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Life history and population dynamics of *Ectinohoplia rufipes* (Coleoptera: Scarabaeidae) on Korean golf courses

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ABSTRACT

Life history and temporal distribution of *Ectinohoplia rufipes* larvae (Coleoptera: Scarabaeidae; Melolonthinae) were studied on multiple courses at two Korean golf clubs in Gapyeong and Anseong, Gyeonggi Provinces. Larval density of *E. rufipes* was higher in roughs than fairways and higher on older courses than on newly constructed ones at each club. Larval density of *E. rufipes* in fall reached three to four times compared with the previous year in five or six year old courses in the first opened courses, but that took two or three years to reach three to four times in the newly constructed courses in the same golf club. Monthly sampling showed that larvae were distributed 3.0 to 5.8 cm beneath the soil surface; mean larval density ranged from 0.2 to 1.2/m^2 at each club. Most larvae overwintered as third instars that pupated in early May. Adults were first observed in late May at each course. Adults were first seen in emergence cages installed over a grub-infested portion of rough in early June. Eggs were deposited from late June to early July. Eggs hatched in mid to late July and larvae developed to become third instars by early October. Implications of these findings for managing *E. rufipes* on Korean golf courses are discussed.

Introduction

The leaf-feeding scarab beetle *Ectinohoplia rufipes* (Motschulsky) (Coleoptera: Scarabaeidae) is an important pest of landscape trees and golf courses in eastern Asia. *E. rufipes* has been recorded in Korea, China, Japan, Siberia, Sakhalin, and Primorskii Krai (Degma, 1997; Kim, 2001). Adults are 9–12 mm long and light to orange or dark brown colored beetles (9.5–12 mm long) with scale-like yellow setae on their prothorax and elytra. They are easily distinguished from other scarabs that occur on Korean golf courses by their long hind legs which are raised backwards during mating and feeding (Choo et al., 1999). Adults feed mainly on the leaf lamina between the veins and cause the foliage to wither and turn brown (Choo et al., 1999; Choi et al., 2001; Lee et al., 2008). They aggregate on preferred hosts (e.g., *Alnus firma* and *Fraxinus rhynchophylla*) and often defoliate them before moving to neighboring hosts (Lee et al., 2008). Ninety-four plant species in 30 families have been recorded as host plants. In addition, the larvae damage roots of turfgrasses on golf courses (Choo et al., 1999, 2000; Choi et al., 2001; Lee et al., 2008). Most Korean golf courses are located close to mountainous forest regions where native host plants of *E. rufipes* are abundant (Lee and Lee, 2007). However, trees on golf courses tend to be more heavily damaged than are trees in nearby forest (Choi et al., 2001).

The vegetational diversity of managed landscapes and their proximity to natural habitats can influence the spatial distribution of phytophagous insects (Crawley, 1989; Nuckols and Connor, 1995; Joshi et al., 2004; Hyun, 2007). Golf courses, where the abundance of scarabs and other insect pests tends to be patchy and strongly influenced by site characteristics, are no exception (Yoshida, 1978; Choo et al., 2000; Dalthorp et al., 2000). Golf course vegetation is dominated by perennial species, mainly turfgrasses and landscape trees. Scarabs and other univoltine pests tend to reoccur at the same sites, although the abundance of particular species may markedly fluctuate from year to year. For example, *Popillia quadriguttata* (F.) occurs continuously at the same golf courses in Jinhae, Gyeongnam province and Gimpo, Gyeonggi province but population densities were different between courses and years (Lee et al., 2007; Kim et al., 2009).

Scarab injury to trees and turf on Korean golf courses appears to have increased in the past 20 years (Lee et al., 1999, 2002; Choo et al., 2002; Kim et al., 2009). Similar increases elsewhere have been tied to range expansion of exotic species (Alm et al., 1999; Facundo et al., 1999) as well as increased cultivation of irrigated turf (Ando, 1986; Potter and Held, 2002), and both factors are likely contributing to increased damage from adult and larval scarabs in Korea (Lee et al.,

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1999, 2002; Kim et al., 2009). Adult *E. rufipes* defoliate landscape trees and recently have become a serious pest on Korean golf courses.

It would be useful to understand how the age of a given course affects white grub occurrence because such information can help golf course superintendents focus their pest management efforts. Some insight can be gained by tracking population fluctuations over successive years after a new course is constructed, but that is complicated by course-to-course variation in abundance of preferred plants and other site-specific ecological characteristics. We therefore studied the life history of *E. rufipes* and sampled its larval density on different-aged courses at two golf clubs in the same area to help clarify how to test the hypothesis that larval densities tend to differ between older and newly-established courses. Our objectives were to clarify the seasonal life cycle of *E. rufipes*, compare larval densities in fairways and roughs, clarify larval establishment time in relation to course age, and analyze temporal fluctuations of grub density on different-aged courses.

Materials and methods

Study sites

Studies and sampling were conducted at two golf clubs: Gapyeong Benest Golf Club in Gapyeong (37° 48′ N, 127° 42′ E) and Anseong Benest Golf Club (formerly Seven Hills Golf Club) in Anseong (37° 00′ N, 127° 31′ E), Gyeonggi province, Korea from 2004 to 2007. Both clubs built additional courses other than the original ones about four years after the facilities were opened for play. Population densities of *E. rufipes* are higher at these golf clubs than at many others in Korea due to the preponderance of many species of preferred adult host plants (e.g., *Fraxinus rhynchophylla*) in neighboring forests and on the courses themselves (Lee and Lee, 2007).

Gapyeong Benest Golf Club consists of three nine-hole courses (27 holes) in a mountainous region (295–428 m above sea level). Two courses (Pine and Maple courses) were opened in 2000, and the Birch course was introduced in 2004, respectively. The turfgrasses in tees, fairways and roughs, and the greens were *Poa pratensis* L., *Zoysia matrella* (L) Merr., and *Agrostis palustris* Huds, respectively. The main ornamental tree is pine (*Pinus densiflora* Parlatore), but *Quercus mongolica* Fisch and *Quercus variabilis* Bl. are dominant native plants around each course (Lee and Lee, 2007). The turf in fairways was cut to a height of 18–26 mm depending on growth condition, and roughs were mowed to a height of about 45 mm. Fairways and roughs were fertilized with 4.2:3.4:3.4 g/m^2 of actual N:P:K per year. No fungicides or insecticides were applied to the sample sites in 2006, but herbicides were applied two times per year. Because high populations of *E. rufipes* damaged landscape trees on the courses in 2007, fenitrothion EC (an organophosphate) was applied three times per week during the peak time of the outbreak.

Anseong Benest Golf Club is a 36-hole facility consisting of four nine-hole courses at 250–400 m above sea level. The North and West courses were opened in 1999, whereas the East and South courses were introduced in 2000 and 2003, respectively. The tees, fairways, and roughs consist of *Zoysia japonica* Steud.; with the greens consisting of *A. palustris. Pinus densiflora* and *Q. mongolica* are the dominant ornamental and native trees, respectively (Lee and Lee, 2007). Fairways were mowed at 19–23 mm height, depending on growth conditions, and roughs were mowed at 40–45 mm. Fairways and roughs were fertilized with 6–9:2–3:5–6 g/m^2 of actual N:P:K per year. Fungicides were applied two or three times per year to control *Sclerotinia homoeocarpa*, the causal agent of dollar spot disease, and herbicides were applied two times a year. None of the courses at Anseong Benest Golf Club had insecticides applied to the fairways or roughs until 2006. Some preferred host plants on or near the courses that had been damaged by *E. rufipes* were removed in 2006, and others were treated with neem oil or fenitrothion EC beginning in 2007. Ethoprophos 5% G was applied two times to control earthworms from July to September, 2007.

Sampling of E. rufipes

Sampling was done on holes 2 and 4 of the Maple course (an older course opened to public in 2000) and on holes 1 and 9 of the Birch course (more recently constructed, opened to public in 2004) at the Gapyeong Benest Golf Club from 2004 to 2007. Samples were taken monthly from May to November. The dates were adjusted when sampling could not be done because of rain or golf club activities. The sample dates were 8 June, 22 July, 26 August, 22 September, and 13 October in 2004; 27 May, 23 June, 2 and 29 August, 25 September, 30 October, and 3 December in 2005; 24 April, 25 May, 24 June, 31 July, 28 August, 2 and 30 October, and 27 November in 2006, and 8 May, 3 July, 8 and 29 October, and 28 November in 2007. The sampling scheduled for September in 2007 was done in early October because there were only eight rain-free days from 1 September to 8 October in that year.

At the Ansung Benest Golf Club, observations were made at holes 1 and 6 of the North course (an older course opened to the public in 1999) and at holes 7 and 9 of the South course (a more recently constructed course; opened to the public in 2003) on 25 August, 23 September, and 22 October in 2004, 23 June, 2 and 29 August, 26 September, 4 November, and 1 December in 2005; 25 April, 31 May, 28 June, 24 July, 28 August, 2 October, 3 and 27 November in 2006, and 2 and 30 July, 27 August, 8 and 29 October, and 26 November in 2007.

At both golf clubs, a standard golf course cup cutter (10.16 cm diameter) was used to take 10 subsamples (11 cm diameter, 15–20 cm deep; 20 total subsamples) of turf and soil from the left and right sides of each fairway. Sampling was done every 10 m along a 100 m interval at the fairway–rough border, taking 10 samples 1 m into the fairway and 10 samples 1 m into the rough. Thus, forty subsamples were taken from two sites on two holes from two golf courses of two different aged courses. Four replications were made by combining the counts from the ten subsamples along each fairway and rough. That sample unit (950 cm^2 of sod sampled per replicate) was selected because four replicates of 900 cm^2 sampling was shown to be >93% accurate in predicting actual from estimated grub densities where typical grub densities (i.e., 303 grubs/m^2) occur (Lee et al., 2002). The sampled soil cores were broken apart and examined for larvae of *E. rufipes* which were sorted to instar and identified by their characteristic rastral pattern (Choo et al., 1999).

Seasonal life history of E. rufipes from the soil

Preliminary observations on the life cycle and seasonal occurrence of *E. rufipes* at Gapyeong Benest Golf Club from 2004 to 2006 indicated that overwintered larvae pupated in May and adults emerged in June. More detailed studies of pupation, emergence, and oviposition of *E. rufipes* population were done in 2007. Seasonal development of *E. rufipes* was monitored in roughs alongside three different holes at Gapyeong Benest Golf Club (holes 4 and 5 of the Maple course; hole 6 of the Pine course). Monitored sites had relatively high larval density. Ten subsamples were taken with golf cup cutter (11 cm diameter, 15–20 cm deep) at each site on each sampling date. Density, developmental stage and instar, and depth in the soil of *E. rufipes* were counted and recorded. Samples were taken on 9 April, 8, 15, 21, and 28 May, 18 and 26 June, 3 and 31 July, 13 and 28 August, 8 and 29 October, and 28 November in 2007. Four replications were made with ten subsamples in one replicate. The numbers of *E. rufipes* were pooled from the ten subsamples taken from each hole (950 cm^2 total sample area per replicate).