SEASONAL FLIGHT ACTIVITY OF THE MAIZE WEEVIL, *SITOPHILUS ZEAMAIS* MOTSCHULSKY (COLEOPTERA: CURCULIONIDAE), AND THE RICE WEEVIL, *S. ORYZAE* (L.), IN SOUTH CAROLINA[1]

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ABSTRACT

Flight activity of *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae) and *S. oryzae* (L.) was monitored during 1987-88 with sticky traps at three sites in South Carolina. Weevils were caught from late March to early November. The results indicate that temperature is the major factor determining seasonal flight activity of these weevils. More *S. zeamais* than *S. oryzae* were trapped at all sites. *Sitophilus oryzae* were abundant only at the site at which wheat was stored. There was no apparent pattern to flight activity within a storage site. The results indicate that there is little flight activity around bins in which recommended pest control practices are followed.

Key Words: Insecta, *Sitophilus zeamais, Sitophilus oryzae,* stored products, seasonal flight activity.

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The maize weevil (SZ), *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae), and the rice weevil (SO), *S. oryzae* (L.), are major pests of stored grains throughout most of the world. The bionomics of these species has been intensively studied in the laboratory (Longstaff 1981); however, field studies on their bionomics are rare.

Knowledge of the seasonal flight activity of both weevil species is an important step toward understanding their population dynamics, which is essential for making knowledgeable pest control decisions. There are several reports on the seasonal flight activity of SZ. Kirk (1965) reported on flight activity of SZ from April through September near a corn storage area in South Carolina. The weevils in that paper were originally designated as *S. oryzae;* however, Giles (1969) later identified the weevils as *S. zeamais.* Giles (1969) moved one suction trap to various sites in Kenya over a 1-year period and reported on SZ flight activity. Williams and Floyd (1970) reported on flight activity of SZ throughout the year at a corn storage site in Louisiana. There are no comprehensive data on the seasonal flight activity of SO. Schwitzgebel and Walkden (1944) caught a few rice weevils on sticky traps at a wheat storage site in Kansas. No previous reports have been published on the comparative seasonal flight activity of the two species. We report here on the seasonal flight activity of SO and SZ at three grain storage sites in South Carolina.

[1] Names of products are included for the benefit of the reader and do not imply endorsement or preferential treatment by USDA.

MATERIALS AND METHODS

Weevil flight was monitored weekly, using sticky traps, in three counties in southern South Carolina from 18 March 1987 to 6 April 1988. At each site, traps were arranged in two approximately concentric rings. At the Hampton Co. and Bamberg Co. sites, the inner ring consisted of four traps placed ca. 0.5 m from a bin in each of the major compass directions. The outer ring consisted of four traps, each of which was placed (if possible) in line (by compass direction) with the inner trap at varying distances from a bin (Fig. 1). Traps were placed in the northwest, northeast, east, southeast, and southwest compass directions at the Barnwell Co. site because of the large size of the storage area.

The site near Scotia (Fig. 1A: Hampton Co.) consisted of three cylindrical, metal grain storage bins (capacities in bushels: 1 - ca. 12,700; 2 & 3 - ca. 5,900 each) arranged in a north-south direction with a fourth bin (capacity ca. 17,000 bu) located east of the northernmost bin. There was a grove of about 50 pecan trees adjacent to the southernmost bin. Corn was grown south of the pecan grove (ca. 50 m south of the bins). Soybeans were grown west and north of the bins, and there were woods ca. 80 m east of the bins.

The site in Bamberg Co. (Fig. 1B) was ca. 17 km southeast of Bamberg, and consisted of four cylindrical metal bins (ca. 3,300 bu capacity each) arranged in a north - south direction. Corn was grown on the east and south sides of the bins, and there were woods ca. 40 m south of the bins. There were storage sheds and 2 - ca. 50 bu capacity bins containing hog feed supplement and oats west of the bins. Peanuts were grown north of the bins, and there was a swine production area ca. 120 m north of the bins.

The site in Barnwell Co. (Fig. 1C) was ca. 3 km northwest of Blackville, and consisted of six cylindrical metal bins (capacities: 1 & 2 - ca. 6,800 bu each; 3 & 4 - ca. 3,900 bu each; 5 & 6 - ca. 7,500 bu each) arranged in an east-west direction. There was a cow pasture on the east and north sides of the bins and a barn and office on the west side of the bins. There was an old wooden barn containing grain residue ca. 15 m southeast of the easternmost bin. There were pesticide and fertilizer storage tanks ca. 20 m south of the bins and another cow pasture ca. 50 m south of the bins. Corn was grown about 250 m south of the bins.

Traps were 12 by 12 by ⅛ in (30.48 by 30.48 by 0.32 cm) clear plexiglass supported vertically on a 2 by 2 by 60 in (5.08 by 5.08 by 152.4 cm) wooden stake. The flat surface of the trap was placed at a tangent to the bin. Twelve inches (30.48 cm) of the stake was buried in the ground. Therefore, the bottom of the plexiglass trap was 4 ft (121.9 cm) above the ground, or at approximately the height of ears of corn on a plant. Kirk (1965) reported that a majority of SZ fly at corn ear height. Clear plastic film was taped to both sides of the traps and a 23 by 23 cm area on both sides of the trap was coated with a sticky substance (Tangle-Trap™, Tanglefoot Co., Grand Rapids, MI).

The traps were changed weekly at each site. Weevils were removed with forceps and identified in the laboratory (Halstead 1964). The plastic film on the traps was removed and discarded, and new film and Tangle-Trap™ were placed on the plexiglass traps.

The type and approximate quantity of commodity stored in each bin at each of the sites was observed and recorded every 4 weeks. Corn, soybeans, and sunflower seeds were stored at the Hampton Co. site (Fig. 2); corn, soybeans, and mixtures

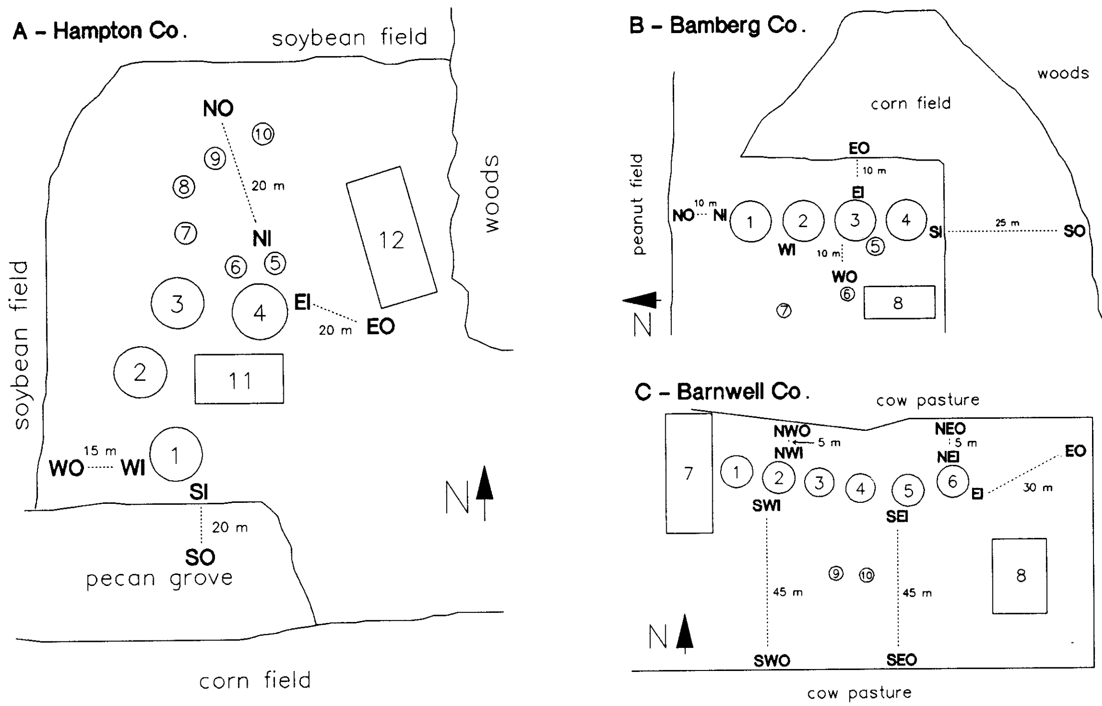

Fig. 1. Location of sticky traps at: A, Hampton Co.; B, Bamberg Co.; and C, Barnwell Co. (not drawn exactly to scale). Location of sticky traps is indicated by a location designation. For example, NI indicates the location of the north inner trap and NO indicates the location of the north outer trap. Distances between the bins and the traps are shown. A: 1-4 - Grain bins; 5-10 small, empty storage bins; 11 - concrete loading slab; 12 - equipment shed. B: 1-4 - Grain bins; 5-7 - small bins containing hog feed supplement or oats; 8 - equipment building. C: 1-6 - Grain bins; 7 - office and barn; 8 - barn; 9-10 - fertilizer and pesticide storage.

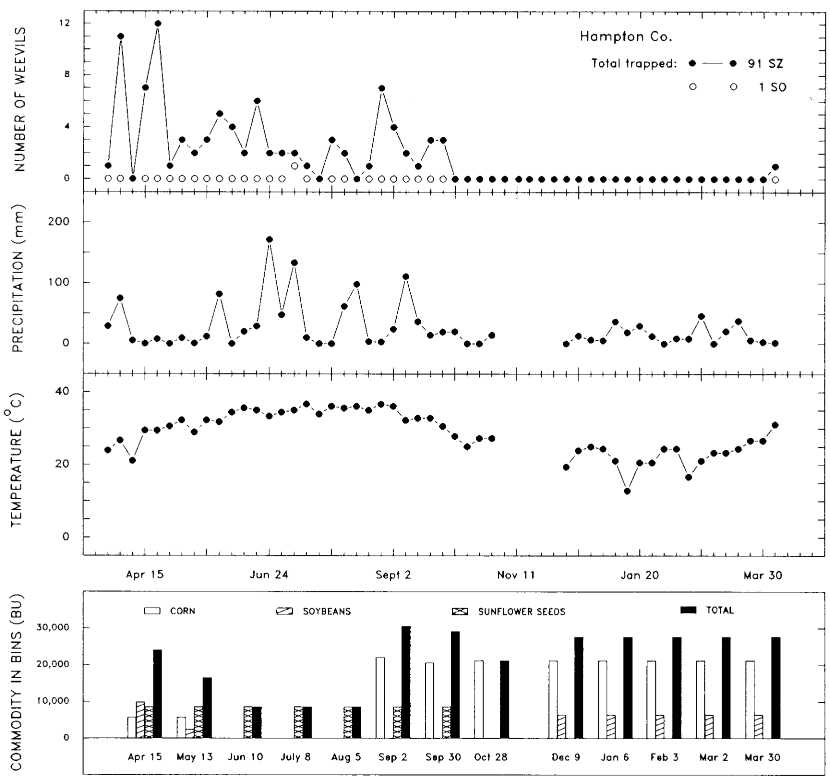

Fig. 2. Number of weevils, total precipitation, and maximum temperature per week; and quantity and type of commodity stored in 4 bins at Hampton Co. Precipitation and temperature data were not reported by NOAA for Hampton Co. for November 1987. Hence, the missing data in the precipitation and temperature curves.

of corn and wheat and corn and sorghum were stored at the Bamberg Co. site (Fig. 3); and corn and wheat were stored at the Barnwell Co. site (Fig. 4). Climatological data (daily precipitation and maximum and minimum temperatures) were taken from National Oceanic and Atmospheric Administration records for Bamberg (Bamberg Co.), Blackville (Barnwell Co.), and Hampton (Hampton Co.), SC (NOAA 1987, 1988). Trap catches were analyzed as a split-plot design with the two sides of a trap being the subplots. Trapping data were analyzed using the ANOVA (analysis of variance) and REG (linear regression) procedures of SAS (SAS Institute, 1987). Probabilities less than or equal to 0.05 were considered statistically significant.

RESULTS

Hampton County

Ninety-one SZ were caught at the Hampton Co. site during the trapping period. SZ were caught during most weeks beginning when the traps were placed in the field in March through 30 September 1987 (Fig. 2). The first SZ for 1988 was caught between 30 March and 6 April.

Weekly trap catch from 18 March through 30 September 1987 was not highly correlated with weekly precipitation (Fig. 2; R=0.08, df=25). No SZ were caught during weeks that had a maximum temperature less than 23.9° C (Fig. 2). Corn, soybeans, and sunflower seeds were stored at this site during the study (Fig. 2).

The proportion of males caught in the traps ($\bar{x}$ = 0.69; SE = 0.05; n = 71) was significantly greater than 0.5 (95% confidence interval: 0.59 to 0.79). Sixty-one males and 30 females were caught. The numbers of SZ caught on the side of the traps facing the bins (38) and the side not facing the bins (53) were not significantly different (F = 2.4; df = 1,381; P > F = 0.12). Significantly more SZ were caught on the 4 inner traps (67) than on the outer traps (24) (F = 18.6; df = 1,162; P > F = 0.00). There were significant differences in the number of SZ caught in each of the 4 compass directions (F = 12.4; df = 3,162; P > F = 0.00). More SZ were caught on the east (43) and north (31) traps than on the west (13) and south (4) traps (means separated by LSD). The only significant first-order interactions were between compass direction and the inner or outer ring of traps (F = 2.85; df = 3,162; P > F = 0.04) and between the inner or outer ring of traps and week (F = 1.6; df = 54,162; P > F = 0.01).

Only one SO was caught at this site during the study (Fig. 2). It was a male and was caught on the bin side of the east inner trap during the week preceding 8 July 1987.

Bamberg County

We caught 173 SZ at the Bamberg Co. site. SZ were caught during most weeks beginning in March through 25 November 1987 (Fig. 3). The first SZ for 1988 was caught between 30 March and 6 April.

Weekly trap catch from 18 March through 25 November 1987 was not highly correlated with weekly precipitation (Fig. 3; R = 0.22, df = 34). No SZ were caught during weeks that had a maximum temperature less than 23.3° C (Fig. 3). Corn, soybeans, and mixtures of corn and wheat and corn and sorghum were stored at this site during the study (Fig. 3).

The proportion of males caught in the traps ($\bar{x}$ = 0.44; SE = 0.04; n = 131) was not significantly different from 0.5 (95% confidence interval: 0.36 to 0.52). Seventy-six males and 97 females were caught. The numbers of SZ caught on the side of the traps facing the bins (76) and the side not facing the bins (97) were not significantly different (F = 3.09; df = 1,381; P > F = 0.08). Significantly more SZ were caught on the inner traps (120) than on the outer traps (53) (F = 14.6; df = 1,162; P > F = 0.00). The numbers of SZ caught in each of the 4 compass directions (W - 53; S - 50; N - 42; E - 28) were not significantly different (F = 1.63; df = 3, 162; P > F = 0.19). The significant first-order interactions were between compass direction and the inner or outer ring of traps (F = 5.0; df = 3, 162; P > F = 0.00) and between bin or non-bin sides of the traps and week (F = 1.42; df = 54,381; P > F = 0.03).

Eight SO were caught between 24 June and 23 September 1987 (Fig. 3). There were five males and three females. Three were caught on west traps, three on

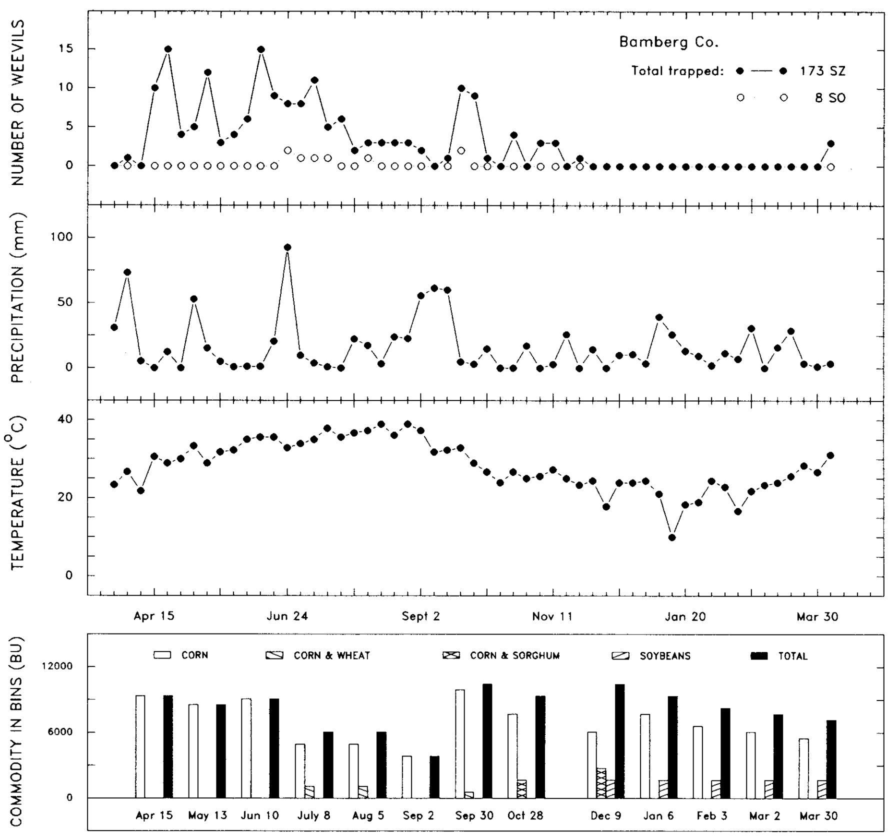

Fig. 3. Number of weevils, total precipitation, and maximum temperature per week; and quantity and type of commodity stored in 4 bins at Bamberg Co.

north traps, and two on south traps. Four were caught on inner traps and four on outer traps. Six were caught on the bin side of the traps and two on the side of the traps not facing the bins.

Barnwell County

We caught 282 SZ at the Barnwell Co. site. SZ were caught during most weeks beginning 1 April and through 4 November 1987 (Fig. 4). The first SZ for 1988 was caught between 16 and 23 March.

Weekly trap catch from 18 March through 4 November 1987 was not highly correlated with weekly precipitation (Fig. 4; R = 0.14, df = 31). No SZ were caught during weeks that had a maximum temperature less than 26.1° C (Fig. 4). Corn and wheat were stored at this site during the study (Fig. 4).

The proportion of males caught in the traps ($\bar{X}$ = 0.37; SE = 0.03; n = 160) was significantly less than 0.5 (95% confidence interval: 0.30 to 0.43). One hundred and seven males and 175 females were caught. Significantly more SZ were caught on the side of the traps facing the bins (166) than on the side not facing the bins (116) ($F = 5.8$; df = 1,490; $P > F = 0.02$). The numbers of SZ caught on the inner (162) and outer (120) traps were not significantly different ($F = 1.7$; df = 1,216; $P > F = 0.20$). Differences in the number of weevils caught in each of the different compass directions were significantly different ($F = 9.3$; df = 3,216; $P > F = 0.00$). More SZ were caught on the east (112) and northeast traps (93) than on the northwest (43), southeast (29), or southwest (5) traps (means separated with LSD). There were significant first-order interactions between compass direction and inner or outer traps ($F = 12.6$; df = 4,216; $P > F = 0.00$); between compass direction and bin or non-bin side of traps ($F = 3.3$; df = 4,490; $P > F = 0.01$); and between bin or non-bin side of traps and the inner or outer ring of traps ($F = 4.1$; df = 4,490; $P > F = 0.04$).

We caught 150 SO at the Barnwell Co. site. SO were caught during most weeks beginning 1 April and through 14 October 1987 (Fig. 4). No SO were caught during the trapping period in 1988 (through April 6), although two were caught in March in 1987.

Weekly trap catch from 18 March through 14 October 1987 was not highly correlated with weekly precipitation (Fig. 4; $R = -0.06$, df = 28). No SO were caught during weeks that had a maximum temperature less than 26.1° C (Fig. 4). Corn and wheat were stored at this site during the study (Fig. 4).

The proportion of males caught in the traps ($\bar{x} = 0.31$; SE = 0.04; n = 89) was significantly less than 0.5 (95% confidence interval: 0.22 to 0.40). Forty-nine males and 101 females were caught. The numbers of SO caught on the side of the traps facing the bins (73) and the side of the traps not facing the bins (77) were not significantly different ($F = 0.1$; df = 1,490; $P > F = 0.74$). Equal numbers of SO were caught on the inner and outer traps (75 each). The numbers of SO caught in the different compass directions (NE - 49; NW - 35; SE - 26; E - 24; SW - 16) were not significantly different ($F = 2.0$; df = 3,216; $P > F = 0.09$). The significant first-order interactions were bin or non-bin side of traps and week ($F = 1.44$; df = 54,490; $P > F = 0.03$) and compass direction and the inner or outer ring of traps ($F = 6.58$; df = 4,216; $P > F = 0.01$).

Trap catch was negatively correlated with the distance of the traps from the bins for SZ across all three sites ($R = -0.42$; df = 24) and for SO at the Barnwell Co. site ($R = -0.60$; df = 8). That is, fewer weevils were caught on the traps as the distance of the traps from the bins increased. There was no apparent trend for more weevils to be caught on outer traps which were in the direction of corn fields at any of the sites.

DISCUSSION

SZ were caught in greater numbers than SO at all sites. SO catches at the Hampton Co. and Bamberg Co. sites (1 and 8, respectively) were negligible. The species composition is probably related to the commodities stored at the sites. The most SO were caught at the site (in Barnwell Co.) that stored wheat throughout the trapping period. No wheat was stored at the Hampton Co. site, and only a small amount of wheat was stored for a short time at the Bamberg Co. site. In field infestations, SO generally infest wheat and SZ infest corn (Coombs and Porter 1986).

Based on the data for Barnwell Co., the two species fly during the same part of the year (i.e., late March to the end of October). SZ generally were flying during the same part of the year at all three sites. Kirk (1965) reported that SZ were

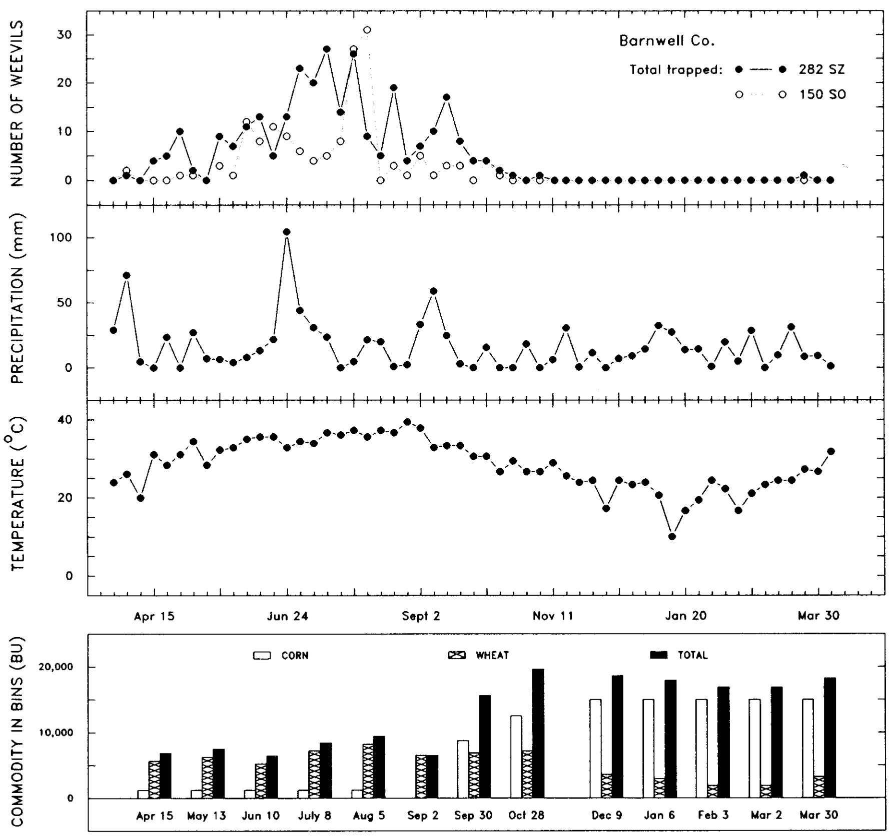

Fig. 4. Number of weevils, total precipitation, and maximum temperature per week; and quantity and type of commodity stored in 6 bins at Barnwell Co.

flying in South Carolina from April through September. However, there is no indication in his paper that he tried to trap weevils from October through March. SZ fly in March through December in Louisiana (Williams and Floyd 1970).

Many species of insects are caught on flight traps throughout the year. We caught numerous insects (mostly Diptera) on the traps throughout the winter, especially when the weather had been clear and sunny. However, SZ and SO did not fly when the maximum temperature recorded during a week was less than 23.3° to 26.1° C. These temperatures probably are not the minimum temperatures for flight, since some minimum amount of time above a threshold temperature probably is required before flight occurs. Previous field studies have indicated that the minimum temperature at which *Sitophilus* flight occurs is between 20° and 23.3° C (Giles 1969, Williams and Floyd 1970, Taylor 1971).

SZ flight is not correlated with rainfall when flight is recorded daily (Giles 1969) or weekly (present study). However, weevils, like most other insects, probably do not fly while it is raining. More frequent monitoring of traps would be required to verify this response. Light does not limit weevil flight, although most SZ fly during the day (Giles 1969). Taylor (1971) found that weevils flew at night in a warehouse when the temperature exceeded 21° C. The actual stimulus that induces *Sitophilus* flight (e.g., starvation or crowding) has not been reported.

Few consistent patterns of weevil catches were evident among the sites. More males than females were caught at Hampton Co., similar numbers of males and females in Bamberg Co., and more females than males in Barnwell Co. Similar numbers of SZ were caught on the bin and non-bin sides of the traps at all sites. However, more SO were caught on the bin sides than on non-bin sides of the traps at Barnwell Co. More weevils were caught on the inner traps than on the outer traps at Hampton and Bamberg Co. However, similar numbers of both SZ and SO were caught on the inner and outer traps at Barnwell Co. More SZ were caught on E = N > W = S traps in Hampton Co.; W = S = N = E in Bamberg Co.; and E = NE > NW = SE = SW in Barnwell Co. More SO were caught on NE = NW = SE = E = SW traps in Barnwell Co. Prevailing winds in South Carolina are from the southwest in the spring, the south and southwest in the summer, the northeast in the autumn, and the northeast and southwest in the fall (Anonymous 1978). There is no apparent correlation between trap catch and prevailing winds.

Numerous studies have indicated that SZ fly from the bins in the spring and summer, breed in corn in the field, and then emerging adults fly back to the bins in the fall to infest newly stored grain (Kirk 1965, Giles 1969, Williams and Floyd 1970, Chesnut 1972). Kirk (1965) caught 23,589 flying weevils on traps in the field during the summer, including 1,372 weevils during a 2-day period in July. We found peaks of flight activity in mid-summer (June - July) when grain stocks were low and then again in September when newly harvested grain was put into bins, indicating a similar seasonal activity pattern. However, we did not catch enormous numbers of weevils, as Kirk (1965) did. The farmers we worked with practiced good insect control procedures. Bins were thoroughly cleaned before new grain was stored. The grain was treated with a protectant insecticide when placed in storage and was aerated at various times throughout the year for temperature and moisture control. Other studies (Arbogast and Throne, unpublished data) have indicated that insect populations inside bins at these sites are generally low. We have observed that on some farms, bins are heavily infested on the inside and have huge numbers of weevils crawling on the outside of the bins. This indicates that poor insect control within bins, and subsequent overpopulation, will increase emigration from bins and possibly increase the level of infestation during the following storage season. Ungsunantwiwat and Pedersen (1978) have shown that more SZ fly from heavily infested corn than from clean corn.

The results of this study indicate that temperature is the main factor determining seasonal flight activity of SZ and SO. As seen here and in other studies, peak flight activity may occur from April through September but generally occurs in midsummer when grain stocks are low and peaks again in the fall when newly harvested grain is put into storage. SZ were generally caught at sites storing corn and SO were caught at sites storing wheat. There was no apparent pattern to where at a storage site weevils would be caught. The small number of weevils caught in this study indicates that good insect control (and, thus, low population levels) in the bins reduced emigration from the bins.

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