Ground Beetle (Coleoptera: Carabidae) Ecology: Their Function and Diversity in Natural and Agricultural Habitats

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Ground beetles have long been recognized as important predators of insects, and recent research is highlighting the complexity of their functions within ecosystems. In the past, much of the research on ground beetles has been to place pitfall traps in different habitats and describe communities. More recently, efforts have been made to incorporate a growing understanding of individual constituents of these communities into the interpretation of sample results, making the analyses much more valuable. Advances in our understanding of ground beetle natural history and multivariate analyses of community data has accompanied a steady rise in the number of publications devoted to Carabidae (Fig. 1). Progress particularly has been made in using ground beetles as bioindicators of habitat qualities and agricultural practices, and in the feeding behavior of ground beetles and determining where they fit into the aggregate of ground-dwelling arthropods.

The heterogeneity in the behaviors and physiological requirements of ground beetle communities make them valuable as bioindicators of a range of ecosystem processes and perturbations. Within natural systems, ground beetles are important indicators of pollution, progress in restoration efforts, and habitat fragmentation and conservation tactics. In agroecosystems, ground beetles have an added importance as biological control agents of pests. Some ground beetles are useful representatives of farm production, such as organic or conventional systems, as well as of specific farming practices. For example, ground beetles have been used as gauges of soil and weed management practices, insecticide use, and fertilizer application, to name a few of the farming practices. Ground beetles are frequently used as meters of the short- and long-term effects of new agricultural practices, such as companion plantings, transgenic insecticidal crops, and novel residue management strategies.

Fig. 1. Recent trend in the number of papers published annually on Carabidae, as found in the AGRICOLA database.

Whereas some species of Carabidae are almost exclusively predatory, many are best described as omnivores; and this expanded dietary range has important implications for the management of insect pests and weed seed banks. The value of ground beetles as predators of weed seeds and mechanisms for shaping the density and dispersion of weed communities is a quickly expanding area of weed ecology. The recognition that many species of ground beetles do not feed exclusively on insects, coupled with the application of sampling methods that better account for actual densities and functions of epigeal predators (versus pitfall samples), has changed our perspective on the dominance and roles of Carabidae in epigeal arthropod communities. Now it is generally recognized that ground beetles are only one component of a complicated network of species that help to regulate insect pests, a fact that pitfall trap captures alone failed to illustrate.

Given the recent advances in our understanding of ground beetles, it was decided that it would be timely to host a symposium highlighting research of scientists currently studying carabids in the Midwest at the North Central Branch meeting in West Lafayette, IN, in March 2005. The participants agreed that we would all benefit from organizing research efforts in the form of the working group, and the Midwestern Carabidologists Working Group (MCWG) was formed (www.midwestcarabids.ars.usda.gov). Through the MCWG, we hope to highlight research efforts, present news and events, and foster collaborations that improve our understanding of all aspects of ground beetles.

Ground beetles as weed control agents: effects of farm management on granivory

Jonathan G. Lundgren

Post-dispersal granivory by insects can shape the density and distribution of weed communities. Consequently, there has been growing interest in using these insects as biological control agents of weeds in agricultural systems (Brust and House 1988, Cromar et al 1999, Gallandt et al. 2005, Mauchline et al. 2005). Ground beetles are often major constituents of granivore communities and are capable of feeding on large numbers of seeds (Brust and House 1988, Gallandt et al. 2005, Mauchline et al. 2005). The effect of ground beetles on weed population dynamics and the effects of management practices on granivory in agricultural systems are poorly understood. I present the efforts to characterize the seed-feeding behaviors of two agronomically important ground beetles and describe the effects of organic transition strategies on seed predation.

Seed Feeding in the Laboratory

Harpalus pensylvanicus DeGeer and *Anisodactylus sanctaecrucis* F. are two abundant granivorous ground beetles that occur throughout much of North America (Bousquet and Larochelle 1993). However, these species are phenologically quite different; *A. sanctaecrucis* is more abundant in spring and summer, and *H. pensylvanicus* occurs later in the summer and fall. Beyond being considered omnivorous, accepting live and dead insects and seeds, the feeding behavior of adults of these species has not been well explored. We examined seed consumption of weed seeds by adults of these species in the laboratory.

The selected seeds encompass a range of sizes and structural characteristics, and 0.15 g of each species was offered. Species offered to *H. pensylvanicus* were common lambsquarters (*Chenopodium album* L.), broccoli (*Brassica oleraceae*), alfalfa (*Medicago sativa*), velvetleaf (*Abutilon theophrasti* Medic.), redroot pigweed (*Amaranthus retroflexus* L.), ivyleaf morning glory [*Ipomoea hederacea* (L.) Jacq.], crabgrass [*Digitaria sanguinalis* (L.) Scop.], giant ragweed (*Ambrosia trifida* L.), and giant foxtail (*Setaria faberi* Herrmann). Giant foxtail, giant ragweed, and redroot pigweed were not offered to *A. sanctaecrucis*; and red fescue (*Festuca rubra*) was substituted for the foxtail. Seeds of a single species were placed with each beetle in a plastic Petri dish, and the number of seeds remaining unscathed at the end of 48 h was recorded. For this research, we controlled for the effects of seed and beetle size on seed consumption by using a consumption index, calculated as the biomass of seeds consumed per gram of beetle biomass.

The seeds of these species varied in their acceptability to the two ground beetle species, and the two ground beetle species differed in their ability to consume the different seed species (Fig. 1). Lambsquarters seed was the most preferred by both beetles, with an average of 208 ± 19 and 74 ± 7 seeds being consumed over 48 h by *H. pensylvanicus* and *A. sanctaecrucis*, respectively. For *H. pensylvanicus,* lambsquarter, broccoli, and redroot pigweed were the most acceptable species. In contrast, broccoli was virtually untouched in the *A. sanctaecrucis* dishes, and alfalfa was a preferred seed.

Farm Management Intensity and Seed Removal

In 2003, the Illinois Natural History Survey and the University of Illinois initiated a multidisciplinary research project to examine the efficacy of different strategies to transition land from conventional to organic production (to be described more completely in an upcoming paper). Based on grower input, three strategies were devised that represented vegetable production, cash grain, and pasture systems—three predominant systems used by growers in the United States to weather the transition process. Inherent in these systems is the level of inputs and disturbances associated with successful operations. For instance, vegetable systems require more inputs than cash grain systems, and pasture systems are associated with a minimum of management. Weed control is a dominant concern of organic producers, and I was interested in how these transition strategies affect granivory rates, as part of a larger study of weed seed banks during the transition process.

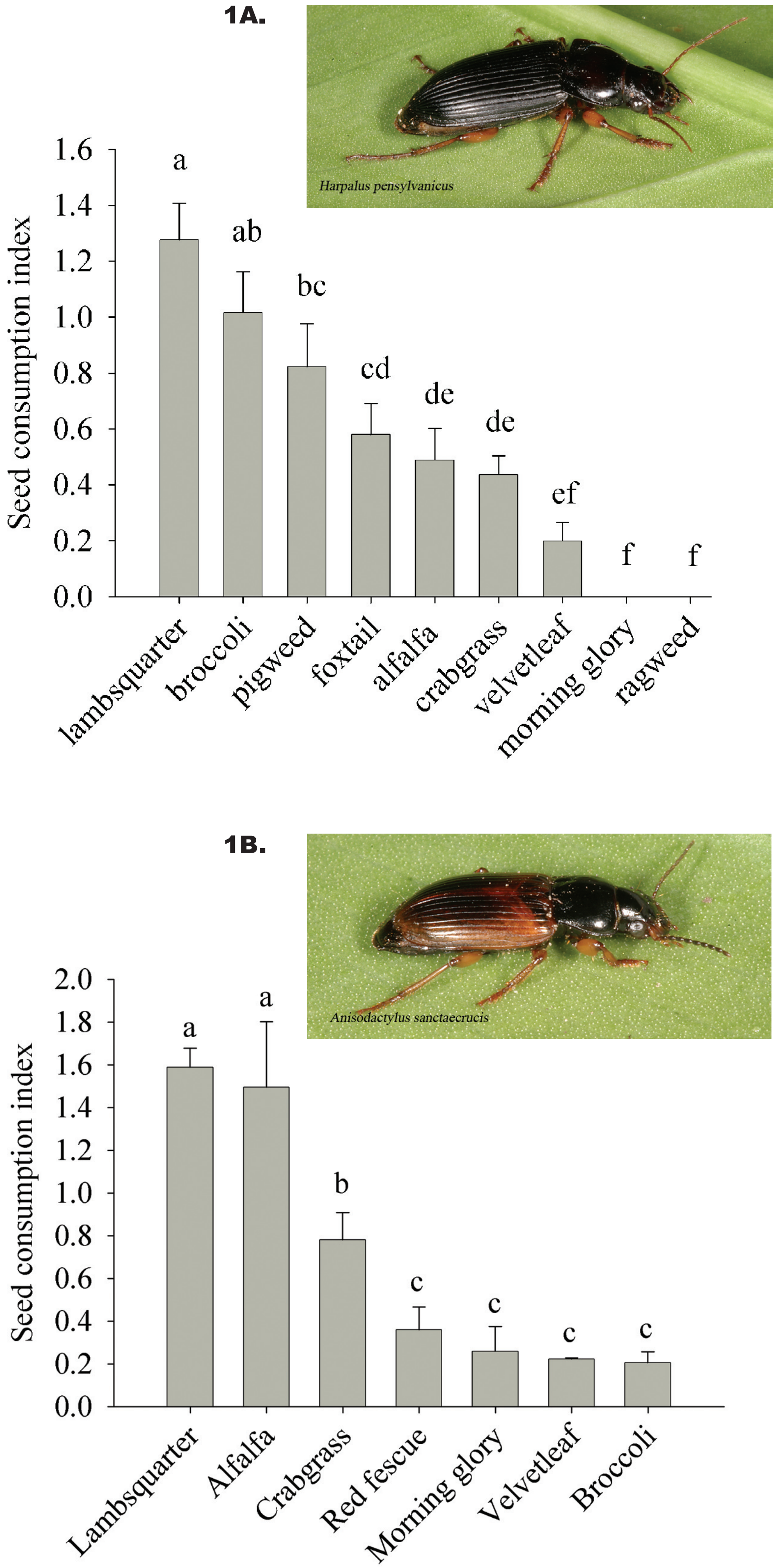

Fig. 1. The acceptability of seeds by Harpalus pensylvanicus (1A) and A. sanctaecrucis (1B) under no-choice conditions. The seed consumption index is the biomass of seeds consumed over 48 h per unit of beetle body mass (seeds consumed/g). Samples sizes ranged from 12 to 15 beetles per treatment. Error bars represent SEMs, and columns preceded by different letters are significantly different (LSD test, $\alpha = 0.05$).

Granivory was measured by examining weekly removal rates of known numbers of weed seeds over a 3-wk interval during September 2004 (methods from Brust and House 1988). The vegetable plots were planted to crucifer crops, the grain treatment was winter wheat stubble, and the pasture was a mixture of grasses and leguminous forages. Pitfall and quadrat samples were used to monitor granivorous insect communities in association with the different transition systems. The density of granivorous insects was measured by identifying the insects occurring within 0.25-m^2 quadrats. Petri dishes with weed seeds (25 each of giant ragweed and ivyleaf morning glory, and 50 each of common lambsquarters, redroot pigweed, crabgrass, giant foxtail, velvetleaf) affixed to the base with double sided tape were placed in the field and buried just beneath the soil surface. A wire cage (1.4-cm mesh) was placed around each dish to exclude vertebrate granivores. At the end of each week, the Petri dishes were replaced, and the number of seeds removed was counted.

Farm management had a significant effect on the seed removal, and there was a distinct preference for certain seed species. In all, 20 species (36.67% of specimens) of granivorous ground beetles were captured in pitfalls. *A. sanctaecrucis* and *H. pensylvanicus* were the most frequently captured granivorous ground beetles, each accounting for 11% of specimens captured. Besides carabids, other granivorous arthropods were collected, mainly crickets (10% of specimens; *Gryllus pennsylvanicus*, *Gryllus veletis*, and *Allonemobius fasciatus*). The densities of granivorous species were significantly affected by the transition strategy ($F_{2,6} = 14.12$, $P = 0.005$), as was the seed removal rate ($F_{2,9} = 7.20$, $P = 0.014$), with the pasture having the highest level of seed removal and greatest density of granivores (Table 1). Seed removal was fourfold higher during the second observation week, the only week with rainfall. In the field, granivores favored the grass species over the seeds of broadleaved species (Fig. 2). Lambsquarters, the seed preferred by predominant carabids in the laboratory (see above), was only of intermediate preference in the field.

Conclusions

Ground beetles can consume large numbers of weed seeds, and seeds clearly vary in their suitability and attractiveness to granivorous species. Several factors related to the morphology and natural histories of beetles and seeds likely play a role in their interactions (Janzen 1971). For instance, the beetles' size and mandibular strength probably limit which seeds they can tackle; and the seed coat thickness, structural and chemical defenses, and seasonal phenology of seeds limit which seeds are acceptable to granivores. This research also demonstrates that farmers influence the rates of granivory on their land through their management decisions. Granivory by beneficial insects has an economic value and should be considered when developing farming protocols and pest management frameworks.

Table 1. Seed removal by arthropods and densities of granivores in different organic transition systems.

Farming system	Number of granivores per m^2 (SEM)	Total seeds removed (SEM) over three weeks
Vegetable	0	449 (51)
Cash grain	1.14 ± 0.40	328 (13)
Pasture	5.14 ± 1.24	559 (53)

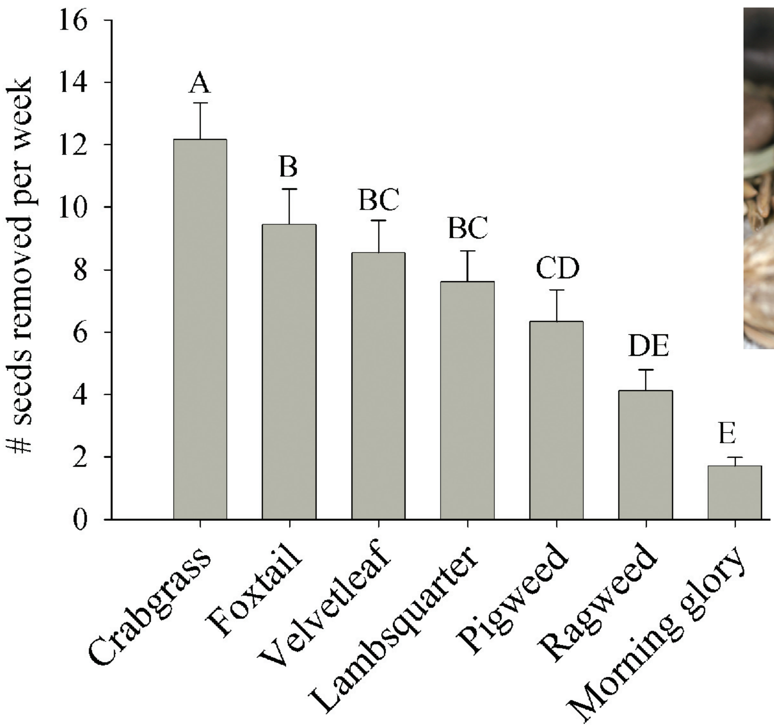

Fig. 2. Mean ± SEM preference for weed seed species by granivorous arthropods under field conditions. The average number of seeds (SEM) consumed per plot over 3 wk (n.=.12). Bars with different letters are significantly different (α.=.0.05, LSD test).

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