Relationships between insect biomass and plant biomass and height in ALMaSS

To increase the realism relating to food supplies for the birds modelled in ALMaSS, a refinement of the prediction of insect food biomass available to the birds was added to the basic model used in (Topping and Odderskær 2004). This refinement was based on the collection of insect and plant biomass data from five crop types (winter wheat, spring barley, winter rye, oil seed rape, and rotational grass).

The aim was to incorporate a relationship into ALMaSS between easily predicted vegetation properties and insect biomass specific to each crop to provide a simple but dynamic model of the development of insect biomass over time suitable for skylark and partridge chick food.

Field Methods

The data for this exercise were available from a large study (Pedersen et al, unpublished) and are briefly described here.

Vegetation samples

Thirteen fields were monitored in 2001 and ten fields in 2002. In each field, six transects were randomly selected perpendicular to the field boundary. On each transect two field samples (1 m and 30 m from the field boundary) and one boundary sample were taken. Winter-sown crops were sampled twice in autumn 2001, and all crops were sampled in spring and summer 2002, resulting in six sampling dates for most fields. Inside the sampling area (0.25 m^2) crop height was measured, and crop and weed biomass were harvested separately. The harvested plants were dried for 48 hours at 80°C and then weighed.

Arthropod samples

Arthropods were sampled by D-vac (vacuum sampler, Dietrick 1961). Each field sample, covering one square metre, consisted of nine suctions of 10 seconds each. Field boundary sample consisted of six suctions covering a length of approximately 2 m. After sampling, the samples were frozen. Upon drying at 80°C animals from all sampling dates were weighed, using a Mettler AT250 balance (accuracy 0.01 mg).

Fitting the data

Samples from the field areas, were used for fitting arthropod biomass data to plant data for each crop, whereas the field margin samples were pooled to create a single data set. The correlation between arthropod and weed biomass was calculated as Pearson correlation coefficient. Linear fitting of the data were performed by stepwise linear regression (SAS Institute 1989), using crop biomass, crop height and weed biomass as variables. The basic regression model thus was

$$\textit{arthropod biomass} = \alpha + \beta 1\,(\textit{crop biomass}) + \beta 2(\textit{crop height}) + \beta 3(\textit{weed biomass}) \quad \text{(Eqn.1)}$$

The criterion for a variable entering and staying in the model was set at $p < 0.15$.

A more complex fit was also performed in SAS procedure NLIN (SAS Institute 1989), based on the Boltzmann equation in order to evaluate whether this improved the predictive power.

arthropod biomass = k1/(1+exp((k2-crop biomass)/k3)) (Eqn.2)

where ***k1*** is the maximum achievable biomass, ***k2*** is the mid-point when it is achieved, and ***k3*** is the slope between the two.

Results

Samples from fields where less than four samples could be collected were discarded, resulting in 117 useable data points. The data were analysed for each crop and year to find a general simple equation that would adequately describe all cases. Based on R^2, a reduced multiple regression equation (Eq.1), excluding weed biomass was found to perform better than or as well as a range of sigmoid or more complex multiple regression curves.

Table 1: Estimates of regression parameters for the insect models used to predict potential bird food from vegetation structure

Crop	No. fields	Intercept (α)	Crop biomass (β1)	Crop height (β2)	Percentage of variance explained
Winter Wheat 2001	27	-2.966	-0.013	0.392	90.8
Winter Wheat 2002	14	-5.937	0.017	0.783	74.0
Spring Barley 2001	26	8.114	0.679	-0.980	63.7
Spring Barley 2002	11	-10.706	1.814	-1.092	91.6
Winter Rye 2001	6	-1.302	-0.051	0.221	99.5
Winter Rye 2002	7	-8.507	0.401	0.313	90.6
Oil Seed Rape 2001	10	-2.763	0.396	-0.031	94.2
Rye Grass 2001	16	4.127	0.151	-0.228	33.3
Overall mean curve for crops	NA	-2.493	0.424	-0.078	NA
Field Boundary (2001&2002 combined)	6	10.718	-0.003	2.537	51.9

Table 2: Insect models used for crop types for which field data did not exist

Crop Type	Insect Model
Winter Barley	Overall mean curve
Field Peas	Overall mean curve
Maize	Overall mean curve
Grass	Overall mean curve
Set-aside & semi-natural habitats	Field Boundary

The resulting estimates of the parameters of the reduced regression model are shown in Table 1. For those crops where fields were sampled in two years, there was clearly a difference between 2001 and 2002, with 2002 always having a higher insect biomass. Since only two years data were available and there were no suitable explanatory variables, equal weighting was given to both years, and mean curves were created by taking the means of the parameter estimates for each crop type. These mean curves were used to predict insect biomass for different crops in the ALMaSS model. Those crops not represented in the field data were assigned the most similar crop equation (Table 2), or if there were no sufficiently similar crops, the overall mean curve of the data set.

Incorporation into ALMaSS

At the beginning of each time-step ALMaSS recalculates the total biomass of insects for every polygon modelled. The expected biomass was given as dry-weight by the equations developed above for each crop or other vegetation type. However, for many reasons, e.g. insecticide spray, the actual expected biomass may deviate from this total biomass of insects. This is handled by calculating a reduction as a result of an operation and then specifying a growth rate which returns the insect biomass slowly towards the expected biomass. The growth rate is simply the difference between current and predicted biomass divided by the duration of effect expected. When the growing insect biomass intersects the predicted curve, insect biomass is again assumed to follow the predicted curve.

References

Dietrick, E.J. 1961. An improved backpack motorised fan for suction sampling of insect populations. Journal of Economic Entomology 54(2): 394-395.

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