Big-Eyed Bug: A MVP of Generalist Natural Enemies

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Introduction

Big-eyed bugs are predatory “true bugs” in the genus *Geocoris*. They are members of the family Lygaeidae (seed bugs), but belong to a subfamily containing only predaceous insects. As the name implies, they have characteristic, large prominent eyes relative to their body size (**Fig. 1**). Many different *Geocoris* species are found throughout the world but there are roughly 25 recognized species in the US. Though big-eyed bugs are prominent in several cropping systems within the US, their importance expands well beyond US borders as they are among the most abundant species of generalist predators occurring naturally worldwide. *Geocoris* are important predators that actively hunt for and feed on a broad spectrum of prey, including several economically important agricultural pests. Several studies have been conducted in laboratories, agricultural fields, turfgrass and natural habitats to determine their potential to serve as biological control agents and protect plants from herbivory (being eaten) by insects and mites. These studies have found that *Geocoris* are capable of reducing herbivore (animals that feed on plants) populations and increasing plant yield. The ability of *Geocoris* to disperse into and reproduce in key cropping and ornamental systems allows them to reduce important pest species. Subsequently, this makes *Geocoris* an ideal target for the development of biological control efforts.

Fig. 1. Big-eyed bug with prominent red eyes. Photo by J. Niland, Creative Commons.

Fig. 2. *Geocoris sp.* adult on tree bark. Photo by J. Coelho, Creative Commons.

Description

Geocoris are small [~ 6.35 mm (1/4 inch) long] oblong-oval, stout bodied, and somewhat flattened insects with a wide head that is broader than it is long. They have short, thick antennae which are enlarged at the tip. They have three developmental stages (egg, nymph and adult). Adults are usually gray, brown or yellowish in color but may appear shiny black and contain red-brown spots (**Fig. 2**). They have characteristic large, prominent, widely separated eyes that curve backward on the sides of their heads (**Fig. 3**). Their large eyes and excellent visual perception provide them an expansive field of vision that enhances their ability to seek out and capture prey. *Geocoris* are fast and often scurry away quickly when disturbed. Thus, they can be easily overlooked when searching crop plants. Being a true bug, they have a piercing-sucking (needle-like) mouthpart known as a stylet ("beak") tucked underneath their head and body at rest. Their stylet is flexible and as such, can be extended in front of their head while feeding. The stylet is a major reason why *Geocoris* are efficient predators as it allows them to devour prey often approaching or exceeding their body weight. Field observations indicate that *Geocoris* usually attack by walking or running up to a potential prey, extending their stylet and quickly inserting it into their target. *Geocoris* may lift prey into the air, which prevents them from escaping by running.

Fig. 3. *Geocoris sp.* adult on leaf. Photo by B. Loboda, Creative Commons.

Identification

Adults. Adults are 3-5 mm (3/16 inch or less) long with two pairs of fully functional wings (forewings and hindwings). The forewings are hardened at the base and membranous (thin and pliable) at the tip. At rest, forewings cross over the back, one over the other, creating a triangle pattern behind the pronotum ("shoulders"), pointing toward the rear. These wing features are characteristic of true bugs.

Eggs. Eggs are oblong/hot-dog shaped. They are pale-colored (white to peach) and typically deposited singly and horizontally on plant leaves or stems. Reddish eyespots develop near the tip of the egg shortly after being laid (**Fig. 4**). These two red eyespots help distinguish them from other insect eggs. Eggs of *G. punctipes* average about 0.9 mm long by 0.38 mm (1/28 in by 1/66 in) at the widest point. They are white, yellowish or tan and bear longitudinal striations. Under laboratory conditions, it took on average, approximately 10 days for eggs to hatch.

Fig. 4. *Geocoris* egg. Photo courtesy of UC IPM program.

Nymphs

Geocoris nymphs (juveniles) look similar to adults, only smaller and without wings. Nymphs of some species resemble miniature grayish adults and some may display a bluish-purple to red hue (**Fig. 5**). Nymphal stages have similar behavior and feeding habits as adults, but tend to feed on smaller prey. Young instars are tiny and easily overlooked. Nymphs hatching from eggs develop through 5 juvenile stages before becoming winged adults. With each successive instar, they shed their skin, develop wing pads and grow larger. Growth of juvenile stages is influenced by temperature and some species have been shown to develop slower at low temperatures. Under laboratory conditions nymphal development takes about 30 and 60 days at 25 and 20 °C (77 and 68 °F), respectively.

Fig. 5. *Geocoris* nymph attacking a *Heliothis* moth egg**.** Photo by Jack K.

Look-alikes

Geocoris can be confused with other hemipterans in the same family (Lygaeidae) as well as insects in the family Miridae, such as the tarnished plant bug **(Fig. 6**). Other lygaeids are more slender and have smaller eyes when compared to *Geocoris* spp. Bugs in the family Miridae do not have their eyes spaced widely apart, generally have longer antennae and only have one or two closed cells in the tip of their forewings. False chinch bugs (*Nysius raphanus*) and black grass bugs (*Irbisia* and *Labops* spp.) are closely related insects and can sometimes be confused with *Geocoris*. However, these look-alikes are more slender than *Geocoris*, have less pronounced eyes and are true plant-feeders.

Fig. 6. A tarnished plant bug *(Lygus lineolaris*). Photo by Scott Bauer, USDA

Life cycle

Geocoris have multiple generations per year and are present throughout the growing season. They overwinter as adults in sheltered sites, weedy areas, and within perennial crops and shrubs as adults or as eggs depending on the species and location. Adults become active in spring and begin depositing eggs on plants or soil duff. Females produce eggs for most of their life, and they average two or more eggs per day. Individual females can deposit an average of 150 eggs during their lifetime, which hatch in 5 to 10 days, depending on average temperature. Optimal temperature has been reported to be 26.7 °C (80 °F). Nymphs emerge and develop over 3-4 weeks. Adults and nymphs may be found taking cover in plant debris, at the base of plant stems, or in cracks at the soil surface. Adults require a pre-mating period of 2 to 5 days and overwinter and lay eggs on plants. Different species of *Geocoris* may vary in their development time. However, it is generally accepted that their speed of development from egg to adult correlates positively with temperature between 21 and 37 °C (69.8 and 98.6 °F); outside this range, eggs may not be viable. Eggs hatch in 1 to 3 weeks depending on temperature (higher temperature = faster development), and nymphs develop through five stages over roughly one month before reaching adulthood. In South Carolina, average development time for *G. punctipes* from egg to adult was reported to be 30 days. The optimal temperature range for development and survival of *G. punctipes* nymphs is 24.5 to 30 °C (76.1 to 86° F) which is in line with adults. However, it is believed that *Geocoris* responses to temperature will differ according to the climate of the region they live in. *Geocoris* live longer than most bugs as they usually live for three to four months.

Biological control

Geocoris represent a very important component of biological control services in agriculture. They commonly inhabit several agronomic and horticultural crops, where they feed on key pests and help in the suppression of secondary and minor pests of turfgrass, ornamentals and agricultural crops. *Geocoris* actively hunt and kill their prey immediately. Adults search plant and soil surfaces for their prey. When foraging on plants for prey, *Geocoris* search buds, flowers and leaves. Once *Geocoris* have found a meal, they insert their stylet ("needle sharp beak"), inject digestive enzymes, and then suck up the partially digested insides of their prey. Among their victims are aphids and many other soft-bodied insects such as thrips and insect eggs. They commonly prey on whiteflies such as the sweet potato and greenhouse whitefly (**Fig. 7**). Additionally, they have been reported to feed on caterpillar eggs, leafhoppers, flea beetles, *Lygus* bugs, tobacco hornworm eggs, mites and stink bug nymphs among other prey (**Fig. 8**). The presence of *Geocoris* eggs and nymphs in a field indicates a healthy, reproducing population with excellent potential for biological control. Nymphs and adults are voracious predators that consume many prey to complete their development. Individual nymphs may consume up to 1600 spider mites during their immature stages, and as many as 80 mites a day as an adult. Other laboratory studies have shown that an individual *G. punctipes* nymph consumes about 250 soybean looper eggs before it reaches the adult stage. In another lab study, adult *Geocoris* consumed up to four *Lygus* bug eggs per day.

Fig. 7. Big-eyed bug with protruded stylet feeding on whiteflies**.** Photo by Jack Dykinga, USDA ARS

Fig. 8. Geocoris sp. feeding on brown marmorated stink bug nymph on pepper plant**.** Photo by Cerruti RR Hooks

Geocoris are known famously for their potential to exert significant mortality on cotton pests as they possess a work-horse reputation in cotton fields. *Geocoris punctipes*, a large gray species, is one of the most dominant and effective predators of corn earworm and tobacco budworm in cotton. In addition to cotton, *Geocoris* are known for their pest suppression in other crops. For example, *G. punctipes and Geocoris uliginosus* (a small black species) are relatively common in soybean. Studies conducted in Georgia soybean fields found that these two species use kudzu bug and stink bug eggs as prey in soybean and corn, peanut and cotton fields, respectively. However, their behavior differs in that *G. punctipes* tends to climb on plants, whereas *G. uliginosus* spends most of its time on or near the ground. As such, *G. uliginosus* has drawn the attention of researchers working in turfgrass habitats where they feed on chinch bugs and fall armyworm eggs and larvae. *Geocoris punctipes* has been found feeding also on squash bug eggs and small nymphs; and adults showed an average consumption rate of 45 corn earworm eggs/24 hours. Another species, *Geocoris pallens*, was identified as a key natural enemy of tomato/potato psyllid in southern California. Sometimes the mere presence of *Geocoris* can affect their prey. For example, the prey may stop feeding and/or fall off of the plant after noting *Geocoris* presence.

Factors shown to influence predation by *Geocoris* are temperature, developmental stage and sex of the predator, and developmental stage, size and defensive behaviors of the prey. The host plant of the prey may play an important role also and has been demonstrated to influence predation of aphids. In general, plant surface features such as trichomes (small hairs or other outgrowth from the epidermis of a plant) can be important to their survival, oviposition, and foraging.

Plant feeding and its role in big-eyed bug survival

Similar to several other generalist predators, *Geocoris* are omnivorous which mean in addition to using insects and mites as food, they can use plant material such as plant sap, nectar, pollen and seed as a food supplement. The ability to switch among insect prey and obtain resources from plant material allows *Geocoris* to persist in cropping systems under conditions with minimal prey and subsequently be present when prey begin arriving in a cropping system or occur at low densities. These attributes make *Geocoris* particularly valuable predators in ephemeral agricultural systems (short term cropping systems such as annual crops). This helps protect them against food shortage especially in patchy environments, where prey numbers can vary.

A study seems to reveal that *Geocoris* prefer plant terminals and young leaves (soft plant tissues) for oviposition, indicating the importance of plants in the ecology of these predators. Although it has been reported that *Geocoris* feed on vegetative plant tissue, several reports indicate that individuals could not survive any better on vegetative tissue than on water alone. However, a study showed that mortality of *G. pallens* offered water and living leaf tissue on plants over eight days was 50%, but for individuals given only water it was 100%. This suggests some nutritional benefits were obtained from leaf tissue. Despite feeding on plant material, their net interactions with plants are usually beneficial, as it does not result in noticeable plant damage; and there is no evidence that their plant feeding causes significant injury to plants. It has been reported that adult *Geocoris* required either free moisture or plant moisture as well as insect prey. An earlier study found that *Geocoris* adults can survive on sunflower seeds and water, without insect food. Though, they may be capable of surviving if given a water source and either insect prey or plant seeds, diets combining insects with seeds or seed pods have been shown to quicken their development and increase their survival rate and fecundity (number of eggs laid). *Geocoris pallens and G. bullatus* developed faster and produced more eggs when reared on a combination diet of green plants, insect prey and sunflower seeds than they did when feeding on any of these dietary components alone. Some *Geocoris* may even require seeds or seed pods in order to complete development. This may be caused partially by the fact that *Geocoris* prey on many different insects of varying nutritional value. Seed pods and seeds are thus important nutritional resources for *Geocoris*. Another theory is this plant feeding behavior is related to their evolution from seed-feeding lygaeid bugs, and allows them to survive periods of low prey abundance.

***Geocoris* diet diversity**

Much has been said about the variable diets of *Geocoris*. It appears that they will pretty much attack any prey that they can subdue. This ability to eat many types of prey and plant material is important as some *Geocoris* species are known to change plant hosts, and must adapt to changes in host quality and herbivore prey abundance over their lifetime. Several researchers have investigated the feeding preferences of *Geocoris*. One study found that under field conditions, 97% of 140 target insect prey of *Geocoris* were adults, larvae or nymphs. Predation on egg and pupa stages accounted for only 3%. The host range of three *Geocoris* species (*Geocoris bullatus, G. punctipes,* and *G. uliginosus*) were studied. During the investigation, 67 host species including three classes of arthropods, plants, seeds, dead insects and even insect feces were consumed. Although they have been observed to feed on dead insects in laboratory and field studies, when given a choice they prefer live prey.

Geocoris interaction with other BC agents

Intraguild predation (IGP) takes place when natural enemies that use similar resources, such as prey, attack each other. The impact of IGP on biological control can be significant if the survival of natural enemy species is disrupted. Several studies have shown that *Geocoris* attack *Orius* (minute pirate bugs), which are a smaller important generalist predator of insect and mite pests. Studies conducted in cotton suggest that by attacking and feeding on *Orius* in the field, they prevent them from inhibiting spider mite outbreaks in cotton. On the other hand, *Geocoris* are vulnerable to IGP as they may be eaten by predators such as lacewings, assassin bugs and spiders. Further, their eggs may be parasitized by a scelionid wasp. Scelionidae is a family of parasitic wasps that lay their eggs inside the eggs of insects and spiders. *Geocoris* are cannibalistic and thus may feed on each other. It has been suggested that they may defend patches of prey and cannibalism may be a part of their defense strategy.

Pesticide effects

An important consequence of plant feeding by *Geocoris* is that it could potentially render them more directly susceptible to agricultural pesticides, especially systemic insecticides and insecticidal proteins incorporated into genetically engineered crops. Studies in cotton have shown reduced *Geocoris* survival on plants treated with systemic soil insecticides. *Geocoris* are sensitive to many broad-spectrum and other insecticides. Two systemic neonicotinoid insecticides, imidacloprid and thiamethoxam, were investigated for their impact on beneficial insects, including *G. punctipes*. Laboratory bioassays based on systemic delivery of these insecticides demonstrated that imidacloprid and thiamethoxam are toxic to *G. punctipes*. Another study compared three neonicotinoids, acetamiprid, thiamethoxam and imidacloprid with dicrotophos, a broad-spectrum organophosphate on beneficial arthropods. Mortality among populations of *G. punctipes* was highest after thiamethoxam and dicrotophos treatments. Another study showed that consumption of corn earworm eggs by *G. punctipes* was significantly lower when exposed to malathion, profenofos, endosulfan, fipronil, azinphos-methyl, and imidacloprid compared with the control. Spinosad was of lower toxicity to *G. punctipe*s, which is consistent with findings in other studies evaluating the impact of insecticides on *G. punctipes*.

Does *Bt* have an effect on *Geocoris*?

Genetically engineered crops have been associated with large reductions in insecticide use for key lepidopteran pests. Research has shown that several *Bt* proteins inserted into crops have had little to no effect on a wide range of nontarget arthropods. Nonetheless, concerns regarding their impacts on nontarget organisms persist. Because *Geocoris* feed on both prey and plant material, they can be exposed to *Bt* inserted into crops through several pathways. A study was conducted to quantify effects of three Cry proteins used to manage insect pests on *G. punctipes* over two generations. Individuals were allowed to consume cabbage looper or fall armyworm caterpillars that fed on maize or cotton containing *Bt* proteins. Their life history was compared to *G. punctipes* feeding on caterpillars not exposed to *Bt*. The study showed that the survival, development, adult mass, fecundity (number of eggs laid) and fertility were similar among the two groups. Their results demonstrated that *G. punctipes* is not negatively impacted through feeding intoxicated prey. A separate study was designed to address the question of direct and indirect effects of *Bt*-transgenic cotton on *G. punctipes*. It was believed that the continuous expression of the *Bt* toxin in plants during the growing season may expose *G. punctipes* to *Bt* toxins indirectly through the consumption of prey that fed on *Bt*-cotton, or directly through plant feeding. However, the combination of prey and *B*t-cotton plants did not affect *G. punctipes* development or reproduction.

Conserving *Geocoris* populations

Many pesticides are just as or more harmful to *Geocoris* as they are to the targeted pest. *Geocoris* can be conserved by eliminating or reducing pesticides that are toxic to insect predators, and by using "soft" or selective pesticides that target the pest more specifically and are less harmful to generalist predator populations. In general, habitats with diverse plantings appear to be more attractive to predators. Consider planting cover crops or flowering plants that can provide alternative food sources, shelter and overwintering sites.

Fig. 9. Flowering plot of crimson clover**.** Photo by Cerruti RR Hooks

It has been shown that interplanting cash crops into winter cover crops encourages and enhances the relay (movement) of predators into cash crops. The concept is to plant the crop by using reduced tillage to maintain natural enemies inhabiting the cover crop so that as the cover crop senesces, these natural enemies will relay or disperse into the main crop. A study designed to investigate the impact of different winter cover crops relay intercropped with spring-sown cantaloupe on *Geocoris* found that *G. punctipes* occurred in higher densities on subterranean clover than on other cover crops (rye, crimson clover, polyculture of six cover crops) and there was evidence that high densities observed on dying mulches (senescing cover crops) translated into greater predation of fall armyworm egg masses on cantaloupe foliage. Rye showed particularly low densities of *G. punctipes* suggesting that the species of cover crop planted is important when trying to conserve *Geocoris*. Another study conducted in cotton found that *G. punctipes* density was higher in cotton previously planted in crimson clover compared with control cotton fields with no prior cover crop (**Fig. 9**). It was suggested that intercropping the cotton in live strips of crimson clover was responsible for the relay of *G. punctipes* onto cotton plants.

Fig. 10. *Geocoris* sp. nearing an ant. Photo by I. Jacobs, Creative Commons.

Because *Geocoris* are omnivorous insects, providing them resources directly through supplementary feedings may be another tactic to enhance their populations in crops. A study was conducted to investigate the use of sunflower seeds to increase *Geocoris* density. Researchers scattered 1/4 pound of chopped sunflower seeds on 180 square feet in replicated sugar-beet field plots and found twice as many *Geocoris* eggs as did plots without sunflower seeds.

Summary
Big-eyed bugs, *Geocoris* spp., are members of the family Lygaeidae (seed bugs), but belong to a subfamily containing only predaceous insects. These generalist predators are common in many different rural and urban landscapes and are found in a variety of crops and non-cultivated plants nationwide. The common name, big-eyed bug, refers to a characteristic feature of these insects, their rather large, protruding eyes (**Fig. 10**). They prey on a variety of insect eggs, mites, aphids and other small prey, if the opportunity arises. In all life stages, they actively search for prey, but will occasionally feed on plants. When these predators are on plants, they search buds, flowers, leaves and other plant areas for prey. Additionally, adults are known to search the soil for prey. Studies have found that maximal survival and reproduction occurs when they have a mixture of plant and insect food. *Geocoris* can be conserved by eliminating or reducing pesticides that are toxic to them and potentially by adding cover crops, flowering plants or other resources that can provide alternative food sources, shelter and overwintering sites.