

Overwintering survival in the seven spot ladybird, *Coccinella septempunctata* (Coleoptera: Coccinellidae)

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Abstract. An East Anglian population of the seven spot ladybird *Coccinella septempunctata* was studied to identify factors that influenced overwintering survival. For their body size, individuals that were still foraging in October were significantly lighter than those taken from stable aggregations. Ladybirds taken from aggregations (and hence those that had stopped foraging naturally) suffered just 9% mortality overwinter, compared with 72% mortality in a sample of active ladybirds that were prevented from continued foraging. Even after accounting for their lower relative weight, these active ladybirds suffered disproportionately higher mortality.

Introduction

The seven spot ladybird *Coccinella septempunctata* L. is the commonest coccinellid beetle in the UK. In common with most ladybirds in the UK, the seven spot spends the winter in a dormant state surviving on reserves accumulated over the summer. They typically form aggregations of a few dozen individuals in sheltered positions, beginning in September and ending during late March (Majerus, 1994).

Obrycki et al. (1983) showed that abiotic cues such as photoperiod can influence the behavioural change from foraging to overwintering in *Adalia bipunctata*. Hodek illustrated the importance of temperature and photoperiod in inducing diapause in the seven spot ladybird (Hodek & Čerkasov 1960, 1961). Hodek & Čerkasov (1960) showed there was genetic variation in diapause behaviour.

The survival of diapausing insects depends largely on the amount of metabolic reserves they can accumulate before diapause (Hodek & Čerkasov, 1963; Tauber et al., 1986; Danks, 1987). In the present study we use field observations of the seven spot ladybird to examine some of the proximate determinants of individual variation in overwintering survival.

Material and methods

Overwinter survival was assessed in the ladybird sample collected from Madingley Wood, near Cambridge, on October 3rd 1994. Ladybirds belonged to three classes: (1) aggregated; ladybirds from aggregations. (2) single; solitary ladybirds which were stationary on the vegetation at the time of sampling. (3) active; ladybirds that were active either on the vegetation or on the woodland floor.

At least 40 ladybirds from each class were anaesthetised with CO₂, sexed and the width of the first abdominal segment was measured to within 0.01 mm as a reliable indicator of body size in ladybirds (Majerus, pers. comm.). Fresh weight was measured with a shock proof electronic balance to within 0.5 mg. The ladybirds were individually placed in small plastic pots (internal volume 9 cm³ approx.) with perforated lids. Inside each pot was a crumpled piece of dry paper. The pots were placed in an unheated outdoor insectary until February 26th when they were transferred to 22°C for 48 h. Survival of the different classes was scored.

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Results

The sex ratios of the behavioural classes were not significantly different from the sex ratio of the whole sample or from 50:50. At Madingley Wood, there were significant differences between the three categories for males (Size: $F = 3.35$, $df = 2,72$, $P = 0.041$; weight: $F = 22.24$, $df = 2,72$, $P < 0.0001$), and for females there were significant differences in weight but not in size between the three categories (size: $F = 2.3$, $df = 2,81$, $P = 0.106$; weight: $F = 24.09$, $df = 2,81$, $p < 0.0001$) (Table 1).

TABLE 1. Body size, weight and relative weight of ladybirds at Madingley Wood. Categories that do not differ at the 5% level share the same superscripts.

	n	Size (mm)		Weight (mg)		Relative weight (mg)	
		Mean	SD	Mean	SD	Mean	SD
Males							
Aggregated	35	4.66 ^a	0.22	39.97 ^a	4.53	2.34 ^a	3.92
Single	19	4.53 ^{ab}	0.24	36.26 ^b	5.58	0.90 ^a	4.17
Active	21	4.49 ^a	0.29	30.33 ^c	5.96	-4.24 ^b	5.69
Females							
Aggregated	40	5.04 ^a	0.25	48.05 ^a	6.1	3.41 ^a	5.44
Single	21	4.95 ^a	0.29	43.23 ^b	5.19	0.31 ^b	3.8
Active	24	4.90 ^a	0.21	35.66 ^c	9.03	-6.38 ^c	5.43

Size and weight were correlated ($r = 0.706$, $n = 159$, $P < 0.0001$). The regression is illustrated in Fig. 1. This shows that active ladybirds were disproportionately lighter for their body size than aggregated or single ladybirds. We estimated the condition of ladybirds by their weight relative to body size (i.e. as the difference between the observed weight and that expected according to the size-weight regression). We called this measure relative weight, it was independent of sex and controls for body size. As indicated in Table 1, active ladybirds always had a lower relative weight than those aggregated, and single ladybirds were usually in intermediate condition.

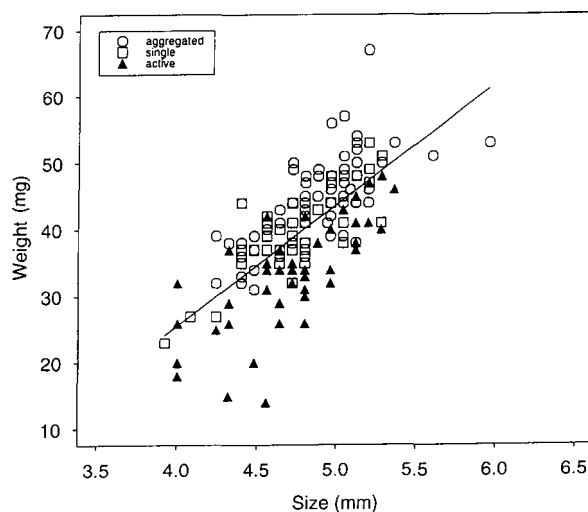


Fig. 1. Relationship between body weight and body size in ladybirds from Madingley Wood. Regression line: $\text{Body weight} = -46.8364 + 18.1263 (\text{body size})$, $F = 157.4$, $df = 1,158$, $P < 0.0001$.

TABLE 2. Survival of the three categories of ladybirds at Madingley Wood.

	Alive	Dead	Total
Aggregated	68 (90%)	7 (9%)	75
Single	35 (85%)	6 (14%)	41
Active	12 (27%)	32 (72%)	44

Active individuals suffered higher mortality than single or aggregated ones ($\chi^2 = 60.06$, $df = 2$, $P < 0.0001$; Table 2). A logistic regression analysis (Crawley, 1993), in which survival was the dependent variable and relative weight and behavioural category were included as terms in the model indicated that for all classes survival probability increased with relative weight. There was no difference in survival probability between the aggregated and single categories, but there was between the active ladybirds and the other two categories combined. The fitted survival estimates for the three behavioural categories are shown in Fig. 2. Clearly, although relative weight is a significant factor determining survival overwinter in all three categories of ladybirds, and especially active individuals, this does not explain the much greater mortality of this category of animals.

Discussion

The logistic regression analysis demonstrated that, within all three behavioural classes, relative weight was positively correlated with survival. In all three groups ladybirds with a high relative weight were more likely to survive.

Mortality among the aggregated and single classes was less than 15% whereas for the active class it was greater than 70%. This supports the hypothesis that the active ladybirds had not accumulated enough reserves to survive the winter. The difference in survival of active and aggregated ladybirds is too great to be explained by the difference in relative weight alone. If the higher mortality of active ladybirds was purely a consequence of poorer condition, then we would expect the survival curves of active and aggregated ladybirds in Fig. 2 to overlap at points where their relative weight overlaps. The cause of the higher

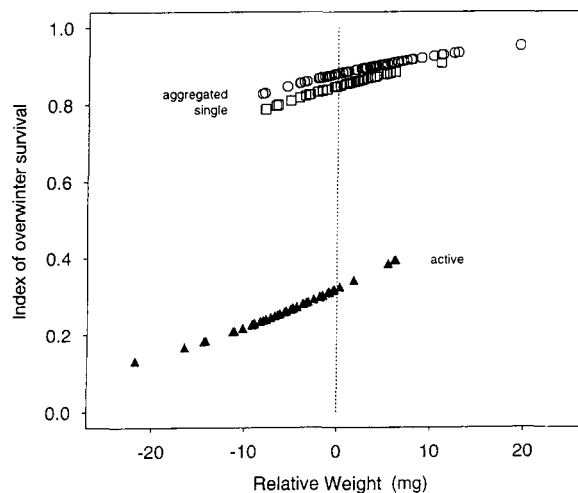


Fig. 2. Relationship between overwinter survival and relative body weight (condition). Symbols indicate the fitted values for the three behavioural categories. Significant terms in the model: relative body weight: $\chi^2 = 28.64$, $df = 1$, $P < 0.0001$; behavioural category (active, aggregated/single): $\chi^2 = 29.25$, $df = 1$, $P < 0.0001$).

mortality of active ladybirds remains unknown, but during the study period ladybird density was unusually high, aphid numbers were very low (M.E.N. Majerus, pers. comm.) and ladybirds were observed feeding on unusual foods such as bramble berries. One possibility is that this class also contained diseased or parasitised individuals. Abnormal foraging behaviours have been observed in parasitised bees (Schmid-Hempel & Müller, 1991). Ladybirds were not dissected at death, but no emergent parasitoids were found.

Both abiotic and genetic factors will influence the switch in behaviour from foraging to overwintering. It is widely understood that ladybirds active late in the year have not accumulated enough reserves to be prepared for dormancy (Hodek & Honěk, 1996). Evidently, ladybirds can accurately estimate their energy budget. We suggest the possibility that in the field the immediate cause of the change in behaviour is the resource status of the individual ladybird. Further study is needed to support this hypothesis, especially with regard to relating fat reserve to aggregation behaviours and survival overwinter.

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