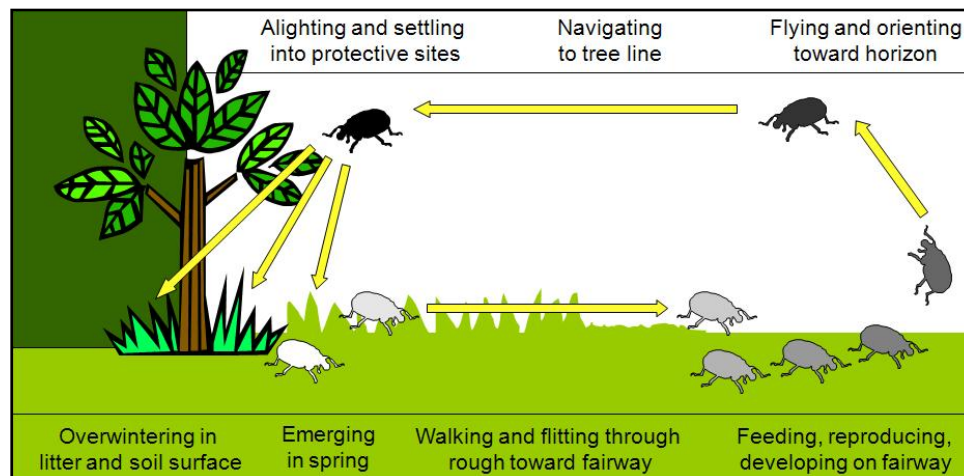


# Turfgrass and Environmental Research Online

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The range and severity of impact from the annual bluegrass weevil, *Listronotus maculicollis*, is expanding across the eastern U.S. Adults overwinter in protected areas off-course, but the life cycle is completed on low-cut turf, particularly fairways dominated by *Poa annua*. Researchers from Cornell University conducted experiments to identify the factors that influence selection of overwintering sites and how the insect disperses to and from those sites.

## PURPOSE

The purpose of *USGA Turfgrass and Environmental Research Online* is to effectively communicate the results of research projects funded under USGA's Turfgrass and Environmental Research Program to all who can benefit from such knowledge. Since 1983, the USGA has funded more than 450 projects at a cost of \$31 million. The private, non-profit research program provides funding opportunities to university faculty interested in working on environmental and turf management problems affecting golf courses. The outstanding playing conditions of today's golf courses are a direct result of ***using science to benefit golf***.

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# Overwintering of the Annual Bluegrass Weevil in Golf Course Landscapes

Daniel C. Peck, Maria Derval Diaz-Lyke, and Masanori Seto

## SUMMARY

The range and severity of impact from the annual bluegrass weevil, *Listronotus maculicollis*, is expanding across the eastern U.S. Adults overwinter in protected areas off-course, but the life cycle is completed on low-cut turf, particularly fairways dominated by *Poa annua*. To better target the insect with control tactics, we need to understand the relationship between overwintering and developmental habitats. Our objectives were to identify the factors that influence selection of overwintering sites and how the insect disperses to and from those sites. Major findings include:

- Based on a survey of natural populations, adults tend to overwinter near tree lines, up to 60 meters from the fairway and 10 meters past the tree line, but not on or near the fairway.
- Based on a survey of natural populations and an experimental choice test, adults do not prefer white pine litter as an overwintering substrate over deciduous tree litter or grass cover.
- Based on linear pitfall trapping, adult movement on the ground peaks in spring and shows directionality toward the fairway from the tree line. There was no peak of activity or directionality in the fall.
- We thereby propose a new conceptual model of flux between overwintering and developmental habitats based on the orientation of flying adults to defined tree lines. Further defining this behavior will strengthen our ability to target this major turf pest – in both space and time - with control tactics.

In golf courses of the Northeast and Mid-Atlantic states, the annual bluegrass weevil (ABW, *Listronotus maculicollis*) is an increasingly troublesome pest of high maintenance turf (6).

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This native insect is most prevalent in annual bluegrass (*Poa annua*), which is a major component of many golf course playing surfaces in those regions (7). Due to the stem-boring activities of younger larvae and the crown-feeding activities of older larvae, unprotected fairways and greens can suffer tremendous damage (1).

Regular control failures in the Northeast validate the idea that annual bluegrass weevil is not being effectively targeted by control interventions. Applications of pyrethroid insecticides against adults has been the pillar of control programs over the last two decades. In certain areas, however, resistance to this class of insecticide has emerged in the last few years, severely compromising the continuity of reliance on this management tactic (8, 9).

While newer insecticides that target larvae (e.g., chlorantraniliprole, indoxacarb, spinosad) now offer alternatives, their best use is still being refined (1). Regardless of insecticide choice, it is the inaccurate timing and placement of control interventions that hamper management efforts. More effective and efficient control hinges not only on an understanding of population fluctuations on susceptible turf (3, 6, 10, 11), but how and when adults move between the sites where they complete their life cycle during the growing season and where they overwinter during the cold season (2).

Annual bluegrass weevils overwinter as adults in protected areas separated from sites where feeding and development occur. Among others, the litter of white pine (*Pinus strobus*) has traditionally been regarded as a preferred surface substrate in which adults settle to survive the cold weather (11). In spring, the reappearance of adults on susceptible turf represents a transect of habitats, from overwintering sites in tree litter and other protected areas, through high-mown turf, toward developmental sites in short-mown turf.



Due to the stem-boring activities of younger larvae, and the crown-feeding activities of older larvae, unprotected fairways and greens can suffer tremendous damage.

## Objectives and Approach

The current challenges of annual bluegrass weevil control highlight a need to better understand the insect's overwintering behavior, in other words, what they do during the "off-season." We therefore sought to identify factors that influence selection of overwintering habitats by gauging how far from fairways they overwinter, what kinds of surface substrates they prefer to settle into, and how they disperse to and from those sites. Among other possibilities, we hoped this information would reveal ways that control tactics might be targeted to either suppress adults at their overwintering sites, or during their transition between habitats.

Our first prediction was that annual bluegrass weevil adults have preferences for overwintering sites based on distance from the fairway and on local microsite conditions such as litter composition. Our second prediction was that the movement of adults between overwintering and developmental habitats is directional, occurring during a relatively brief window of time that coincides with warming spring temperatures (immigration to fairways) and cooling fall temperatures after completion of the last generation (emigration from fairways).

All studies were conducted on two golf courses in western New York with a known history of annual bluegrass weevil infestation: the Onondaga Golf and Country Club (Fayetteville,

Onondaga county) and the Robert Trent Jones Golf Course (Ithaca, Tompkins county). The No. 12 fairway studied at Fayetteville was a mix of annual bluegrass and bentgrass (*Agrostis stolonifera*), while the associated rough was a mix of Kentucky bluegrass (*Poa pratensis*) and perennial ryegrass (*Lolium perenne*). The number 4 fairway studied in Ithaca was predominately annual bluegrass, while the associated rough was a mix of annual bluegrass, perennial ryegrass, and fine fescue (*Festuca spp.*).

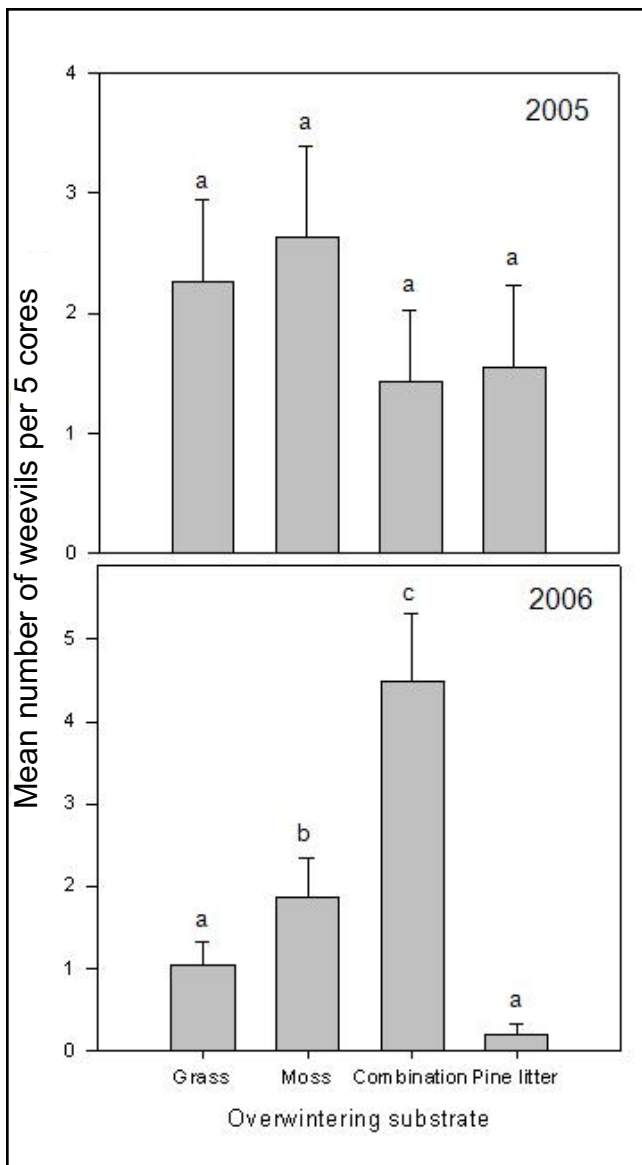
## Microhabitat Selection

We conducted two studies to ascertain how local microhabitat conditions influence where adults overwinter. The first study was a



Adults were sampled from four microhabitats: white pine litter, moss, rough-mown grass, and a combination of pine and deciduous tree leaf litter.





**Figure 1.** In 2006, significantly more adults were in the combined pine and leaf litter (23.2/ft<sup>2</sup>) than all other substrates, followed by moss (9.3/ft<sup>2</sup>), grass (5.6/ft<sup>2</sup>) and then pine litter (0.9/ft<sup>2</sup>). In both years, the lowest number of adults was recovered from pine litter.

survey of natural field populations and the second study was a manipulative field experiment.

Microhabitat surveys were conducted on natural populations in early spring over two years. This was done in Ithaca where the fairway was surrounded by a rough area that was relatively diverse in terms of surface substrates. In each of six blocks separated by more than 30 meters, overwintering adults were sampled from four microhabitats: white pine litter, moss, rough-mown grass, and a combination of pine and deciduous tree leaf litter.

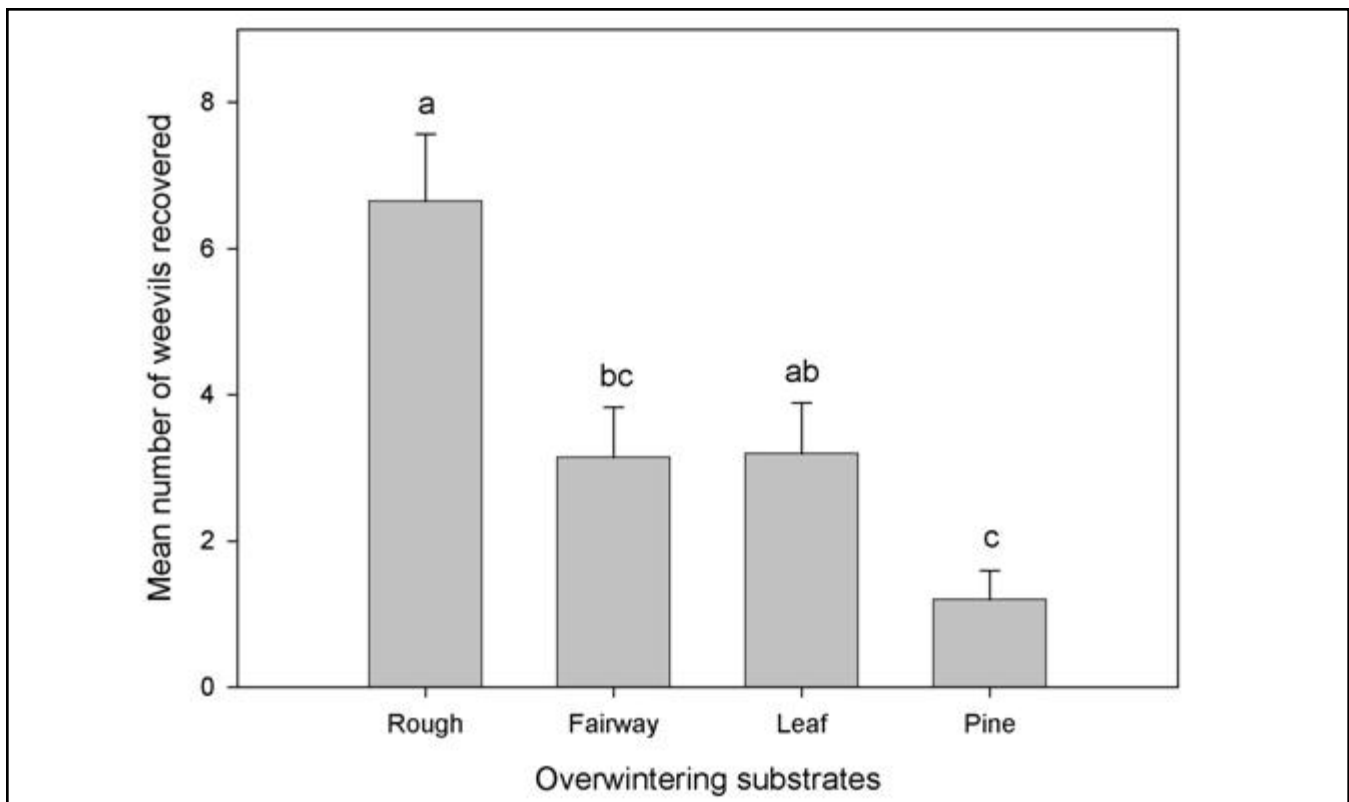
The soil and associated surface substrate were collected using a 15-cm diameter turf mender to a depth of 10 cm. Five such samples were taken from each microhabitat in each block. Collection dates were March 29, 2005 and March 13, 2006, soon after snow melt and soil thaw permitted sampling. We extracted adults from samples using modified Tullgren funnels where heat, desiccation, and light forced them down through a mesh screen and into a collection cup.

The overall density of sampled insects was 10.2 adults/ft<sup>2</sup>. There was a significant effect of microhabitat on the number of overwintering adults recovered in 2006, but not 2005. (Figure 1). In 2006, significantly more adults were in the combined pine and leaf litter (23.2/ft<sup>2</sup>) than all other substrates, followed by moss (9.3/ft<sup>2</sup>), grass (5.6/ft<sup>2</sup>) and then pine litter (0.9/ft<sup>2</sup>). In both years, the lowest number of adults was recovered from pine litter.

A multiple-choice experiment was conducted in Ithaca over two separate weeks in October and November 2005. The four microhabitats tested were white pine litter, deciduous leaf litter, fairway-mown grass, and rough-mown grass. Microhabitats were represented by cores collected using a 11-cm diameter cup cutter to a depth of 5 cm obtained from areas on the golf course with no history of annul bluegrass weevils. One core of each microhabitat type was placed in field arenas, which were 28-cm diameter and 13-cm tall rings cut from a 5-gallon bucket and pounded into the ground leaving a 1-inch lip exposed.

The existing turf inside the arena was stripped off before placing the microhabitat cores, and then gaps were filled with sand to level off the surface. Ten arenas (replicates) were used in each of the two trials. Fifty adults were released into each arena, which was capped with a wire screen cage to prevent their escape. After one week, each microhabitat core was removed, and the adults were counted after extraction in Tullgren funnels.

While only 28% of adults were ultimately recovered, there was a significant effect of microhabitat on where they were recovered (Figure 2). Pairwise comparisons showed that the number



**Figure 2.** In a multiple-choice experiment conducted in Ithaca over two separate weeks in October and November 2005, the number recovered from the rough-mown grass was significantly greater than the other microhabitats. The recovery from pine litter was significantly lower than leaf litter but not fairway-mown grass.

recovered from the rough-mown grass was significantly greater than the other microhabitats. The recovery from pine litter was significantly lower than leaf litter but not fairway-mown grass.

Overall, the results from our studies on microhabitat selection do not support the idea that white pine litter is a preferred substrate for annual bluegrass weevil overwintering. The supposition that pine litter harbors and even attracts annual bluegrass weevil populations is so prevalent among golf course superintendents that some practice pine litter removal in an attempt to suppress weevil damage. In the extreme, tree removal has even been justified based on its potential to solve problems in areas of the course with consistent infestations. While early work has shown that weevil populations can be quite high under white pine trees (11), until now there has been no explicit comparison with other potential microhabitats. We learned through other studies that adults are capable of overwintering under all microhabitat conditions, but our choice experiments showed pine litter to be the least preferred microhabitat.

### Macrohabitat Selection

We conducted one study to ascertain how macrohabitat conditions influence where annual bluegrass weevil adults overwinter. The study was a survey of natural populations in early spring over two years (2005-2006) with respect to distance from developmental sites on the fairway. This was done in Fayetteville because the fairway was surrounded by a long stretch of relatively homogenous rough-mown turf before a defined tree line.

Six transects were laid out perpendicular to the fairway edge in areas known to harbor annual bluegrass weevil populations. At each designated survey site along the transects, five samples were collected and extracted for adults as in the microhabitat survey described above. These sites were located 1 meter into the fairway, center of the intermediate rough (~1 meter from the edge of both fairway and rough), 1 meter into the rough, plus every 5 meters up to the edge of the tree line, including (in 2006) 10 meter past the tree



In a study to ascertain how macrohabitat conditions influence where annual bluegrass weevil adults overwinter, surveys were conducted of natural populations in early spring over two years (2005-2006) with respect to distance from developmental sites on the fairway. This was done in Fayetteville because the fairway was surrounded by a long stretch of relatively homogenous rough-mown turf before a defined tree line.

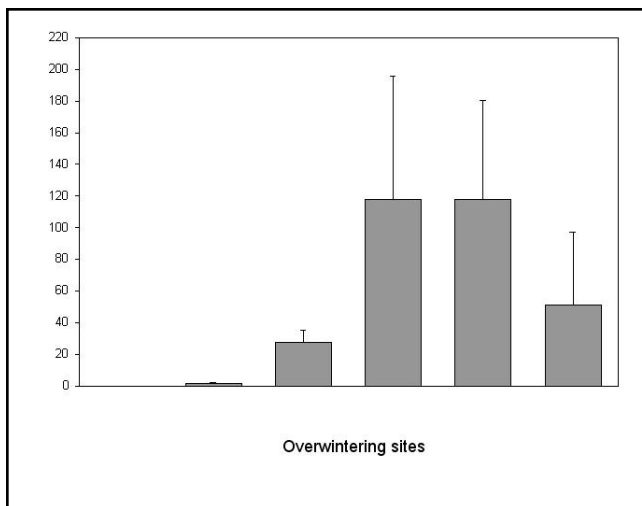
line into the woods. The number of sampling points therefore varied with the length of the transects, which ranged from 42-62 meters. Samples were collected between March 13 and April 4, soon after snow melt and soil thaw.

In both years, overwintering adults were absent in areas sampled on the fairway, intermediate rough, and 1-5 meters into the rough (Figure 3). Weevils were recovered 10-60 meters away from the intermediate rough, and as deep as 10 meters into the woods past the tree line. There was a significant difference among distance groupings with respect to the number of overwintering adults collected. Pairwise comparisons showed that significantly more weevils were

recovered from the near woods than the fairway edge or near rough. However, the number of weevils recovered from the far rough, wood edge, and far woods was not significantly different.

Under the conditions of our study, overwintering adults were absent from the fairway, the intermediate rough, and up to 5 meters into the rough. Although this supports the idea that adults dispersed completely away from the main developmental sites to overwinter, it does not take into account differential overwintering mortality. The chance that adults overwinter everywhere, but only survived where our surveys found them, remains to be tested.





**Figure 3.** Overwintering adults were absent in areas sampled on the fairway, intermediate rough, and 1-5 meters into the rough. Weevils were recovered 10-60 meters away from the intermediate rough, and as deep as 10 meters into the woods past the tree line.

### Directional Movement

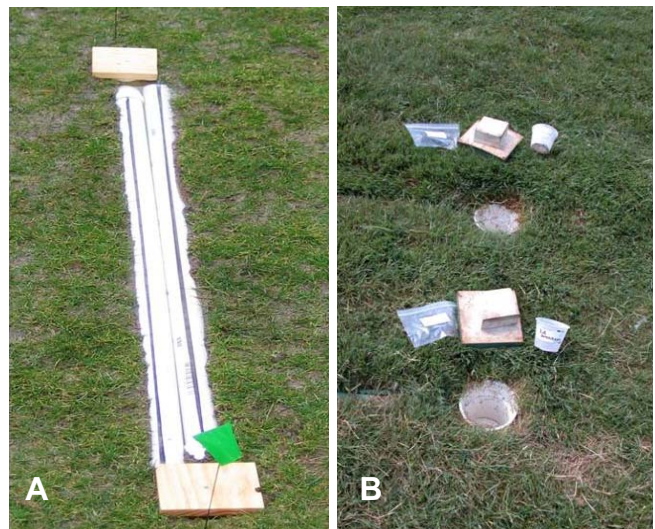
We conducted a study to determine the timing and directionality of adult movement over the season. To do this, we installed and monitored directional pitfall traps in both Ithaca and Fayetteville. The traps were permanently established in the ground by early April to capture adults emigrating from overwintering sites to developmental sites on the fairway. Traps were 2 meters long sections of 6.4-cm diameter PVC pipe with a 0.6-cm wide longitudinal slit cut into the up-facing side. One end of the pipe was sealed with a plastic cap while the other end led to a capture cup. Six pairs of traps were set up at each site, installed parallel to and 5-13 meters away from the edge of the fairway. With this arrangement, one trap would largely capture adults walking from the tree line toward the fairway, while the other would measure surface movement in the opposite direction. Captures were removed daily throughout the season and the number of adults was assessed.

Across the two sites and years, totals of 52-707 adults were captured over the course of the season. Captures were greatest in spring, where 76-86% of adults were captured during weeks 2-7 (Figure 4). Captures declined over the rest of the

sampling period into fall. In Ithaca over both years, there were significantly more adults captured approaching from the tree line versus the fairway. In Fayetteville, however, there was no difference in adult captures between the paired pitfall traps.

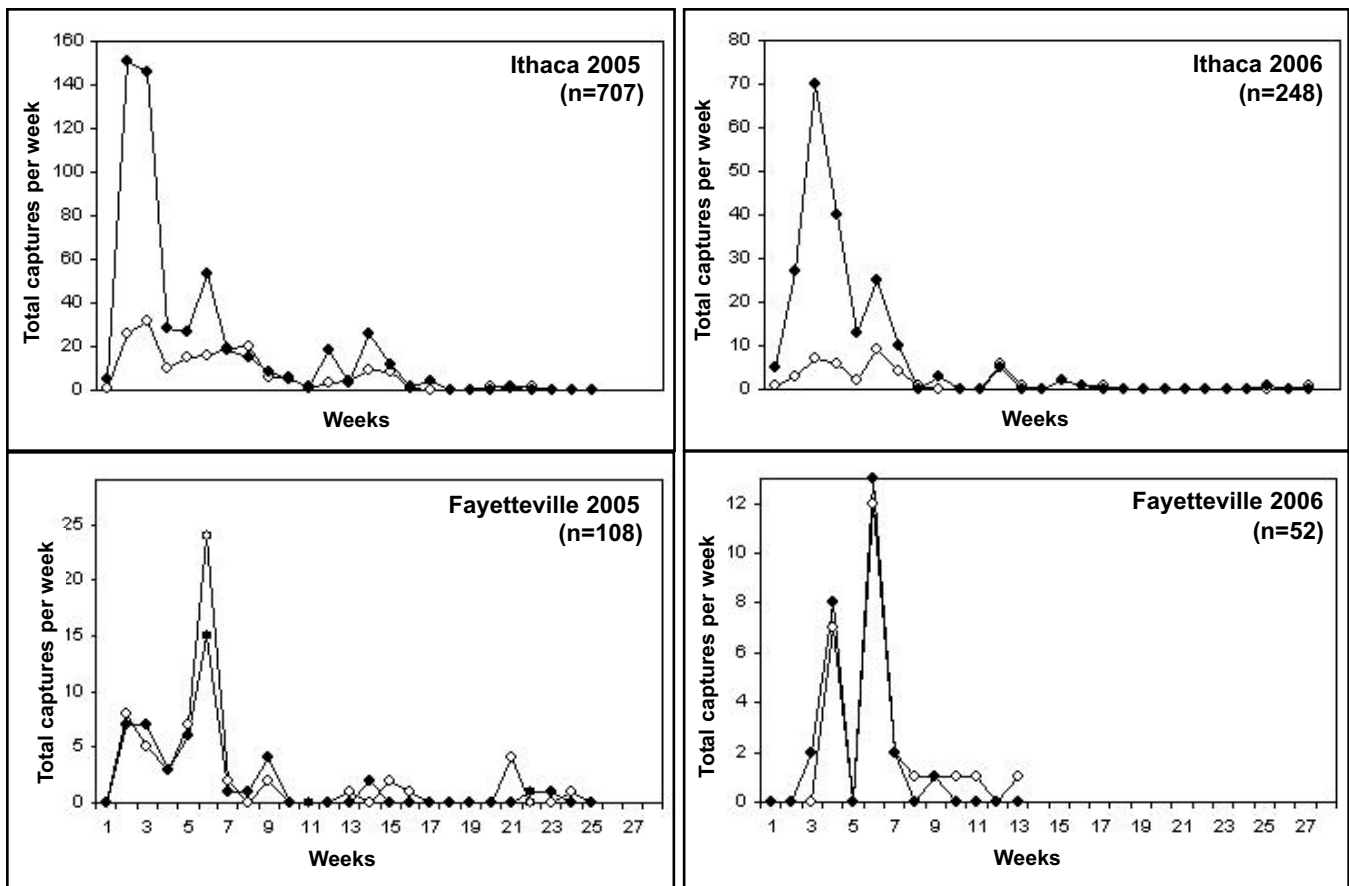
Based on the relatively high rates of capture in the spring, we conclude that a substantial proportion of weevils transition from off-course overwintering sites to fairway developmental sites by walking. While traps in both sites showed an early spring window of adult activity, directionality based on those captures was expressed at only one of the two sites. Besides overall size of the population, the other major difference between sites was that paired traps in Fayetteville were separated by ~ 0.6 meters; those in Ithaca were side by side.

We propose one scenario under which separated traps might not register directional movement. If weevils make short-distance flights away from overwintering areas, and then follow these by making explorative non-directional walks of less than 0.6 meters, followed again by flight, we would not expect differential capture rates between traps. If an adult were to land in the gap between the two traps, then either trap would be as likely to capture them walking over the surface.



Traps were 2 meters long sections of 6.4-cm diameter PVC pipe with a 0.6-cm wide longitudinal slit cut into the up facing side (A). One end of the pipe was sealed with a plastic cap while the other end led to a capture cup. Six pairs of traps were set up at each site, installed parallel to and 5-13 meters away from the edge of the fairway (B).





**Figure 4.** Total captures per week collected in linear pitfall data for both Ithaca and Fayetteville sites in both 2005 and 2006.

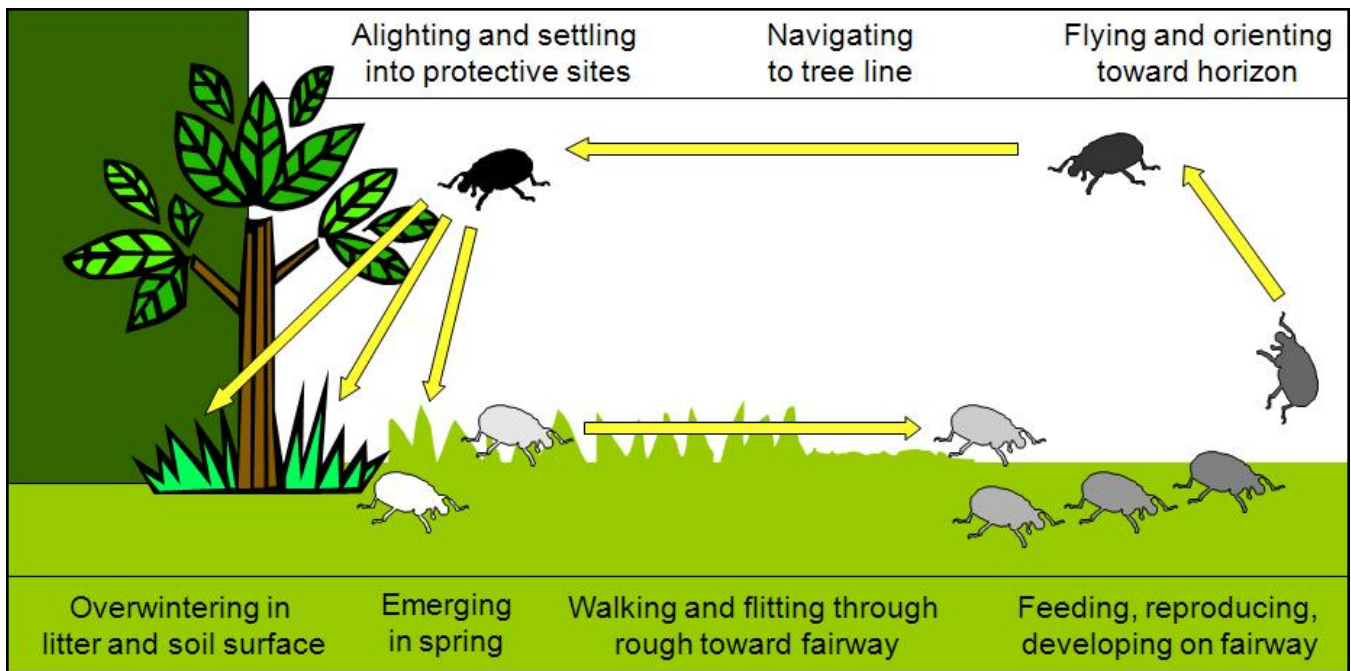
There are two explanations for why we did not detect a “reverse commute” (i.e. adults returning to overwintering sites in the fall). First, so few weevils were caught in the traps from late summer through fall that this may have led to the absence of any detectable pattern indicative of directional movement. A second explanation is that adults might fly, rather than walk, to return to the overwintering sites.

### Conceptual Model of Habitat Transition

Based on our results, we propose a conceptual model to explain the seasonal flux of annual bluegrass weevil adults in the golf course landscape (Figure 5). In the late summer and fall, adults emigrate from developmental habitats and immigrate to overwintering habitats largely by flight. To accomplish this, they orient to defined tree lines as a broad visual cue. Once they reach

the edge of tree line, they drop to the ground and settle into preferred microhabitats according to secondary cues related to composition of the surface substrate.

In the spring, adults emigrate from overwintering habitats and immigrate to developmental habitats largely by walking or a combination of walking and flitting (very short flights). As a group, weevil pests are known for their ability to navigate between habitats and for being good hikers and capable fliers. The overwintering behavior of at least one species, the boll weevil, has been attributed to a “snow-fence effect” (4). That is, when adults fly into the woods they descend on the far side of intercepting trees or bushes and remain there to overwinter. For annual bluegrass weevils, this hypothesis matches the prevalence of overwintering adults along the tree line, as well as the lack of a window of directional movement on the ground in the fall.



**Figure 5.** In the late summer and fall, adults emigrate from developmental habitats and immigrate to overwintering habitats largely by flight. In the spring, adults emigrate from overwintering habitats and immigrate to developmental habitats largely by walking or a combination of walking and flitting (very short flights).

Our improved understanding of how annual bluegrass weevils overwinter in the golf course landscape will help us to overcome the challenge of targeting the insect in space and time. The results of our ecological studies should refine how superintendents interpret annual bluegrass weevils on their own course. This may be as small as shifting the focus to defined tree lines, not white pine needle litter, per se (unless those pines comprise the tree line). On the other hand, it might open the path to entirely new approaches, such as how adults might be intercepted as they transition between habitats.

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