Stacy Philpott
Department of Zoology
P.O. Box 351800
University of Washington
Seattle, Washington 98195-1800

EXOTIC LADYBIRD BEETLES IN WASHINGTON PRAIRIES AND THEIR INTERACTIONS WITH NATIVE ANTS

Stacy Philpott

Abstract

In western Washington prairies, six ladybug species are commonly seen including four natives, *Coccinella novemnotata* (CN), *Coccinella transversoguttata* (CT), *Cycloneda polita* (CP), and *Hippodamia convergens* (HC) and two exotics, *Coccinella septempunctata* (C7), and *Harmonia axyridis* (HA). Because these two exotic ladybugs are widely distributed and may be displacing native ladybugs, there is interest in finding mechanisms explaining C7 and HA success.

I studied interactions between these six species of co-existing ladybugs and one species of aphid-tending ant, *Formica obscuripes*, in a prairie dominated by Scotch broom, *Cytisus scoparius*. *F. obscuripes* is well known to form mutualistic relationships in which the ants defend aphid colonies from predators in exchange for honeydew. Where this behavior is common (such as in Scotch broom dominated prairies) ladybug access to their aphid prey is limited. Differences in ant-guarding response among ladybug species might influence ladybug prevalence thus providing an explanation for the success of these exotic species in the prairie. Specifically, I placed ladybugs on Scotch broom stems with one of two aphid densities tended by 1-5 ants and recorded behavioral reactions.

Both the species identity of ladybug individuals and aphid density had significant impacts on degree of aggression elicited by ants, ladybug feeding success, and behavioral reactions of ladybugs. First, ants were more likely to be aggressive when there were more aphids present, with average frequency of aggression being 69.77% across all species for the lower aphid density compared to an average frequency of aggression of 91.4% for the higher density. Different species elicited variable amounts of aggression, but all species elicited aggression in more than 50% of the trials. There was, however, no clear dichotomy between native versus exotic species, although there were pronounced differences between species. For example, the exotic C7 fared very well in the sense that it fed more frequently than any of the other ladybug species; however, the other successful exotic (HA) was the most infrequent feeder of all species (see figure 1). On the other hand, HA seemed to elicit less aggression from ants compared to all species; but C7 elicited the second highest level of aggression over all six species (see figure 2: data are presented only for 10-100 aphid density, since the higher density almost always elicited aggression). In summary, with respect to differences among ladybug species, their interaction with ants were dynamic enough to play a role in a ladybug's success -- but no tidy patterns in these differences emerged for exotics versus natives. Obviously many other factors enter the story to explain the prevalence of exotics in Washington prairies.

INTRODUCTION

The invasion of our prairies by exotic plants is a well-known problem -- but plants are not the only exotic species to be found in prairie ecosystems. Insect invaders can also be important. For example, the spread of two non-native ladybugs, *Coccinella septempuncata* and *Harmonia axyridis* throughout North America represent an enormously successful incursion of exotic predators that has found its way into Western Washington prairies. These generalist predators were introduced by the USDA as biocontrol agents of agricultural pests, especially aphids. However, these ladybugs have established large populations well beyond their targeted agricultural systems and there is some worry that they may be displacing our native coccinellid fauna (Elliot et al, 1996). Six species of ladybugs are now commonly found in western Washington prairies including four natives*, Coccinella novemnotata*, *Coccinella transversoguttata*, *Cycloneda polita*, and *Hippodamia convergens* , and the two exotics, *C. septempunctata* and *H. axyridis*. In this report, I quantify the numerical success of the exotic ladybugs in five Washington prairies, and explore the possibility that interactions with ants may play an important role in the success of ladybugs in prairies, because ants and ant-tending of aphids are so widespread in these prairies. I studied ant-ladybug interactions by direct field observation, recording aggressive encounters and the ability of ladybugs to feed when aphids were guarded by ants.

METHODS

Coccinellid and prey survey

In mid June and again in late August, field surveys were carried out in 24 western Washington locations to asses the abundance of native and exotic ladybug species and their prey in the region. These two times roughly coincide with the population peaks for ladybug adults in this area. The sites were categorized into 4 different types: roadsides, agricultural margins, clearcuts, and open fields (which included as a subset prairies). The main areas surveyed were: Mt. Vernon, the Ft. Lewis Military Reservation, Mt. St. Helens, Cle Elum, Snoqualmie Pass, and Discovery Park. At each of these 24 locations, we walked five 25 meter transects while searching for ladybugs. Every five meters, and additionally at every point where ladybugs were encountered, data on vegetative characteristics and prey availability were noted. Five of the locations sampled are prairie or prairie remnant locations with substantial populations of Scotch broom. At each of these prairie locations, in addition to the data described above I also recorded the presence of *Formica obscuripes* at each station or ladybug occurrence. I used this information to quantify how likely one is to find aphids tended by *F. obscuripes* in Scotch broom dominated prairies, as well as the success of exotic ladybugs in these ecosystems.

Behavioral Experiments

The behavioral experiments took place in a single prairie dominated by the exotic invasive plant Scotch broom (*Cytisus scoparius*) located in Discovery Park, in Seattle, Washington. This was a location for one of the survey sites and is fairly representative of broom-dominated prairies in Western Washington. Experiments were carried out on 16 different warm sunny days from 16 July to 10 September 1996. All observations were conducted between the hours of 10:30 AM and 5:30 PM, which coincides with the period of maximal coccinellid foraging activity.

Ladybug adults for all six species were handled identically. Ladybugs were starved for 24 hours previous to the observations, and then brought to the field in coolers packed with ice. They were individually placed on a Scotch broom stems approximately 2-5 centimeters from naturally occurring aphid colonies of either 10-100 aphids or >100 aphids tended by 1-5 ants. The data I recorded included: behaviors of ants and ladybugs upon encountering one another, whether or not the ladybug successfully fed on aphids, and the time from commencement of ladybug foraging to their discovery by an ant. An observation was terminated when a) a ladybug was chased >15 cm from the aphid colony, b) a ladybug was being bitten by an ant and was unable to escape the grip of its mandibles, c) an ant gave up its attack and returned to its normal aphid tending behavior or d) 10 minutes elapsed and the ant had not yet discovered the ladybug. A minimum of 22 trials per ladybug species per aphid density were observed using at least 10 different individuals for each species.

Ants were observed using three types of aggressive behavior towards ladybugs in order to defend the aphid colonies from predation: 1) pushing or pulling the ladybugs from the aphid colony with their head or forelegs, 2) biting the ladybugs underneath their elytra, and 3) chasing ladybugs as they ran away as previously mentioned by Völkl (1995). In some trials, ants did not use any aggressive behavior towards the ladybugs. Ladybugs defended themselves against ant aggression in five different ways. They were seen to 1) drop from the stem or be pushed off by ants, 2) run down the stem away from the ants and the aphid colony, 3) fly away, 4) "reflex bleed" (see Eisner et al. (1986); Pasteels et al. (1973); and Tursch et al. (1971), and 5) "cower" by putting their legs underneath them and huddling close to the stem as previously described by Bradley (1973) and Völkl (1995). Both ants and ladybugs were observed to exhibit more than one type of behavior on occasion.

RESULTS

Coccinellid and Prey Survey

At all five prairies exotic ladybugs were numerically dominant (Figure 1). Indeed, when averaged over all prairies sites, C. septempunctata comprised 19% of the individuals found, H. axyridis 78 %, and natives only 3% (these percentages are based on a total of 168 individuals encountered in the surveys). I also found *F. obscuripes* to be present at each of the five survey sites dominated by Scotch broom, and on average at 52% of the sample stations within each site. At some prairie sites this ant occurred at as many as 83% of the sample stations. More pertinent to the question of ladybug fitness is the frequency with which randomly located aphids are guarded by these ants. It appears that whenever one finds aphids, there is a very high chance that *F. obscuripes* is on the same plant -- in particular, seven out of eight of the aphid colonies encountered during prairie surveys were tended by *F. obscuripes*.

Behavioral Experiments

The frequency with which ladybugs elicited aggression from tending ants was higher when aphids were more abundant, regardless of the ladybug species being examined (Figure 2). The general tendency was for ants to almost always be aggressive if there were greater than 100 aphids on a plant. However, when there were fewer than 100

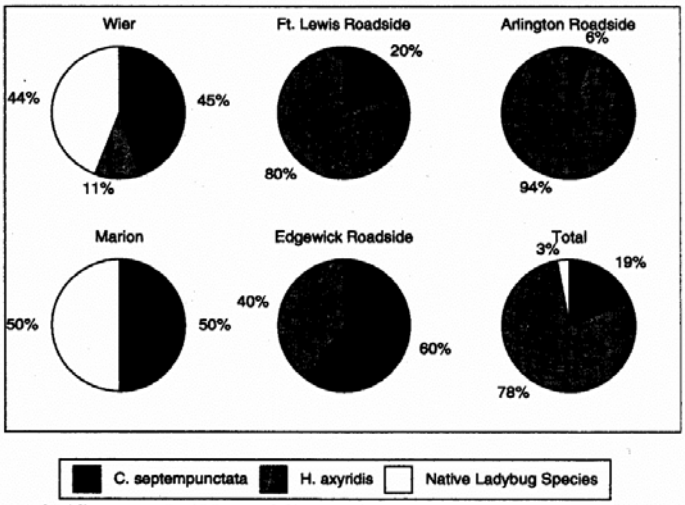

Fig. 1. Percent of exotic (*C. septempunctata and H. axyridis*) and native ladybugs encountered in each of five prairie with predominant Scotch broom. Also shown are the percents of exotics and natives encountered for all sites combined (out of a total of 168 ladybugs seen).

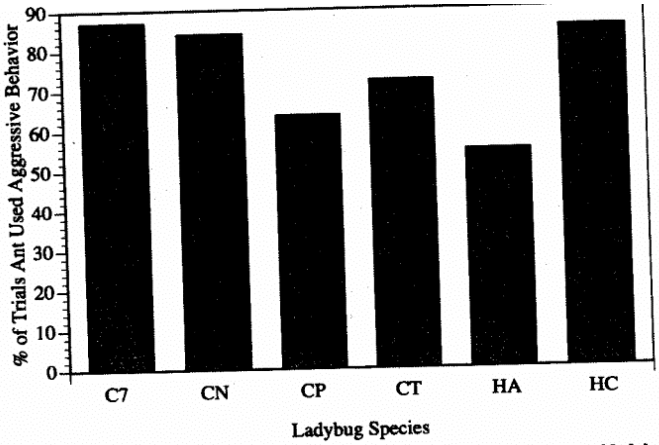

Fig. 2. Percent of trials that ants were aggressive towards ladybugs (bit, pushed, or pulled ladybugs from aphid colony) for the 10-100 aphid density. For each species: C7=*Coccinella septempuncata* (n=30), CN=*Coccinella novemenotata* (n=25), CP=*Cycloneda polita* (n=35), CT=*Cocinella transversoguttata* (n=32), HA=*Harmonia axyridis* (n=68), HC=*Hippodamia convergens* (n=25).

aphids, different ladybug species elicited contrasting rates of aggression -- with *C. septempunctata* evoking the highest frequency of aggression (86.6% of the time), and *H. axyridis* evoking the lowest frequency of aggression (54% of the time). Interestingly, ant aggression did not imply ladybugs could not feed, since *C. septempunctata* was the species that fed most frequently (Figure 3), in spite of the fact it elicited aggressive reactions from *F. obscuripes* more often than any other ladybug included in the study. Conversely, *H. axyridis* fed least often, even though it elicited the aggression from ants less frequently than any of the other ladybug species (Figure 3).

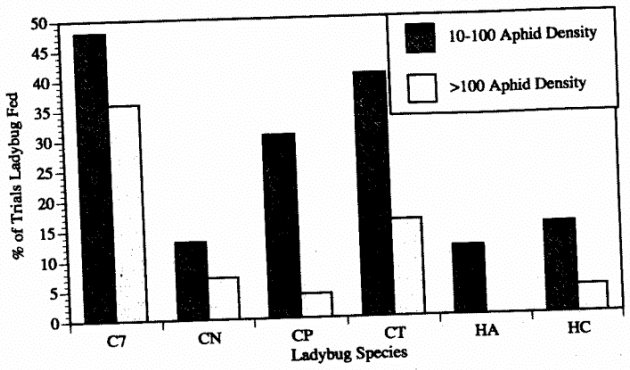

Fig. 3. Percent of trials ladybugs succeeded in feeding for the 10-100 and >100 aphid densities. C7=*Coccinella septempuncata* (n=25 & 28), CN=*Coccinella novemenotata* (n=24 & 29), CP=*Cycloneda polita* (n=30 & 26), CT=*Cocinella transversoguttata* (n=30 & 26), HA=*Harmonia axyridis* (n=62 & 23), HC=*Hippodamia convergens* (n=22 & 26).

One reason ant aggression by itself does not predict feeding success on the part of ladybugs, is that there are many different ways a ladybug can respond to the aggression. For example, the native ladybug, *Cycloneda polita*, cowered more frequently than any other species when attacked by ants (59% of the time, out of 56 observed encounters). According to previous accounts in the literature cowering is supposed to enable coccinellids to stay near aphids and resume feeding after ants lose interest. Interestingly, *C. polita* did stay near aphid colonies more often than any other ladybugs (Figure 4), and it may have been able to do this because of the cowering behavior.

DISCUSSION

Western Washington prairies have been successfully invaded by exotic ladybugs, to such a large extent that exotic coccinellids are far more common than native species (almost by a 10 to 1 ratio). In these prairies, the ant *Formica obscuripes* interacts frequently with ladybugs through its guarding behavior of aphids. Unfortunately, there is no clear pattern of exotic ladybugs being more successful than native species when they do interact with ants, even though ladybug species certainly do differ markedly in their response to ants. It appears that the interaction of ladybugs with ants is common enough and important enough that it must be one factor explaining the relative success of different species. But

it does not provide an easy explanation for the numerical dominance of *Harmonia axyridis*, which feeds infrequently in the presence of ants, yet is by far the most prevalent ladybug in the prairies we surveyed. The success of *C. septempuncata* and *H. axyridis* as invaders of Washington prairies will have to be explained by a composite of variables, of which immunity to ant aggression is only one factor.

Literature Cited

Addicott JH (1979) A multispecies aphid-ant association: Density dependence and species specific effects. Can J Zool 57: 558-569

Bradley GA, Hinks JD (1968) Ants, aphids, and jack pine in Manitoba.Can Entomol 100(1):40-50

Buckley R (1987) Interactions involving plants, homoptera, and ants. Annu Rev Ecol Syst 18: 111-135

Chapin JB, Brou VA (1991) Harmonia axyridis (Pallas), the third species of the genus to be found in the U.S. (Coleoptera: Coccinellidae). Proc Entomol Soc Wash 93: 630-635

Coulson JR, Carnell A, Vincent DL (1981) Releases of beneficial organisms in the United States and territories- 1981. U.S Dept Agric, Agric Res Serv, Misc Publ No 1464. 324 pp

Eisner T, Hicks K, Eisner M, Robson DS (1978) "Wolf-in-sheep's-clothing" strategy of a predaceous insect larva. Science 199: 790-794

Elliott N, Kieckhefer R, Kauffman W (1996) Effects of an invading coccinellid on native coccinellids in an agricultural landscape. Oecologia 105: 537-544

Gordon RD (1985) The Coleoptera (Coccinelliae) of America North of Mexico. J New York Entomol Soc 93: 1-912

Howarth FG (1991) Environmental impacts of the classical biological control. Ann Rev Entomol 36: 485-509

Koptur S (1991) Extrafloral nectaries of herbs and trees: Modeling the interaction with ants and parasitoids. In Huxley, CR and Cutler, DF (eds.), Ant Plant Interactions, Oxford Science Publications, Oxford pp. 213-230

McLain DK (1980) Relationships among ants, aphids, and Coccinellids on wild lettuce. J Georgia Entomol Soc 15 (4): 413-417

Nault LR, Montgomery ME, Bowers WS (1976). Aphid-ant associations: Role of aphid alarm pheromone. Science 192: 1349-1351

Pasteels JM, Deroe C, Tursch B, Braekman JC, Daloze D, Hootele C (1973) Distribution et Activités des alcaloïdes défensifs des Coccinellidae. J Insect Physiol 19: 1771-1778

Pierce NE, Easteal S (1986) The selective advantage of attendant ants for the larvae of a lycaenid butterfly, *Glaucopsyche lygdamus*. J Anim Ecol 55: 451-462

Schaefer PW, Dysart RJ, Specht HB (1987) North American distribution of *Coccinella septempunctata* (Coleoptera: Coccinellidae) and its mass appearance in coastal Delaware. Environ Entomol 16: 368-373

Staines CL, Jr, Rothchild MJ, Trumble RB (1990). A survey of the Coccinellidae

(Coleoptera) associated with the nursery stock in Maryland. Proc Entomol Soc Wash 92: 310-313

Tursch B, Daloze D, Dupont M, Pasteels JM, Tricot M (1971) A defense alkaloid in a Carnivorous Beetle. Experientia 27: 1380-1381

Völkl W (1995) Behavioral and Morphological Adaptations of the Coccinellid, *Platynapsis luteorubra* for Exploiting Ant-Attended Resources (Coleoptera: Coccinellidae). J Insect Behav 8(5): 653-670

Way MJ (1954) Studies on the life history and ecology of the ant *Oecophylla longinoda* Latreille. Bull Entomol Research 45: 93-112

Way MJ (1954) Studies on the association of the ant *Oecophylla longinoda* (Latr.) with the scale insect *Saissetia Zanibarensis* Williams. Bull Entomol Research 45: 113-134

Way MJ (1963) Mutualism between ants and honeydew producing Homoptera. Ann Rev Entomol 8: 307-344