Aggregation of coccinellid species at hibernation sites

A. Honek, Z. Martinkova, S. Pekar
Research Institute of Crop Production, Drnovska 507, CZ 16106 Praha 6 - Ruzyne, Czech Republic.

Introduction

Lady-beetles (Coleoptera: Coccinellidae) of central Europe overwinter in the imaginal stage. The larvae of aphidophagous species develop in stands of field crops, on herbaceous weeds, shrubs or trees. All species leave the places of larval development in mid summer and migrate to the sites of hibernation. In the hibernacula adults occur from August to April, but some individuals enter the overwintering sites earlier and leave them later. Hibernation thus occupies more than three quarters of individual life. Consequently, the physiological and behavioural adaptations that minimize mortality and help to survive the period of overwintering are very important. In some species hibernating adults often aggregate into groups. Clustering of several individuals into a dense bunch may change the probability of survival compared to singles. Clumping may decrease the risk of predation and/or parasitation but at the same time it also facilitates the spreading of diseases.

We studied the tendency to clumping in hibernating *Coccinella septempunctata* L., *Semiadalia undecimnotata* (Schneider) and *Adonia variegata* (Goeze). Hibernation behaviour of these species is plastic. In Central Europe these species often use hilltop hibernacula where they overwinter in grass tussocks or under stones, singly or in groups. We studied the tendency to clumping, i.e. forming a group of 2 or more individuals within one tussock or below one stone. We established (i) whether the tendency to clumping is proportionate to overall population density and (ii) whether the clumping behaviour differs between species.

Material and methods

Overwintering adults of *C. septempunctata*, *S. undecimnotata* and *A. variegata* were counted at a hibernation site at Rana in the western Czech Republic (50°24' N, 13°46' E, atitude 390 m a.s.l.). This hibernation site is a steppe area grown by individual grass tussocks separated by 5-20 cm wide spaces of bare ground. It is situated on a southwestern slope below the western top of the Rana hill. The steppe character of the location is maintained because plant succession is prevented by a very dry shallow (2-3 cm) soil stratum covering volcanic bedrock, fully exposed to sun and wind. Adults of all three species overwinter within the grass tussocks between the densely packed stalks, sitting as deeply as possible. Coccinellids were counted every year between 1978-2004, using the same method. Counts were made on a single day between September 20 - October 20, at a time when immigration to the overwintering site was complete but winter mortality still at a minimum. The tussocks were carefully spread apart and the individuals inside were counted. On each occasion, coccinellids were counted at 3x100 to 9x100 (usually 5x100) tussocks. The average number of coccinellids tussock^{-1} was calculated for each hundred tussocks as (number of established adults+1)*100^{-1}. Average number of coccinellids for a year was calculated as an arithmetic mean (±SE) of mean numbers per each hundred tussocks. In determinig overwintering habits of *C. septempunctata* we investigated four other hibernacula: Srdov (50°24' N, 13°47' E, altitude 440 m a.s.l., coccinellids overwintering in grass tussocks), Velky Studenec (50°50' N, 14°27' E, altitude 720 m, coccinellids under stones), Obri Hreben (50°44' N, 15°45' E, altitude 1420 m, coccinellids under stones) and Studnicna hora (50°43' N, 15°42' E, altitude 1480 m, coccinellids under stones). These hibernacula were investigated in 1979-1988, then in 2002-2003. Each year we recorded the distribution of adults in a sample of 300-800 stones or tussocks.

The degree of clumping for each sample was measured using the index of dispersion, i.e. variance to mean ratio. The deviation from random (Poisson) distribution was tested using chi-square test. If the value of the statistics fell within the critical region (P=0.05), the null hypothesis, i.e. random distribution was accepted. The probablity of clumped distribution as a function of total number of individuals sampled at each site was modelled using Generalised Linear Models (GLM-bi) within R environment. From the obtained model 95% probability of clumped distribution was estimated for each species.

Results

In all species the distribution under stones or tussocks became clumped as their overall abundance increased. In *C. septempunctata*, clumped distribution was found in 74 % of the total of 72 investigated samples. The likelihood of clumped distribution increased significantly with the total abundance of individuals at the overwintering sites (GLM-bi, P<0.00001). From the binary model it was estimated that distribution was clumped if abundance was >18 individuals per 100 stones or tussocks.

In *S. undecimnotata* 54 % of the total of 13 samples was clumped. The likelihood of clumped distribution increased significantly with the total abundance of individuals at study sites (GLM-bi, P=0.00003) From the binary model it was estimated that 95 % likelihood of finding a clumped distribution was if abundance was higher than 7 individuals per 100 tussocks.

In *A.variegata* the distribution was clumped in 36 % of the total of 11 samples. The likelihood of clumped distribution increased significantly with the total abundance of individuals at the study sites (GLM-bi, P=0.04). From the binary model it was estimated that 95 % likelihood of finding a clumped distribution was if abundance was higher than 9 individuals per 100 tussocks.

Discussion

All investigated species manifested a significant tendency for grouping into small aggregations as population density increased. The individuals were then clumped in groups of more than two, even when there was a plenty of free stones or tussocks available. This tendency for clumping was more expressed in *S. undecimnotata* and *A. variegata*, species typically overwintering at hilltop hibernacula. By contrast, in *C. septempunctata*, a species overwintering in many kinds of hibernacula including forest margins, roadsides etc. (Honek, 1989; Zhou et al., 1995) the tendency to clumping was smaller.

The advantage of clumped distribution is not well understood. Aggregation is sometimes interpreted as protection against predators and/or parasitoids. Whether the clumped distribution of coccinellids is efficient and against which predators or parasitiods remains to be investigated. The advantage of clumping may be greater than the danger of spreading diseases which are the main factor of winter mortality (Honek, 1997). The probability of spreading disease is probably greater in clumped than solitary populations. However, in experimental populations of *C. septempunctata* the occurrence of diseases and winter mortality was smaller in populations originating from hilltop than lowland populations (Honek, 1997). This may be caused by selection against diseased individuals which might occur during autumn migration to hibernation sites. It was demonstrated that hilltop hibernacula are occupied by more quality individuals than lowland hibernacula (Honek, 1997). The proces of "selecting" healthy individua during migration to hilltop hibernacula may be important also in *S. undecimnotata* and *A. variegata*.

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