Ent. exp. & appl. **30** (1981) 265—268. *Ned. Entomol. Ver. Amsterdam*

THE MORTALITY AND FAT CONTENT OF *ADALIA BIPUNCTATA* DURING HIBERNATION

N. J. MILLS[1])

School of Biological Sciences, University of East Anglia, Norwich NR7 4TJ, England

Coccinellids were sampled at intervals from natural hibernation sites, to determine mortality in relation to fat content. The fat content was reduced by 65%, while fresh weight remained constant. A 36% mortality occurred in early spring, which was independent of the fat content and attributable to fungal pathogens.

KEY WORDS: Mortality, fat content, hibernation, coccinellid, *Adalia bipunctata*

Coccinellids as predators of the Homoptera: Sternorrhyncha are of considerable interest as potential biological control agents. However, little is known of the dynamics of coccinellid populations and the causes of mortality through the life-cycle. While partial life-tables can be constructed for the developmental stages (e.g., Mills, 1979), the discontinuity from year to year, characteristic of insects associated with ephemeral food resources, prevents completion of the adult phase of the life-table.

Coccinellids overwinter as adults in sites often remote from the foraging area (Hodek, 1973, Hagen, 1962) and little attempt has been made to investigate mortality at this stage in the life-cycle. Hariri (1966) has looked at changes in the metabolic reserves of coccinellids during hibernation in artificial hibernacula. The presence of protozoan and fungal pathogens in hibernating coccinellids has also been documented by Iperti (1964) and Lipa *et al.* (1975).

In the present study, groups of *Adalia bipunctata* (L.) were collected at intervals over the winter in order to determine mortality in relation to depletion of the fat reserves. In urban environments, this coccinellid hibernates in buildings (Benham & Muggleton, 1978), but in more rural environments it hibernates under the bark of trees. Groups of from 3 to 50 individuals occur from ground level up to a height of about 10 m under the bark of mature Scots Pine (*Pinus sylvestris* L.) from which they can readily be obtained.

METHODS

Groups of between 15 and 25 adult coccinellids were collected on eight occasions between August 1976 and May 1977, from around the campus of the University of East Anglia. The size of each individual was determined by measurement of the maximum pronotal width and elytral length, using a microscope with an eyepiece graticule. The fresh weight of the coccinellids on collection and their dry weight after drying in an oven at 60° for 5 days, were estimated using a Cahn micro-electrobalance. The fat of the coccinellids was extracted 5 times by daily immersion of individuals in closed tubes of petroleum ether in an oven at 38°, before drying and re-weighing to obtain the fat-extracted dry weight.

RESULTS

The fresh weight, total dry weight and fat dry weight of *A. bipunctata* over the hibernation period can be seen from Fig. 1. The fresh weight remained remarkably constant over this period, while dry weight decreased rapidly at first, and then more steadily as the fat reserves were consumed. The initial fat content of 3.3 mg (54% dry weight) was reduced to 1.2 mg (30% dry weight) by the end of the hibernation period. The fat content decreased by 2.1 mg (65%) at an average daily consumption of 0.010 mg fat. While metabolic water is produced on consumption of the fat reserves, it is likely that the coccinellids maintained their constant fresh weight with water obtained from the hibernation site.

The maintenance of a constant fresh weight indicates that this measure cannot be used as

[1]) Present address: Department of Zoology, South Parks Road, Oxford OX1 3PS, England

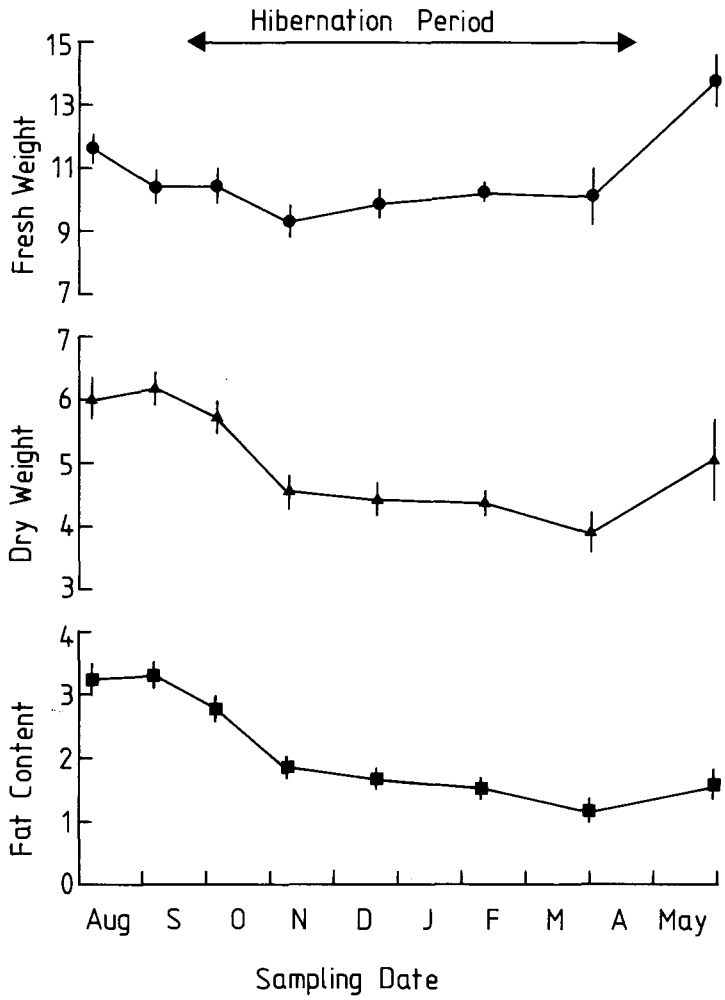

Fig. 1. Mean (± S.E., n = 15—25) fresh weight, dry weight, and fat content of adult coccinellids during the winter in mg.

an indicator of coccinellid fat content. However, the dry weight fat content can be derived from the total dry weight and size of the coccinellid. The first half of each sample of hibernating coccinellids (a total of 63 individuals) was used in a regression analysis of the linear dependence of fat-extracted dry weight (We in mg) on size (S in mm^2), estimated as the product of pronotal width and elytral length. This gave:-

$$We = 0.459\ (\pm .029)\ S - 0.868\ (\pm .033)$$
$$n = 63,\ R^2 = 0.80,\ P < 0.001$$

Since the dry weight fat content (Wf in mg) is the difference between the total dry weight (Wt in mg) and the fat-extracted dry weight (We), the following relation can be used to estimate fat content:-

$$Wf = Wt - 0.459S + 0.868$$

An analysis of variance of this relation is given in Table I, indicating that 94% of the variance in dry weight fat content is explained.

No mortality was observed in the samples of overwintering coccinellids until February and March. On no occasion was parasitism by the braconid parasitoid, *Perilitus coccinellae* Schrank, observed. Of the 36 individuals sampled at this time 13 were dead, giving a survival rate of 64%. The primary cause of death was the fungal pathogen *Beauveria bassiana* (Bals.) (see Lipa *et al.*, 1975), mycelium of

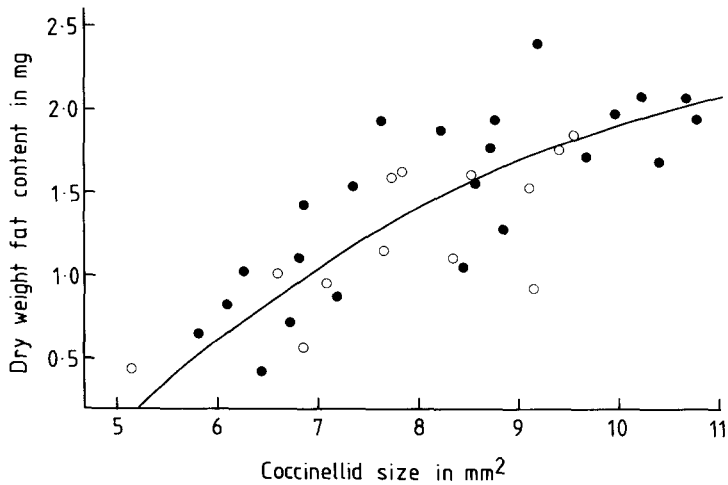

Fig. 2. Fat content of coccinellids sampled in February/March in relation to their size. Live individuals •, dead individuals ○.

TABLE I

Analysis of variance for relationship between dry weight fat content, total dry weight and coccinellid size

	Sum of squares	d.f.	Mean square	F
1. Regression	68.788	1	68.788	992.6
2. Residual	4.224	61	0.069	
3. Total	73.012	62		

$R^2 = 0.94$, $P < 0.001$

which was found in the bodies of 12 of the 13 dead individuals.

The dry weight fat content of the coccinellids in these last two samples of hibernating individuals is shown in relation to size in Fig. 2. An orthogonal polynomial has been fitted to the data by least-squares regression in order to separate individuals with greater than and less than the average fat content for their size. A two-way contingency table of coccinellid survival and relative fat content gives a χ^2 value of 0.73 with $P > 0.25$. The mortality of the hibernating coccinellids is therefore independent of their fat content.

DISCUSSION

The pattern of fat reserve consumption by *A. bipunctata* under natural conditions is comparable to that of other studies on coccinellids (Hariri, 1966, Hodek & Cerkasov, 1963). The initial fat content of these coccinellids in the field is higher than that reported by Hariri (1966) who fed adult coccinellids in an insectory prior to their hibernation in artificial hibernacula. The absolute consumption of fat during hibernation is also greater, although the % consumption is similar.

Previous studies of overwintering coccinellids indicate that absolute water content remains constant giving an increase in the relative % water content through winter. In this study, since fresh weight remained constant while dry weight decreased, there was an increase in absolute water content.

The overwintering mortality of 36%, which is largely attributable to fungal infection, is greater than previously recorded for this coccinellid by Lipa *et al* (1975). However, these authors estimated mortality from the number of dead individuals as a proportion of the total number of coccinellids collected on various occasions through the winter. If mortality due to fungal pathogens is confined to the latter part of the hibernation period, as found in this study, this derivation of mortality clearly underestimates the impact of the pathogen. In contrast, Hariri (1966) observed the greatest mortality during early autumn for coccinellids in artificial hibernacula. However, such mortality is likely to be the result of early confinement in the hibernacula, as well as the unnatural micro-climate.

While mortality during hibernation is independent of the depletion of fat reserves, this may not be so for survival on emergence from the hibernation site. During the pre-oviposition period in early spring the coccinellids mate and complete development of the reproductive

system. At this time prey populations are small and ephemeral and considerable mortality may occur if sufficient food sources are not found before the fat reserves are exhausted.

Since mortality in *A. bipunctata* during hibernation is primarily the result of fungal pathogens, more detailed observations would indicate any density-dependence at this stage in the life-cycle. In contrast, adult mortality during the pre-oviposition period may prove to be the key factor influencing population change (see Varley *et al.*, 1973), being dependent on the unpredictability of the ephemeral food source.

Carried out while in receipt of a N.E.R.C. studentship under supervison of Professor A. F. G. Dixon, to whom I am grateful.

RÉSUMÉ

*La mortalité et la teneur en craisse d'*Adalia bipunctata *pendant l'hibernation*

Des échantillons de coccinelles ont été récoltés à plusieurs reprises au cours de l'hiver, dans leurs lieux naturels d'hibernation, pour déterminer la mortalité en fonction de l'épuisement des réserves en graisse.

Le poids frais reste constant pendant l'hibernation, tandis que la teneur en graisse baisse de 65% par un taux moyen de 0,01 mg par jour. On constate que la teneur en graisse dépend du poids sec et de la taille de la coccinelle. Une mortalité de 36% se produit au début du printemps, indépendemment de la teneur en graisse, par suite de l'action de champignons pathogènes.

REFERENCES

Benham, B. R. & Muggleton, J. (1978). Observations on the overwintering of Coccinellidae in the British Isles. *Entomologists mon. Mag.* **114** : 191—197.

Hagen, K. S. (1962). Biology and ecology of predaceous Coccinellidae. *Ann. Rev. Ent.* **7** : 289—326.

Hariri, G. (1966). Studies on the physiology of hibernating Coccinellidae (Coleoptera): changes in the metabolic reserves and gonads. *Proc. R. ent. Soc. Lond.* (A) **41** : 133—144.

Hodek, I. (1973). *Biology of Coccinellidae*. The Hague, Netherlands, Dr. W. Junk, Publ., 260 pp.

Hodek, I., Cerkasov, J. (1963). Imaginal dormancy in *Semiadalia undecimnotata* Schneid. (Coccinellidae, Col.) II. Changes in water, fat and glycogen content. *Vest. Cs. spol. zool.* **27** : 298—318.

Iperti, G. (1964). Les parasites des Coccinelles aphidophages dans les Basses-Alpes et les Alpes-Maritimes. *Entomophaga* **9** : 153—180.

Lipa, J. J., Pruszynski, S. & Bartkowski, J. (1975). The parasites and survival of the lady bird beetles (Coccinellidae) during winter. *Acta Parasitol. Pol.* **23** : 453—461.

Mills, N. J. (1979). *Adalia bipunctata* (L.) as a generalist predator of aphids. Unpublished Ph. D. Thesis, University of East Anglia.

Varley, G. C., Gradwell, G. R. & Hassell, M. P. (1973). *Insect population ecology*. Oxford, Blackwell Scientific Publications, 212 pp.

Accepted: April 24, 1981