WIND-DIRECTED DISPERSAL OF BOLL WEEVILS, *ANTHONOMUS GRANDIS* (BOH.)

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Abstract

Boll weevils, *Anthonomus grandis* Boh., disperse from late-season cotton fields into overwintering habitats in late-summer, and return to emergent cotton fields in the spring. A study was conducted near Caldwell, Texas, to investigate the effect of prevailing wind direction on the distribution of daily capture of boll weevils. Pheromone traps were placed at 1, 2, 3, 4, and 5 miles within each of eight sectors (45˚ span of compass direction per sector) radiating from a non-irrigated, 2-acre cotton plot (core field). Boll weevils were marked with paint, released at the core field, and recaptured to verify the distribution of insect flight displacements and their association with prevailing wind direction in 1998 and 1999. Daily recapture of marked boll weevils within the 1- to 5-mile range in the late-summer of 1998 and 1999 was generally too low for logistic regression. However, logistic regression established a significant positive relationship between the proportion of daily mean capture and the daily proportion of wind heading by sector for a five-day period following the shredding of the core field on 6 September 1999. The results of this study have direct implication to the development of strategies for monitoring and managing boll weevil populations that are moving from late-season cotton into overwintering habitats.

Introduction

The propensity for boll weevils, *Anthonomus grandis* Boh., to disperse from late-season cotton has been reported for several geographic regions (Rummel and Summy 1997). Previous studies have focused on seasonal spatial patterns and distances of boll weevil dispersal. For example, Beerwinkle et al. (1996) captured relatively high numbers of boll weevils in uncropped areas at distances of 13 to 20 km from cotton fields during late-summer in the Brazos River Valley of east-central Texas. Wade and Rummel (1978) also reported peak late-summer and fall dispersal of boll weevils into overwintering habitats, with reproductive weevils dispersing in late-summer and diapausing boll weevils dispersing in the fall on the Texas High Plains. Hopkins et al. (1971), however, showed that boll weevil flight in South Carolina was primarily toward, rather than away from, an 8-acre cotton field in the fall. Moody et al. (1993) used mark-capture techniques and found that reproductive boll weevils dispersed in late-summer and diapausing weevils dispersed about 45 days later in Texas, with the proportion of dispersing weevils that were diapausing decreasing with distance from their origin. Johnson et al. (1975) determined that marked boll weevils dispersed as far as 53 km (33 miles) from late-season cotton fields in Mississippi. Previous studies have not reported on the effect of wind direction on the spatial pattern of boll weevil dispersal. The present study was conducted to investigate the influence of wind direction on the dispersal of boll weevils from late-season cotton fields.

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Methods

Trapping of Boll Weevils

A 2-acre cotton plot (core field) near Caldwell, TX, represented the only dryland cotton produced in Burleson County in 1998 and 1999, and was at least 8 miles from the nearest irrigated cotton which was grown in the Brazos Valley. Boll weevil movement was monitored using pheromone traps (Southeastern Boll Weevil Eradication Foundation) baited with 10- mg pheromone lures (Plato Industries, Houston, TX) and placed at 1, 2, 3, 4, and 5 miles from the core field within each of eight sectors (45˚ span of compass direction per sector) (e.g., the north sector was bounded by the north and northeast radial lines from the core field). Recapture of marked boll weevils was also monitored in traps at ranges of 6, 7, 8, and 9 miles from the core field in the northwest, north, northeast, and east sectors. Further, traps monitored boll weevil movement at 1 to 4 locations around the perimeter of the core field, at 8 locations near previous cotton fields (1 to 2 miles from the core field), and at a total of nine locations between 9 and 11 miles in the north (8) and east (1) sectors. Pheromone lures were replaced every two weeks. Traps were checked daily following releases of marked boll weevils. Captured boll weevils were returned to the lab for examination. Statistical analysis was restricted to captures in the set (40) of traps from 1 to 5 miles in each of the eight sectors. A Campbell CR21XL weather station (Campbell Scientific, Logan, UT) was operated adjacent to the core field to record hourly mean values of wind speed and wind direction.

Release and Recapture of Marked Boll Weevils

Boll weevils were released from or near the core field on several dates in an attempt to represent the variability of prevailing wind headings. The use of a unique mark for each release date permitted the identification of the release date for an indefinite duration.

1998

During late-summer, 35,888 boll weevils were collected from pheromone traps and maintained on either 2.5M sucrose solution or distilled water in the laboratory until release. Cohorts were sprayed with a unique color of fluorescent enamel paint to identify their date of release. The productivity of the core field was severely limited due to a drought and an outbreak of grasshoppers, so the field was shredded earlier than anticipated. After the core field was shredded, releases were made near the core field on 27 August, 1 September (2 colors), and 14 September (Table 1). Released boll weevils dispersed immediately from containers on 27 August and 1 September when weather conditions were hot and dry, but boll weevils dispersed primarily to nearby grass and hay bales on 14 September when heavy rains occurred. Fluorescent spray-painted boll weevils were visually detected with blacklight illumination after recapture.

1999
Adult boll weevils were obtained from pheromone traps in the Caldwell trapline and in the nearby Brazos Valley, and were collected by hand from the core field on 9-10 August. From the time of collection until release, adult boll weevils were maintained in the laboratory. Boll weevils were provided a source of distilled water and maintained on a diet of one debracted square or one small boll per 25 boll weevils. Food was replaced three times per week.

Boll weevils for seven releases were marked on the right or left elytra using an acrylic paint pen. Boll weevils for six releases were marked using an airbrush with acrylic paint. Equal numbers of marked boll weevils for each release were evenly distributed into 10-15 containers several hours before each release. Before release, boll weevils in each container were mixed and an equal number were removed from each container for determination of sex using the method of Agee (1964). A total aliquot of ≥ 50 boll weevils was obtained for each release. On the ten release dates before the core field was shredded and plowed (6 September), boll weevils were released directly onto cotton plants throughout the core field at 2000 h CST (Table 1). The core field received sufficient precipitation to sustain fruiting during the summer, and retained a large proportion of released boll weevils. Consequently, a decision was made to shred and plow the core field on 6 September in order to force the released boll weevils to depart from the field. Three subsequent releases were made at 0600 h CST in grass adjacent to the core field (Table 1). These times of release were selected to promote movement of boll weevils into the vegetation and to discourage immediate dispersal by flight. Hand-painted boll weevils were detected by unaided visual inspection. Fluorescent spray-painted boll weevils were visually detected under blacklight illumination.

Statistical Analysis
Daily capture was calculated for each sector. The proportion of capture for each sector was calculated as the sector daily capture divided by the total captures. Values of hourly wind heading were excluded from analysis for nighttime hours or when the hourly mean wind speed was less than 1 m/s. Logistic regression (Wilks 1995) was performed using PROC LOGISTIC (SAS Institute 1989) to relate hourly mean wind heading and the spatial distribution of daily capture of boll weevils. Our null hypothesis was that sector captures would be uniformly distributed such that the proportion of capture for each sector would equal 1/8 (0.125) of the total capture. A binary response variable was derived by identifying a sector capture event (value=1) whenever the sector daily capture exceeded 1/8 of the total daily capture, otherwise a non-event (value=0) was assigned. A logit value (y') for the probability of a greater-than-expected proportion (i.e., > 1/8 or 0.125) of boll weevil captures within a given sector was estimated through linear regression based on the proportion of hourly wind heading (x) observed within that sector as $y' = ax + b$. Given the proportion of wind heading in a given sector, the probability that the capture of boll weevils within the sector exceeds that estimated from a uniform distribution is given as $P[y > 0.125 \mid x] = \exp(y') / (1 + \exp(y'))$.

Results

1998
Seven-hundred ninety marked boll weevils were recaptured from the 35,888 boll weevils released (2.2%). Marked boll weevils were recaptured as late as 29 days after release. Forty-seven marked weevils were recaptured one or more miles from the core field one day after release. Total recapture decreased from 86 to 6 marked boll weevils in the range of 1 to 5 miles, respectively (Fig. 1). Marked weevils were recaptured at a range of 5 miles in six of the eight sectors with maximum resultant displacement (7 miles) toward the north. Maximum dispersal (25.3%) occurred within the south sector (i.e., 180˚ to 225˚) (Table 2). The frequency of wind was fairly evenly distributed within the eight sectors, but was maximal (19.3%) within the south sector (Table 2). Logistic regression did not indicate a relationship between daily sector totals of unmarked boll weevils and sector wind frequency. Also, logistic regression analyses were ineffective for analyzing distributions of marked boll weevils because generally only 1 or 2 marked weevils were captured within the 1- to 5-mile range per day.

1999
Marked boll weevils were released at the core field on 13 dates in late summer. Four-hundred seventy-seven (1.1%) were captured from the total release of 43,764 weevils. Total recapture decreased from 178 to 3 marked boll weevils in the range of 1 to 5 miles, respectively (Fig. 1). Marked weevils were recaptured as late as 35 days after release. Marked weevils were recaptured at a range of 5 miles in two of the eight sectors with maximum displacement (11 miles) toward the north (2 marked weevils). Maximal wind occurrence (22.2%) occurred in the northeast sector and maximum capture of marked weevils (77%) occurred in the north sector (Table 3).

Daily sector totals of unmarked boll weevils was not significantly related to sector wind frequency using logistic regression, and prior to shredding and plowing, logistic regression could not be used effectively for analysis of capture patterns of marked weevils because numbers of recaptured weevils were very low. However, recaptures of marked weevils increased immediately after the core field was shredded and plowed (6 September), and 18,500 marked boll weevils released on 8 September further contributed to subsequent high trap captures. Among the set of boll weevils released between 17 August and 2 September, twenty marked weevils were captured before shredding and 111 were captured after shredding (Table 4). Recaptures of marked boll weevils totaled 8, 126, 58, 12, and 4 on 7-11 September, respectively. After the core field was plowed, the relationship between the proportional capture of marked weevils and proportional occurrence of wind by sector was significant using logistic regression ($\chi^2 = 7.477$, 1 df, $P \leq 0.01$). Maximum capture and maximum wind occurrence were both identified in the north sector on 8 September (Fig. 2a). Following the passage of a cold front on the night of 8 September, the maximum capture occurred in the north sector but the maximum wind occurrence was identified in the south sector (9 September) (Fig. 2b). The sector of maximum capture more closely matched the sector of maximum wind occurrence on 10-11 September (Fig. 2c-d).

Discussion

Logistic regression was an effective analytical approach for assessing the daily influence of wind heading on the spatial distribution of recaptured boll weevils following shredding and plowing of the core field when numbers of weevils recaptured were adequate. Failure of this approach to indicate such relationships for unmarked weevils was not surprising because many of the weevils likely originated from sources other than the core field. The deviation between the sector of maximum occurrence of wind heading and the sector of maximum recapture on 9 September was likely caused by high captures on the afternoon of 8 September before a cold front passage and ensuing change to northerly winds. Additionally, the captures on 9 September may in part reflect the northward displacement of weevils for 1 or more days before their capture.

The diminishing captures of marked weevils with increasing distance from the core field appears to indicate that the distance of weevil displacement was generally short. However, interpretation of these data is not straightforward because the area of habitat represented by each trap increases with the square of the distance from the core field. Thus, decreased trap captures at the more distant traps may be expected even if considerable displacement to these distances occurs.

Our results provide significant insight that will be valuable in the continued study of boll weevil dispersal, and should facilitate refinement of techniques for studying this important aspect of boll weevil ecology. These findings and similar information should prove useful in designing and implementing both region-specific buffer zones for boll weevil management programs and monitoring programs for detection of immigrants into eradicated areas.

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Table 1. Release of marked boll weevils near Caldwell, TX.

	Marked Boll Weevils		Aliquot
Date	Source	No. Released	Females : Males
8/27/98	traps	9908	--
9/1/98	traps	494	--
9/1/98	traps	5869	--
9/14/98	traps	19617	--
8/12/99	cotton	1400	18 : 49
8/17/99	cotton	1042	16 : 33
8/19/99	cotton	787	24 : 26
8/20/99	traps	1134	22 : 28
8/21/99	traps	1180	27 : 23
8/22/99	traps	1664	28 : 22
8/24/99	traps	1147	28 : 22
8/26/99	traps	5050	29 : 30
9/1/99	traps	1467	23 : 26
9/2/99	traps	8250	23 : 28
9/8/99	traps	18500	25 : 25
9/9/99	traps	1100	25 : 25
9/14/99	traps	1043	24 : 26

Table 2. Sector summary of prevailing wind heading and recapture of marked boll weevils in pheromone traps located 1, 2, 3, 4, and 5 miles from the core field (2-acre cotton plot) near Caldwell, TX, from 28 August 1998 to 13 October 1998.

		Recaptured Boll Weevils	
Sector	Percent Frequency of Wind	No.	Percent of Total
East	4.9	26	16.5
Southeast	13.4	21	13.3
South	19.3	40	25.3
Southwest	18.6	15	9.5
West	14.6	12	7.6
Northwest	17.8	20	12.7
North	6.8	11	7
Northeast	4.7	13	8.2

Table 3. Sector summary of prevailing wind heading and recapture of marked boll weevils in pheromone traps located 1, 2, 3, 4, and 5 miles from the core field (2-acre cotton plot) near Caldwell, TX, from 12 August 1999 to 19 October 1999.

		Recaptured Boll Weevils	
Sector	Percent Frequency of Wind	No.	Percent of Total
East	8.1	6	3
Southeast	3.0	2	1
South	2.4	9	4
Southwest	13.3	8	4
West	15.6	5	2
Northwest	19.1	15	7
North	16.3	172	77
Northeast	22.2	7	3

Table 4. Total recapture of marked boll weevils before and after a 2-acre cotton plot (core field) near Caldwell, TX, was shredded and plowed on 6 September.

	Marked Boll Weevils	
Date	< 6 September	≥ 6 September
8/12/99	0	0
8/17/99	3	0
8/19/99	1	0
8/20/99	8	0
8/21/99	0	1
8/22/99	0	0
8/24/99	2	5
8/26/99	6	57
9/1/99	0	1
9/2/99	0	57
9/8/99	--	310
9/9/99	--	4
9/14/99	--	11

Total captures represent captures from all (N=71) pheromone traps in trapline.

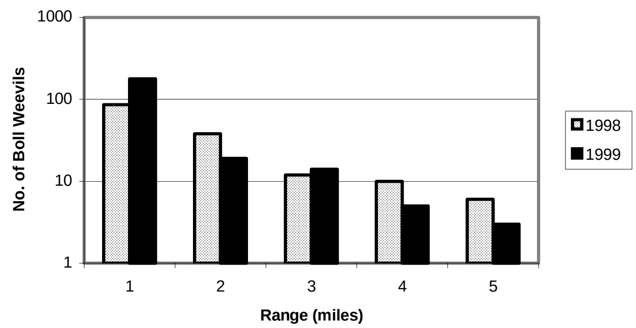
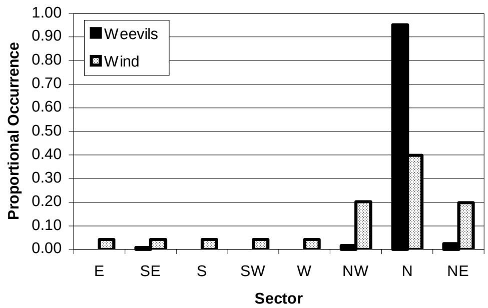
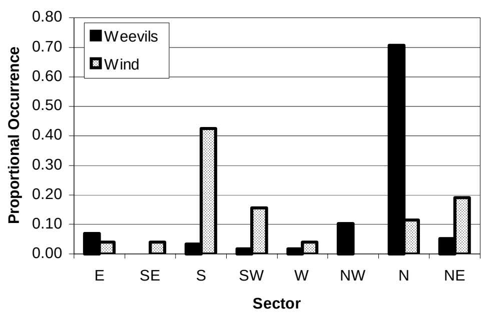


Figure 1. Recapture of marked bollweevils in pheromone traps at 1, 2, 3, 4 and 5 miles form a 2-acre cotton plot (core field) near Caldwell, TX.

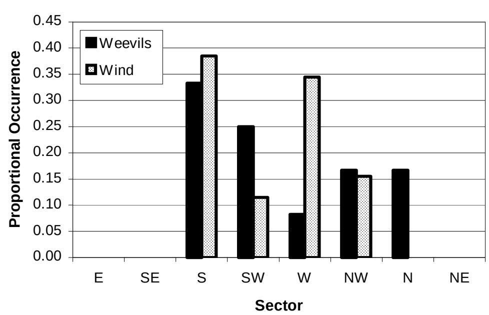
a. 8 September (N=126 boll weevils)



b. 9 September (N=58 boll weevils)



c. 10 September (N=12 boll weevils)



d. 11 September (N=4 boll weevils)

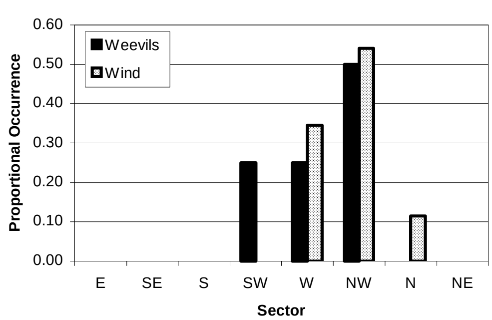


Figure 2. Propostional occurrence of prevailing wind heading (during daylight hours of previous and current date) and capture of marked boll weevils in pheromone traps located at ranges of 1, 2, 3, 4 and 5 miles form a central release location near Caldwell, TX on 8-11 September 1999.