Some statistical aspects of the monitoring of GM plants

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This paper will focus on spatial heterogeneity, temporal heterogeneity and spatio-temporal heterogeneity

VDI 4330

Monitoring the effects of genetically
modified organisms (GMO)

Standardised monitoring of butterflies and moths
(Lepidoptera)

Transect method, light trap, and larval survey

- illustrate spatio-functional environmental features due to their mobility and often complex habitat requirements [19],
- are therefore particularly suitable for landscape-level monitoring as well [20] and
- via the spatio-temporal availability of subhabitats

Beet

Maize

SOSR

WOSR

Conventional

heteroptera

spiders

carabids

bees

collembola

butterflies

gastropods

biomass

seedlings, following crop

seed rain

seedbank

GMHT

HEARD MS, ROTHERY P, PERRY JN & FIRBANK LG (2005) 1

Predicting longer-term changes in weed populations under GMHT crop management.

Weed Research, **45**, 331–338.

Context for this paper:
 Heard et al (2003b) predicted from FSE results that seedbank decline might increase from 3% per annum to 10%.
But this would all depend on the rotation.

Fig. 1 Illustration of model for seedbank density dependence. (A) For beet in break crop, the change in logarithmically transformed dicotyledon seed count, $D(t+1) - D(t)$, is plotted against initial logarithmically transformed dicotyledon seed count, $D(t)$. (B) In following cereal crop $D(t+2) - D(t+1)$ is plotted against $D(t+1)$. Lines show mean values of change in D over different ranges of initial values of D (see Table 2) for the two treatments: conventional (open circles, solid lines); GMHT (crosses, dashed line). In the following cereal crop there were no differences between treatments.

Fig. 2 Model projections of $\log_{10} N$, mean logarithmically transformed predicted seedbank density, for conventional (solid circles) and GMHT management (crosses) in 4-year rotations, plotted against time, in years. (A) Beet, cereal, cereal, cereal; (B) spring rape, cereal, cereal, cereal; (C) beet, cereal, spring rape, cereal. Predictions of seed density are shown for individual species and for total dicotyledons over the nine selected species.

Crop Rotations : Survey results from Selommnes, Burgundy

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Different rotations in Selommès landscape, with differing lengths

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Rotation ID	Years in rotations						Rotation Length
	0	1	2	3	4	5	
0	sa						1
1	W	OSR					2
2	W	OSR	Wb				3
3	W	Wb	OSR				3
4	W	Sb	OSR				3
5	W	Sb	Wb	OSR			4
6	W	Wb	Sb	Sb	Wb		5
7	W	W	OSR	W	Wb	OSR	6
8	W	Wb	OSR	W	Sb	OSR	6
9	W	Wb	OSR	W	Wb	sa	6
10	W	OSR	Wb	W	sa	Wb	6
11	W	Sb	Wb	OSR	Wb	OSR	6
12	W	OSR	W	OSR	W	sa	6
13	W	OSR	W	OSR	sa	sa	6
14	W	OSR	sa	sa	sa	sa	6
15	Wb	OSR	sa	sa	sa	sa	6
16	Sb	sa	sa	sa	sa	sa	6
17	R	OSR	R	sa	sa	sa	6
18	R	R	OSR	sa	sa	sa	6
19	W	W	sa	sa	R	OSR	6
20	W	sa	sa	Sb	Wb	OSR	6

66.7 % of rotations have a 6 years length

80.98 % of rotations have a length that is a multiple of 3 years

A taxonomy of crop rotations (1)

Various types of crop rotation

1) pre-defined, fixed crop rotation

(example from Dijon & Selommès)

Cyclical, fixed length

here six years

A taxonomy of crop rotations (2)

1) pre-defined, fixed crop rotation

(another example from south-east England)

Cyclical, fixed length,

here five years

2) flexible crop rotations

Stochastic, multi-pathway, cyclical, fixed length, here five years

A taxonomy of crop rotations (3)

In what sense 'Stochastic'?

not decided by random choice of the farmer

determined by events that are themselves governed by chance
and whose long-term chance of occurring may be estimated

A taxonomy of crop rotations (4)

3) flexible crop rotations

Stochastic, multi-pathway, cyclical, variable length;

return period to the second wheat may be four, five, nine, , , years, etc

4) Less structured crop rotations

Highly flexible, exponentially multi-pathway, cyclical but with undefined length

Representation of rotations within software (2)

Most rotations may be represented by a transition matrix

→ sugar beet → fallow → wheat → OSR → wheat

		Current year				
		Sugar beet	Fallow	First wheat	OSR	Second wheat
Previous year	Sugar beet	0	1	0	0	0
	Fallow	0	0	1	0	0
	First wheat	0	0	0	1	0
	Oilseed rape (OSR)	0	0	0	0	1
	Second wheat	1	0	0	0	0

... in which the probabilities of going from a crop in one year to a crop in the next year are represented numerically

Representation of rotations within software (2)

		Current year								
Previous year		S. beet	Fallow	1 st S. barley	l.d. wheat	1 st wheat	2 nd S. barley	Beans	OSR	2 nd wheat
	S. beet	0	0.3	0.35	0.35	0	0	0	0	0
	Fallow	0	0	0	0	1	0	0	0	0
	1 st S. barley	0	0	0	0	1	0	0	0	0
	l.d. wheat	0	0	0	0	0	1	0	0	0
	1 st wheat	0	0	0	0	0	0	0.5	0.5	0
	2 nd S. barley	0	0	0	0	0	0	0.5	0.5	0
	Beans	0	0	0	0	0	0	0	0	1
	OSR	0	0	0	0	0	0	0	0	1
	2 nd wheat	1	0	0	0	0	0	0	0	0

Transition matrices:

square matrix

entries are probabilities

exactly equal to 0 or 1 if fixed; between 0 & 1 if stochastic

sum of each row = 1

Need to estimate proportions of crops

want to be able to estimate long-term proportion
of each crop grown within a rotation

Year 1

Year 2

Year 3

Year 4

years	1	2	3	4
winter barley	2	0	5	1

eight fields, four years

overall proportion of winter barley = 0.25

Calculation of long-term average crop proportions (1)

T =

0	0.3	0.35	0.35	0	0	0	0	0
0	0	0	0	1	0	0	0	0
0	0	0	0	1	0	0	0	0
0	0	0	0	0	1	0	0	0
0	0	0	0	0	0	0.5	0.5	0
0	0	0	0	0	0	0.5	0.5	0
0	0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	0	1
1	0	0	0	0	0	0	0	0

Pre-multiply the transition matrix **T** by itself many times

Obtain a new matrix **T(n)**, where **T(n) = T × T(n-1) = Tⁿ⁻¹ × T = Tⁿ**

T(n) converges as *n* increases and the elements in any column become ever more similar

The average of the *j*th column represents the long-term average proportion of the *j*th crop

Calculation of long-term average crop proportions (2)

$T^n =$

S. Beet	Fallow	1 st S. barley	l.d. wheat	1 st wheat	2 nd S. barley	Beans	OSR	2 nd wheat
0.2	0.06	0.07	0.07	0.13	0.07	0.1	0.1	0.2
0.2	0.06	0.07	0.07	0.13	0.07	0.1	0.1	0.2
0.2	0.06	0.07	0.07	0.13	0.07	0.1	0.1	0.2
0.2	0.06	0.07	0.07	0.13	0.07	0.1	0.1	0.2
0.2	0.06	0.07	0.07	0.13	0.07	0.1	0.1	0.2
0.2	0.06	0.07	0.07	0.13	0.07	0.1	0.1	0.2
0.2	0.06	0.07	0.07	0.13	0.07	0.1	0.1	0.2
0.2	0.06	0.07	0.07	0.13	0.07	0.1	0.1	0.2

Transitions between rotations (1)

wheat → oilseed rape → beans Rotation **R1**

wheat → oilseed rape Rotation **R2**

c. Transitions between rotations R1 & R2

Previous year	Current year	
	Rotation R1	Rotation R2
Rotation R1	r	$1 - r$
Rotation R2	$1 - s$	s

Transitions between rotations can themselves be represented as a single transition matrix

Temporal heterogeneity: Blocks of Fields

Blocks of Fields: are fields managed by 1 farmer, following the same crop succession *and starting with the same crop*.

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Farmer	FieldID	Rotation	Years in rotations			Start Year		
			1	2	3	1	2	3
4	40	3	W	Wb	OSR	1		
	52	3	W	Wb	OSR	1		
	38	3	OSR	W	Wb			1
7	24	3	W	Wb	OSR	1		
	35	3	W	Wb	OSR	1		
	43	3	Wb	OSR	W		1	
	47	3	Wb	OSR	W		1	
	65	3	OSR	W	Wb			1
9	7	3	W	Wb	OSR	1		
	21	3	W	Wb	OSR	1		
	16	3	Wb	OSR	W		1	
	18	3	Wb	OSR	W		1	
	22	3	Wb	OSR	W		1	
	23	3	Wb	OSR	W		1	
	26	3	OSR	W	Wb			1
	27	3	OSR	W	Wb			1
	28	3	OSR	W	Wb			1
	34	3	OSR	W	Wb			1

Block of fields

Oil seed rape
Winter barley
Wheat

Table 1
Example of temporal heterogeneity for a 3-year rotation

Field number	Observed			E1			E2		
	1995	1996	1997	1995	1996	1997	1995	1996	1997
7	W	wB	OSR	wB	OSR	W	W	wB	OSR
16	wB	OSR	W	wB	OSR	W	W	wB	OSR
18	wB	OSR	W	wB	OSR	W	wB	OSR	W
21	W	wB	OSR	wB	OSR	W	W	wB	OSR
22	wB	OSR	W	wB	OSR	W	wB	OSR	W
23	wB	OSR	W	wB	OSR	W	wB	OSR	W
26	OSR	W	wB	wB	OSR	W	OSR	W	wB
27	OSR	W	wB	wB	OSR	W	OSR	W	wB
28	OSR	W	wB	wB	OSR	W	OSR	W	wB
34	OSR	W	wB	OSR	W	wB	OSR	W	wB

Observed crop sequences for the 10 out of 13 fields in which grower 9 adopted the 3-year rotation: oilseed rape (OSR), wheat (denoted W), winter barley (wB), over the period 1995–1997. Also shown are two imaginary possible reallocations of the starting crop of the rotation to yield different extremes of temporal heterogeneity. In E1 temporal heterogeneity is deliberately made almost maximal; in E2 it is made minimal.

Spatio-temporal analysis : blocks of fields

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- Same owner
- Same rotation (A)
- different starting year (i)

$$D = \frac{m(m-1)}{L \times q} \times \sum_i \left[\frac{W_i}{N_i(N_i-1)} \right]$$

- L** : distance between all centroids
- m** : number of fields of an owner following rotation A
 $m(m-1) / 2 =$ number of pair-wise for all
- W_i** : $\sum w_{ij}$, distance between centroids of pair-wise (i)
- N_i** : number of fields with same starting year (i)
 $N_i(N_i-1) / 2 =$ number of pair-wise for (i)
- q** : number of groups with more than 1 field
 (same owner, same rotation, same starting year)

Rotation featured

W	Wb	OSR
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All possible pair-wise (for L)

High aggregation ($D \ll 1$)

Random allocation ($D = 1$)

Fig. 1. Burgundy study landscape (France). A subset comprising the north and east of the Burgundy study landscape in 1997, showing the observed allocation of four crop types: wheat, barley, oilseed rape and set aside, to 23 fields, by five growers. Each field is shown with its reference number. Inset at top right shows the full landscape, comprising 72 fields and 10 growers. Inset at bottom right distinguishes different growers.

Fig. 2. Imaginary extreme spatial patterns for Burgundy data. Two examples of possible reallocations of the crop types in Fig. 1, to yield different extremes of spatial pattern. (a) In the nine wheat fields, five barley, five oilseed rape and four set aside crops are reallocated to achieve a large degree of aggregation of crops, where identical types cluster together. (b) In the crop types are reallocated to demonstrate homogeneity, so that no crop type is a nearest neighbour of itself. Shading for crop types as in Fig. 1.

Coexistence scenarios – need for separation distance between GM and non-GM farmers

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Temporal pattern – Temporal conditions *User interface*

Agronomic conditions (C)

Temporal conditions

Same crop | Crop groups | Additional conditions

Crop: Wheat, Return period: 1, Maximum repetition: 3, Remove

Crop: spring Barley, Return period: 3, Maximum repetition: , Remove

Crop: , Return period: , Maximum repetition: , Remove

Add new crop, Save, Clear, Cancel, Help

Return periods
Max repetitions
Specific conditions

Temporal conditions

Same crop | Crop groups | Additional conditions

Crop: Wheat, Return period: 1, Maximum repetition: 3, Remove

Crop: spring Barley, Return period: 3, Maximum repetition: , Remove

Crop: , Return period: , Maximum repetition: , Remove

Add new crop, Save, Clear, Cancel, Help

return period of 3: 2 years are required between the same crop.
maximum repetition of 3: the crop may be consecutive for 3 years maximum.

Save all, Clear all, Cancel, Help

Temporal conditions

Same crop | Crop groups | Additional conditions

Group 1
Crop group: Wheat, Return period: 1, Maximum repetition: 3, Remove group

Group 2
Crop group: , Return period: , Maximum repetition: , Remove group

(from crop list)

Add new group, Save, Clear, Cancel, Help

Save all, Clear all, Cancel, Help

Temporal conditions

Same crop | Crop groups | Additional conditions

Crop (year n): Wheat, y: preceded in year -1 by, Crop (year n - y): Fallow, cannot be followed by, Crop (year n + 1): Wheat, Remove

Crop (year n): , y: preceded in year by, Crop (year n - y): , cannot be followed by, Crop (year n + 1): , Remove

Crop (year n): , y: preceded in year by, Crop (year n - y): , cannot be followed by, Crop (year n + 1): , Remove

Add new condition, Save, Clear, Cancel, Help

Save all, Clear all, Cancel, Help

jn1

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Definition of transition matrix - rotation

Crop rotations definition | Fields assignments to sets

☐ Rotation length
☐ Crop frequencies within rotation
☐ Crop proportions (area) ☒ within sets ☐ overall

Set 1 | Set 2 | Set 3

Rotation length
rotation length: years [Save] [Clear] [Cancel]

Crop frequencies in rotation
Crop A :
Summary: [v] [^]
proportions: $0 \leq p \leq 1$

Crop proportions
Crop A :
Summary: [v] [^]
proportions: $0 \leq p \leq 1$

Overall crop proportions
Crop A :
Summary: [v] [^]
proportions: $0 \leq p \leq 1$
[Save] [Cancel] [Clear] [Help]

[Save] [Create transition matrix - rotation] [Clear] [Cancel] [Help]

Definition of final crop matrix

Crop rotations definition | Fields assignments to sets

Three possible assignments:

- ☒ user-assignment of fields to sets
- ☐ user-assignment of the number of fields to sets
- ☐ program-assignment of fields to sets (random)

[Save] [Clear] [Cancel] [Help]

Set 1 | Set 2 | Set 3

Fields list
Complete list of fields: [list]
Fields within set 1 : [list]
[Save] [Clear]

Number of fields per set
Set 1 :
Summary: [v] [^]
[Save] [Clear]

[Save] [Clear] [Cancel] [Help]

Temporal pattern – Definition of final temporal matrix *User interface*

Resulting transition matrix - rotation

Probabilities of the transitions between crops.
e.g.: 0 indicates forbidden transition
1 indicates probability of 100% of the transition.

		crop grown in year n + 1				
		Crop A	Crop B	Crop C	Crop D	Crop E
crop grown in year n	Crop A	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
	Crop B	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
	Crop C	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
	Crop D	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
	Crop E	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>

[Accept] [Delete and Reconfigure temporal conditions] [Cancel] [Help]

jn1

I am now not sure that this transition matrix of rotations (master transition matrix) is necessary. I think we agreed that jumping to a predetermined rotation would be too complex to implement, and unrealistic. If we want to incorporate the practice of jumping between rotations this can, in any case, be modelled through the user-defined transition matrix approach. Indeed, my current thinking is that perhaps it will not be necessary to incorporate this at the user-entry stage since it is not very realistic. If we, as researchers, wanted to study the effects of a stochastic change of rotations, we can do so by using the 'rotations_and_transition_matrices.doc' document to calculate the appropriate transition matrix and then we can specify it directly. In that case, the user does not actually need the 'master transition matrix' or 'transition matrix between rotations' at all.

perry; 23.01.2006

Parcels within fields, fields within holdings,

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,... holdings within cooperatives,
Cooperatives within landscapes,
Landscapes within regions....

1

Agriculture, Ecosystems and Environment 118 (2007) 339–349

New measures and tests of temporal and spatial pattern of crops in agricultural landscapes

M.S. Castellazzi ^{a,*}, J.N. Perry ^a, N. Colbach ^b, H. Monod ^c,
K. Adamczyk ^c, V. Viaud ^c, K.F. Conrad ^a

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Agricultural Systems 97 (2008) 26–33

A systematic representation of crop rotations

M.S. Castellazzi ^{a,*}, G.A. Wood ^b, P.J. Burgess ^b, J. Morris ^b, K.F. Conrad ^a, J.N. Perry ^a

3

Simulation scenarios of spatio-temporal arrangement of crops at the landscape scale

M. S. Castellazzi ^{a, b}, J. Matthews ^a, F. Angevin ^c, C. Sausse ^d, G.A. Wood

P. J. Burgess ^e, I. Brown ^b, K. F. Conrad ^a, J. N. Perry ^a.

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Availability: <http://www.rothamsted.ac.uk/pie/LandSFACTS/> - free to use under the

GNU Public licence, version 2. Subsequent versions:

<http://www.macauley.ac.uk/LandSFACTS/>

Decreases in abundance and occupancy of the garden tiger moth, *Arctia caja*, in the UK

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- The proportion of occupied sites has declined ~ 30%
- The abundance at occupied sites has also declined ~ 30%

Changes in where the moth is found

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- Map co-ordinates of traps catching *Arctia caja*
- Centres of occupancy moved north and slightly west over time

Patches and gaps in distribution

- SADIE Identifies clusters of sampling points with similar counts
- Cluster of relatively large counts is a patch (red)
- Cluster of relatively small counts is a gap (blue)
- Areas where spatial pattern is weak (random distribution of counts) coloured white
- Patch and gap size not strongly affected by 'good' and 'bad' years

for up-to-date and free SADIE software visit:

<http://home.cogeco.ca/~sadiespatial/index.html>

and also http://www.rothamsted.bbsrc.ac.uk/pie/sadie/SADIE_home_page_1.htm

Spatial pattern reversal over time

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Papers on *Arctia caja* and decline of monitored lepidoptera

Conrad, K.F., Perry, J.N. & Woiwod, I.P. (2001). An Abundance-Occupancy Time-lag During the Decline of an Arctiid Tiger Moth. *Ecology Letters*, **4**, 300-303.

Conrad, K.F., Woiwod, I.P. & Perry, J.N. (2002). Long-term decline in abundance and distribution of the garden tiger moth (*Arctia caja*) in Great Britain. *Biological Conservation*, **106**, 329-337.

Conrad, K.F., Woiwod, I.P. & Perry, J.N. (2003) East Atlantic teleconnection pattern and the decline of a common arctiid moth. *Global Change Biology*, **9**, 125-130.

Conrad, K.F., Perry, J.N., Woiwod, I.P. & Alexander, C.J. (2006) Large-scale temporal changes in spatial pattern during declines of abundance and occupancy in a common moth. *Journal of Insect Conservation*, **10**, 53-64. DOI 10.1007/s10841-005-1618-2.

Conrad, K., Woiwod, I.P., Perry, J.N. & Alexander, C.J. (2006) Decline of a common

J. N. Perry, Y. Devos, S. Arpaia, D. Bartsch, A. Gathmann, R. S. Hails, J. Kiss, K. Lheureux, B. Manachini, S. Mestdagh, G. Neemann, F. Ortego, J. Schiemann, and J. B. Sweet (2009)

A mathematical model of exposure of non-target Lepidoptera to Bt-maize pollen expressing Cry1Ab within Europe.

Proceedings of the Royal Society series B, **277**, 1417-1425.

doi: 10.1098/rspb.2009.2091

(EXiS Open Choice

<http://rspb.royalsocietypublishing.org/cgi/content/abstract/277/1686/1417>)

... and three Lepidopteran species

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The Peacock butterfly:

Inachis io

with host plant *Urtica dioica*

The Red Admiral butterfly:

Vanessa atalanta

with host plant *Urtica dioica*

The Diamond-backed moth pest:

Plutella xylostella

with host plant *Brassicaceae*

<i>Parameter</i> (bold type and orange shading indicates parameter reduces worst-case exposure)		<i>Large/Small scale</i>	<i>Generic/Specific to lepidopteran species</i>	<i>Generic/Specific to host-plant</i>	<i>Generic/Specific to region</i>	<i>How derived</i>
z <i>proportion crops in maize</i>		Large	Generic	Generic	Specific	official statistics
v <i>Bt uptake rate</i>		Large	Generic	Generic	Specific	Spain: statistics; elsewhere:: set as worst-case
y <i>propn. host-plants in arable</i>		Large	Generic	Specific	Specific	surveys/experts
C <i>size of maize fields</i>		Small	Generic	Generic	Specific	official statistics
D <i>width of margin</i>		Small	Generic	Generic	Specific	surveys/experts
e <i>density host-plant in crop</i>		Small	Generic	Specific	Specific	surveys/experts
f <i>density host-plant in margin</i>		Small	Generic	Specific	Specific	surveys/experts
x <i>physical effects</i>		Small	Specific	Specific	Specific	experts
a <i>temporal coincidence</i>		Large	Specific	Specific	Specific	experts
$g(E)$ <i>worst-case mortality: margin</i>		Small	Specific	Generic	Generic	calculated
h <i>worst-case mortality : crop</i>		Small	Specific	Generic	Generic	calculated

'Large-scale' parameters: y , z , v

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proportion of the host-plant found within arable fields and their margins, y

proportion of arable fields in maize, z

proportion of maize that is *Bt*, the 'uptake' parameter, v

'Small-scale' parameters: C , D , e , f

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These parameters: C , D , e , f , do not reduce mortality.
They provide a means of *weighting* overall mortality
between the 'within-crop' and 'within-margin' components

Time of
start of
period

Any point in area A is entirely within the ellipsoid for instar development, but outside that of maize pollen shed;

Any point in area B is within both ellipsoids.

The larger the proportion $B/(A+B)$ the larger is the overlap, the greater the temporal coincidence and the greater the mortality –

this proportion is the temporal overlap parameter, a

physical effects parameter,

X ,

proportion of larvae
remaining exposed, after
allowance for:

larvae feeding on underside of leaves,

'shading' of lower leaves by upper,

rain washing pollen off leaves,

etc., etc.

Mortality due to pollen in the field

proportion of larvae suffering
mortality in the field –
worst-case scenario, h

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Mortality due to pollen in the margin

proportion of larvae suffering mortality
at distance E from edge of field -
worst-case scenario, $g(E)$

Overview of new approach - biological

We would like to be able to estimate the mortality of a larva at any position either within a crop

or outside it in the field margin

bioassays in the laboratory
relate mortality to dose

field measurements of maize
pollen relate dose to
distance from field

Can we combine these two common sources of information to obtain a relationship between mortality and distance?

Overview of new approach - mathematical

$$p = f(d)$$

$$d = g(E)$$

$$p = f[g(E)] = h(E)$$

Calculation of 'worst-case' mortality

Different sigmoid curves show differing increase in mortality with increase of dose

Mortality-dose regression lines

Dose-distance relationships

relating d , dose, to E , distance from edge of field

from Lang *et al.*, 2004 for *Bt176*

LC50 *V. atalanta & I. io*

LC50 *P. xylostella*

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Wraight *et al.* (2000, especially fig. 2) amended after Pleasants *et al.* 2001 and Lang *et al.* 2004):

$$\log_{10} d = 1.891 - 0.145E$$

for *P. xylostella* exposed to pollen falling onto smooth-leaved food plants of **Brassicaceae**

$$\log_{10} d = 2.346 - 0.145E$$

for *V. atalanta & I. io* exposed to pollen falling onto hairy-leaved ***Urtica dioica*** food plants

Figure 1. Estimated values of the parameter values h (worst-case within-crop mortality, assumed constant over the crop) and $\mu(D)$ (worst-case average mortality within a field margin of width D metres, declining with D) for the butterflies *I. io* and *V. atalanta* and the moth *P. xylostella*. Here, the term worst-case refers to potential mortality, as measured in the laboratory or under controlled conditions, before allowance for factors such as physical effects and temporal coincidence, and as opposed to more realistic values observed in the field

Parameter values

Table 1. Parameter values used in the model. (Values given within curly brackets {,,,} are, respectively, the number of regions considered, and the minimum, maximum and median of authors' estimates across regions. For parameter v , values for nine of 11 regions (all those outside Spain) were set at 0.8, to model the worst-case scenario for potential uptake, defined as that which gives maximal predictions of mortality.)

parameter	type (units)	species <i>I. io</i> on <i>U. dioica</i>	<i>V. atalanta</i> on <i>U. dioica</i>	<i>P. xylostella</i> on Brassicaceae	Which values of this parameter give 'worst-case' estimates?
margin mortality, $g(E)$	probability (—)	equation (2.5)	equation (2.5)	equation (2.6)	
within-crop mortality, h	probability (—)	0.0805	0.0805	0.148	
physical effects, x^a	proportion (—)	{10, 0.2, 0.8, 0.4}	{10, 0.1, 0.7, 0.4}	{11, 0.1, 0.8, 0.5}	large
temporal coincidence, a^a	proportion (—)	{10, 0.01, 0.6, 0.5}	{10, 0.01, 0.6, 0.5}	{11, 0.1, 0.8, 0.5}	large
maize cropping, z^a	proportion (—)		{11, 0.024, 0.7, 0.2}		large
utilization rate, v^a	proportion (—)		{11, 0.035, 0.8, 0.8}		large
host plant in arable, y^a	proportion (—)	{11, 0.1, 0.5, 0.23}	{11, 0.1, 0.5, 0.23}	{11, 0.1, 0.8, 0.5}	large
host plant within-crop, e^a	density (m^{-2})	{11, 0, 0.01, 0}	{11, 0, 0.01, 0}	{11, 0, 0.5, 0}	
host plant in margin, f^a	density (m^{-2})	{11, 0, 10.0, 0.5}	{11, 0, 10.0, 0.5}	{11, 0, 15.0, 0.5}	
size of maize fields, C^a	area (ha)		{11, 1.1, 58.0, 15.0}		
width of margin, D^a	distance (m)		{11, 1.0, 4.5, 2.0}		

^aAll parameters vary regionally and were estimated by authors.

Summary of results

Table 2. Estimated population mortality rates. (For the butterflies, *I. io* and *V. atalanta*, the computed and median values exclude Spain.)

region	mortality		
	<i>I. io</i>	<i>V. atalanta</i>	<i>P. xylostella</i>
Bonn	2.95×10^{-5}	2.95×10^{-5}	6.11×10^{-5}
Oderbruch	5.03×10^{-5}	5.03×10^{-5}	6.16×10^{-5}
Aachen	1.68×10^{-4}	1.68×10^{-4}	6.16×10^{-6}
Berkatal	2.32×10^{-4}	2.32×10^{-4}	3.04×10^{-4}
Grebbin	6.36×10^{-4}	6.36×10^{-4}	7.69×10^{-4}
Upper Rhine Valley	4.40×10^{-4}	4.40×10^{-4}	2.55×10^{-3}
Tolna County	1.91×10^{-5}	9.57×10^{-6}	1.53×10^{-4}
Po Valley (central)	4.06×10^{-4}	3.55×10^{-4}	9.79×10^{-4}
Po Valley (coastal)	—	—	5.13×10^{-5}
Madrid	0	0	1.00×10^{-9}
Ebro Valley	0	0	2.30×10^{-8}
minimum over regions	1.91×10^{-5}	9.57×10^{-6}	1.00×10^{-9}
maximum over regions	6.36×10^{-4}	6.36×10^{-4}	2.55×10^{-3}
median over regions	2.00×10^{-4}	2.00×10^{-4}	2.29×10^{-4}

Heterogeneity of pollen deposition

(Hofmann, 2007)

Some statistical aspects of the monitoring of GM plants, Joe N. Perry

$\log_{10} d$ is shown to decline linearly with $\log_{10} E$, as expected, but with variability about the regression line that may be represented by a normal random variable with variance about 0.175, so that the 99% confidence interval around the line encompasses about 12-fold variation in concentration, at any given distance, in both directions. For linear systems, the average expected effect of such variation would be zero,

Conclusions

- 1) Relationships between mortality and dose and between dose and distance may be integrated to estimate mortality both a crop within the field margin at varying distances from the crop edge.
- 2) A full exposure assessment *is* possible for several Lepidopteran species
- 3) Many factors must be accounted for, some of which must be modelled with relatively little data. This results in uncertainty in estimated mortality and sublethality, which is compounded by natural variation between areas and differences between experts' interpretation.
- 4) However, even in the worst-case scenarios, in ***all*** areas considered, the **estimate for mortality was less than one individual in every 1500**, and **of sub-lethality was less than one individual in 390**, for the two butterfly species
- 5) For ***all*** the areas considered, the **estimate for mortality was less than one individual in every 390**, and of **sub-lethality was less than one individual in 95**, for the pest moth species .

Conclusions (continued)

6) These estimates were made under the worst-case scenario of minimal probit slope and maximum uptake of MON810 maize by growers for the areas in Germany, Hungary and Italy.

7) Allowing for heterogeneity of pollen resulted in slight increases in estimated mortality, which were 1.33 times the corresponding deterministic value for *I. io* and *V. Atalanta* and 1.17 times for *P. xylostella*.

8) The amounts of MON810 pollen grains found in and around maize fields are unlikely to adversely affect a significant proportion of non-target lepidopteran larvae, after allowing for spatial heterogeneity of pollen deposition.

9) But data are required to reduce the uncertainty of the estimates reported here.