PENNSTATE

College of Agricultural Sciences • Cooperative Extension

Entomological Notes

Department of Entomology

GROUND AND TIGER BEETLES

(Coleoptera: Carabidae)

Carabid beetles, an insect group containing ground and tiger beetles, are important biological control agents in agroecosystems. With their large eyes, spiny powerful legs, and large jaws, carabid beetles are formidable predators in the insect world. They live on the surface of the soil where they capture and consume a wide assortment of soil dwelling insects, including caterpillars, wireworms, maggots, ants, aphids and slugs. Several ground beetles will also eat the seeds of troublesome weeds and are considered one of the "many little hammers" that help regulate weed populations (Liebman and Gallandt 1997). Conserving ground beetles through habitat manipulations and cultural practices can enhance the natural regulation of arthropod pest and weed populations, reducing the need for chemical controls.

GENERAL INFORMATION

Carabid beetles are an incredibly diverse group of insects with over 40,000 species worldwide, 2,000 of which inhabit North America. Adult ground beetles range in size from 2mm to over 35mm (about 1/8 inch to 1 ¼ inch). Many of the nocturnal species are dark black or brown; these are the ones that scurry away for cover when you turn over a dirt clod, rock, or log. Ground beetles can be distinguished from darkling beetles, which are also dark colored and reside on the soil surface, by how fast they move. Diurnal (day- active) species tend to be iridescent and brightly colored or patterned. Carabid beetles typically have long legs, which allow them to move rapidly to capture prey and avoid other predators.

Carabid beetles live in nearly every available habitat, although some species are associated with particular ecosystems, like meadows, woodlands, or crop fields. Due to the habitat specificity of some species, these beetles can be used as biological indicators to assess land use changes among different ecosystems.

ECOLOGY

Carabid beetles employ a wide variety of ecological strategies, however some generalizations can be made to represent the majority of species. Carabid beetles exhibit complete metamorphosis. This means that the insect passes through four separate stages of growth: egg, larva, pupa, and adult. On average, carabid beetles produce one generation per year. After finding a suitable site, females will singly deposit between 30 and 600 oval eggs within the soil or in the layer of plant residues on the soil surface. Protected egg sites are very important because young larvae have limited mobility for finding food and their relatively soft bodies are vulnerable to predators. Parental care, including egg guarding and seed cacheing, has been observed in some species that produce small litters. Species are sometimes distinguished as either having winter or summer larvae. Larvae live entirely under the soil surface, where they pupate usually after three larval stages. Adults can live between one and four years. Larger species, as well as those that over-winter as larvae, tend to have the longest life spans (Lovei and Sunderland 1996). While many ground beetle species have functional wings, flight is used primarily for dispersal, such that they spend nearly their entire lives on the ground. Some have also been observed climbing plants in search of prey.

Carabid beetles are considered to be mostly opportunistic feeders that consume a variety of foods; however, the majority of species have been observed as primarily predatory, feeding on other insects and related organisms. Most species locate food by random search, although some day-active (diurnal) species hunt by sight. A few species have also been observed to detect chemical cues from springtails, mollusks, and aphids (Lovei and Sunderland 1996). Females tend to have a more varied diet than males. A greater diversity of food types in females has been linked to greater egg size and egg number (Lovei and Sunderland 1996). Larvae and adults typically have similar feeding habits; however, larval diets are more restricted due to a limited search range underground. The natural diets of carabid beetles are still widely undetermined. Laboratory studies have shown that carabid beetles will eat nearly anything offered, however they typically show food preferences and it is unclear whether or not these feeding habits are typical in nature (Larochelle 1990, Tooley and Brust 2002). Prey preferences can change throughout their life cycle based on nutritional needs or a change in the resources or environment.

Several ground beetle species are phytophagous (feed on plants). Of particular interest is "seed predation," where plant seeds are not only consumed by ground beetles, but destroyed in the process (as opposed to merely ingesting the seed). It has been suggested that plant feeding (herbivory) and weed seed predation (granivory) is largely underestimated in ground beetles (Tooley and Brust 2002).

BIOLOGICAL CONTROL

Carabid beetles play a major role in agroecosystems by contributing to the mortality of weed seeds, insects, and slugs. They can consume up to their body weight daily. They eat a wide variety of pest organisms including aphids, moth larvae (such as armyworm, cutworm and gypsy moth larvae), beetle larvae (such as the corn rootworm, Colorado potato beetle and the cucumber beetle), mites, and springtails. They have also been used effectively to control slugs in greenhouses (Kromp 1999). However, as generalist natural enemies, they may be better suited for prolonging the period between pest outbreaks than for quickly reducing a pest population whose density has already exceeded an economic threshold. Collectively, generalist predators, like carabid beetles, can prevent damage to crops by as much as 40%, compared to areas where generalist predator numbers are kept experimentally low (Clark et al., 1994). Studies have also shown that utilizing different species at different times of the year can improve biological control (Tooley and Brust 2002). For example, an early season predator such as the ground beetle, Bembidion sp., can create a buffer against colonizing aphids. During mid-season, the presence of another generalist predator along with an aphid specialist can then limit aphid population growth (Kromp 1999).

At $27 billion per year in management costs, weeds are the most costly pest in North American agriculture (White and Landis 2007). For this reason, weed seed consumption or predation by ground beetles is of great interest. Weed seed predation by arthropods such as ground beetles could potentially be used to lower costs associated with weed populations and to increase crop yield. A number of North American carabid species have been identified as weed seed predators. They have been shown to consume a variety of agriculturally important weed species seeds including common ragweed, common lambsquarters, and giant foxtail (Lundgren 2005). Seed preferences may be due to the differential oil content of seeds as well as the ability of the beetles to handle the seeds. Post-dispersal consumption of seeds (feeding on fallen seeds) is more common among ground beetles in comparison to pre-dispersal consumption (eating seeds from the plant) because ground beetles rarely climb plants. The ground beetle, Harpalus pensylvanicus, has also been observed to feed on seeds that have been buried up to about 10 mm (3/8 inch). H. pensylvanicus is thought to synchronize breeding period with the ripening of some grass seeds, such as foxtail (Tooley and Brust 2002). Overall, weed seed predators may alter the plant species composition in an area rather than eliminate a weed species. Changing the species composition could give crop species a better chance for success by reducing competition for resources such as light, nutrients, and water, thus increasing crop yields. Understanding weed seed preferences is critical to effectively utilizing weed seed predators in biological control programs. Gut analysis of ground beetles for different weed seed proteins and laboratory food preference studies may help reveal these relationships.

COMMON GROUND AND TIGER BEETLES IN CENTRAL PENNSYLVANIA

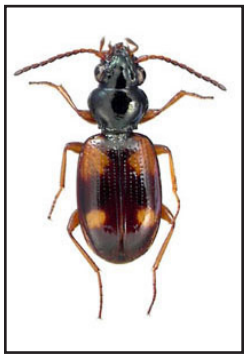
In this section we present detailed descriptions of the most common ground beetle species that we have found in organic feed and forage systems in Central Pennsylvania. With the exception of Cyclotrachelus furtivus, these species are also well documented in research from other parts of the US, indicating their general importance to agroecosystems. The description of each species includes body length, body color, distinguishing morphological features, breeding season (when known), period of peak activity (when known), habit (when known) and general diet. Included in the subsection "pests consumed" are specific weeds, arthropods, and mollusks that the ground beetle has consumed in the field or laboratory, as summarized by Sunderland (2002) and LaRochelle (1990) and found in other studies. The stage of the pest when consumed is indicated by the letters E (eggs), L (larvae), P (pupae) and A (adults).

Anisodactylus sanctaecrucis

Description: 10 to 12 mm; dark brown body with lighter colored elytra. The pronotum has a reddish translucent margin and the hind angles of the pronotum come to a point. This species is commonly found in agricultural fields.

Pests consumed: Weeds: seeds of alfalfa; crabgrass; lambsquarters; red fescue; morning glory; velvetleaf (Lundgren 2005). Arthropods: Colorado potato beetle (E), carrot weevil (E, L, and A).

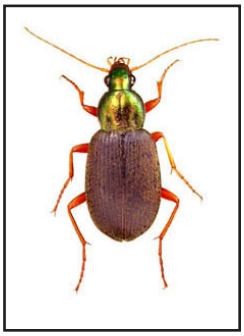
Bembidion quadrimaculatum



Description: 3 mm; dark brown body with four distinctive yellow marks on the elytra (wings). The section between the thorax and abdomen is constricted. These very small, fast–moving insect predators can commonly be found in open soil.

Pests consumed: Arthropods: carrot weevil; Japanese beetle (E); onion fly (E); turnip maggot (E); cabbage fly (E); carrot rust fly; black bean aphid; grain aphid; black cutworm; red backed cutworm (L); European corn borer (L); common stalk borer (L); armyworm (L); fall armyworm (L).

Chlaenius tricolor tricolor

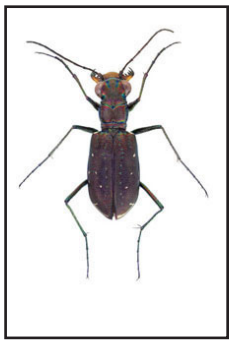


Description: 12 to 13 mm; metallic green head; metallic burgundy pronotum; auburn legs; and dark blue to purple elytra covered with fine hairs. Their diet consists of mollusks and a variety of insects.

Pests consumed: Arthropods: Japanese beetle (E); black cutworm (L); European corn borer (L); common stalk borer (L); armyworm (L); fall armyworm (L).

Cicindela punctulata

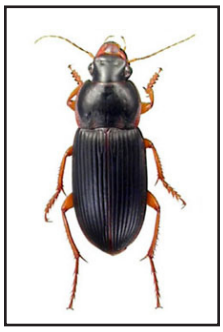
Description: 11 to 14 mm; iridescent brown to copper, often with white spots. This species is differentiated from other tiger beetles by a row of metallic green pits, or punctures on each elytron. Like other tiger beetles its head is larger than the thorax. These beetles are diurnal, overwinter as larvae, and are active during the summer (Hilchie undated). C. punctulata is fast-moving, alert, and when approached can fly away several yards. This beetle is commonly found in cultivated fields and is known to have a broad insect diet.



Pests consumed: Arthropods: fall armyworm (L); ants; grasshoppers; crickets; moth and butterfly larvae.

Harpalus pensylvanicus

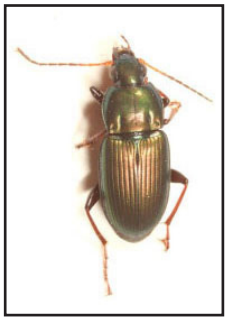
Description: 13 to16 mm; dark brown body with auburn legs and mandibles. This group of weed seed predators is dominant in Central Pennsylvania crop fields. They breed in autumn and overwinter in the larval stage. Peak activity density for this species occurs in August and September, and is rarely seen before mid-July (Leslie 2009). Although this group is considered primarily as a weed seed predator, it will also eat a variety of insects.



Pests consumed: Weeds: seeds of green bristle grass; lambsquarters; redroot amaranth (Kromp 1999); redroot pigweed; giant foxtail; velvetleaf; Japanese bristle grass; spacer.jpgbroomcorn millet; hairy cupgrass. Arthropods: cucumber beetles (A); aphids; black cutworm (L); alfalfa butterfly (L); codling moth; zebra caterpillar; European corn borer (L); common stalk borer; green clover worm (L and P); armyworm (L).

Poecilus chalcites

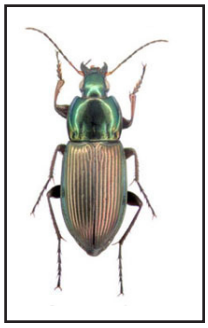
Description: 10 to 12 mm; striated elytra that range in color from black to iridescent red or green; base of the pronotum has deep indentations These beetles breed in the spring and spend their larval stages in the early summer. Peak activity density occurs from late June through the end of July (Leslie 2009). With higher abundances in tilled fields in comparison to reduced tillage fields, P. chalcites may be a species that is more tolerant of tillage practices (Menalled et al 2007).



Pests consumed: Weeds: seeds of broomcorn millet; redroot amaranth. Arthropods: onion fly (P); black cutworm (L); European corn borer (L); Colorado potato beetle (E and L); velvetbean caterpillar (P); western corn rootworm (E, L, and A).

Poecilus lucublandus

Description:10 to 12 mm; striated elytra; dark iridescent blue to copper in color; base of pronotum has indentations, although not as deep and defined as P. chalcites. This species has been found in greater numbers in reduced tillage and organic systems in comparison to conventionally tilled fields (Menalled et al 2007).



Pests consumed: Weeds: seeds of Japanese bristle grass; broomcorn millet; redroot amaranth. Arthropods: onion fly (E, L, and P); Colorado potato beetle (E); carrot weevil; black cutworm (L); red backed cutworm; European corn borer (L); common stock borer (L); armyworm (L); fall armyworm (L); green clover worm (P).

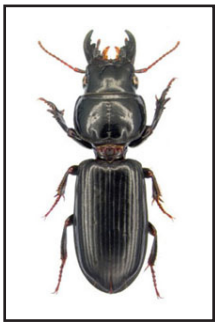
Pterostichus melanarius

Description: 15 to 16 mm; glossy black with striated elytra. These beetles breed in autumn, overwinter as larvae, and peak in numbers during August (Leslie 2009). Although able to adapt to a variety of environments, they prefer open habitats and are common in agriculture. They are largely generalist feeders, but will synchronize activity with that of some prey groups such as aphids or slugs (Fournier 2002). Weed seed predation has also been observed in this species.

Pests consumed: Weeds: seeds of European field pansy; lambsquarters; common chickweed; rough bluegrass; mayweed; wild oat; slender meadow foxtail; spotted ladysthumb; sticky willy; poverty brome; Arthropods: Colorado potato beetle (E); carrot weevil; onion fly (E, L, and P); turnip maggot; black been aphid; leaf beetle; common fruit fly; crane fly; cabbage aphid; rose-grain aphid; bird cherry oat aphid; grain aphid; cabbage moth; winter moth; armyworm (L); fall armyworm (L); black cutworm (L); European corn borer (L); common stalk borer (L). Mollusks: gray field slug.

Scarites quadriceps

Description: 22 to 24 mm; body is glossy black with large mandibles; the region between the thorax and the abdomen is constricted. These relatively large ground beetles breed in the spring and reach peak activity from June until early July.



Pests consumed: Arthropods: Japanese beetle (E); black cutworm (L); European corn borer (L); common stock borer (L); armyworm (L); fall armyworm (L).

Note: The photograph on the right is of *Scarites subterraneous*, whose appearance is very similar to *S. quadriceps*. The main difference is that *S. quadriceps* has longer antennal segments.

Stenolophus comma

Description: 5 to 7 mm; body, legs, and antennae are translucent amber; inner portion of elytra have dark maroon/black stripes running lengthwise; head is black. These carabids are spring-breeders and are active as adults from April to November, peaking from June to early July (Kirk 1975). They are primarily carnivorous.

Pests consumed: Unknown

CONSERVATION PRACTICES AND HABITAT MANAGEMENT

The key to taking advantage of the benefits from carabid beetles in agriculture is improving their survival. Certain farming practices can help to conserve carabid beetle populations. Carabid beetles are more likely to survive in fields where non-inversion (e.g., chisel plow) tillage is used. In comparison with inversion tillage practices (e.g., moldboard plow), non-inversion tillage causes less soil disturbance and thus, less direct mortality of the eggs, larvae, and adults. Due to their relatively soft bodies, carabid beetle larvae are especially sensitive to tillage practices. Minimum tillage systems also preserve surface vegetation and mulch, which can provide microhabitats for ground and tiger beetles as well as protection from environmental conditions and other predators. When marked and released, the weed seed predator Harpalus rufipes was more than twice as likely to be recaptured in fields with surface residue as in bare fallow fields (Shearin et al., 2008). Both chisel plowed and no-tillage systems show approximately double the activity of weed seed predators than conventional tillage systems (Shearin et al., 2007). The choice of mowing technique is also important for conserving carabid beetles. Flail mowers at a 5 cm cutting height were shown to reduce numbers of ground-dwelling arthropods by 50% whereas bar and rotary mowing did not cause significant damage (Humbert et al., 2008).

Habitat management also plays a critical role in conserving ground beetles (Menalled et al., 2001). For ground beetles to survive and reproduce, they need a protected place to overwinter, mate, and lay eggs. That habitat should also provide food (arthropods, mollusks, and plant seeds), a favorable microclimate, and shelter from other predators. While cover cropped fields can provide excellent winter cover for ground beetles, the eventual mowing or tillage that occurs may make these environments unsuitable for long-term conservation.

So what is ground beetle "habitat" and how much of it do ground beetles need? Ground beetle habitat is a permanent piece of vegetated land. Field edges, marginal lands or select areas within a crop field can make excellent sites for ground beetle conservation. Creating a "beetle bank" involves raising a 2-5 ft wide bed, seeding the bed with a native perennial grass mixture (approximately 30 lbs/acre broadcast seeded), and laying down a mulch layer (Ellen undated). Carabid beetles have been show to be twice as abundant in crop fields adjacent to beetle banks and other uncultivated habitat than in fields without this habitat (Hance 2002). Generally, stands of diverse perennial plants, which offer a diversity of microhabitats and food resources, will support diverse carabid beetle communities.

PESTICIDE EFFECTS

To take advantage of the benefits of carabid beetles, it is important to maintain an environment conducive to their survival. It is therefore critical to consider the effects of pesticides. One study showed that application of insecticides contributed to 81% mortality rates among small adult species (Navntoft et al., 2006). It has been suggested that the decline of three carabid species, including Pterostichus melanarius, a ground beetle that consumes a particularly wide assortment of agricultural pests, was caused by an increase in insecticide use (Navntoft et al., 2006). Some herbicides can also alter the species composition of carabid communities from predominately small species to predominately larger species.

There are four ways to categorize the effects of pesticides on beneficial insects (Mulligan et al., 2006):

1. **Direct Lethal Effects**. The pesticide kills the carabid beetle by contact or direct consumption.
2. **Direct Sublethal Effects.** The pesticide has some direct effect on survivorship but does not kill the organism on contact. For example, by interfering with the reproductive development or behavior of the organism, the pesticide directly contributes to a reduction in the number of offspring.
3. **Indirect Lethal Effects.** The carabid beetle feeds on a prey item that has been poisoned by the pesticide and consequently dies.
4. **Indirect Sublethal Effects.** The pesticide has a secondary effect on survivorship, but does not kill the organism.

Carabid beetles display varying degrees of susceptibility to different pesticides across species and across life stages (Leslie et al., 2009). For example, some species are tolerant to even the most toxic pyrethroids, while at the same time are sensitive to neonicotinoids. It has also been shown that both conventional insecticides and neonicotinoid seed treatments can result in high mortality rates of Harpalus pensylvanicus (Leslie et al., 2009).

Broad spectrum insecticides have been shown to have devastating effects on carabid beetles at normal application rates. As a consequence, pest species normally controlled by carabid beetles can increase after application of some insecticides. One way to mitigate the effects of insecticides is to establish beetle banks (See section on habitat management/conservation practices). Beetle banks have been shown to provide a site for colonizing beetle populations while crops are treated with pesticides (Lee 2001). Furthermore, the results of one study suggests that reducing pesticide treatment to one quarter the normal application rate can lead to an increase in the overall abundance of carabid beetles (Navntoft et al., 2006).

SUMMARY

Carabid beetles can have beneficial impacts on agriculture. By consuming a variety of weed seeds and insect pests they can help protect crops from pest damage and associated losses, and decrease costs associated with pest controls. The types of ground and tiger beetles found at a location can also be a valuable biological indicator to assess the impacts of different habitat management and tillage practices. To capitalize on the potential benefits from ground and tiger beetles, land managers can conserve habitats that are beneficial to the survival of the beetles. Informed decisions regarding tillage practices, pesticide use, and the establishment and management of beneficial habitats can enhance carabid beetle abundance and diversity. Carabid beetles can play a significant role in ecologically-based integrated pest management programs that focus on avoidance or reduction of pest pressure through cultural practices and biological controls.

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