MOVEMENT BETWEEN WILD AND CULTIVATED BLUEBERRY[1] BY TWO SPECIES OF SHARPNOSED LEAFHOPPERS (HOMOPTERA: CICADELLIDAE)[2] IN NORTH CAROLINA[3]

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ABSTRACT

Field-collected *Scaphytopius* spp. adults were marked with fluorescent pigment, released in a cultivated blueberry (*Vaccinium corymbosum* L.) field and an adjacent wooded site in Bladen Lakes State Forest, NC, and recaptured on yellow sticky traps. Of those *S. magdalensis* (Provancher) released in the wooded site, 17.3, 27.1 and 43.7% were recaptured in the wooded area during generations I-III, respectively. Of those *S. magdalensis* released in the cultivated field, recapture in the same field was 11.5 and 27.9% during the first two generations, but only 1.5% at the beginning of the 3rd generation. Adults apparently moved out of the wild habitat during the 1st generation and out of cultivated fields during the 3rd. This movement pattern was not found in *S. verecundus* (Van Duzee). First-generation *S. magdalensis* should be controlled during their flight into cultivated fields.

Key Words: Homoptera, Cicadellidae, dispersal, migration, *Scaphytopius magdalensis, Scaphytopius verecundus,* blueberry, *Vaccinium corymbosum*

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INTRODUCTION

Scaphytopius magdalensis (Provancher), a sharpnosed leafhopper and vector of the etiologic agent of blueberry stunt disease (Tomlinson et al. 1950), is a serious pest of cultivated highbush blueberry, *Vaccinium corymbosum* L., in North Carolina (Milholland and Meyer 1984). Recorded along the Atlantic seaboard from Canada to Florida, it has also been found associated with wild blueberry species in New Jersey (Hutchinson 1955), Arkansas (Hopkins and Johnson 1984), and North Carolina (Meyer 1984). In North Carolina, *S. verecundus* (Van Duzee), a non-vector sharpnosed leafhopper, has also been found in cultivated and wild blueberry (Meyer 1984). This species cannot be distinguished externally from the vector species; only males of the two species can be identified by examination of the paraphyses (Hutchinson 1955).

Based on observations of population fluctuations, Marucci (1948) suggested that *S. magdalensis* migrates from wild hosts into cultivated fields each spring and back into woods in autumn. He further hypothesized that many overwintering eggs

[1] *Vaccinium corymbosum* L.

[2] *Scaphytopius magdalensis* (Provancher) and *S. verecundus* (Van Duzee).

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are laid on wild hosts. Meyer (1984) quantified adult populations of this species in wild and cultivated habitats of North Carolina and found that cultivated fields harbored the highest density of 2nd-generation individuals, whereas wild habitats had higher numbers of 1st- and 3rd-generation adults. Hopkins and Johnson (1984) also noted higher numbers of 1st- and 3rd-generation *Scaphytopius* adults in wild habitats of Arkansas. This pattern supports Marucci's migration hypotheses.

Migration between host species has been reported for other Deltocephalinae leafhopper species. Rose (1978) studied flight between natural grasslands and cultivated grains by *Cicadulina* spp. Migration from host plants in southern states to northern grain and vegetables has been recorded for the six-spotted leafhopper, *Macrosteles fascifrons* (Stal), a vector of aster yellows virus (Chiykowski and Chapman 1965; Medler 1962). Movement of *Circulifer tenellus* (Baker), vector of sugarbeet curly top, from various host plants into cultivated beet has been reviewed by Bennett (1967).

Blueberry stunt has also been reported in wild blueberry (Doehlert 1948; Hutchinson et al. 1960; Meader et al. 1964; Gocio and Dale 1982). If wild hosts are a reservoir for stunt organisms, leafhoppers could initiate infestation of cultivated fields by moving from wild hosts. This paper presents results of a dispersal study of *Scaphytopius* spp. using mark-recapture techniques designed to determine if *S. magdalensis* adults move from wild hosts into cultivated fields each spring and back into woodlands in autumn.

MATERIALS AND METHODS

To determine retention of the fluorescent pigment (Day Glo®, Cleveland, OH), 51 laboratory-reared adults were marked (17 per color) and caged on blueberry in the laboratory. Mortality and presence of marks were recorded daily for 7 da. Another sample, 20 marked adults, was emersed in water and observed for fluorescence after the adults had dried.

Release-recapture sites were established in a 120-ha commercial blueberry field in Bladen County, NC, and adjacent woodlands of Bladen Lakes State Forest during the summer of 1985. Forest understory included creeping blueberry, *V. crassifolium* Andrews; sheepkill, *Kalmia angustifolia* (Small); huckleberry, *Gaylussacia frondosa* (L.) Torrey & Gray; wild highbush blueberry and other ericaceous plants. Immediately before each release of marked leafhoppers, sticky traps were positioned in the cultivated field and woods to detect recaptured adults. Leafhoppers are attracted to yellow (Alverson et al. 1977). Thus wooden boards (23.0 × 14.0 cm) were painted yellow and coated on both sides with adhesive (Tanglefoot ®, Grand Rapids, MI). Eight of these traps were hung in blueberry bushes (cultivar Murphy) in a 12.0 × 8.5-m block along the edge of the cultivated field. This block contained four rows of bushes perpendicular to the field edge and 4.0 m apart. Two traps were hung per row; the first in each row was 5.5 m from the field edge and 3.0 m from the other trap. No insecticides were applied to this field during the summer. Wooden frames held 16 traps in a similar 12.0 × 8.5-m block along the edge of the woods. Traps in this block were arranged in four rows 4.0 m apart; each row had four traps ca. 3.0 m apart. All traps were ca. 0.5 m from the ground. A 9.0-m wide dirt path and drainage ditch separated the cultivated field site from that in the woods.

Sweepnet collections of *Scaphytopius* spp. were taken from huckleberry 3.0 km from the release-recapture sites. Collecting began when vegetation had dried in late morning and continued until dusk. All sweep collections were placed in a clear-topped wooden transfer box with a cloth sleeve on one side. The sleeve could be opened to allow insertion of the sweepnet contents, closed to prevent escape of specimens, and partially opened to permit removal of specimens with an aspirator. Adult sharpnosed leafhoppers were immediately aspirated from the box, transferred in groups of 50 to mason jars containing ca. 0.5 g of pigment, and shaken with the pigment for ca. 15 sec to ensure marking. A stem of creeping blueberry was added to provide nutrition and each jar was held in a cooler without ice 0.5-1.0 hr until release.

Each week ca. 300 marked adults were released at each of two locations inside the blocks of sticky traps: the center of the woodland block and 3.0 meters from the edge of the cultivated field in a center row. Leafhopper release dates were: 6, 13, 20, 27 May and 3 June (generation I); 17, 22, 31 July and 5 August (generation II); 9, 16, 23 October (generation III). Generation II samples were combined to form two samples, each 14 days. Adults released in the cultivated field were marked green; those released in the woods were marked either red or blue. Gently tapping inverted jars within creeping blueberry released adults in the woods. In the cultivated field, adults were released under bushes onto cut grass. Traps were replaced 5 to 9 da after each release. Leafhoppers removed from traps were viewed under UV light through a dissecting microscope. Marked adults were separated according to color and placed in paint thinner to remove adhesive and facilitate sex determination. Dissection of male genitalia (up to 50 per sample) established species identification; dissection of weekly subsamples of 50 adults estimated the ratio of the two species released.

To obtain recapture proportions for a species, the number of males of that species recaptured at a site with the color for that site was divided by the estimated number of males of that species released in that site. Comparisons of recapture proportions between sites could not be made due to differences in vegetation; comparisons between species of leafhoppers could not be made due to differences in species attractiveness to yellow sticky traps (Meyer 1984). Statistical analysis for each species at each site first compared proportion of recapture between sample dates within a generation; values that showed no significant differences were identified by within-generation chi-square tests and pooled. Then recapture values between generations were analyzed by between-generation chi-square tests. Chi-square contingency tables consisted of numbers of recaptured and escaped adults. To rank recapture values from lowest to highest within a site, Z tests for pair-wise comparisons of proportions (Brown and Hollander 1977) were conducted.

RESULTS

All 51 adults in the mark retention study were still marked on day 7. Of these 25 were alive. This is an average life expectancy for field collected adults (unpublished data). After washing, all marked adults retained their color. Marked and released adults totaled 7729. From subsample dissections, it was estimated that 18.7% were *S. magdalensis* males and 26.5% were *S. verecundus* males; the remaining 54.8% were *Scaphytopius* females. No adults released in the woods were recaptured in the cultivated field; only 6 adults released in the cultivated field were recovered on woodland traps.

Table 1 gives *S. magdalensis* male recapture and release (estimated) numbers per sample per site, five within-generation chi-square values, samples after pooling, and percentage of recapture. Three chi-square tests showed no significant differences ($P < 0.05$); thus, the five samples of generation-I woods were combined (33 males recaptured in woodlands per 191 estimated males released in woodlands) as were the samples of generation-II woods (48/177) and generation-II cultivated field (36/120). Since 25% of expected cells for 1st-generation data from the cultivated field have less than five individuals, only the first week's recapture (12/104) was used in further tests. Significant differences were found at both sites for the 3rd generation, thus the three samples were not combined for either site.

Between-generation chi-square tests at both sites showed significant differences ($P < 0.05$): woods, 31.7 (df = 4); cultivated field, 50.1 (df = 4). Thus, Z tests were conducted to establish rankings of the samples. Table 1 shows estimated percent recapture for 10 pooled samples, and their ranking from lowest (w) to highest per site. Fewer individuals (17.3%) of 1st-generation *S. magdalensis* in woods were recaptured than those of later generations; recaptures during generation II and at the beginning of generation III (27.1 and 22.2%, respectively) were intermediate between the end samples; recapture at the end of generation III was highest (36.7, 43.7%). In the cultivated field, fewer 1st-generation *S. magdalensis* males (11.5%) were recovered than of generation II (30.0%); however, the lowest proportion of recovery was at the beginning of generation III (1.5%).

Table 2 reports similar data for *S. verecundus* males. Three within-generation chi-square tests showed no significant differences ($P < 0.05$); thus, the following samples were pooled: generation-I woods (49/619) and generations II and III in the cultivated field (30/211, 26/193). For the cultivated field during the 1st generation, 25% of expected cells have less than five individuals. Thus, only the first week's recapture (1/35) was used in further tests.

Both between-generation chi-square values showed significant differences ($P < 0.05$): woods, 78.5 (df = 5); cultivated field, 33.1 (df = 2). Thus, Z tests were conducted to establish rankings. Recapture rates of *S. verecundus* in both habitats were low in spring and increased into autumn.

DISCUSSION

Migration has been defined as enhanced locomotor activity, suppressed feeding behavior and lack of attraction to normal stimuli that in other circumstances would cause flight to cease (Johnson 1969; Dingle 1972). Trivial flight, in contrast, exhibits interruptions caused by such stimuli as food or mates. Recapture rates of marked leafhoppers in this study are a measure of yellow trap attractiveness or lack of attractiveness and also, indirectly, migration. When woodland adults engage in migratory flight, few of them should be distracted enough by yellow traps to cause flight to cease; thus, their numbers on traps in woodlands should be low. In contrast, when these adults are engaged in trivial flight, more of them should be captured. Thus, it should be possible to reconstruct a pattern of migration by comparing recapture proportions in a mark-recapture study.

Fewer woodland *S. magdalensis* were recaptured at the beginning of the year than at the end, either due to migration, predation or weather factors. If the latter

Table 1. Numbers of recaptured and estimated released marked *S. magdalensis* males, within-generation chi-square values, samples after pooling, percent recapture and rank from lowest (w) to highest across time in woods and cultivated field (comparisons of recapture were not made between sites).

Release date	Woods: No. recapture/ release	Woods: χ^2	Woods: Pooled No. recapture/ release	Woods: %* recapture	Cultivated Field: No. recapture/ release	Cultivated Field: χ^2	Cultivated Field: Pooled No. recapture/ release	Cultivated Field: %* recapture
Generation I								
6 May	29/154				12/104			
13 May	3/12				2/5			
20 May	0/7	1.2†	33/191	17.3 w	0/5	§	12/104	11.5 x
27 May	0/12				0/6			
3 June	1/6				0/4			
Generation II								
17, 22 July	29/90	2.4†	48/177	27.1 x	12/39	0.3†	36/120	30.0 yz
31 July, 5 August	19/87				24/81			
Generation III								
9 October	48/216		48/216	22.2 wx	2/132		2/132	1.5 w
16 October	72/196	19.1‡	72/196	36.7 y	20/98	41.3‡	20/98	20.4 xy
23 October	55/126		55/126	43.7 y	24/69		24/69	34.8 z

* Values in a column followed by the same letter are not significantly different at $P=0.05$ level (Z test).

† No significant difference; $df=1$, $P<0.05$ level

‡ Significant difference; $df=2$, $P<0.05$ level

§ 25% of expected cells less than 5

Table 2. Numbers of recaptured and estimated released marked *S. verecundus* males, within-generation chi-square values, samples after pooling, percent recapture and rank from lowest (x) to highest across time in woods and cultivated field (comparisons of recapture were not made between sites).

Release date	Woods No. recapture/ release	Woods χ^2	Woods Pooled No. recapture/ release	Woods %* recapture	Cultivated Field No. recapture/ release	Cultivated Field χ^2	Cultivated Field Pooled No. recapture/ release	Cultivated Field %* recapture
Generation I								
6 May	3/53				1/35			
13 May	17/187				1/91			
20 May	11/109	2.9†	49/619	7.9 x	5/90	¶	1/35	2.9 x
27 May	14/180				2/93			
3 June	4/90				0/63			
Generation II								
17, 22 July	14/142	8.4‡	14/142	9.9 x	11/79	0.1†	30/211	14.9 y
31 July, 5 August	36/162		36/162	22.2 y	19/132			
Generation III								
9 October	31/126		31/126	24.6 yz	9/77			
16 October	27/140	9.0§	27/140	19.3 y	12/70	1.6**	26/193	13.5 y
23 October	31/83		31/83	37.3 z	5/46			

* Values in a column followed by the same letter are not significantly different at $P=0.05$ level (Z test).
† No significant difference; $df=1$, $P<0.05$ level
‡ Significant difference; $df=1$, $P<0.05$ level
§ Significant difference; $df=2$, $P<0.05$ level
¶ 25% of expected cells less than 5
** No significant difference; $df=2$; $P<0.05$ level

two factors were responsible for these recapture values, then the pattern of recapture for *S. magdalensis* in both sites should have been similar. In addition, if predation in the culitvated field during the 3rd generation caused the recapture rate found in *S. magadalensis,* predator population abundance would have had to fluctuate greatly within a 7-day period.

Variation in recapture rates for *S. verecundus* in woods may have been the result of weather, greater predation in spring or early summer dispersal. It is difficult to generalize about this species in cultivated fields, because it is uncommon in that habitat (Meyer 1984). Since most individuals are found in woodlands, an exchange of populations between wild and cultivated fields is unlikely.

Either of two migration hypotheses could explain the recapture rates found in this study for *S. magdalensis.* In the first hypothesis, adults in woods during the 1st generation migrated into cultivated fields and those in cultivated fields during the 3rd generation returned to wild habitats. In the second hypothesis, adults from both sites migrated in early spring. Because 1st-generation individuals are more abundant in woods (Meyer 1984), net movement would have been into cultivated fields. At the beginning of generation III, adults in both sites again migrated. Because 2nd-generation individuals are more abundant in cultivated fields (Meyer 1984), net movement would have been into woodlands. Results of either pattern of movement resemble Johnson's class III migration, emigration to hibernation sites and return flights after diapause (Johnson 1969). Considering the results of this movement study and the possibility that blueberry stunt disease may be present in wild hosts, the need to control 1st-generation sharpnosed leafhoppers is essential.

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