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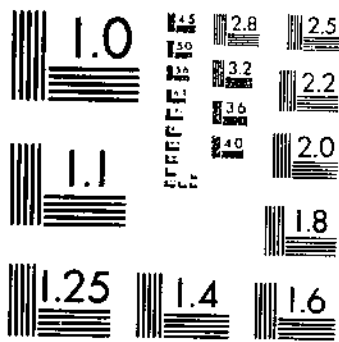
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AIRBORNE MOVEMENT OF THE PINK BOLLWORM AND OTHER ARTHROPODS

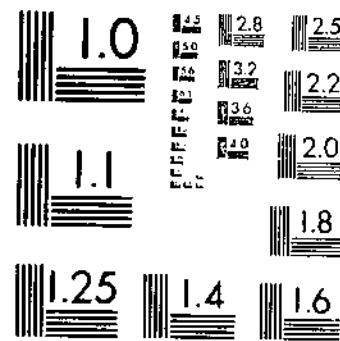
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Airborne Movement of the Pink Bollworm and Other Arthropods

By PERRY A. GLICK and L. W. NOBLE, *entomologists, Entomology Research Division, Agricultural Research Service*¹

The pink bollworm (*Pectinophora gossypiella* (Saunders)) has infested the areas surrounding Monterrey, Nuevo León, and Torreón, Coahuila, Mexico, since 1911, and the southwestern border of Texas since 1918. No doubt its advance into the United States has been greatly checked by quarantines and other measures. Despite these measures, however, the infested area has gradually increased, with a rather rapid spread in some years.

Infestation became established in central Texas through spread from the southern part of the State. The insect was first found in the lower Rio Grande Valley in 1936. It gradually advanced northward to the Robstown and Taft sections of the coastal bend by 1943 and to the Navasota, College Station, and Waco sections by 1950. Further spread was continuing at the time of this study.

The possibility of long-distance dispersal of pink bollworm adults was recognized when specimens were collected as high as 3,000 feet on airplane flights over the heavily infested Laguna District of Mexico in 1928 (Glick 1939).² The moths were again taken at altitudes of 100 to 1,000 feet on similar flights over the lower Rio Grande Valley and King Ranch areas of Texas in 1954 (Glick 1957). Long-distance movement of moths and their ability to reproduce after such flights are evident from infestation records of isolated cotton plots in western Texas, 35 to 65 miles from the nearest infested fields (Noble 1955).

The airborne movement of this insect was studied again in 1956. A series of airplane flights were made over central Texas and other localities, extending to the northeastern fringe of the quarantined area. Data were obtained on the insects and other arthropods collected at various altitudes over these localities.

PROCEDURE

An airplane equipped with insect-collecting traps, as described by Glick (1939), was used in a total of 100 flights from August 10 to October 12, 1956. The flights were made over the heavily infested area along the Brazos River from Waco to Navasota and

¹ In cooperation with the Plant Pest Control Division of the Agricultural Research Service and the Texas Agricultural Experiment Station.

² References to Literature Cited, p. 19, are herein indicated by the name of the author followed by the year of publication.

over the Red River Valley in northeastern Texas, northwestern Louisiana, southwestern Arkansas, and southeastern Oklahoma (fig. 1).

Three daily flights were scheduled—near dawn (5–7 a.m.), midday (11 a.m.–2 p.m.), and evening (7–9 p.m.). During each

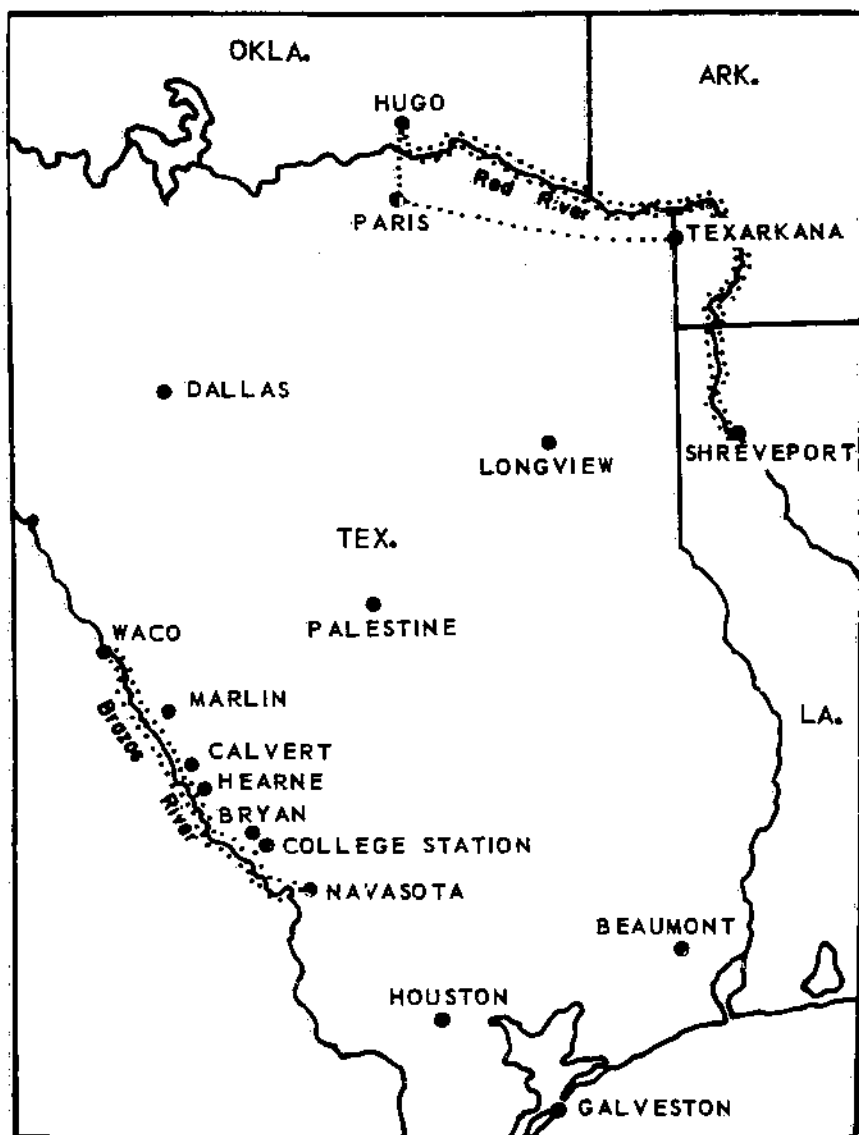


FIGURE 1.—Map showing areas over which airplane flights were made to study the airborne movement of the pink bollworm moth. Dotted lines indicate the heavily infested central Texas area and the lightly infested northeastern fringe area.

flight insect-collecting screens were exposed for approximately equal periods of time at altitudes of 200, 500, 1,000, 2,000, and 3,000 feet. The exposures totaled about 99 hours over central Texas and 40 hours over the northeastern fringe area.

Meteorological data, including temperature and humidity, were recorded during the screen exposures. Wind direction and velocity of surface and upper air were obtained from the U.S. Weather Bureau stations at localities where the flights were made. The amount of convection was determined or estimated by the "feel" of the air when flying—that is, whether the air was smooth, slightly rough, or very rough. To determine the direction of upper air currents to which moths might be subjected, 2,000 small hydrogen-filled balloons, tagged with a return address, were released at Waco and College Station during the flights. The direction and distance of balloon drift were indicated by the place of descent noted on the recovered tags.

PINK BOLLWORM

During the 100 flights 18 pink bollworm moths were collected at altitudes ranging from 200 to 2,000 feet, as shown in table 1. The greatest number were taken at 500 feet and none at 3,000 feet. The sexes were about equally represented. Four moths were taken at midday and seven each in the morning and evening. The difference in number was probably due to chance rather than the time of day. Sixteen moths were collected over central Texas, the more heavily infested area, and two over the fringe area—one at 500 feet near Garland, Ark., and the other at 2,000 feet near the intersection of the Red River and the Louisiana-Arkansas line, probably in Louisiana.

Several of the moths collected over central Texas were taken during the drift period of balloons, which were recovered. One moth was taken at 2,000 feet between College Station and Navasota on August 17, and a balloon released at College Station on the same day drifted 170 miles north. Another moth was taken at 200 feet near Waco on September 1, when a balloon drifted 100 miles north from Waco.

The moth collected at 2,000 feet between Shreveport, La., and Texarkana, Ark., on October 7 was taken during an air disturbance resulting from the passage of a cold front. Effects of the cold front on the abundance and distribution of insects in the air are discussed under Cold Front, page 6.

It is thus evident that pink bollworm moths may drift or be carried by the wind to the north and northeast from the heavily infested central Texas area. The near-surface wind was mostly from a southerly direction, and balloons released at Waco and College Station drifted predominantly to the north and northeast as far as 195 miles. Although only a few of these balloons were recovered, the data were similar to those of Gaines and Ewing (1938), who reported that during May and June balloons drifted as far as 375 miles from south-central Texas, with prevailing winds to the north and northeast.

TABLE 1.—*Pink bollworm moths collected during 100 flights, with screens exposed for equal periods of time at various altitudes, and some meteorological data, August 10 to October 12, 1956*

CENTRAL TEXAS (EXPOSED 5,985 MINUTES)

Altitude (feet) and date	Time of day	Wind		Condition of air	Sex of moths ¹
		Direction	Speed (m.p.h.)		
200:					
Aug. 21	9:56 a.m.	NE	14	Slightly rough.	Male.
23	7:16 p.m.	SSE	8	Smooth	Do.
Sept. 1	5:41 a.m.	SSE	3	do	Do.
500:					
Aug. 13	5:38 a.m.	SSW	4	do	Female.
14	{5:35 a.m.	SSW	4	do	Male.
	{7:34 p.m.	SE	10	do	Female.
25	6:09 a.m.	SSE	7	do	Do.
27	7:17 a.m.	ESE	7	Slightly rough.	Male.
28	5:38 a.m.	SE	6	Smooth	Do.
Sept. 4	4:00 p.m.	E	6	Slightly rough.	Do.
1,000:					
Aug. 11	9:50 p.m.	SE	8-10	Smooth	Female.
22	9:53 a.m.	Calm		do	Do.
Sept. 27	{9:47 a.m.	WSW	6	Rough	Do.
	{7:06 p.m.	E	4	Smooth	Do.
2,000:					
Aug. 17	8:05 p.m.	S	8	do	Do.
20	8:06 p.m.	NNE	10	do	Do.
NORTHEASTERN FRINGE OF INFESTED AREA (EXPOSED 2,370 MINUTES)					
500, Oct. 3	10:43 a.m.	SSE	7	Slightly rough.	Female.
2,000, Oct. 7	6:18 a.m.	ENE	12	Smooth	Do.

¹ Each record indicates one moth.

OTHER INSECTS, SPIDERS, AND MITES

Insect populations during this study were undoubtedly lower than usual owing to drought conditions. The flights were made during the last part of a long dry period, reported by the U.S. Weather Bureau to be the worst drought in central Texas since 1916 (Mitchell 1957). Effects of the drought were less severe in the area from Shreveport to Texarkana, where many bayous and small lakes intertwined through swamps, dense woods, and cultivated land (fig. 2).



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FIGURE 2.—Typical Red River Valley area between Shreveport, La., and Texarkana, Ark., over which insect-collecting flights were made. The Red River is in upper left, with cottonfields bordering the winding bayou in foreground.

The average number of specimens collected per 10-minute trap exposure at various altitudes over the two areas are shown in table 2. The specimens totaled 1,894 and represented 14 orders. They were collected in 138 hours and 25 minutes at altitudes of 200 to 3,000 feet. They were identified as to order, family, genus, and species when recovered in a condition permitting determination. There were 113 families, 241 genera, and 151 determined species represented in the collections. These specimens are listed in table 3.

METEOROLOGICAL DATA

Distribution of insects, spiders, and mites in the air in relation to certain meteorological conditions was reported by Glick (1939, 1957). Our findings were similar to the previous data, except that fewer insects were collected per unit of screen-exposure time, probably because of drought conditions, and there was some difference in insect activity in relation to temperature.

TABLE 2.—Number of insects, spiders, and mites collected by airplane at different altitudes over central Texas and area bordering the northeastern Texas line, August 10 to October 12, 1956

Order	Number collected at indicated altitude (feet)					Total	Percent of grand total
	200	500	1,000	2,000	3,000		
Araneida.....	27	15	13	11	10	76	4.3
Acarina.....	0	0	2	0	1	3	.2
Collembola.....	1	0	0	0	1	2	.1
Orthoptera.....	2	0	2	2	0	6	.3
Neuroptera.....	1	0	1	0	0	2	.1
Odonata.....	1	1	1	0	0	3	.2
Psocoptera.....	0	0	0	0	1	1	.1
Hemiptera.....	48	16	14	16	8	102	5.8
Homoptera.....	281	155	137	102	76	751	42.5
Coleoptera.....	50	29	21	7	1	108	6.1
Trichoptera.....	7	0	4	1	1	13	.7
Lepidoptera.....	23	18	8	14	4	67	3.8
Diptera.....	170	123	107	73	33	506	28.6
Hymenoptera.....	56	29	19	17	5	126	7.1
Unrecognizable.....	58	25	25	13	4	125	.....
Total.....	728	411	354	256	145	² 1,894	100.0
Percent of grand total.....	38.4	21.7	18.7	13.5	7.7	.....	.....
Total flying time (minutes).....	1,622	1,581	1,937	1,545	1,620	8,305	.....
Average number of specimens per 10 minutes of flying time.....	4.5	2.6	1.8	1.6	.9	2.9	.....
Central Texas.....	3.6	1.7	1.2	.6	.7	1.6	.....
Border area.....	7.4	5.0	2.8	4.5	1.5	4.0	.....

¹ Not included in calculation of percentages of grand total.

² Grand total.

Temperature

Collections in the 1956 flight compared closely with those in the Louisiana flights for 1926-31 (Glick 1939) as to temperature, except that the peak in the number of insects collected in 1956 per unit of flying time occurred when the surface temperature was about 72° F., as compared with 75° to 79° in the 1926-31 flights.

Cold Front

Wellington (1954) recognized the effects of cold fronts on insect activity and, in connection with such phenomena, the value of weather forecasts in ecological studies. He cited, as an example, an observed association between mass flights of the spruce budworm (*Choristoneura fumiferana* (Clemens)) and passages of cold

TABLE 3.—*Insects, spiders, and mites collected by airplane at different altitudes over central Texas and area bordering the northeastern Texas line, August 10 to October 12, 1956*

Order, family, genus, and species	Number collected at indicated altitude (feet)				
	200	500	1,000	2,000	3,000
ARANEIDA (spiders):					
Argiopidae:					
Undetermined sp. (immature).....	1	0	0	0	0
Ctenidae:					
<i>Zora</i> sp. (immature).....	0	0	0	0	1
Undetermined spp. (immature).....	3	1	0	0	0
Linyphiidae:					
<i>Estrandia</i> sp.	0	0	1	0	0
Undetermined spp. (immature).....	0	1	0	1	0
Undetermined spp.	1	0	0	0	1
Microphythidae:					
<i>Phleceopsis</i> spp.	2	1	0	0	0
Undetermined spp. (immature).....	1	0	0	3	0
Oxyopidae:					
<i>Oxyopes salticus</i> Hentz.	3	2	0	2	1
<i>Oxyopes</i> spp. (immature).....	2	1	0	1	1
<i>Oxyopes</i> spp.	2	0	0	2	2
Undetermined (immature).....	0	1	1	0	0
Undetermined sp.	0	0	0	0	1
Salticidae:					
<i>Phidippus</i> spp. (immature).....	1	0	1	0	0
Undetermined sp. (immature).....	0	0	0	0	1
Undetermined spp.	5	5	2	1	2
Thomisidae:					
<i>Misumenops asparatus</i> (Hentz).....	0	0	2	0	0
<i>Misumenops</i> spp. (immature).....	5	1	3	1	0
<i>Misumenops</i> spp.	1	2	3	0	0
ACARINA:					
Erythraeidae:					
<i>Balaustium</i> sp.	0	0	1	0	0
Phytoseiidae:					
Undetermined sp. (larva).....	0	0	0	0	1
Tropodidae:					
Undetermined sp.	0	0	1	0	0
COLLEMBOLA:					
Undetermined spp.	1	0	0	0	1
ORTHOPTERA:					
Gryllidae:					
<i>Acheta</i> spp.	2	0	2	1	0
Tettigoniidae:					
<i>Conocephalus</i> sp. (nymph).....	0	0	0	1	0
NEUROPTERA:					
Chrysopidae:					
<i>Chrysopa</i> sp., <i>plorabunda</i> group....	1	0	0	0	0
<i>Chrysopa</i> sp., <i>rufilabris</i> group.....	1	0	0	0	0
Hemerobiidae:					
<i>Symphorobius</i> sp. near <i>killingtoni</i> Carpenter	1	0	0	0	0
<i>Symphorobius</i> sp. near <i>perparvus</i> (McLachlan)	0	0	1	0	0
Myrmeleontidae:					
<i>Hesperoleon</i> sp.	1	0	0	0	0

TABLE 3.—*Insects, spiders, and mites collected by airplane at different altitudes over central Texas and area bordering the northeastern Texas line, August 10 to October 12, 1956—Continued*

Order, family, genus, and species	Number collected at indicated altitude (feet)				
	200	500	1,000	2,000	3,000
ODONATA:					
Aeshnidae:					
<i>Anax junius</i> (Drury).....	1	0	0	0	0
Coenagrionidae:					
<i>Enallagma</i> sp.....	0	1	0	0	0
Libellulidae:					
<i>Pantala flavescens</i> (F.).....	0	0	1	0	0
PSOCOPTERA:					
Liposcelidae:					
<i>Liposcelis</i> sp.....	0	0	0	0	1
HEMPTERA:					
Anthocoridae:					
<i>Orius insidiosus</i> (Say).....	10	2	3	3	2
<i>Orius tristicolor</i> (White).....	2	1	0	1	1
Coreidae:					
<i>Arhysus lateralis</i> (Say) (nymph).....	1	0	0	0	0
<i>Harmostes reflexulus</i> (Say).....	1	0	0	0	0
<i>Jadera haematoloma</i> (H. S.).....	0	1	0	0	0
Corixidae:					
<i>Rhampocorixa acuminata</i> (Uhler).....	0	0	0	1	0
<i>Trichocorixa kanza</i> Sailer.....	3	1	0	1	1
Lygaeidae:					
<i>Citigenes</i> spp.....	0	0	2	0	0
<i>Ezptochionera confusa</i> Barber.....	0	0	0	1	0
<i>Ezptochionera fuscicornis</i> (Stål).....	1	0	1	0	0
<i>Geocoris pallens</i> Stål.....	1	0	0	0	0
<i>Geocoris punctipes</i> (Say).....	0	1	0	0	0
<i>Heraeus plebejus</i> Stål.....	0	1	0	0	0
<i>Kleidocerys resedae geminatus</i> (Say).....	0	0	0	1	0
<i>Nysius californicus alabamensis</i> Baker.....	1	0	0	0	1
<i>Nysius ericae</i> (Schill.).....	4	0	1	0	0
<i>Nysius raphanus</i> Howard.....	5	2	2	1	1
<i>Pachybrachius bilobatus</i> (Say).....	1	0	0	0	0
<i>Perigenes constrictus</i> (Say).....	1	0	0	0	0
<i>Phleggyus annuliferus</i> Stål.....	0	0	0	1	0
<i>Vulonetus puberulus</i> (Stål).....	1	0	0	0	0
Miridae:					
<i>Ceratocarpus apicalis</i> Knight.....	1	0	1	0	0
<i>Lygus lineolaris</i> (P. de B.).....	2	0	0	0	0
<i>Lygus pallidulus</i> (Blanchard).....	0	1	0	1	0
<i>Psallus seriatus</i> (Reuter).....	2	0	0	1	1
<i>Reuterocopus sulphureus</i> (Reuter).....	0	0	0	1	0
<i>Trigonotylus dohertyi</i> (Distant).....	0	1	0	0	0
Nabidae:					
<i>Nabis alternatus</i> Parshley.....	1	1	0	0	0
Neididae:					
<i>Aknisus multispinus</i> Ashm.....	1	2	0	1	1
Pentatomidae:					
<i>Amnesus pusio</i> of authors, not Stål.....	6	0	0	0	0
<i>Corimelaena incognita</i> (McA. & M.).....	0	0	0	1	0
<i>Oebalus pugnax</i> (F.).....	1	0	0	0	0
Piesmididae:					
<i>Piesma cinereum</i> (Say).....	1	1	2	1	0

TABLE 3.—*Insects, spiders, and mites collected by airplane at different altitudes over central Texas and area bordering the northeastern Texas line, August 10 to October 12, 1956—Continued*

Order, family, genus, and species	Number collected at indicated altitude (feet)				
	200	500	1,000	2,000	3,000
HEMIPTERA—Continued					
Reduviidae:					
<i>Sinea</i> sp. (nymph).....	1	0	0	0	0
Tingidae:					
<i>Corythucha marmorata</i> (Uhler).....	0	1	1	0	0
<i>Corythucha morrilli</i> Osb. & D.....	1	0	0	0	0
HOMOPTERA:					
Aleyrodidae:					
<i>Trialeurodes abutilonea</i> (Hald.).....	2	1	0	0	0
Undetermined spp.....	0	2	2	0	0
Aphidae:					
<i>Aphis</i> spp.....	3	0	0	0	0
<i>Myzocallis</i> spp.....	1	0	0	0	3
<i>Pemphigus</i> spp.....	5	3	1	0	1
<i>Rhopalosiphum fitchii</i> Sand.....	1	0	0	0	0
<i>Therioaphis maculata</i> (Buckl.).....	2	0	0	0	1
Tribe Aphini, undetermined sp.....	0	0	0	1	0
Cicadellidae:					
<i>Aceratagallia uhleri</i> (Van D.).....	0	1	0	0	0
<i>Aceratagallia</i> spp. (females).....	1	1	0	1	1
<i>Acinopterus angulatus</i> Lawson.....	1	1	0	0	0
<i>Acinopterus</i> spp. (females).....	3	3	0	0	0
<i>Alconeura macra</i> Griff.....	2	2	2	1	0
<i>Alconeura</i> spp. (females).....	0	1	2	0	0
<i>Carneocephala flaviceps</i> (Riley).....	3	2	2	0	0
<i>Carneocephala</i> spp.....	2	0	0	0	0
<i>Chlorotettix</i> sp. (female).....	1	0	0	0	0
<i>Circulifer tenellus</i> (Baker).....	0	0	0	0	1
<i>Deltocephalus sonorus</i> Ball.....	25	21	10	9	1
<i>Dikraneura</i> sp. (female).....	0	0	0	1	0
<i>Drucculacephala</i> sp. (female).....	1	0	0	0	0
<i>Empoasca fabae</i> (Harris) (males).....	6	1	0	0	0
<i>Empoasca fabae</i> (Harris) (females).....	12	0	2	1	0
<i>Empoasca fabae</i> (Harris) (sex not determined).....	3	3	7	0	0
<i>Empoasca sativae</i> Poos (female).....	0	0	1	0	0
<i>Empoasca solana</i> DeL. (males).....	2	2	3	1	1
<i>Empoasca soiana</i> DeL. (females).....	18	10	4	4	2
<i>Empoasca</i> spp. (females).....	6	11	14	16	2
<i>Empoasca</i> spp. (sex not determined).....	1	1	1	3	0
<i>Empoasca</i> spp. (nymphs).....	2	0	0	0	0
<i>Erythroneura</i> (<i>Erythroneura</i>) sp. (female).....	1	0	0	0	0
<i>Eritianus eritiosus</i> (Uhler).....	55	21	31	17	32
<i>Flexamia pirta</i> (Osborne).....	0	1	0	0	0
<i>Flexamia</i> sp.....	1	0	0	0	0
<i>Graminella nigrifrons</i> (Forbes).....	6	4	2	1	0
<i>Gyponana angula</i> DeL.....	1	0	0	0	0
<i>Limotettix</i> spp. near <i>striolus</i> (Fall.).....	0	0	2	0	0
<i>Limotettix</i> sp. (female).....	1	0	0	0	0
<i>Macrosteles fusiformis</i> (Stål).....	3	6	0	3	1
<i>Macrosteles</i> spp. (females).....	17	7	10	6	3
<i>Macrosteles</i> spp.....	1	2	0	2	3

TABLE 3.—*Insects, spiders, and mites collected by airplane at different altitudes over central Texas and area bordering the northeastern Texas line, August 10 to October 12, 1956—Continued*

Order, family, genus, and species	Number collected at indicated altitude (feet)				
	200	500	1,000	2,000	3,000
HOMOPTERA—Continued					
Cicadellidae—Continued					
<i>Mesamia nigridorsum</i> (Ball).....	1	2	0	1	1
<i>Nesosteles neglectus</i> (DeL. & D.).....	12	5	8	7	2
<i>Nesosteles</i> spp. (females).....	19	4	6	4	10
<i>Nesosteles</i> spp.....	2	2	2	1	3
<i>Ollarianus strictus</i> (Ball).....	4	1	1	0	1
<i>Paraphlepsius irroratus</i> (Say).....	0	0	0	2	0
<i>Scaphytopius frontalis</i> (Van D.).....	0	0	0	1	0
<i>Scaphytopius loricatus</i> (Van D.).....	11	5	5	1	1
<i>Scaphytopius</i> spp. (females).....	0	2	0	0	0
<i>Scaphytopius</i> sp.....	0	1	0	0	0
<i>Scaphytopius</i> sp. (nymph).....	1	0	0	0	0
<i>Stirellus bicolor</i> (Van D.).....	2	2	1	0	0
<i>Zygina</i> sp. (female).....	0	0	1	0	0
Undetermined spp.....	0	2	0	0	0
Cixiidae:					
<i>Cixius</i> spp. (females).....	6	0	2	0	0
<i>Cixius</i> spp.....	3	0	1	1	0
<i>Oecleus</i> sp. (female).....	0	1	0	0	0
<i>Ollarius aridus</i> Ball.....	0	1	1	0	0
<i>Ollarius texanus</i> Metc.....	1	0	0	1	0
<i>Ollarius</i> sp. (female).....	0	1	0	0	0
<i>Ollarius</i> sp.....	1	0	0	0	0
<i>Pseudocixius stigmatus</i> (Say).....	3	0	0	0	0
Undetermined sp.....	1	0	0	0	0
Delphacidae:					
<i>Delphacodes basivitta</i> (Van D.).....	1	0	0	1	0
<i>Delphacodes puella</i> (Van D.).....	3	2	0	1	0
<i>Delphacodes</i> spp. (females).....	3	1	1	0	0
<i>Delphacodes</i> spp.....	1	0	1	0	1
<i>Euidella magnistyla</i> (Cwfd.).....	0	1	0	0	0
<i>Liburniella ornata</i> (Stål).....	8	7	3	1	4
<i>Peregrinus maidis</i> (Ashm.).....	1	0	1	0	0
<i>Pissonotus 4-pustulatus</i> (Van D.).....	0	1	0	0	0
<i>Sogata meridiana</i> Bmr.....	0	1	0	0	0
<i>Sogata</i> spp. (females).....	1	0	0	1	0
<i>Sogata</i> sp.....	1	0	0	0	0
Undetermined spp.....	4	2	2	0	1
Membracidae:					
<i>Campylenchia latipes</i> Say.....	0	1	0	0	0
<i>Vanduzeeia laeta segmentata</i> (Fowl.).....	0	1	0	0	0
Psyllidae:					
<i>Heteropsylla terana</i> Cwfd.....	0	0	0	1	0
<i>Pachyopsylla cellidis-mamma</i> (Riley).....	0	1	4	1	0
<i>Trioxa diospyri</i> (Ashm.).....	1	1	1	1	0
COLEOPTERA:					
Anobiidae:					
<i>Cutorama</i> spp.....	1	1	0	0	0
Anthicidae:					
<i>Anthicus</i> spp.....	4	0	3	0	0
<i>Nolatus</i> spp.....	0	3	1	0	0

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TABLE 3.—Insects, spiders, and mites collected by airplane at different altitudes over central Texas and area bordering the northeastern Texas line, August 10 to October 12, 1956—Continued

Order, family, genus, and species	Number collected at indicated altitude (feet)				
	200	500	1,000	2,000	3,000
COLEOPTERA—Continued					
Bruchidae:					
<i>Zabrotes subfasciatus</i> (Boh.)	1	0	0	0	0
Carabidae:					
Undetermined spp.	2	0	0	0	0
Chrysomelidae:					
<i>Chaetocnema</i> sp., probably <i>pulicaria</i> Melsh.	0	1	1	0	0
<i>Diachus</i> sp., probably <i>auratus</i> (F.)	3	1	0	0	0
<i>Epitrix</i> sp., probably <i>hirtipennis</i> (Melsh.)	1	2	2	0	0
<i>Glyptina</i> sp., probably <i>atriventris</i> Horn.	0	0	0	1	0
<i>Lema</i> sp., probably <i>lecontei</i> Clark	0	0	1	0	0
<i>Pachybrachys</i> sp.	1	0	0	0	0
Coccinellidae:					
<i>Hippodamia convergens</i> G. M.	0	0	1	0	0
<i>Hyperaspis fimbriolata</i> Melsh.	2	0	0	0	0
<i>Scymnus</i> (<i>Pallus</i>) <i>loewii</i> Muls.	6	4	4	2	0
Cucujidae:					
<i>Cathartus quadricollis</i> LeConte	1	1	0	0	0
Curculionidae:					
<i>Anacentrinus deplanatus</i> (Csy.)	1	1	0	0	0
<i>Anthonomus grandis</i> Boh.	1	1	0	0	0
<i>Apion</i> sp.	0	0	0	0	1
Elateridae:					
<i>Conoderus bellus</i> (Say)	1	0	0	0	0
Lathridiidae:					
<i>Corticaria</i> spp.	2	1	0	0	0
<i>Melanophthalma distinguenda</i> (Com.)	2	2	1	0	0
<i>Melanophthalma</i> spp.	1	2	1	0	0
Melyridae (Malachiidae):					
<i>Collops balteatus</i> Lec.	1	0	0	0	0
<i>Collops vittatus</i> (Say)	2	2	2	0	0
<i>Collops</i> spp.	0	1	1	1	0
Mordellidae:					
<i>Mordellistena</i> sp.	0	1	0	0	0
Mycetophagidae:					
Undetermined spp.	3	1	0	0	0
Nitidulidae:					
<i>Carpophilus</i> spp. (male, female)	2	0	0	0	0
Phalacridae:					
Undetermined spp.	1	1	0	1	0
Scolytidae:					
<i>Hylastes</i> sp.	1	0	0	0	0
Staphylinidae:					
<i>Aleochara</i> sp.	1	0	0	0	0
<i>Astenus</i> sp.	0	0	1	0	0
<i>Carpelimus</i> sp.	0	1	0	0	0
<i>Erichsonius</i> sp.	0	0	0	1	0
<i>Lobrathium</i> sp.	0	0	1	0	0
<i>Philonthus</i> spp.	6	1	1	0	0
<i>Tachyporus jocosus</i> Say	0	1	0	0	0

TABLE 3.—*Insects, spiders, and mites collected by airplane at different altitudes over central Texas and area bordering the northeastern Texas line, August 10 to October 12, 1956—Continued*

Order, family, genus, and species	Number collected at indicated altitude (feet)				
	200	500	1,000	2,000	3,000
COLEOPTERA—Continued					
Staphylinidae—Continued					
<i>Tachyporus</i> sp.	0	0	0	1	0
Undetermined sp.	1	0	0	0	0
TRICHOPTERA:					
Hydropsychidae:					
<i>Cheumatopsyche</i> spp. (females)	2	0	0	0	0
<i>Cheumatopsyche</i> sp. (female) different....	1	0	0	0	0
<i>Hydropsyche</i> spp. (females)	2	0	3	0	1
Hydroptilidae:					
Undetermined sp.	0	0	0	1	0
Leptoceridae:					
<i>Oecetis inconspicua</i> (Walk.) (males)	2	0	1	0	0
LEPIDOPTERA:					
Coleophoridae:					
<i>Coleophora</i> spp.	2	3	0	4	1
Cosmopterygidae:					
<i>Cosmopteryx</i> sp.	1	0	0	0	0
Undetermined spp.	0	3	0	1	0
Gelechiidae:					
<i>Anacampsis</i> sp.	1	0	0	0	0
<i>Battaristis concinusetta</i> (Chamb.)	5	1	0	1	0
<i>Eucordylea</i> sp.	1	0	0	0	0
<i>Glyphidocera</i> sp.	1	0	0	0	0
<i>Pectinophora gossypiella</i> (Saund.) (males)	3	4	0	0	0
<i>Pectinophora gossypiella</i> (Saund.)					
(females)	0	5	3	3	0
<i>Stegasta basqueella</i> (Chamb.)	1	1	0	0	0
Undetermined sp.	0	0	0	1	0
Noctuidae:					
<i>Trichoplusia ni</i> (Hbn.)	1	0	0	0	0
Olethreutidae:					
Undetermined spp.	1	0	0	2	0
Phalonidae:					
<i>Phalonia</i> sp.	0	0	1	0	0
Phycitidae:					
<i>Elasmopalpus lignosellus</i> (Zeller)	0	0	1	0	0
Undetermined sp.	0	0	0	0	1
Pterophoridae:					
<i>Oiduematophorus</i> sp.	0	0	0	0	1
Pyraustidae:					
<i>Loxostege similalis</i> (Guen.)	1	1	0	0	0
<i>Microtheoris</i> spp.	0	0	1	0	1
Undetermined spp.	2	0	1	1	0
Scythrididae:					
<i>Scythris</i> spp.	1	0	1	1	0
Undetermined sp.	1	0	0	0	0
Tortricidae:					
Undetermined sp.	1	0	0	0	0
DIPTERA:					
Anthomyzidae:					
<i>Cerodontha dorsalis</i> (Lw.)	0	1	0	0	0
<i>Mumetopia occipitalis</i> Mel.	4	3	1	2	1
<i>Mumetopia</i> sp.	0	0	1	0	0

TABLE 3.—Insects, spiders, and mites collected by airplane at different altitudes over central Texas and area bordering the northeastern Texas line, August 10 to October 12, 1956—Continued

Order, family, genus, and species	Number collected at indicated altitude (feet)				
	200	500	1,000	2,000	3,000
DIPTERA—Continued					
Bombyliidae:					
<i>Mythicomyia</i> sp.	0	0	1	0	0
Cecidomyiidae:					
<i>Anarete</i> spp.	1	2	0	1	0
<i>Itonidini</i> , undetermined sp.	0	0	1	0	0
<i>Lasiopterini</i> , undetermined sp.	0	1	0	0	0
Ceratopogonidae:					
<i>Culicoides variipennis</i> (Coq.) (females)....	0	2	0	0	0
<i>Culicoides variipennis</i> (sex undetermined)	0	1	4	0	0
<i>Dasyhelea</i> spp.	0	0	1	0	1
<i>Helea</i> sp.	1	0	0	0	0
<i>Stilboclinini</i> , undetermined sp.	1	0	0	0	0
Chironomidae:					
<i>Cricotopus</i> sp.	1	0	0	0	0
<i>Diamesia</i> sp. (male)	0	0	0	1	0
<i>Diamesinae</i> , undetermined spp.	0	1	0	1	0
<i>Hydrobaeninae</i> , undetermined sp. (male)	0	0	0	0	1
<i>Hydrobaeninae</i> , undetermined sp. (female)....	0	0	1	0	0
<i>Pelopia</i> spp. (females)	4	2	0	1	0
<i>Pelopia</i> spp.	7	12	6	2	3
<i>Pelopiinae</i> , undetermined spp.	0	1	0	1	0
<i>Pentaneura</i> sp.	0	1	0	0	0
<i>Tendipedidae</i> , undetermined sp. (female)	1	0	0	0	0
<i>Tendipedinae</i> , undetermined spp. (females)....	2	0	0	0	0
<i>Tendipedini</i> , undetermined spp. (females)....	1	1	0	2	0
<i>Tendipedini</i> , undetermined spp.	6	4	7	4	2
<i>Tendipes</i> spp. (females)	4	1	2	0	1
<i>Tendipes</i> spp.	2	5	6	2	1
Chloropidae:					
<i>Chlorops certima</i> Ad.	1	0	0	0	0
<i>Diptotoza versicolor</i> Lw.	1	0	0	0	0
<i>Elachiptera nigriceps</i> (Lw.)	0	1	0	0	0
<i>Hippelates dissidens</i> (Tuck.)	2	1	3	1	1
<i>Hippelates particeps</i> (Beek.)	0	2	3	0	1
<i>Hippelates pusio</i> Lw.	4	8	1	0	0
<i>Madiza parva</i> (As.)	0	2	0	0	0
<i>Madiza</i> sp.	1	0	0	0	0
<i>Meromyza americana</i> Fitch.	2	1	2	0	0
<i>Oscinella carbonaria</i> (Lw.)	1	0	0	1	0
<i>Oscinella coxendix</i> (Fitch)	2	0	0	0	0
<i>Pseudogaurax anchora</i> (Lw.)	0	1	0	0	0
<i>Thaumatomyia glabra</i> (McG.)	18	9	8	8	4
Undetermined sp.	0	0	1	0	0
Culicidae:					
<i>Culex tarsalis</i> Coq.	0	2	3	1	0
<i>Culex</i> spp.	2	5	1	0	0
Dolichopodidae:					
<i>Chrysotus</i> spp.	7	5	3	0	0

TABLE 3.—Insects, spiders, and mites collected by airplane at different altitudes over central Texas and area bordering the northeastern Texas line, August 10 to October 12, 1956—Continued

Order, family, genus, and species	Number collected at indicated altitude (feet)				
	200	500	1,000	2,000	3,000
DIPTERA—Continued					
Dolichopodidae—Continued					
<i>Hydrophorus</i> spp. (females).....	0	0	0	2	0
<i>Hydrophorus</i> sp.....	1	0	0	0	0
<i>Thrypticus</i> spp.....	2	0	0	0	0
Undetermined spp.....	18	8	7	7	2
Drosophilidae:					
<i>Drosophila</i> spp.....	2	1	2	1	0
<i>Scaptomyza</i> spp.....	1	2	0	3	0
Empididae:					
<i>Drapetis</i> spp. (females).....	16	9	9	10	4
Ephydriidae:					
<i>Discocerina</i> spp.....	1	0	2	0	0
<i>Ephydra</i> sp.....	1	0	0	0	0
Ephydrini, undetermined sp.....	1	0	0	0	0
Notophiliinae, undetermined sp.....	0	1	0	0	0
Parydrinae, undetermined sp.....	0	1	0	0	0
<i>Philygria debilis</i> Loew.....	1	0	0	0	0
<i>Scatella</i> spp.....	2	0	1	0	1
Lonchaeidae:					
<i>Lonchaea</i> sp.....	0	1	0	0	0
Mülichiiidae:					
<i>Desmometopa M-nigrum</i> (Zett.).....	5	4	3	0	2
<i>Desmometopa</i> spp.....	1	0	1	5	0
Muscidae:					
<i>Fannia</i> spp.....	1	0	1	0	0
<i>Hylemya</i> spp.....	0	0	1	2	1
<i>Siphona irritans</i> (L.).....	1	0	0	0	0
Mycetophilidae:					
Undetermined sp.....	0	0	0	1	0
Otitidae:					
<i>Euzesta notata</i> (Wied.).....	0	1	0	1	0
Phoridae:					
<i>Megaselia</i> spp.....	3	0	2	2	0
Undetermined spp.....	3	2	1	4	1
Pipunculidae:					
<i>Tomosvaryella</i> sp.....	0	0	1	0	0
Sarcophagidae:					
<i>Sarcophaga (Rariviva) ochracea</i> Ald.....	1	0	0	0	0
<i>Sarcophaga (Orysarcodexia) ventricosa</i> Wulp.....	1	0	1	0	0
Sciariidae:					
<i>Bradysia</i> sp.....	1	0	0	0	0
Sepsidae:					
<i>Sepsis</i> spp.....	2	0	0	0	1
Undetermined spp.....	1	0	1	0	1
Sphaeroceridae:					
<i>Leptocera exigua</i> Spuler.....	1	0	1	0	0
<i>Leptocera fontinalis</i> (Fall.).....	1	0	0	0	0
<i>Leptocera wheeleri</i> Spuler.....	0	0	1	0	0
<i>Leptocera</i> spp.....	9	3	3	1	0

TABLE 3.—Insects, spiders, and mites collected by airplane at different altitudes over central Texas and area bordering the northeastern Texas line, August 10 to October 12, 1956—Continued

Order, family, genus, and species	Number collected at indicated altitude (feet)				
	200	500	1,000	2,000	3,000
DIPTERA—Continued					
Syrphidae:					
<i>Allograpta obliqua</i> (Say).....	0	1	0	0	0
<i>Baccha</i> sp.....	0	0	1	0	0
<i>Mesograpta emarginata</i> (Say).....	0	0	0	1	0
<i>Mesograpta marginata</i> (Say) (females).....	0	1	2	0	0
<i>Mesograpta marginata</i> (Say).....	5	4	0	1	0
<i>Mesograpta polita</i> (Say).....	2	0	0	0	0
<i>Sphaerophoria</i> sp. (female).....	0	0	0	1	0
Tachinidae:					
<i>Paradidyma</i> sp.....	1	0	0	0	0
Undetermined sp.....	1	0	0	0	0
Tephritidae:					
<i>Euaressta bella</i> (Lw.).....	0	0	4	0	0
<i>Neaspilota</i> sp.....	1	0	0	0	0
<i>Orellia</i> sp.....	0	0	0	0	1
<i>Paroxyta</i> spp.....	1	2	0	1	0
<i>Trupanea actinobola</i> (Lw.).....	0	0	2	2	1
<i>Trupanea</i> spp.....	2	1	2	0	0
Tipulidae:					
<i>Gonomyia helophila</i> (Alex.).....	0	0	1	0	0
<i>Gonomyia</i> spp.....	0	2	0	0	1
<i>Limnophila</i> sp.....	0	1	0	0	0
<i>Limonia</i> spp.....	2	0	0	0	0
<i>Polymeda cana</i> (Walk.).....	2	2	1	0	0
<i>Polymeda tantilla</i> (Alex.).....	0	1	0	0	1
HYMENOPTERA:					
Baetidae:					
<i>Baetis</i> sp. (subimago) (female).....	1	0	0	0	0
Bethyliidae:					
<i>Epyris</i> spp.....	0	2	0	0	0
<i>Pseudisobrachiium</i> spp.....	1	0	0	1	0
<i>Rhabdepyris</i> sp.....	0	1	0	0	0
Braconidae:					
<i>Apanteles aristoteliae</i> Vier.....	1	0	0	0	0
<i>Apanteles</i> sp.....	1	0	0	0	0
<i>Blacus</i> spp.....	0	0	0	3	0
<i>Bracon mellitor</i> Say.....	0	1	1	0	0
<i>Bracon</i> spp.....	0	0	0	2	0
<i>Chelonus</i> spp.....	2	0	0	0	0
<i>Doryctinae</i> , n. genera, n. sp.....	1	0	0	0	0
<i>Hormius vulgaris</i> Ashm.....	1	0	0	0	0
<i>Orgilus geleckiae</i> (Ashm.).....	0	0	1	0	0
Geraphronidae:					
<i>Conostigmus</i> spp.....	2	0	0	0	0
Chalcididae:					
<i>Haltichella</i> sp. (female).....	0	0	1	0	0
Cynipoiden (Eucolini):					
<i>Eucoilidea</i> sp. (female).....	1	0	0	0	0
Eucharitidae:					
<i>Oraema</i> sp.....	0	0	1	0	0

TABLE 3.—*Insects, spiders, and mites collected by airplane at different altitudes over central Texas and area bordering the northeastern Texas line, August 10 to October 12, 1956—Continued*

Order, family, genus, and species	Number collected at indicated altitude (feet)				
	200	500	1,000	2,000	3,000
HYMENOPTERA—Continued					
Eulophidae:					
<i>Aphelinini</i> , undetermined sp. (male).....	0	1	0	0	0
<i>Closterocerus cinctipennis</i> Ashm. (male)....	0	0	1	0	0
<i>Closterocerus cinctipennis</i> Ashm. (female)...	1	0	0	0	0
<i>Euplectrus</i> sp. (male).....	0	1	0	0	0
<i>Euplectrus</i> sp.....	0	1	0	0	0
<i>Tetrastichus</i> sp. (female).....	1	0	0	0	0
Eurytomidae:					
<i>Bruchophagus gibbus</i> (Boh.) (male).....	1	0	0	0	0
<i>Bruchophagus gibbus</i> (Boh.) (females)....	3	2	0	0	0
<i>Bruchophagus gibbus</i> (Boh.) (sex undetermined).....	2	0	0	0	0
<i>Bruchophagus mexicanus</i> Ashm. (males)....	2	0	0	1	0
<i>Bruchophagus mexicanus</i> Ashm. (female)...	0	0	0	1	0
<i>Bruchophagus</i> spp. (females).....	2	0	1	1	0
<i>Eurytoma</i> spp. (females).....	2	0	0	1	0
Formicidae:					
<i>Crematogaster</i> spp. (males).....	0	5	0	1	0
<i>Leptogenys elongata</i> (Buckley) (males)....	1	0	0	1	0
<i>Pheidole</i> spp. (males).....	2	1	1	1	0
<i>Pheidole</i> spp. (workers).....	3	0	1	0	0
<i>Solenopsis zyloni</i> McCook (workers).....	0	2	0	0	0
<i>Solenopsis</i> spp. (males).....	3	0	0	0	0
<i>Solenopsis (Diplophorum)</i> sp. (female)....	0	1	0	0	0
Halictidae:					
<i>Halictus (Chloroictus)</i> spp.....	2	0	1	0	0
Ichneumonidae:					
<i>Mesostenus longicaudis</i> Cress. (males)....	1	0	1	0	0
Ormyridae:					
<i>Ormyrus</i> sp. (female).....	1	0	0	0	0
Perilampidae:					
<i>Perilampus carinifrons</i> Cwfd. (female)....	1	0	0	0	0
<i>Perilampus subcarinatus</i> Cwfd.....	1	0	0	0	0
<i>Perilampus</i> spp.....	1	1	0	0	0
Pteromalidae:					
<i>Colotrechnus ignotus</i> Burks (male).....	1	0	0	0	0
<i>Cyrtogaster glasgowi</i> Cwfd. (female)....	1	0	0	0	0
<i>Eupteromalus tuckiana</i> Gibson (female)...	1	0	0	0	0
<i>Habrocytus</i> spp. (females).....	1	1	0	0	1
<i>Haliocoptera uenae</i> (Walk.) (females)....	2	0	2	0	0
<i>Haliocoptera</i> spp. (females).....	1	0	0	1	0
<i>Pachyneuron</i> spp. (females).....	1	2	0	1	0
<i>Pachyneuron</i> spp.....	1	0	0	1	0
<i>Psiloneura reftipes</i> (Ashm.) (male).....	0	0	1	0	0
<i>Pteromalini</i> , undetermined sp. (female)....	1	0	0	0	0
<i>Pteromalus</i> sp.....	0	0	1	0	0
<i>Zatropis</i> spp. (males).....	2	1	0	0	1
Scelionidae:					
<i>Ceratotelciu marlattii</i> (Ashm.).....	1	0	0	0	0
<i>Hudronotus</i> spp.....	0	2	1	0	0
<i>Teleas</i> sp.....	0	1	0	0	0
<i>Telenomus podisi</i> Ashm.....	0	0	1	0	0

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 TABLE 3.—*Insects, spiders, and mites collected by airplane at different altitudes over central Texas and area bordering the northeastern Texas line, August 10 to October 12, 1956—Continued*

Order, family, genus, and species	Number collected at indicated altitude (feet)				
	200	500	1,000	2,000	3,000
HYMENOPTERA—Continued					
Scelionidae—Continued					
<i>Telenomus</i> sp.	0	0	1	0	0
<i>Trimorus</i> sp.	0	1	0	0	0
Tiphidae:					
<i>Tiphia</i> sp.	0	1	0	0	0
Torymidae:					
<i>Liodontomerus perplexus</i> Gahan (males)...	0	0	1	0	1
<i>Liodontomerus perplexus</i> Gahan (females)	2	0	0	1	1
<i>Zaglyptomatus schwarzi</i> Cwfd. (female)...	0	1	0	0	0
Trichogrammatidae:					
<i>Trichogramma</i> sp. (male).....	0	0	1	0	0

fronts, and he gave other examples of an association between insect activity and cold-front passages, as revealed in daily variations in abundance of insects collected in a rotating net near the ground.

Two collecting flights were made in the Shreveport-Texarkana area after passage of a cold front on October 7. The cold front passed Shreveport in a southerly direction about 2:30 a.m., with a marked drop in surface temperature. The flights were from Shreveport to Texarkana and return, with respective screen exposures from 5:55 to 7:26 and 9:36 to 11:01 a.m. The insect collections were compared with those of the preceding day. This is the only known record of airplane insect-collecting flights made just before and following the passage of a cold front. Although the data are limited, they do give some information of value on the effect of this weather condition on insect distribution at various altitudes.

As shown in table 4, many more insects were taken behind the cold front on October 7 than on the preceding day ahead of the cold front. The maximum taken for both flights behind the cold front occurred at 2,000 feet, but the count at this altitude was lower for the second flight than the first. The count of 44 at this altitude was more than five times greater than that at the same level and time on the preceding day. After reviewing these data from a meteorological standpoint, Jacobs and Barre³ indicated

³ JACOBS, W. C., and BARRE, L. A., III. PERSONAL COMMUNICATION. Air Weather Serv., Mil. Air Transport Serv., U.S. Air Force, Washington, D.C. 1956.

TABLE 4.—Number of insects collected on flights between Shreveport, La., and Texarkana, Ark., ahead of and behind a cold front, and some meteorological data, 1956

Altitude (feet)	AHEAD OF COLD FRONT (OCT. 6)			AHEAD OF COLD FRONT (OCT. 6)			AHEAD OF COLD FRONT (OCT. 6)		
	5:58-7:24 a.m.			9:50-11:15 a.m.			5:40-7:06 p.m.		
	Insects collected	Temperature	Wind direction	Insects collected	Temperature	Wind direction	Insects collected	Temperature	Wind direction
	<i>Number</i>	<i>°F.</i>		<i>Number</i>	<i>°F.</i>		<i>Number</i>	<i>°F.</i>	
200.....	5	70	SSE	14	81	WSW	11	80	S
500.....	6	73	SSE	11	79	WSW	6	88	W
1,000.....	4	74	SSE	11	75	WSW	3	85	NNW
2,000.....	8	72	SSE	7	74	NNE	1	81	NW
3,000.....	4	66	ESE	8	71	NNE	1	75	N

	BEHIND COLD FRONT (OCT. 7)			BEHIND COLD FRONT (OCT. 7)			BEHIND COLD FRONT (OCT. 7)		
	5:55-7:26 a.m.			9:36-11:01 a.m.			BEHIND COLD FRONT (OCT. 7)		
	Insects collected	Temperature	Wind direction	Insects collected	Temperature	Wind direction	Insects collected	Temperature	Wind direction
200.....	22	64	ENE	21	71	ENE	.....	.....	.....
500.....	13	64	NE	12	68	ENE	.....	.....	.....
1,000.....	17	63	NNW	16	65	ENE	.....	.....	.....
2,000.....	44	61	NW	22	59	ENE	.....	.....	.....
3,000.....	6	66	NW	11	53	ENE	.....	.....	.....

that it seemed unlikely that the insects collected at 2,000 feet on October 7 were always at ground level in the area where trapped.

Comments by Franceschini and Boudreau⁴ afford an explanation of the concentration of insects at 2,000 feet following the cold front, and their explanation is founded on basic meteorological concepts. The air following the cold front has had a long trajectory over land north of the area and therefore a long sweep over insect-source areas. Furthermore, the air following the cold-front temperature inversion is unstable and is characterized by strong, gusty winds. These features, with associated turbulence and vertical mixing, would tend to stir the insects near the ground and distribute them to higher levels. However, within the cold-front temperature inversion, vertical motions are inhibited or damped. Consequently, any insects carried aloft by vertical air currents may likely be deposited within the inversion layer. Essentially, the temperature inversion acts as a lid, which prevents or restricts the vertical motion of the air. This fact may explain the maximum insect count of 44 at 2,000 feet in the cold-front temperature inversion following the cold front.

SUMMARY

In a study of airborne movement of pink bollworm moths (*Pectinophora gossypiella* (Saunders)), 100 airplane insect-collecting flights were made in 1956 over central Texas and other localities, extending to the northeastern fringe of the quarantined area. The insect-collecting screens were exposed for a total of 138 hours and 25 minutes at altitudes of 200 to 3,000 feet. Balloon drift during the collecting period indicated that pink bollworm moths may be carried by wind currents to the north and northeast from central Texas.

Spiders, mites, and 12 orders of insects were represented among 1,894 specimens collected, which included 113 families, 241 genera, and 151 determined species. Two flights after passage of a cold front showed a greatly increased number of insects in the air, particularly at the higher altitudes, and indicate the effect of such a cold front on insect dispersal.

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⁴FRANCESCHINI, G. A., and BOUDREAU, R. PERSONAL COMMUNICATION. Dept. Oceanog. and Met., Texas A. & M. Col., College Station. 1957.

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