferns remains unknown, except that it is likely that the native ferns are very susceptible to asulam (Horrill *et al.*, 1978).

(b) **Ecological relevance of the damage detected**
Although damage has been detected it is impossible to relate this to an effect under field conditions. Damage has been measured as an increased % of leaves showing chlorosis/necrosis, a reduction in height, or a reduction in dry weight, all relative to unexposed plants. It is likely that these damage symptoms are transient and the plants would recover given time. Indeed, even plants that had appeared dead in one season produced new leaves in the next. The implications that this damage has on population performance, including fecundity (which is difficult to measure in ferns) and survivorship in communities where the competitive balance between species has been altered as a result of drift damage remains to be investigated.

In order to investigate these aspects further detailed studies of native fern communities under sprayed and unsprayed conditions are needed.

(c) **Relationship with drift deposition**
In all studies the biological damage was only related crudely to drift deposition measured using the water sensitive papers. This damage is inferred rather than related to actual amounts of herbicide drift. In Experiment 4 a more sophisticated technique was used with the addition of a lithium tracer. This technique is not as good as

measuring the herbicide directly, but it allowed an estimate of asulam deposition to be made and related to damage.

It was estimated that asulam deposition rate at 180 m downwind in this study was 8% of that assumed to be applied during treatment, but even this rate was enough to cause biological damage to both test species. This calculation of course assumes that the asulam behaves exactly like the lithium tracer. Nevertheless, it demonstrates that even relatively small amounts of drift can have deleterious effects.

Addition of the lithium tracer gave valuable additional information, which helped to corroborate the data from water sensitive papers. Addition of a tracer should be used wherever possible in future studies.

2.4.3 Effects of direction of wind and spraying on drift damage

The results from the small pilot study demonstrated two interesting although fairly obvious phenomena. First, although damage occurred on the windward side it did not extend as far as on the downwind side. The implications of this result is that where possible areas adjacent to SSSI's should be sprayed when the wind blows from the protected to sprayed site. However, some drift upwind did occur and as this was only a small scale pilot study further investigation of drift upwind should be done before detailed recommendations are made. It may also be impossible to delay spraying until the wind is in the correct quarter because of operational reasons.

Second, obvious deposition and damage was detected at both ends of the spray run, indicating overspray through errors in switching-on and switching-off the spray. This might have been expected given that a very small patch was sprayed, a small distance was tested and there are bound to be errors in switching the spray on and off at speed. It was, therefore, no surprise to find damage up to 20 m. However, the data illustrates that herbicide deposition can occur beyond the patch boundary, and it would be unwise to suggest that spraying up to rather than along SSSI boundaries gave better protection. Again this was as small scale pilot study and further investigation of the distances that overspray occurs under more realistic situations is needed.

2.4.4 Determination of downwind buffer zone distances

The results from the Bamford Edge showed that deposition on water sensitive papers was detected up to 33 m with only small amounts being detected thereafter. Damage to *Rumex* was found, however, up to 161 m downwind. This experiment was, however, done when the wind speeds were greater than those recommended for aerial spraying (> 5 m s^{-1}; MAFF/HSE,1989) and was considered to be a worst case scenario. The Painscastle experiment gave disappointing results. However, the deposition curve was similar to the one at Bamford Edge with little drift detected by water sensitive papers beyond 40 m. Damage to bioassay plants was perhaps found at two places downwind (60 m and 100 m), but it is difficult to draw too many conclusions from it in view of the poor performance of the asulam on the treated bracken. At Wooler the deposition curve was similar to the other two but a small amount was detected even at 180 m. Damage to the bioassay plants also declined rapidly to an asymptote at either 50 or 100 m.

However, in this experiment the asymptote showed damaged relative to unsprayed controls. Thus biological damage was detected even at the greatest distance tested - 180 m.

Thus, on the current evidence safe buffer zone distances need to be at least 160 m. This figure was derived originally as a worst case scenario under very high wind speeds. The later study at Wooler was done at a lower wind speed (near the maximum recommended level), but although showing a more rapid fall off in damage maintained a low level of damage to the maximum distance tested.

This buffer zone requirement is much greater than for herbicide applications from ground sprayers. For tractor-mounted ground sprayers a buffer zone of 6-10 m was considered adequate to protect a range of established perennial species from four herbicides (Marrs, Frost & Plant, 1989), and 20 m for the protection of establishing seedlings from glyphosate drift (Marrs *et al.*, 1993b). Buffer zone distances for aerial applications (Cessna 188B 'Ag-Truck') of glyphosate to sensitive tree species were estimated to be between 200-750 m (Payne, 1992), although these estimates did not include field measurements of damage. Other published estimates of buffer zone distances for aerial applications include 20-30 m for the protection of fish from glyphosate (Payne, Feng & Reynolds, 1990), but > 200 m to protect threespine sticklebacks (*Gasterosteus aculeatus*) from applications of endosulfan (Ernst, *et al.*, 1991).

The results also suggest that the critical factors in controlling damage are the amounts and type of spray drift droplets that produced under different conditions. These conclusions have been found in other studies of aerial drift deposition (Payne, 1992). Further studies are needed to measure and model spray drift deposition from aerial sources.

2.4.5 Potential effects of asulam on native ferns in bracken treated areas

Clearly there were considerable differences in the amounts of herbicide deposited in the different positions within the Clough. However, even where the lowest amounts of drift deposition were detected, there was still considerable damage to both species of test plant. There was very little protection afforded either in the different locations tested or under the bracken canopy. All ferns growing in bracken areas sprayed with asulam from the air must be viewed as at risk. However, this risk must be offset against any risks to the native ferns from suppression by increasing bracken. The relative long-term risks on populations of rare ferns from herbicide damage versus bracken encroachment remains to be tested.

2.4.6 Future research

Areas where further research are needed include:

- Development of the water sensitive papers test as a practical method of monitoring aerial spray drift around SSSI's.
- Assessment of the effect of asulam use and asulam drift on native fern populations.

- Further experiments to assess the possibilities of spraying downwind of SSSIs and the overspray drift from inaccurate switch-on switch-off of the sprayer.
- Further development of models which relate spray produced under different operator and environmental conditions to bioassay damage.
- A comparison of the effects of asulam damage <u>versus</u> suppression from bracken on populations of rare ferns.

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APPENDIX I. Fitted non-linear equations to the data presented in the figures in this report; equations fitted are of two types exponential (exp) and logistic (log);

equations are - exp: $y=a+c*m^x$
log: $y=a+c/(1+\exp(b(x-m)))$

Figure	Type of equation	a	c	b	m	r^2
2.5	log	0.44206	116.0856	0.09502	8.48837	0.71
2.6	log	3.41984	95.32509	0.05693	84.01972	0.99
2.10	exp	0.36328	109.0125	0.93327	-	0.97
2.11	log	0.07508	9.56136	0.16232	3.21596	0.98
2.12	log	0.66318	10.55977	0.17728	0.4791	0.97
2.13	exp	16.8170	68.9028	0.97682	-	0.99
2.14	exp	2.17899	-0.59406	0.95993	-	0.98
2.15	log	2.04328	14.0234	-0.0300	15.204	0.96
2.16	log	6.79696	3.21066	-0.0665	14.5839	0.91

ANCILLARY STUDIES ON AERIAL SPRAYING AND INSECTICIDES

3 ANCILLARY STUDIES ON AERIAL SPRAYING AND INSECTICIDES

B N K Davis

3.1 INTRODUCTION

In addition to the field trials, the Contract Annex specified that information was needed on methods for reducing drift hazards by modifying application techniques, and on long term effects of pyrethroids on terrestrial invertebrates. These two aspects are briefly reviewed below, and a comparative summary of environmental risks from insecticides has also been made.

3.2 AERIAL APPLICATION TECHNIQUES

Most of the research on aerial spraying equipment and techniques for optimising efficiency and minimising drift was done in the 1970s and 1980s, eg on "Systems for reducing airborne spray losses and contamination downwind..." (Yates & Akesson 1975), "The use of wing tip sails...to reduce the amount of material carried off target..." (Parkin & Spillman 1980), "The determination of flight lane separations..." (Parkin & Wyatt 1982). Such research has been brought together in several books for practitioners, eg Matthews (1979), Joyce (1985), Quantick (1985a, 1985b).

In Britain, much of this work was done at the Department of Bio-aeronautics, Cranfield Institute of Technology. This department was disbanded about five years ago and it is unlikely that there will be much further development work in Britain. However, courses on aerial spraying (mainly for overseas students) are still run at Silsoe College (now part of Cranfield University) by Dr C S Parkin, and techniques for studying and reducing drift from ground sprayers still attract attention, eg the Spray Drift Workshop run by the Association of Applied Biology in February 1994.

Consultations with Dr Parkin suggest that the spraying equipment and procedures used by Apple Aviation are fairly standard. In 1985, when Dr Parkin undertook an extensive study of spray deposit patterns and drift for the International Agricultural Aviation Centre at Cranfield, he found that "Piper Pawnee aircraft (the most common in the UK) usually used 37 D6-45 nozzles operating at 2.5 bar giving 18 l/ha application rate at a 15 m swath" (Parkin, pers.comm.). The D number gives nozzle size and the swirl plate number (45) determines the quality of spray. The study showed that it was very important for avoiding drift not to use nozzles placed close to the wing tips. Orientation of nozzles was also important in determining VMD; this was maximised (giving minimum drift) when nozzles were vertical. Specific nozzle configurations were recommended to produce optimum deposit patterns for both the Piper Pawnee and the Bell 47/Hiller 12E helicopter (as used by MD Air Services in the Holme Lacey and first asulam trials).

So far as "opportunities for reducing drift" are concerned, Parkin (pers. comm.) favours the use of Solid Cone nozzles which produce a drop spectrum similar to that produced by Raindrop nozzles but are cheaper. These might be appropriate for asulam spraying but insecticide applications require nozzles giving a lower VMD for efficient pest control; Himel (1969) considered that the optimum size for insecticide spray droplets is in the range of 20 µ diameter.

Practical measures for reducing drift from aerial spraying may, therefore, depend less on new research, and more on implementing existing knowledge and in formulating standard routines that are applicable to commercial spraying under realistic conditions. Leaving a broader unsprayed margin at the downwind edge of a field, for example, would considerably reduce drift deposition (as a percentage of the application rate) over the first 50 m beyond the target zone. This would be comparable to the unsprayed "conservation headland" advocated by the Game Conservancy for ground-based applications. It could make a significant difference to the off-target impact from compounds with moderate field hazard rating (see Figure 1.33) though it would be less useful for those with a high field hazard. In the latter case, no technical measures are likely to remove the risk of drift impacts over quite substantial distances.

3.3 LONG TERM PYRETHROID EFFECTS

There is a very large literature on the synthetic pyrethroids. Their effects on non-target organisms are reviewed by Smith & Stratton (1986), Hill (1987) and Inglesfield (1987). Most of the studies are concerned with the degree to which they affect field populations and the rates of recovery. Because they have a short persistence in the environment, most toxicological studies on non-target organisms have concentrated on short-term bioassays. This contrasts with the organochlorine insecticides where persistence and sublethal effects on arthropods are well known (Moriarty 1968).

The deltamethrin bioassay trial with *P. brassicae* at Holme Lacey was monitored for seven days in contrast to the standard three day obervations used in most previous bioassays. In terms of direct mortality, the results after three days were generally about 75% of those after seven days for the helicopter and 75-100% for the ground sprayer, excluding results similar to controls. The slopes of the curves in Figures 1.2 and 1.3 suggested that little further direct mortality would be expected. Similar results were found in the second fenitrothion trial after six days (Figure 1.20). Since the caterpillars were continuously exposed to residual contact and stomach poisoning from the target cabbage plants, this probably represents maximum insectidal effect.

It is not feasible to monitor such large scale field bioassays, involving 500-800 caterpillars, beyond about a week as the plants are largely consumed and there is a risk of increasing mortality among controls (see the phosalone trial, section 1.6.2). Earlier experiments with dimethoate, fenitrothion and diflubenzuron were done with green-veined white *P. napi* up to pupation (Davis *et al.* 1991). It was found that the larvae that survived "showed no evidence of sublethal effects upon subsequent growth rates or weights at pupation". Experiments with deltamethrin and *P. brassicae* apparently do show some persistent sublethal effects (Cilgi & Jepson in press) but I have been unable to obtain a copy of the paper or further details. One likely effect on fecundity would be through the size of adult and this can vary considerably, even among untreated caterpillars, depending on food supply (Davis *et al.* 1991).

3.4 COLLATION OF ENVIRONMENTAL RISKS FROM INSECTICIDES

The 1993 UK Pesticide Guide lists some 48 insecticides which are approved under the MAFF/HSE 1986 Regulations (Ivens 1993). This Guide cites the mode of action and the main pests controlled on different crops. It therefore provides an indication of the spectrum of insecticidal activity (orders of insects) and breadth of use (number of major crops). These are summarised in Table 3.1 for 25 of the most commonly used insecticides. Mites and minor insect groups such as earwigs are excluded for this purpose as well as soil groups such as springtails, symphylids, millipedes and woodlice. Similarly, grass and ornamentals are excluded from the list of crops and certain crops are combined into categories such as roots.

Table 3.1 also includes hazard ratings for bees and fish taken from the Guide. Data on sprayed hectares are taken from the Pesticide Usage Survey Reports, and hazard indices for honey bees and *Pieris brassicae* from earlier spray drift reports or published papers.

This information is used to compile a 2-way classification of insecticides according to recent usage and risk (Table 3.2). The vertical ranking by spectrum of activity is fairly crude as it assumes that non-pest Coleoptera, Diptera, Lepidoptera, Heteroptera etc are comparable in sensitivity with pest species such as pea and bean weevils, frit fly, codling moth, apple sucker etc. Note that a compound with a narrow stated spectrum of activity may nevertheless pose a risk to certain groups, eg chlorfenvinphos and omethoate are toxic to Diptera. It is also likely that the use of newer products such as cyfluthrin may be extended to a wider range of pests and crops if they are commercially successful. The ranking also ignores some important groups like spiders though some compounds are known to be toxic to them, eg dimethoate (Vickerman and Sunderland 1977).

The horizontal ranking is clearly affected by pest incidence, weather, relative costs etc, and can change considerably from year to year. Thus the pyrethroids bifenthrin and cyfluthrin were not even listed in the 1989 Guide while azinphos-methyl has recently been withdrawn.

Aerial spraying is three orders of magnitude smaller in extent than ground spraying, with a total sprayed area in 1991 of 10820 ha (excluding disulfoton 609 ha applied as granules)(Table 3.1). The eight compounds listed as available in the 1993 Guide are shown with asterisks in Table 3.1 but approval for dimethoate may have been or may about to be revoked.

The predicted field hazard ratings for insecticides to *Pieris brassicae* are given in previous reports (1990, Table 7.14; 1992, Table 4.2, p 5.9). They are divided into three groups in Table

3.1 with roughly tenfold differences in average indices between groups (Figure 3.1). Thus the most toxic group consists of carbaryl, cypermethrin, deltamethrin, diflubenzuron, fenitrothion, pirimiphos-methyl and triazophos. These estimates are based on contact effect only. Compounds with stomach acting (ingested) or residual effects are likely to pose greater risks to non-target organisms (see column 2 in Table 3.1). No spray drift bioassays have been done with pirimiphos-methyl. Results from hydraulic or air-assisted ground spraying drift studies for carbaryl, cypermethrin, deltamethrin, diflubenzuron and triazophos suggest that these all need similar buffer zones, of the order of 15-20 m for hydraulic sprayers and 50-60 m for orchard sprayers to prevent mortality to *P. brassicae* above that in controls.

Table 3.1 Usage of 25 insecticides with insect groups controlled and hazard ratings for honeybees, *Pieris brassicae* and fish.

Compound	Type/Action		Ground Spraying 1990 ha ('000)	Aerial Spraying 1987	1991	1993	Insect orders controlled	Approved uses 1993 crops	Field Toxicity Bees		*Pieris*	Fish
alpha-cypermethrin	Py	I, R	120	1161	4151		A C D L	C O P S	D	?	?	ED
amitraz	Am		-				Ht L	Ft	-	?	?	H
bifenthrin	Py		30				A C D L	C L O Fts	D	?	?	ED
carbaryl	Cb		-				C D Ht Ho L S T	B L O Ft	D	3	3-4	H
chlorfenvinphos	Op	I	√	131			D	B C R	-	2	?	D
chlorpyrifos	OP	I	√	131			A C D Ht L S T	B C L P R S Fts	D	3-4	?	D
cyfluthrin	Py	R	30				A C D Ht Ho L	B C L D Fts	D	?	?	D
cypermethrin	Py	I	1620				A C D Ht Ho L S T	B C L O P R S Fts	D	3	3	ED
deltamethrin	Py	R	600	315	1032		A C D Ht Ho L S T	B C L O R S Fts	D	2	3	ED
demeton-S-methyl	Op	S	180	4342	577	√	A D Ht S	B C L P R Fts	H	3	?	H
diflubenzuron	M	I, R	-				L Ht S	B Fts	-	0	3	-
dimethoate	Op	S	510	13250	348	√	A D Ht S T	B C L R Fts	D	2	0/1	H
endosulfan	Oc	I	-				A C D	O Fts	H	1	2	ED
fenitrothion	Op		√	397		√	A D Ht L S T	C L Ft	D	4	3	H
fenvalerate	Py		200	2465	1047		A C Ht L	B C L O Ft	H	2	2	ED
gamma-HCH	OC	I	40	30			A C D Ht Ho L	B C R S Ft	D	1-3	?	-
heptenophos	Op	S	-	632		√	A Ho T	B C L Fts	D	?	?	H
malathion	Op		-				A C D Ho S T	L P R Fts	H	3	?	H
omethoate	Op	S	√	470		√	A D	C Ft	H	?	?	H
oxydemeton-methyl	Op	S	140	174		√	A D Ho S	C L P R Fts	H	?	?	H
permethrin	Py	I	-	314			A L Ht Ho S	B Ft	D	3	?	ED
phosalone	Op	I	-	25227	223	√	A C D L	B O Ft	-	1	2	H
pirimicarb	Cb		540	14262	2415	√	A	B C L O P R S Fts	-	0	0/1	-
pirimiphos-methyl	Op		-				C D L Ht Ho S T	B C R S Ft	-	3	3-4	-
triazophos	Op	I	80	5578	25	(√)	A C D L Ht	B C L O P R Ft	D	3-4	3-4	H

Cb = carbamate
M = moult disrupter
Oc = organochlorine
Op = organophosphate
Py = pyrethroid

I = ingested
R = residual
S = systemic

√ mentioned but not listed separately

plus disulfoton as granules

√ approved
(√) off label (Ivens, 1993)

A aphids
C Coleoptera
D Diptera
Ht Heteroptera
Ho leaf hoppers
L Lepidoptera
S sawflies
T thrips

B brassicas, C cereals
L peas/beans,
O oilseed rape
P potatoes, R roots
S sugar beet,
Ft top fruit
Fs soft fruit

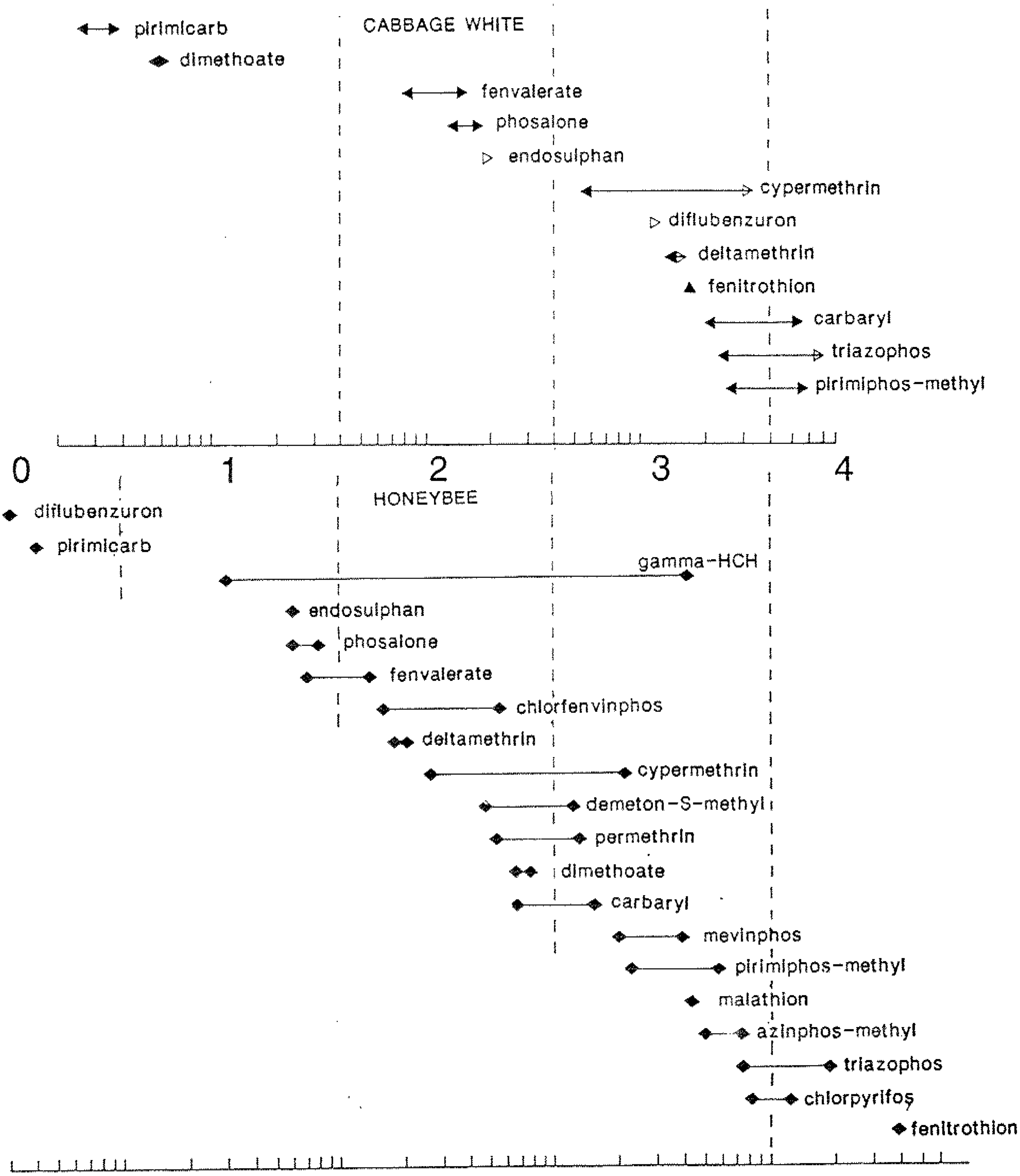
H = hazardous
D = dangerous
ED = extremely dangerous
1-4 'field hazard
ratings from Fig 1.20
? = no data

Table 3.2 Two-way classification of insecticides according to 1990 usage (sprayed ha) and number of insect orders controlled (broad, medium and narrow spectrum activity).

* 1993 aerial spraying approval, 0 mainly applied to orchards, F dangerous or extremely dangerous to fish, bold - compounds with field hazard rating 3 for *P. brassicae* (see Table 1.5).

Insect Orders	1990 sprayed ha ('000)			
	very high > 1000	high 500-600	medium 30-200	low < 10
6-8	**cypermethrin** F	**deltamethrin** F	gamma HCH	**carbaryl** 0 chlorpyrifos F **fenitrothion** * malathion **pirimiphos-methyl**
3-5		dimethoate (*)	alpha-cypermethrin F bifenthrin F cyfluthrin F demeton-S-methyl * fenvalerate F oxydemeton-methyl • **triazophos**	**diflubenzuron** 0 endosulfan 0F heptenophos * permethrin F phosalone *
1-2		pirimicarb •		amitraz 0 chlorfenvinphos F omethoate •

Figure 3.1. Field hazard ratings for *P. brassicae* larvae and honeybees based on range of recommended application rates for insecticides divided by contact LD$_{50}$ values. Results plotted on logarithmic scales (without units) and divided into 4 or 5 hazard categories at 10-fold intervals for Table 1.6. Open ended arrows for *P. brassicae* indicate compounds with additional stomach-acting or residual toxicity.



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BUFFER ZONES AND RECOMMENDATIONS TO PROTECT CONSERVATION INTERESTS

4 BUFFER ZONES AND RECOMMENDATIONS TO PROTECT CONSERVATION INTERESTS

A S Cooke

4.1 BACKGROUND

The contract annex requires advice on "what levels of damage are unacceptable to both plants and invertebrates in both SSSIs and the wider countryside". I will attempt to provide this advice by answering two related questions.

(i) How might buffer zones be calculated to protect sensitive sites and organisms from drift from aerial spraying?

(ii) What general conclusions can be drawn from our work about how to protect SSSIs and the wider countryside?

4.2 BUFFER ZONES

Theoretical or experimental studies allow the derivation of "safe distances" ie the distance a spray source should be from a sensitive site or organism to prevent serious acute effects occurring (Cooke, 1993). These safe distances can then be used to advise on the extent of buffer zones needed on the ground. Cooke (1993) discussed buffer zones in some detail; while it is not worth repeating that account, it may be relevant to outline briefly the whole subject of buffer zones.

The point of introducing a buffer zone is to reduce a perceived risk by increasing the distance between a spray source and a vulnerable site or organism, and so protect conservation interests. It is conceivable that English Nature might introduce buffer zones when using herbicides on its own reserves. More probably, however, English Nature will request them when discussing specific situations with site owners or spray contractors, or approval of a specific product with the regulatory authorities.

It might be imagined that the aim of a buffer zone is to avoid all effects from drift, no matter how slight. In practice, such an aim is probably unachievable. For instance, the effects of vapour drift are unpredictable and it may be impossible to guarantee total protection from vapour drift with buffer zones. In addition, although attempts have been made to study relatively sensitive bioassay species with relatively hazardous pesticides, only a few situations have been studied. To guarantee total protection in unstudied circumstances would require unrealistic extrapolation in deriving the buffer zones - a process that is likely to appear unconvincing to owners and contractors.

The aim has therefore been to try to ensure that unacceptable effects are avoided. In some cases the buffer zone has been taken to be the shortest distance where no effects were noted in bioassay tests. This approach was used, for instance, for protecting moorland ferns against asulam drift; the species in question may be rare and English Nature would wish to see them remain undamaged. With plants, one important consideration is to avoid unsightly obvious damage (even though the plants may recover). Nevertheless, it can be acceptable to set buffer zones that do not totally protect against sublethal effects on established plants (eg a reduction in seed) or against lethal effects on seedlings. In these cases, however, it is necessary to ensure that unacceptable long-term impacts will not occur. Thus where seedling establishment is important for maintaining a species population level, loss of seedlings to drift is unlikely to be acceptable.

Bioassays involving terrestrial invertebrates have employed exposure of a sensitive stage of a sensitive species to insecticides with a range of activity. Buffer zones have often been recommended that are the distances at which 10% mortality was observed in tests. It is arguable that limited mortality at an early stage for insect larvae may make no appreciable difference to final numbers. It is debatable whether unnoticed (lethal) effects really matter if they are not translated into population effects. It also makes the argument for a particular buffer zone more credible and persuasive if English Nature can show experimental data to indicate that the buffer zone may not give total protection.

Aquatic invertebrates have been used in the bioassay tests for two principal reasons. First, they allow confirmation that effects seen on terrestrial invertebrates are real and not an artefact of the protocol, handling or local conditions. Secondly, they expand the range of species tested. In general, effects on aquatic species are not as severe or no more severe than effects on *Pieris brassicae* larvae even in the worst case (invertebrates exposed in 2 cm of water in the field).

Despite what has been written above, some doubts must remain about the effectiveness of buffer zones so derived. Indeed, no amount of research can guarantee buffer zones will provide acceptable protection in all situations. It is never possible to study all situations, and hypersensitive species may be affected even though adequate buffers appear to have been imposed. Aspects that it has not proved possible to study in detail are sublethal effects and delayed mortality in terrestrial invertebrates. But the widespread adoption of buffers should lead to reductions in drift effects. Vigilance is needed on the part of field staff to identify possible problems that may still persist; if they warrant it, such issues can be further investigated and remedied if appropriate.

4.3 AERIAL SPRAYING CONCLUSIONS

Taken together with the aerial spraying experiments in Cooke (1993), we have now undertaken five tests with asulam and seven with insecticides.

Typically we have looked for - and found - effects downwind with the plane flying perpendicular to the wind (Fig. 4.1a). Drift effects have been detected at 200 m or more for certain insecticides and to at least 180 m for asulam. In the phosalone trial, overspraying effects were noted upwind when the plane flew more or less parallel to the wind (Fig. 4.1b). In contrast in the first fenitrothion trial, no effects were detected upwind when the plane flew perpendicular to the wind (Fig. 4.1c). One potential safeguard mechanism for the protection of SSSIs might therefore appear to be to insist on the contractor flying parallel to the reserve boundary and only spraying when the wind is blowing away from the reserve (Fig. 4.1d). However, this should be rejected because in practice it is not realistic to expect contractors to wait for the wind to blow from the correct direction or to expect the wind to maintain its direction once a decision to spray has been made (refer to the first fenitrothion trial).

Nevertheless, insisting on the contractor flying parallel to the reserve boundary is, where possible, a good policy. In order to protect SSSIs from the drift effects of insecticides or asulam, a buffer zone is required between the reserve and the target area. The extent of the buffer zone should be based on downwind drift ie the worst case scenario (Fig. 4.1e).

It is recommended that a statutory buffer zone of 250 m is required for SSSIs, at least for insecticides. Such a distance will provide acceptable protection from both downwind drift and overspraying, except perhaps in a few cases eg under very stable meteorological conditions. Having a statutory buffer will mean that it should be automatically applied and English Nature will not have to persuade the contractor to accept it.

There are, however, some drawbacks with this approach and some issues that require further consideration. It is suggested that if they are not resolved before, then the Environmental Panel of the Advisory Committee on Pesticides is asked to address them at its meeting in June 1993.

(i) Pirimicarb had no downwind effects on *Pieris brassicae* larvae. It is clearly very toxic to aphids, but is known to be a relatively narrow spectrum insecticide and does not seem to be particularly toxic to freshwater life. Should therefore an exception be made for pirimicarb ie should it not require a statutory buffer beside SSSIs?

(ii) A buffer zone for asulam spraying of about 160 m was indicated by earlier work and has been accepted in some quarters. The work done in 1993 demonstrates such a buffer may not be sufficient to protect against effects on sensitive plants. Does asulam also require a statutory buffer of 250 m beside SSSIs?

(iii) In some situations, a buffer zone of 250 m may not be sufficient eg with forestry spraying involving ULV. How can this be best tackled? Should the regulators be made aware of the need for flexibility over new approvals?

(iv) Statutory labelling will not apparently allow English Nature to waive the buffer zone where there is no risk eg perhaps with aerial spraying near a geological SSSI. Does this matter?

(v) Are we wise to ignore fungicides?

(vi) What should be done about new active ingredients for aerial spraying? One suggestion might be that the firm has to demonstrate that a new insecticide compound is safe to aquatic and terrestrial bioassay invertebrates, otherwise buffer zone labelling will be imposed. Alternatively is it now possible to calculate the likely extent of effects downwind from laboratory toxicity to invertebrates?

As regards aerial spraying well away from SSSIs, it is recommended that input through the regulatory committees will be adequate to protect the wider countryside satisfactorily. Reasons behind this statement include:

(i) Aerial spraying is little used and the total area sprayed is progressively decreasing.

(ii) Switching from aerial to ground spraying reduces rather than eliminates the risk to adjacent semi-natural habitats.

(iii) For some products, statutory buffers are already in force (eg for pyrethroids near water) and for others aerial approval has been revoked.

The recommended regulatory input includes:

(i) Ensuring that aerial uses of compounds under review are revoked or have statutory buffers imposed consistent with recent precedents.

(ii) Ensuring that aerial uses of new compounds are not allowed or have statutory buffers, again consistent with precedents.

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Figure 1. Diagrammatic representations of aerial spraying situations. (a) Typical bioassay trial observing downwind effects. (b) Phosalone trial which, in part, showed overspray effects upwind. (c) First fenitrothion trial which showed no effects upwind. (d) Rejected mechanism to protect SSSIs. (e) Recommended mechanism to protect SSSIs (the buffer zone is calculated to protect the site irrespective of wind direction).

The target field is indicated by the box, wind direction by the arrow, plane flightpath by the broken lines and bioassay transects by the crosses with effects as circles.