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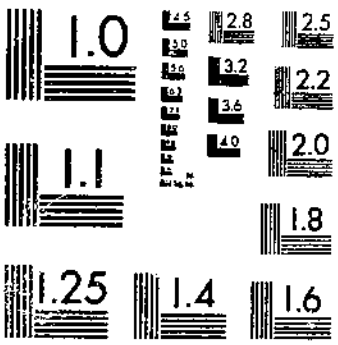

MICROCOPY RESOLUTION TEST CHART
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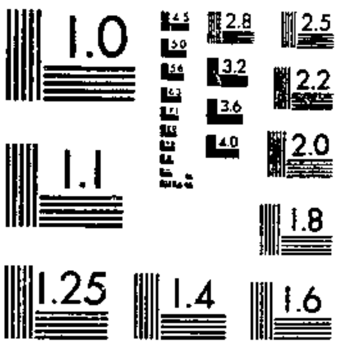

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Technical Bulletin No. 673 — May 1939

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

THE DISTRIBUTION OF INSECTS, SPIDERS, AND MITES IN THE AIR[1]

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CONTENTS

INTRODUCTION

Knowledge regarding the height to which insects may ascend has hitherto been obtained chiefly from observations made on mountains, where the insects, after all, were near terra firma; and from lighthouses,

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[1] Submitted for publication May 16, 1938.

[2] The collecting of insects by airplane was first made possible by L. O. Howard, and the late W. D. Hunter, under the supervision of B. R. Coad. The work was continued under the direction of C. L. Marlatt while he was Chief of the Bureau of Entomology, F. C. Bishopp, acting in charge of Cotton Insect Investigations in 1930 and 1931, R. W. Harned, in charge of the Division of Cotton Insect Investigations, and R. C. Gaines of the Tallulah, La., laboratory. Acknowledgments are due to R. H. Flake, W. L. Bowes, M. D. Kearney, R. G. Long, R. C. Young, C. A. Bennett, and the late pilot, G. C. McGinley, for assistance in the construction of the airplane insect traps; and to the pilots who flew the airplanes that were used, G. C. McGinley, John F. Payne, R. L. Mitchell, and O. E. Thomas. Appreciation is also extended to Franklin Sherman III, Robert Spinks, Robert Tate, C. F. Rainwater, Albert Sherwin, J. W. Holley, R. G. Long, and especially to J. M. Yeates, for their assistance in the manipulation of the traps on many of the flights and in recording the meteorological data. Most of the specimens that were collected were separated as to orders by C. F. Rainwater and the writer before they were mounted and sent to various specialists for further determination. Most of the material was mounted by P. A. Woke. The insects taken during the first 2 years of collecting, however, were prepared and mounted by the specialists in the Division of Insect Identification of the Bureau. Naturally the identification of the immense numbers of mangled insects that were collected was a laborious undertaking. For its efficient performance thanks are due to C. F. W. Muesebeck, in charge of the Division of Insect Identification, and to Harold Morrison, formerly in charge of that Division, of this Bureau, who made arrangements for handling the major portion of the material. The specialists who identified the insects in the various orders are as follows: Araneida, E. A. Chapin, H. E. Ewing, Irving Fox, and the late C. R. Crosby; Acarina, H. E. Ewing; Collembola, the late J. W. Folsom; Thysanura, F. Silvestri of Italy, J. W. Folsom, A. B. Gurney, and H. E. Ewing. Orthoptera, Neuroptera, and Mecoptera, the late A. N. Caudell; Corrodentia, A. N. Caudell and A. B. Gurney; Isoptera, T. E. Snyder; Ephemeroptera, A. N. Caudell and J. G. Needham; Odonata, J. G. Needham; Thysanoptera, Harold Morrison and J. D. Hood; Heteroptera, H. G. Barber and H. L. Dozier; Homoptera, Harold Morrison, P. W. Mason,

monuments, high buildings (*25*)[3], and forest lookout stations (*75*). To collect insects thousands of feet above the earth's surface was quite a different problem to handle, and to accomplish this it was necessary to await the development of a method of observing or collecting them while in flight in some form of aircraft, and thus study, as it were, the "plankton" of the air.

The collection of insects in the upper air has been under consideration for many years. In the winter of 1924, at a meeting of the New York Entomological Society, there was a discussion of insect migration. At this meeting there were present L. O. Howard, then Chief of the Bureau of Entomology, the late W. J. Holland, E. P. Felt, Frank E. Lutz, Charles Leng, William T. Davis, W. T. M. Forbes, A. J. Mutchler, George P. Engelhardt, and others. In the course of the discussion the value of obtaining information on the dispersal and migration of insects and of determining the heights to which they flew was emphasized, and everyone present was urged to give some thought and attention to the problem of getting this information, and in contriving some device whereby insects could be collected in the air high above the earth's surface. The use of airplanes was naturally suggested for this work, but no suggestions were made as to what kind of collecting device might be used on the airplanes.

The writer had not the remotest idea at that time that he would ever have the opportunity to work along this line. Late in the spring of 1925, however, he was transferred from what was then the Federal Horticultural Board to the Bureau of Entomology, and sent to Tallulah, La., where airplanes were being used in dusting experiments for the control of the boll weevil and mosquitoes. This equipment being available, it was suggested by Dr. Howard that someone on the staff of the Tallulah laboratory should work out a means of using an airplane to collect insects in the upper air. B. R. Coad, who was in charge of the laboratory at that time and the logical person for directing this work, asked the writer to present some plan whereby

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P. W. Oman, W. L. McAtee, and Wm. T. Davis; Coleoptera, A. G. Böving, M. W. Blackman, E. A. Chapin, H. S. Barber, W. S. Fisher, L. L. Buchanan, and J. C. Bridwell; Lepidoptera, August Busck, Carl Heinrich, Wm. Schaus, and the late F. H. Benjamin and H. G. Dyar; Hymenoptera, S. A. Rohwer, R. A. Cushman, A. B. Gahan, L. H. Weld, C. F. W. Muesebeck, Wm. Mann, Miss Grace Sandhouse, M. R. Smith, and H. H. Ross; Diptera, Alan Stone, the late J. M. Aldrich, J. R. Malloch, C. T. Greene, G. H. Bradley, W. V. King, E. P. Felt, and D. G. Hall; Siphonaptera, F. C. Bishopp.

The seeds collected at various times in the upper air were identified by the late F. V. Coville, S. F. Blake, the late A. S. Hitchcock, and Mrs. Agnes Chase, all of the Bureau of Plant Industry. Appreciation is extended to Mabel Colcord, in charge of the library of the Bureau of Entomology and Plant Quarantine, for many suggestions and for help in obtaining bibliographical references, and to Paul M. Gilmer for the interpretation and preparation of the meteorological data. The writer also wishes to thank the staff of the Tlahualilo Agricultural & Colonization Co., Tlahualilo, Durango, Mexico, for the preparation of a landing field and their kindness and consideration in offering their assistance and hospitality, at the time the airplane collections of insects were made in Mexico. Those especially to be mentioned are Thomas Fairbairn, general manager, U. C. Loftin, and W. Ohlendorff, field managers of the company.

In order to have a better understanding of the meteorological conditions, which were of paramount importance in the study of the insect population of the upper air, it was necessary to consult various workers of the Weather Bureau of the U. S. Department of Agriculture. The writer is especially indebted to C. F. Marvin, former Chief of the Weather Bureau, who personally arranged introductions and assistance, as well as gave valuable suggestions and information; to W. J. Humphreys, meteorological physicist, for his interest, time, and valuable assistance given personally, in the explanation and interpretation of the meteorological data used in this study; to W. E. Hurd, of the Marine Division; to R. T. Lindley, in charge of the climatological station at Vicksburg, Miss., who cooperated in checking meteorological records for comparison with those of the Tallulah laboratory; and to W. R. Gregg, Chief of the Bureau, for his many helpful suggestions. The writer had the opportunity of visiting England and the continent in December 1937. While there he interviewed C. B. Williams, head of the department of entomology, Rothamsted Experimental Station, Harpenden, near London, and B. P. Uvarov, entomologist of the department of entomology, British Museum of Natural History. All references to their publications used in this report were personally checked by these eminent entomologists. The writer also met John A. Freeman of London, who has done important work in collecting insects with kites, both in the United States and in England. In England Mr. Freeman worked under the direction of A. C. Hardy, of the department of zoology and oceanography, University College, Hull, who has published several papers and reports on collecting insects in the upper air with kites, and on insect dissemination. In Paris the writer met Lucien Berland, entomologist of the Museum National D'Histoire Naturelle.

[3] Italic numbers in parenthesis refer to Literature Cited, p. 146.

an airplane could be used for collecting insects. The following year, July 1926, the writer submitted diagrams and suggestions for an airplane insect trap. The drawings were accepted and the trap was made, as described later, and installed on an airplane.

On August 10, 1926, at Tallulah, the first flight was made with this trap to collect insects, and, so far as is known by the writer, this was the first attempt to use an airplane in collecting insects. Several insects belonging to the orders Diptera and Hymenoptera were taken on this flight. Many insects were collected on several other flights made on August 23 and 27. The first published record of insects taken in a trap on an airplane was that of Felt (*22, 23*). On August 30, 1926, or just 20 days after the first flight at Tallulah, Dr. Felt succeeded in taking three insects. Only a few flights were made under Dr. Felt's direction and on only the one flight were insects taken.

This new means of investigating the insect fauna of the upper air is of both scientific interest and economic importance, for some of the most dangerous insect enemies of cultivated plants and the carriers of dreaded diseases of man and animals spread to distant places with the aid of air currents.

SCOPE OF THE WORK

The discussion of the airplane collection of insects which is given in the following pages is based on the data collected during the years from August 1926 to October 1931, inclusive. During the 5 years of the work more than 1,007 hours were spent in the exposures of the collecting screens. The actual flying time, including the exposures of the screens, amounted to 1,538 hours, of which 150 hours were flown at night. A total of 1,358 separate flights were made, most of them in Louisiana, but 44 were made in Mexico.

In addition to the day collections at altitudes of from 200 to 5,000 feet, which netted 22,580 specimens, 2,204 insects were taken at other heights, from 20 to 100 feet and from 6,000 to 15,000 feet, inclusive, (tables 1 and 2). In the night collections, at from 500 to 5,000 feet, 3,955 insects were taken (table 3). In all the data covers the collection of 28,739 specimens in Louisiana and 1,294 in Mexico.

In general, in the discussions the spiders and mites are counted with the insects.

TABLE 1.—*Insects, spiders, and mites, collected in the daytime by airplane according to orders and altitudes, Tallulah, La., 1926–31*

Altitude (feet)	Araneida	Acarina	Thysanura	Collembola	Orthoptera	Isoptera	Corrodentia	Ephemeroptera	Odonata	Thysanoptera	Heteroptera	Homoptera	Coleoptera	Neuroptera	Trichoptera	Mecoptera	Lepidoptera	Hymenoptera	Diptera	Siphonaptera	Unrecognizable	Total insects	Total flying time	Insects per 10 minutes' flight
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Minutes*	*Number*
20	28	1			1	2	3		2	3	83	191	400	5			5	161	773		207	1,865	721	25.87
50	2										6	10	16				1	4	21		1	61	79	
100	3										20	3	6					1	18			51	63	
200	629	24	11	6	4	8	31	2	12	44	555	1,497	2,207		2		36	1,646	5,170	1	1,444	13,389	10,277	13.03
300	3											5	9					1	16			34	92	
400											1	4	2						6		1	14	40	
600											1	1	1				2		1		1	7	23	
1,000	362	13	15	5	5	6	15	1	6	21	216	573	518	2			12	508	1,979		494	4,751	10,101	4.70
2,000	224	4	4	4	3	2	4	2		10	107	363	161				12	235	1,024		196	2,355	9,767	2.41
3,000	97	2	3	4		1	8		1	8	57	284	96	3			6	113	586		95	1,364	10,102	1.35
4,000	3										3	14	6					6	17		5	54	291	
5,000	36			5			6			3	23	100	52		1	3	1	62	279		41	612	9,622	.64
6,000	1										1	3	5					6	9		5	30	321	
7,000	1			1							2	8	4					3	25		2	46	385	
8,000	1		1				2				2	2	2					3	9		3	25	338	
9,000	4										1		1					2	4			12	270	
10,000	2						1			1	1	6	11					8	18		2	50	399	
11,000	3			1						1	1	1	4					3	7		1	22	224	
12,000	1											4	5					2	2		1	15	204	
13,000												5						4	6		1	16	171	
14,000												5						2	3			10	118	
15,000	1																					1	20	
16,000																							5	
Total:																								
20 to 16,000 feet	1,401	44	34	26	13	19	70	5	21	91	1,080	3,079	3,566	10	3	3	75	2,770	9,973	1	2,500	24,784	53,633	4.62
200 through 5,000 feet	1,354	43	33	24	12	17	64	5	19	86	963	2,841	3,112	5	3	3	69	2,571	9,078	1	2,277	22,582	50,315	4.49

TABLE 2.—*Spiders and insects of the important orders taken at selected altitudes per 10 minutes of exposure of the collecting screens by daylight, Tallulah, La., 1926–31*

Altitude (feet)	Total flying time	Araneida	Heteroptera	Homoptera	Coleoptera	Hymenoptera	Diptera	Total insects[1]
	Minutes	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
20	721	------	------	------	------	------	------	25.87
200	10,277	0.61	0.54	1.46	2.20	1.60	5.03	13.03
1,000	10,101	.38	.21	.57	.51	.50	1.96	4.70
2,000	9,767	.23	.11	.37	.16	.24	1.05	2.41
3,000	10,102	.09	.06	.28	.09	.11	.58	1.35
5,000	9,622	.04	.02	.10	.05	.06	.29	.64
200–5,000[2]	50,315	.27	.19	.56	.62	.51	1.80	4.49
All altitudes[2]	53,633	.26	.20	.57	.66	.52	1.86	4.62

[1] Includes other orders in addition to those shown.
[2] Includes other altitudes in addition to those shown above.

TABLE 3.—*Insects, spiders, and mites collected at night by airplane according to altitudes from 500 to 5,000 feet, with the number per 10 minutes' flying time in the important orders, Tallulah, La., 1926–31*

Order	500 feet		1,000 feet		2,000 feet		3,000 feet		5,000 feet		Total insects	
	Total insects	Insects per 10 minutes' flying time	Total insects	Insects per 10 minutes' flying time	Total insects	Insects per 10 minutes' flying time	Total insects	Insects per 10 minutes' flying time	Total insects	Insects per 10 minutes' flying time	Total insects	Insects per 10 minutes' flying time
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Araneida	26	0.17	18	0.12	7	0.06	6	0.05	1	0.008	60	0.09
Acarina	2	------	------	------	------	------	------	------	------	------	2	.003
Thysanura	4	------	------	------	2	------	------	------	------	------	6	.009
Orthoptera	------	------	1	------	2	------	------	------	------	------	3	.004
Corrodentia	7	------	------	------	1	------	------	------	------	------	8	.01
Ephemeroptera	2	------	2	------	------	------	1	------	------	------	5	.007
Thysanoptera	6	------	------	------	------	------	------	------	1	------	7	.01
Heteroptera	115	.69	45	.30	12	.10	2	.02	5	.04	179	.26
Homoptera	521	3.13	198	1.33	88	.70	34	.28	14	.12	855	1.26
Coleoptera	680	4.09	120	.81	26	.21	12	.10	16	.14	854	1.26
Neuroptera	8	.05	9	.06	5	.04	3	.02	1	.008	26	.04
Lepidoptera	105	.63	31	.21	5	.04	2	.02	7	.06	150	.22
Hymenoptera	101	.61	47	.31	16	.13	4	.03	9	.08	177	.26
Diptera	788	4.74	314	2.11	130	1.04	62	.51	37	.32	1,331	1.96
Unrecognizable	181	------	68	------	20	------	10	------	13	------	292	------
Total	2,548	15.31	853	5.73	314	2.52	130	1.11	104	.89	3,955	5.83
[Total collecting time, minutes]	1,664	------	1,488	------	1,248	------	1,225	------	1,165	------	6,790	------

From the number of minutes flown and the average speed of the several planes used, it is estimated that approximately 88,827 miles were flown in the actual exposure of the screens in Louisiana. If the flights are reckoned from taking off on a collecting trip until landing, a distance of six times the circumference of the earth, or more than 150,000 miles, was flown in collecting insects.

THE COLLECTING GROUND

Tallulah, La., where most of the flying was done, is located in the lower Mississippi Valley and is from 80 to 85 feet above sea level.

The terrain in the vicinity of Tallulah is almost ideal for collecting insects. In Madison Parish alone there are approximately 80,000 acres of land in clearings and in cultivation, with nearly four times as much, or over 300,000 acres, covered with swamps and forests. Viewing the country from an airplane at a high altitude, one notices little of the cultivated areas, but the eye follows extensive forests. They extend for 150 miles in a continuous line north and south, and run part way across the State east and west. Much of the swamp country is almost impenetrable, with great forests bordering many hundreds of small lakes, bayous, and rivers, lined with enormous cypress trees from which great festoons of Spanish moss hang down to the water's edge (pl. 1, *A*). The entire section is intertwined with bayous, which serve as the natural drainage canals of the region (fig. 1). The many lakes and swamps (pl. 1, *B*) are mostly connected with bayous, which finally empty into small rivers and thence into the Mississippi. In Madison Parish alone there are more than 60 lakes. This section is still an important logging center. One reservation, part of which is in Madison Parish, covers over 80,000 acres of forests and contains cypress, gum, ash, and oak.

Following the main highways through Madison and adjoining parishes, are located the clearings, and the land planted in cotton. The soil is rich and crops grow luxuriantly.

AIRPLANE INSECT TRAPS

Several types of insect traps were devised and used in making the collections of insects in the upper air. The original trap, as designed by the writer for use on a JN6H army primary training ship, was constructed on the principles of a plate holder for a camera. It consisted of five screen-covered frames for catching the insects, with two suitable compartments or magazines for protecting the screens before and after exposure. The compartments were made of aluminum, covered with tin, and reinforced with wood. The trap was smaller in size, although heavier than those developed later. Refinements in construction, manipulation, and adaptation for use on different types of airplanes were made from time to time, but the basic principles remained unchanged throughout the work. In order to increase the strength to resist the tremendous air pressure and to reduce the weight, the compartments in later models were made of steel tubing, welded together and covered with airplane fabric. The later models were further simplified so that only one compartment was needed.

Only one trap was used on the airplane during 1926 and 1927. Later two improved traps were installed between the wings of a biplane. These traps were used on four different DeHaviland H1 army biplanes. The two insect traps were placed either between the wings of a biplane or under the wing of a monoplane (pl. 2, *A*), one on each side of the fuselage (pl. 2, *B*). The wing structure, as well as the supporting struts, had to be made stronger than is customary for ordinary flying to compensate for the added wind pressure. When it became possible for the Bureau of Entomology to purchase a specially designed airplane for insect collecting, the late Eddy Stinson came to Tallulah and studied the insect trap construction. He then returned to his factory at Detroit and built a Stinson Detroiter SM1 monoplane (pl. 2, *B*), in which special attention was given to the wing structure and the supporting struts. In 1930 a Travelair 4,000 biplane (pl. 3, *B*) was secured on which two of the last-model single compartment traps

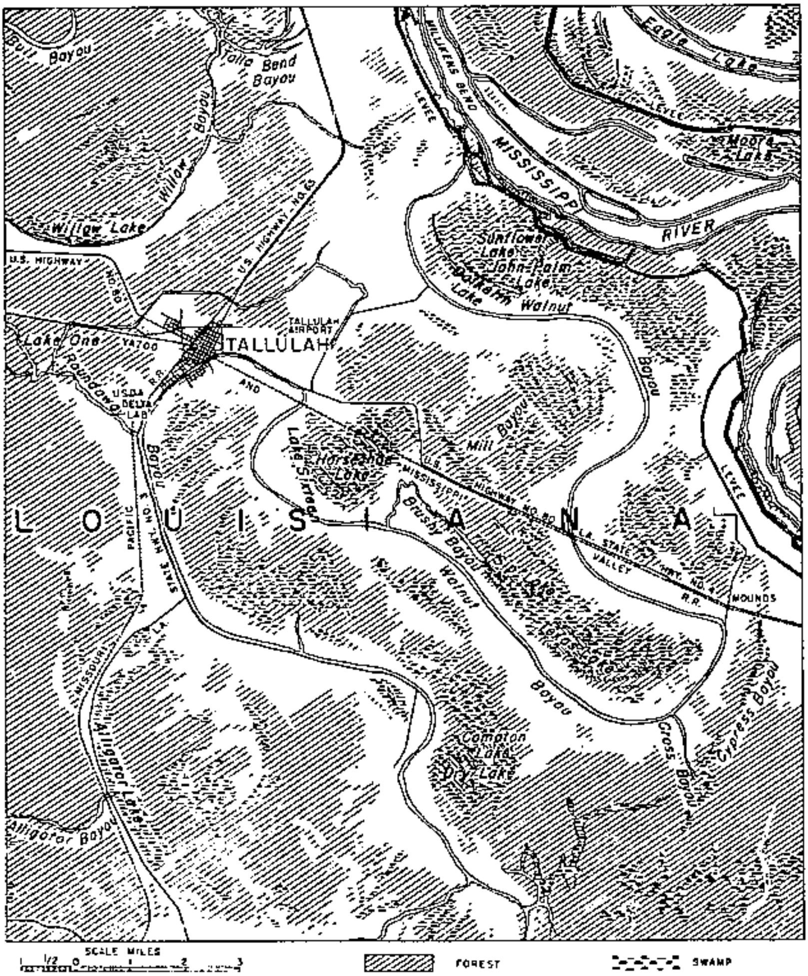


FIGURE 1.—Map of the country around Tallulah, La., showing the relation between the cultivated areas and the swamps and natural drainage channels.

(pl. 3, *A*) were used. This type of trap was adapted for use on the leading edge of the lower wing by Pilot G. C. McGinley. It differed from the ones previously used in that the exposed trays were pulled back to the original compartment by a mechanism controlled by a single wire to the cockpit. The screen trays, or traps proper, are steel tubing frames fitted with a fine-mesh copper screen. In all of the types of airplane insect traps used, five screens, each 1 square foot in size, were used.

OPERATION AND EFFICIENCY OF THE TRAPS

The manipulation of the two-compartment trap is as follows: The unexposed screens are placed in compartment *a* (pl. 2, *A*). A steel wire runs from each screen, through guides, to the rear cockpit. When a desired altitude is reached, screen No. 1 is pulled into the open portion of the trap (*b*) and exposed for the desired length of time, then pulled into compartment *c*, where it is protected from further exposure. The remaining four screens are each exposed in the same manner. In the single-compartment traps (pl. 3, *A*) the screens are pulled back to the original compartment. The ends of the frames of the screens are

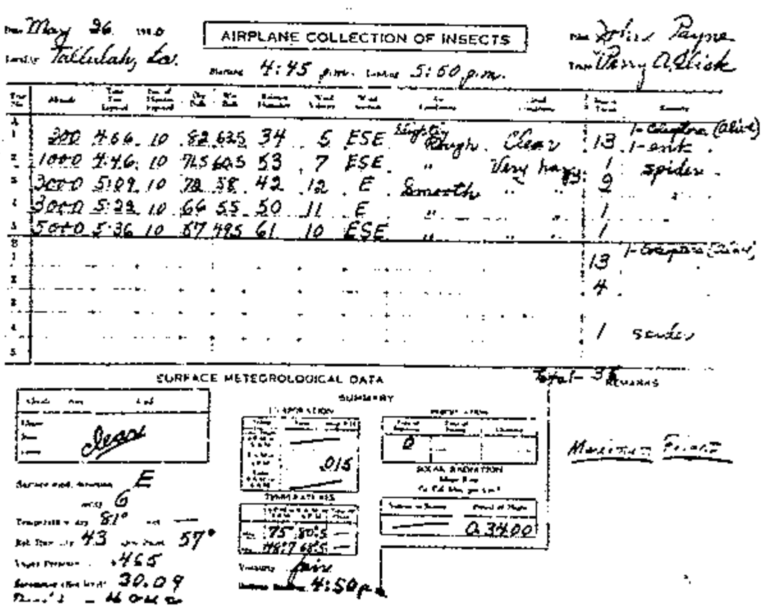
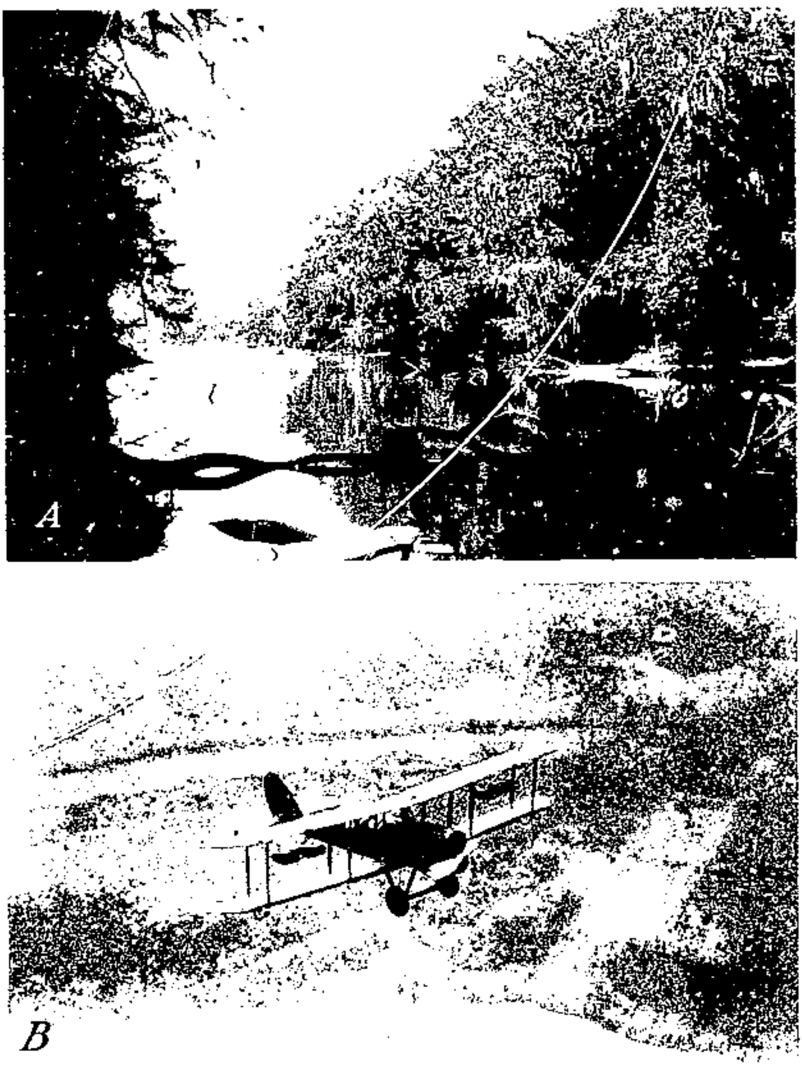


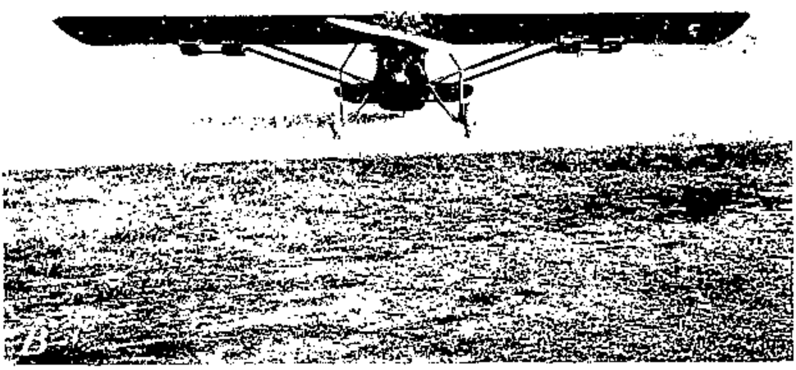
FIGURE 2.—Record chart, showing the data recorded for one of the flights made on May 26, 1930. Records such as these were kept of each flight on which insect collections were made by airplane in the upper air. The insects collected at each altitude were kept separate after removal from the screens, and identified later.

made to fit snugly, and they completely close the opening to the compartment. In this way insects were prevented from entering until the desired elevation had been reached, and this eliminated the possibility of picking up insects as the airplane was taking off or landing.

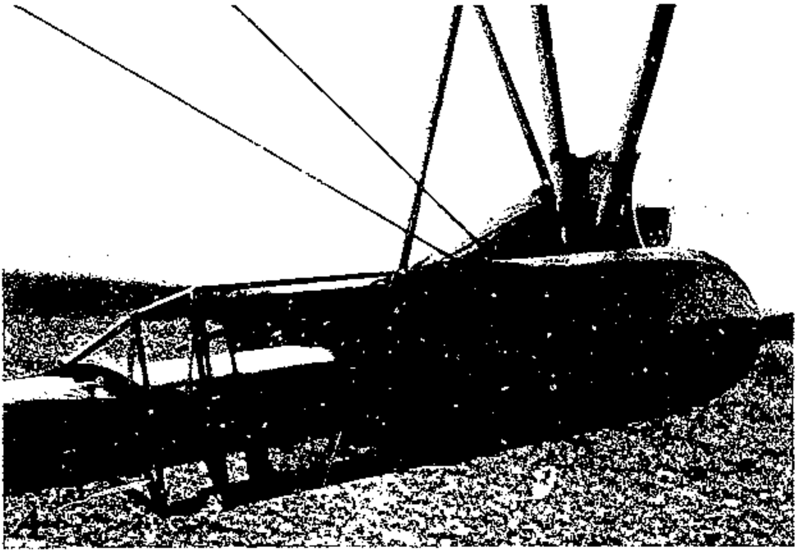
The screens were covered with a thin coating of adhesive to retain the insects that came into contact with them. This adhesive is made of a saturated solution of castor oil and resin. If the adhesive is not thin enough and is not spread over the surface properly, the air will not pass through the mesh, and thus will cause many of the insects to be carried over or under the exposed tray. The period of exposure and rate of speed were standardized, and all records are based on the catch of one screen exposed for 10 minutes at a known speed. The insects were removed immediately after each flight, and placed in small vials, properly labeled according to time of collection and altitude (pl. 4, *A* and *B*). Special flight record sheets (fig. 2) were used on which to enter all the data for each flight.

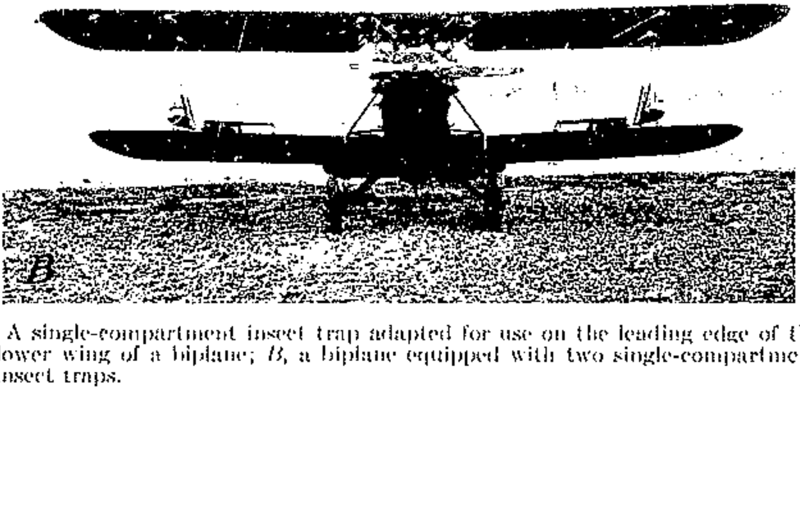


A, Little Rainy Lake near Tallulah, La., showing a dense growth of moss-draped cypress trees. Much of the flying to collect insects was made over this and numerous similar lakes, many of which are hidden in almost impenetrable swamps and forests. *B*, Biplane equipped with insect traps flying over the swamps collecting insects.

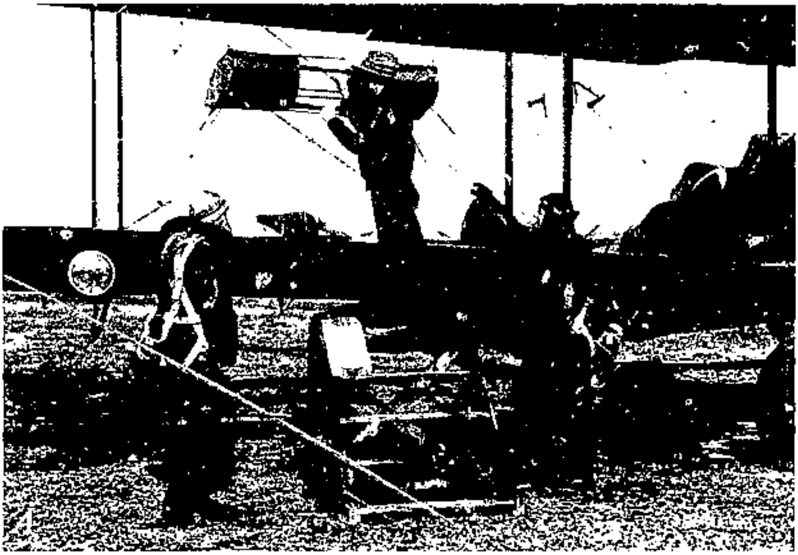


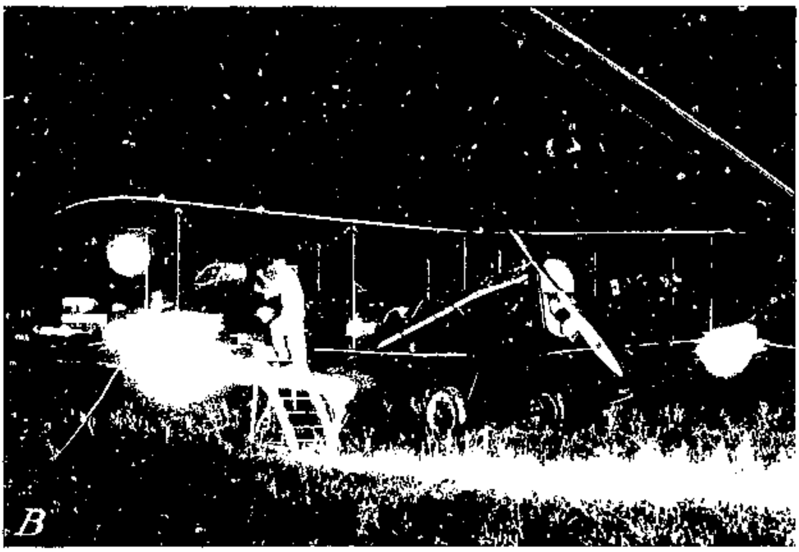
A, Insect-collecting trap attached to the wing of a monoplane. The unexposed screens are carried in compartment *a*. At *b* is shown a screen pulled into position for exposure. After exposure the screen is pulled into compartment *c*, the movements of the screens being controlled by wires *d* leading to the cabin of the airplane. *B*, a monoplane especially constructed to accommodate the insect traps such as the one shown in *A*.





A, A single-compartment insect trap adapted for use on the leading edge of the lower wing of a biplane; *B*, a biplane equipped with two single-compartment insect traps.





A, Removing insects from the screens after the landing of the airplane. On account of the low temperatures experienced at high altitudes heavy flying suits are necessary. *B*, Removing insects from the traps after a night flight. Certain insects are found in the air only at night.

None of the specimens collected could have been carried up by suction caused by the ascent of the airplane, for the effect of the air blast from the propeller is to blow through the airplane and downward during ascent, as is evidenced during airplane dusting. The air is forced downward behind the airplane, and when the airplane is "chocked" and stationary, with the engine running, the force of the air blast is as great as the driving speed of the propeller.

Unquestionably some insects were carried away from the screens by swirl currents set up by the resistance of the screen in its passage through the air. It is probable that the weight and bulk of the insect affected this factor considerably, those insects of light weight (with a high aerostatic coefficient) probably being carried past the screen in a greater proportion to their total numbers than was the case with the heavier species. So far as is known there is no way of even approximately evaluating actual conditions.

Most of the insects were completely smashed by coming into contact with the screens at high speeds, and in most cases it could not be determined whether they were alive or dead when caught. Yet, surprisingly enough, some of the delicate, soft-bodied insects (such as Diptera and aphids) were alive and in fair condition when removed. These battered specimens, often covered with adhesive, were difficult to determine and only the taxonomists' keen interest in the work enabled determinations to be made as to species in many cases.

The skill of the pilots who flew the collecting airplanes is evidenced by the fact that no fatalities occurred. For 5 years flights were made in all kinds of weather, and many of the night landings were made on an improperly lighted airfield by the aid of automobile lights. During 1930 and 1931, however, the airfield was equipped with standard lighting equipment, including a beacon, a powerful floodlight, and border lights. The airplanes were also equipped with landing lights as shown in plate 4. There were many forced landings, and several airplanes were "washed out." Only one major accident occurred, when a forced landing resulted in the destruction of the craft and injury to both the pilot (McGinley) and the writer. Such mishaps must be expected in a more or less hazardous undertaking.

SEASONAL DISTRIBUTION OF INSECTS

In order that insects could be collected in every month, it was most important that the flights be made in a region where they were active throughout the year. As far as 100 miles or more north of Tallulah many species of insects are more or less active during every month of the year. Accordingly, every month was represented in one or more years during the 5 years of flying to collect insects.

There is an abundance of data on the seasonal distribution of insects as they occur on the surface, but as to the height to which they fly, or at which they may be found from month to month, very little has been known. It is of interest as well as of economic and scientific importance to know at what heights insects may be found throughout the year. These altitudes depend to a great extent on weather conditions, which are considered under a later heading.

Including all altitudes, in the daytime the greatest numbers of insects per 10 minutes of collecting were taken in May, with November and September following. The fewest insects were taken in January and December (tables 4 and 5). In the night flights the greatest numbers were taken in October, followed by May. No night flights were made in January, February, or March (table 6).

TABLE 4.—*Insects, spiders, and mites collected by airplane in the daytime according to the orders and months of year at all altitudes, Tallulah, La., 1926–31*

Order	January	February	March	April	May	June	July	August	September	October	November	December	Total
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Araneida	126	77	80	144	133	147	92	77	132	134	119	140	1,401
Acarina	------	8	16	16	------	1	2	------	------	------	1	------	44
Thysanura	2	------	10	6	4	3	------	2	1	2	3	1	34
Collembola	------	1	2	5	8	4	1	1	------	2	1	1	26
Orthoptera	------	------	------	------	1	2	1	2	2	4	1	------	13
Isoptera	------	------	------	13	6	------	------	------	------	------	------	------	19
Corrodentia	1	3	5	11	16	6	6	2	1	5	8	6	70
Ephemeroptera	------	------	------	1	------	2	1	------	1	------	------	------	5
Odonata	------	------	1	1	9	5	3	------	------	2	------	------	21
Thysanoptera	------	------	4	9	14	34	15	6	2	7	------	------	91
Homoptera	20	74	212	322	426	237	117	245	578	482	270	66	3,079
Heteroptera	44	30	73	89	139	150	97	93	130	143	48	44	1,080
Coleoptera	95	200	482	484	377	374	266	336	422	256	196	78	3,566
Neuroptera	------	------	------	1	2	1	------	3	2	1	------	------	10
Trichoptera	------	------	------	------	------	------	1	------	------	2	------	------	3
Mecoptera	------	------	------	------	------	------	------	------	3	------	------	------	3
Lepidoptera	1	1	1	3	------	5	6	6	26	20	5	1	75
Hymenoptera	6	10	123	262	447	366	427	326	398	288	91	26	2,770
Diptera	248	407	658	1,104	1,493	1,420	981	959	1,239	933	325	206	9,973
Siphonaptera	------	------	------	------	------	------	1	------	------	------	------	------	1
Unrecognizable	66	65	112	256	339	342	251	208	410	207	115	39	2,600
Total	609	876	1,809	2,727	3,414	3,099	2,208	2,356	3,347	2,488	1,183	608	24,784
Total flying time, minutes	2,992	3,042	4,305	6,025	5,209	5,973	5,022	5,649	6,286	4,732	1,984	2,414	53,633

TABLE 5.—*Spiders and insects of the important orders taken per 10 minutes of flying time by daylight in the different months of the year, Tallulah, La., 1926–31*

Month	Araneida	Homoptera	Heteroptera	Coleoptera	Hymenoptera	Diptera	Total insects, including other orders	Total flying time
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Minutes*
January	0.42	0.07	0.15	0.32	0.02	0.83	2.03	2,992
February	.25	.24	.10	.66	.03	1.34	2.88	3,042
March	.18	.56	.17	1.12	.28	1.53	4.20	4,305
April	.24	.53	.15	.80	.43	1.83	4.53	6,025
May	.25	.82	.27	.72	.86	2.87	6.55	5,209
June	.25	.40	.25	.63	.61	2.38	5.19	5,973
July	.18	.23	.19	.53	.85	1.95	4.52	5,022
August	.14	.43	.16	.59	.58	1.70	4.17	5,649
September	.21	.92	.21	.67	.63	1.97	5.33	6,286
October	.28	1.02	.30	.54	.61	1.97	5.20	4,732
November	.60	1.36	.24	.99	.46	1.64	5.96	1,984
December	.58	.27	.18	.32	.11	.85	2.52	2,414
Total	.26	.57	.20	.66	.52	1.86	4.62	53,633

At the altitude of 200 feet the greatest numbers were taken in May and the next greatest in November. The smallest numbers were collected in January and the next smallest in December.

At the altitude of 1,000 feet the maximum numbers of insects were collected in November, with slightly fewer in May; the fewest were found in January and December.

At the altitude of 2,000 feet the greatest numbers of insects appeared in May with slightly smaller numbers in October, and the fewest in January and February.

TABLE 6.—*Spiders and insects of the important orders caught per 10 minutes of flying time at night, arranged by months, Tallulah, La., 1926–31*

Month	Araneida	Homoptera	Heteroptera	Coleoptera	Lepidoptera	Hymenoptera	Diptera	Total insects, including other orders	Total flying time
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Minutes*
April	0.33	0.55	0.11	0.22	0.22	0.22	1.78	3.56	90
May	.10	1.24	.18	2.40	.08	.36	3.12	8.36	500
June	.09	.51	.16	.97	.06	.19	1.63	4.13	1,175
July		.24	.17	.84	.10	.12	.93	2.84	805
August	.05	.73	.23	1.14	.16	.21	1.55	4.53	1,638
September	.11	2.02	.30	1.29	.32	.27	1.70	6.33	1,457
October	.13	4.04	.74	2.16	.77	.69	5.32	14.91	700
November	.22	.51	0	.91	.08	.11	.09	2.94	275
December	0	0	0	0	0	0	0	.13	150
The above 9 months	.09	1.26	.26	1.26	.22	.26	1.96	5.83	6,790

At 3,000 feet the most insects were taken in October and September, and the fewest appeared in January, February, and December.

At the 5,000-foot altitude the peak of abundance of insects appeared in September. Nearly twice as many insects were taken in this month as in June, in which the next highest numbers were collected. The smallest numbers of specimens were found in December; and next to the smallest in January and February, in which months approximately equal numbers were collected.

In every month of the year, for the day collections, the order Diptera led in numbers taken (table 5). The other orders represented in the collections varied considerably in numbers with altitude and season. Many species were found in every month of the year.

The months in which the maximum and minimum numbers of insects were taken varied somewhat from year to year during the 5 years. The peaks of abundance were usually at about the same time each year, as were also the low catches, but in 1929 the greatest numbers were collected in September with a minor peak in June, whereas in 1930 and 1931 the maximum numbers were taken in May. The variation in the monthly maximum and minimum occurrences of insects for each year may be assigned to differences in the weather. The meteorological factors are discussed later.

The numerical abundance of the orders as they occur in the day collections for the various months are shown in table 4, and the figures in table 5 give the number per 10 minutes of flying.

Araneida were most abundant in November and December, with slightly more in November (table 5). The fewest specimens were taken in August. At the altitude of 1,000 feet most spiders were collected in November, and at 2,000 feet more were taken in December.

Homoptera appeared in greatest numbers in November (table 5). Fewest were found in January. During the summer the fewest specimens were collected in July. At the altitude of 2,000 feet the maximum numbers were taken in October and the fewest in January, and for the altitudes of 3,000 and 5,000 feet the most Homoptera were collected in September.

Heteroptera were found in greatest numbers in October, and fewest in February. At the altitude of 1,000 feet more specimens were collected in November and fewest in January. At altitudes above 1,000 feet the numbers taken varied considerably.

Coleoptera were at their maximum abundance in March, with a few less in November, and fewest in January and December. At the altitude of 2,000 feet the greatest numbers were collected in May, June, September, and October, with about equal numbers for each; and the fewest were taken in January, February, August, and December. At 3,000 feet Coleoptera were most abundant in June and October, and at 5,000 feet in June and September, with more in September.

Hymenoptera appeared in maximum numbers in May and July, about equal numbers having been taken in each of those months. Fewest Hymenoptera were found in January and February. At 1,000 feet Hymenoptera were most abundant in May and October, with a drop for the summer months in August. At 5,000 feet most specimens were taken in June, and no specimens in January, February, or November.

Diptera were most abundant in May and were fewest in January and December. At the altitude of 3,000 feet they were most abundant in April, May, and June, with about equal numbers for each of those months. In July and August there was a decided drop in the numbers taken at 3,000 feet and the lowest number was taken in February. At 5,000 feet Diptera appeared in greatest numbers in September, with the next highest numbers in June and the fewest in December.

Thysanoptera were collected mostly in June. Isoptera were taken only in the months of April and May, and too few specimens of the other orders were taken to justify comparative estimates.

In the night collections the Homoptera appeared in greatest numbers in October. At the altitude of 5,000 feet, Homoptera were taken only in the months of August, September, October, and November.

Heteroptera were collected at night mostly in October. At the altitude of 3,000 feet they were found only in July and August and at 5,000 feet in August and September.

Coleoptera were taken at night in greatest numbers in May, with slightly fewer in October. They fell off considerably during July. At the altitude of 1,000 feet most specimens of Coleoptera were taken in May, August, and October, and at 2,000 feet, in May and October, with more in October.

Hymenoptera were collected at night mostly in October, with the next highest numbers in May.

Lepidoptera were most abundant in October at all altitudes.

Diptera were most abundant at night in October, with May second in the numbers taken. There was a decided drop in July. At 3,000 feet most specimens appeared in May, and at 5,000 feet most in October.

ALTITUDINAL DISTRIBUTION OF INSECTS

Twenty-four different altitudes, ranging from 20 to 16,000 feet, were flown. Six altitudes were used in the systematic studies, these being 200, 1,000, 2,000, 3,000, and 5,000 feet for the daytime, and 500, 1,000, 2,000, 3,000, and 5,000 feet for the night collections.

DAY COLLECTING

The numbers of insects collected in the daytime and arranged according to orders and altitudes are given in table 1. Eighteen orders of insects and the orders of spiders and mites were taken. Fourteen thousand feet was the highest altitude at which insects were taken, there being five Homoptera and two Hymenoptera collected at this height. The highest altitude at which any specimen was taken was 15,000 feet, at which one spider was caught on the screen. Had more flights been made at these higher altitudes more specimens would

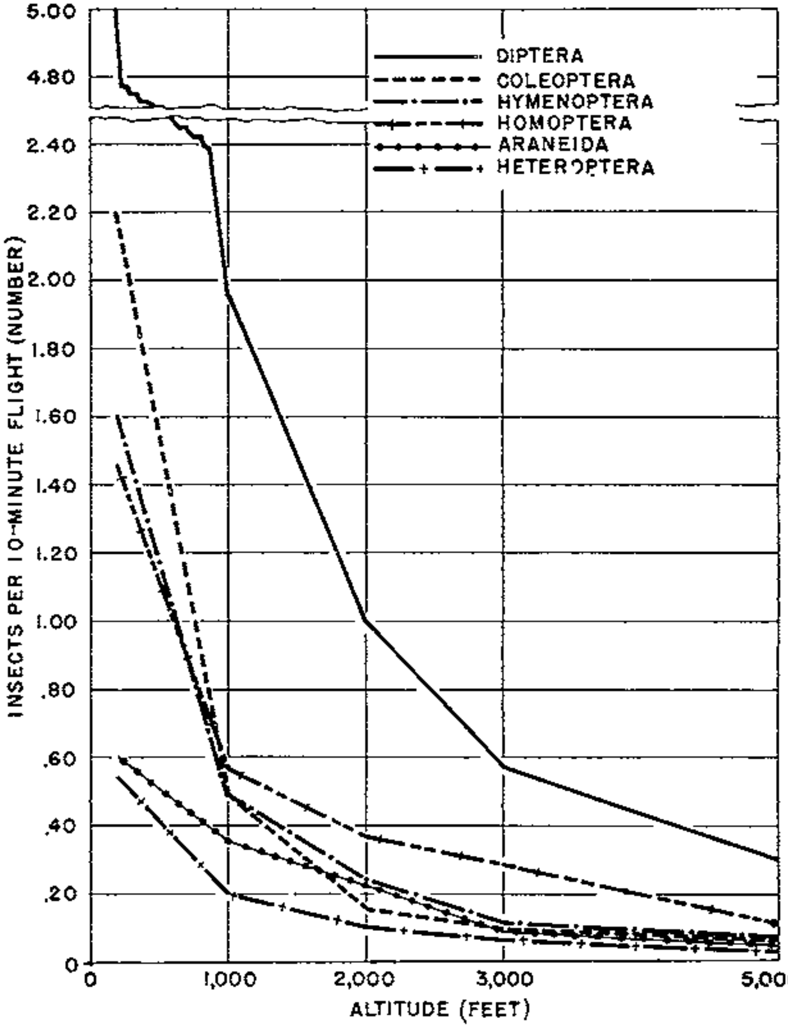


FIGURE 3.—Average numbers of insects of the important orders collected by airplane in 10 minutes flying by day at the indicated altitudes.

doubtless have been taken, but because of the difficulty in climbing, the time and expense involved, the types of airplanes used, and the air resistance offered by the insect traps, high altitudes were difficult to attain, and only one flight of 5 minutes was accomplished at 16,000 feet.

The comparative abundance of various orders according to altitudes may be learned from figure 3. Only the orders Homoptera, Heteroptera, Coleoptera, Hymenoptera, Diptera, and the order of spiders

(Araneida), are covered in the studies of these systematic collections, as too few specimens belonging to the other orders were collected upon which to base conclusions. In every flight made the screen was exposed for a period of 10 minutes, the comparative estimates being based on this period.

At the altitude of 200 feet the order Diptera led in numbers of specimens taken (5.03), with Coleoptera (2.20), Hymenoptera (1.60),

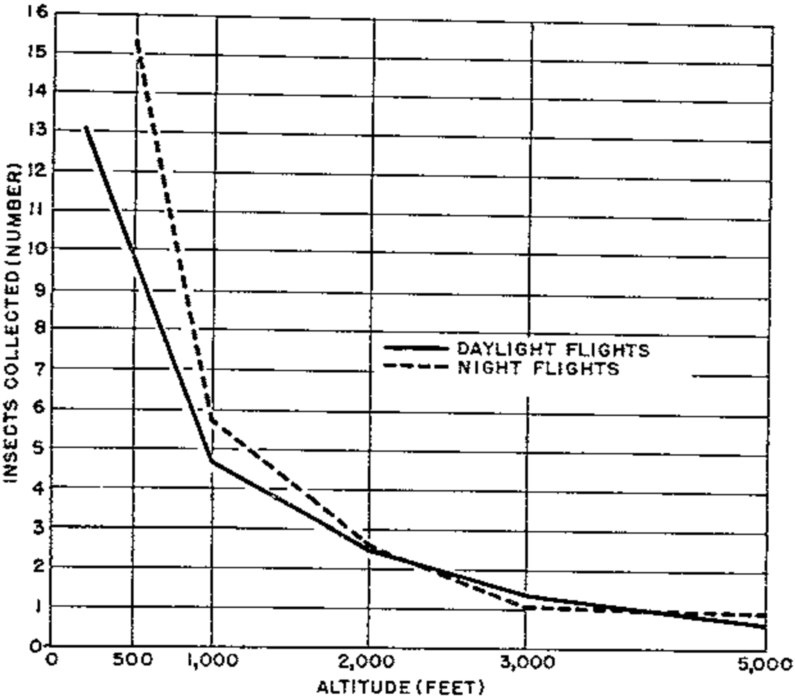


FIGURE 4.—The average numbers of insects collected by airplane in 10 minutes of flying at altitudes of from 200 to 5,000 feet by day, and from 500 to 5,000 feet by night. Tallulah, La.

Homoptera (1.46), Araneida (0.61), and Heteroptera (0.54) following for the average period of 10 minutes of flying time.

At the 1,000-foot altitude the orders appeared in the following sequence: Diptera (1.96), Homoptera (0.57), Coleoptera (0.51), Hymenoptera (0.50), Araneida (0.36), and Heteroptera (0.21).

For the altitude of 2,000 feet they were as follows: Diptera (1.05), Homoptera (0.37), Hymenoptera (0.24), Araneida (0.23), Coleoptera (0.16), and Heteroptera (0.11).

At the altitude of 3,000 feet Diptera led with 0.58 specimen taken, followed by Homoptera (0.28), Hymenoptera (0.11), Coleoptera (0.09), Araneida (0.09), and Heteroptera (0.06).

For the altitude of 5,000 feet the orders were Diptera (0.29), Homoptera (0.10), Hymenoptera (0.06), Coleoptera (0.05), Araneida (0.04), and Heteroptera (0.02).

The average number of Diptera taken was 1.80, with Coleoptera following with 0.62 specimen taken in a period of 10 minutes flying. The other orders came in the following sequence: Homoptera (0.56), Hymenoptera (0.51), spiders or Araneida (0.27), and Heteroptera (0.19). These estimates are for day collections only, at the altitudes of 200, 1,000, 2,000, 3,000, and 5,000 feet.

When the total numbers of insects at the altitudes of from 200 to 5,000 feet, inclusive, for daytime collecting are considered, there is found a regular decrease in the numbers taken for each ascending altitude. The comparative numbers taken in 10 minutes of collecting, according to the altitudes are as follows: At 200 feet, 13.03; 1,000 feet, 4.70; 2,000 feet, 2.41; 3,000 feet, 1.35; and 5,000 feet, 0.64 (table 2 and fig. 4).

The altitude of 20 feet was as low as any flights could be made with safety, and then only under the best of flying conditions. It is interesting and of value to know the comparative abundance of insects to be found in the air from a very few feet above the ground to greater levels, or to the altitude where our flight studies began. To determine this near-the-surface insect population of the air an experiment was conducted by G. L. Smith in 1930 and 1931.[4] The standard 3- by 5-foot sticky screens were placed on a towerlike stairway with 3-foot intervals between each elevation of these screens, making the height of the screens above the ground as follows: 3, 9, 15, 21, 27, 33, 39, 45, 51, and 57 feet, with the bottom of the first screen 3 feet above the ground as in the field flight screen studies. There were 420,468 insects taken on these screens during the period from August 1 to November 14, 1930. Approximately one-fourth of the total collection were taken from the screen that was 3 feet above the ground. This number is twice as great as that taken from the next screen, which was 9 feet above the ground, and more than five times as great as that taken from the highest screen, which was 57 feet above the ground. The number of insects taken from the screens at intervening elevations diminished gradually from the 9-foot elevation to the 57-foot elevation.

From the average speed of the airplane, the area of the exposed screen, and the number of minutes of flight at each altitude the average insect population of the air was determined as shown in table 7.

TABLE 7.—*Average density of the insect population of the air at various altitudes, Tallulah, La., 1926–31*

Altitude (feet)	Day		Night	
	Volume of air per insect	Approximate distance apart of the insects in all directions	Volume of air per insect	Approximate distance apart of the insects in all directions
	Cubic feet	*Feet*	*Cubic feet*	*Feet*
20	3,400	15		
200	6,750	19		
500			5,667	18
1,000	15,902	25	13,248	24
2,000	30,981	31	29,621	31
3,000	55,370	38	68,862	41
5,000	117,510	49	85,186	44

Of course there were times, as during the dispersal flights of termites or nuptial flights of ants or bees, when the numbers of insects for any given volume of air was considerably greater.

[4] Unpublished records at the Tallulah, La., laboratory.

NIGHT COLLECTING

The altitudes flown at night were 500, 1,000, 2,000, 3,000, and 5,000 feet. Five hundred feet was considered to be the lowest altitude safe to fly at night. More insects were collected at night in proportion to the amount of time flown than during the day, the figures being 5.83 per 10 minutes of flight, as against 4.62 for the day. There were, however, only 12 recognizable orders of insects taken at night as compared with 20 orders of insects and mites taken in the day flights (tables 1 and 3). The orders of insects not represented in the night collections were Collembola, Isoptera, Odonata, Trichoptera, Mecoptera, and Siphonaptera. Even in the day flights, only a few insects belonging to these orders were taken.

At 1,000, 2,000, and 5,000 feet more insects were taken per 10 minutes at night than during the day, but at 3,000 feet there were fewer insects taken than in the day collections. The actual numbers taken at night at the altitudes of 3,000 and 5,000 feet, however, are so small as compared with the day collections that great significance cannot be placed upon the figures. Wingless forms could not, of course, attain any height at night, since the general convectional movement of air at night tends to be downward rather than upward. Thus the few spiders and others wingless forms that were in the upper air would tend to come down at night. Table 7 also shows the approximate number of cubic feet of air per insect at night.

NOTES ON THE INSECTS COLLECTED

A discussion of each order is given with notes on the more interesting and the economic species taken. There were represented in the collections taken in the upper air 18 insect orders, and the orders of spiders and mites. Of the total of 28,739 specimens collected in Louisiana there were represented 216 families, 824 genera, 4 new genera, 700 species, and 24 new species (table 8). The insects are shown in detail in tables 9 and 10.

TABLE 8.—*Insects, spiders, and mites collected by airplane according to the orders, families, genera, and species, Tallulah, La., 1926–31*

	Insects taken	Families	Determined genera	New genera	Determined species	New species
	Number	*Number*	*Number*	*Number*	*Number*	*Number*
Araneida	1,461	10	37		30	1
Acarina	46	2	1			
Thysanura	40	2	4		1	
Collembola	26	3	7		4	
Orthoptera	16	3	4		5	
Corrodentia	78	4	8		6	
Isoptera	19	1	1		1	
Ephemeroptera	10	1	3		1	
Odonata	21	2	6		4	
Thysanoptera	98	2	12		15	
Heteroptera	1,259	19	63		69	
Homoptera	3,934	9	73		80	3
Coleoptera	4,420	46	193		175	
Neuroptera	36	4	4		6	
Trichoptera	3	1	1		1	
Mecoptera	3	1	1			
Lepidoptera	225	20	38		32	
Hymenoptera	2,947	33	244	4	195	20
Diptera	11,304	46	123		74	
Siphonaptera	1	1	1		1	
Unrecognizable	2,792					
Total	28,739	216	824	4	700	24

TABLE 9.—*Insects, spiders, and mites collected by airplane, according to altitudes, Tallulah, La., August 1926 to October 1931, inclusive*

Order, family, genus, and species	Total insects taken		Collected at altitudes of—																		
	Day	Night	20 feet (day)	50 feet (day)	100 feet (day)	200 feet (day)	300 feet (day)	400 feet (day)	500 feet (night)	600 feet (day)	1,000 feet Day	1,000 feet Night	2,000 feet Day	2,000 feet Night	3,000 feet Day	3,000 feet Night	4,000 feet (day)	5,000 feet Day	5,000 feet Night	Over 5,000 feet[1] (day)
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Araneida:																				
Dictynidae.																				
Dictyna bellans Chamberlin		1										1								
Dictyna cruciata Emerton	2					1							1							
Dictyna sp.	1										1									
Dictyna, n. sp.	1										1									
Oecobiidae:																				
Oecobius parietalis Hentz	1										1									
Gnaphosidae:																				
Zelotes sp.	1					1														
Gnaphosidae, undetermined sp.	1														1					
Pholcidae:																				
Modisimus sp.	1														1					
Theridiidae:																				
Euryopis sp.	1					1														
Theridion globosum Hentz (male)	1										1									
Theridion sp.	4	1				3					1			1						
Theridula opulenta (Walckenaer)	1					1														
Dipoena sp.		1							1											
Crustulina guttata Wider (female)	1					1														
Ceratinops annulipes Banks	1					1														
Ceratinops sp.	1					1														
Theridiidae, undetermined spp.	3										2				1					
Micryphantidae:																				
Eperigone tridentata Emerton	16					9					1		5					1		
Walckanaera vigilax Blackwall	3										1		1		1					
Micryphantidae, undetermined sp.	1					1														
Ceraticelus creolus Chamberlin	1					1														
Ceraticelus limnologicus Crosby and Bishop	1																	1		
Ceraticelus emertoni (Cambridge)	1					1														
Ceraticelus sp.	4					3					1									
Ceraticelus sp. (females)	4					3					1									
Ceratinopsis anglicana (Hentz)	3					1					1				1					
Ceratinopsis atolma Chamberlin	1														1					
Oedothorax parvus Banks	12					6					3		2					1		

[1] See table 10 for details.

TABLE 9.—*Insects, spiders, and mites collected by airplane, according to altitudes, Tallulah, La., August 1926 to October 1931, inclusive*—Con.

Order, family, genus, and species	Total insects taken		Collected at altitudes of—																	
	Day	Night	20 feet (day)	50 feet (day)	100 feet (day)	200 feet (day)	300 feet (day)	400 feet (day)	500 feet (night)	600 feet (day)	1,000 feet Day	1,000 feet Night	2,000 feet Day	2,000 feet Night	3,000 feet Day	3,000 feet Night	4,000 feet (day)	5,000 feet Day	5,000 feet Night	Over 5,000 feet (day)
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Araneida—Continued.																				
Linyphiidae:																				
Microneta meridionalis Crosby and Bishop	10		1			4					3				2					
Microneta meridionalis Crosby and Bishop (young)	5					1					1		3							
Microneta zonaria (Keyserling) (*M. micaria*)	3										2		1							
Microneta micaria (Emerton)	1																	1		
Microneta sp.	90					37					30		16		6			1		
Microneta sp. (females)	11	1				3						1	4		3			1		
Microneta sp. (young)		2												1		1				
Erigone autumnalis Emerton	18					5					6		7							
Erigone barrowsi Crosby and Bishop (males)	1	1	1											1						
Erigone sp.	2					1							1							
Erigone sp. (females)	1												1							
Erigone sp. (young)	1					1														
Erigoneae, undertermined spp.	5					2					2		1							
Erigoneae, undetermined sp. (female)	1										1									
Erigoneae, undetermined sp. (young)	1										1									
Pelecopsis moestum Banks (female)	1										1									
Linyphia communis Hentz	2					1					1									
Linyphia communis Hentz (young)	1					1														
Linyphia coccinea Hentz	3					3														
Linyphia sp.	1					1														
Linyphiidae, undetermined spp.	4				2															2
Argiopidae:																				
Araneus stellatus Walckenaer	1										1									
Araneus sp.	3					2									1					
Araneus sp. (young)	7					2					4		1							
Tetragnatha sp.	9		1			3					5									
Tetragnatha sp. (young)	12	1				4					5				1	1		2		
Mangora placida Hentz	1					1														
Mimognatha foxi McCook	2					1									1					
Argiopidae, undetermined spp.	10	1			1	2	2		1		1		2		1			1		
Argiopidae, undetermined spp. (young)	3	2				2						1			1	1				

Thomisidae:																				
Xysticus sp.	15					8					5		1		1					
Xysticus sp. (young)	13					6					3		2					2		
Philodromus sp. (male)	1					1														
Misumeninae, undetermined sp.	1					1														
Thomisidae, undetermined spp.	28	2	1			11					7	1	1	1	3		1	3		1
Thomisidae, undetermined spp. (young)	10	1				5					1		3			1		1		
Pisuridae:																				
Dolomedes sp.	2					1					1									
Clubionidae:																				
Castaneira sp.	1														1					
Clubionidae, undetermined spp.	4					2					2									
Lycosidae:																				
Lycosa sp.	4					2					1							1		
Lycosa sp. (young)	9		1			4					3				1					
Pirata sp.	14					6					7		1							
Pirata sp. (young)	5					3							2							
Pardosa sp.	19	2	1			5			1		3	1	7		2			1		
Pardosa sp. (young)	2					1							1							
Lycosidae, undetermined spp.	29		1	2		11					10		3		2					
Lycosidae, undetermined spp. (young)	1												1							
Oxyopidae:																				
Peucetia sp.	1														1					
Oxyopes sp.	20					12					4		3		1					
Oxyopes sp. (young)	1										1									
Salticidae:																				
Synemosyna formica Hentz	2		1												1					
Wala palmarum Hentz	1										1									
Phidippus purpuratus Keyserling	1														1					
Phidippus sp.	1					1														
Dendryphantes capitatus (Hentz)	3		1								1		1							
Dendryphantes sp.	4					4														
Salticidae, undetermined sp.	18		2			10					4		2							
Salticidae, undetermined sp. (young)	4												3							1
Araneida, unrecognizable sp. (young)	1																			1
Araneida, unrecognizable spp.	908	44	17			423	1		25		229	13	147	3	61	2	2	19	1	9
Total	1,401	60	28	2	3	629	3		28		362	18	224	7	97	6	3	36	1	14
Acarina:																				
Parasitinae (undetermined nymph)	1										1									
Parasitidae, undetermined spp. (females)	32					15					12		4		1					
Oribatidae:																				
Dameosoma sp.		1							1											
Acarina, undetermined spp.	10	1	1			8			1						1					
Acarina (undetermined nymph)	1					1														
Total	44	2	1			24			2		13		4		2					

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Order, family, genus, and species	Total insects taken		Collected at altitudes of—																	
	Day	Night	20 feet (day)	50 feet (day)	100 feet (day)	200 feet (day)	300 feet (day)	400 feet (day)	500 feet (night)	600 feet (day)	1,000 feet Day	1,000 feet Night	2,000 feet Day	2,000 feet Night	3,000 feet Day	3,000 feet Night	4,000 feet (day)	5,000 feet Day	5,000 feet Night	Over 5,000 feet (day)
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Thysanura:																				
Campodeidae:																				
Campodea sp.	1					1														
Lepismatidae:																				
Lepisma sp.	16	4							2		9		3	2	3					1
Thermobia domestica Packard	4	2				2			2		2									
Thermobia sp.	1					1														
Ctenolepisma sp.	2					2														
Lepismatidae, undetermined sp.	8					5					2		1							
Thysanura, undetermined sp.	2										2									
Total	34	6				11			4		15		4	2	3					1
Collembola:																				
Poduridae:																				
Onychiurus sp.	1												1							
Entomobryidae:																				
Entomobrya multifasciata Tullgren	1					1														
Entomobrya spp.	5					1							1		2			1		
Sira nigromaculata Lubbock	6					1					2		1		2					
Orchesella ainsliei Folsom	3					1					1							1		
Tomocerus flavescens Tullgren var. *americanus* Schött	1										1									
Sminthuridae:																				
Bourletiella sp.	3																	1		2
Sminthurus sp.	1																	1		
Collembola, undetermined spp.	5					2					1		1					1		
Total	26					6					5		4		4			5		2
Orthoptera:																				
Gryllidae:																				
Nemobius carolinus Scudder (male)		1												1						
Nemobius carolinus Scudder (females)		2										1		1						
Tridactylus minutus Scudder	2					1					1									

Acrididae:																				
Melanoplus femur-rubrum (DeGeer) (males)	3		1			1					1									
Melanoplus femur-rubrum (DeGeer) (female)	1										1									
Tettigidea acuta Morse (female)	1												1							
Tettigidea lateralis (Say) (male)	1												1							
Tettigidea lateralis (Say) (females)	2										2									
Phasmidae (undetermined nymph)	1					1														
Orthoptera, undetermined spp	2					1							1							
Total	13	3	1			4					5	1	3	2						
Isoptera:																				
Termitidae:																				
Reticulitermes virginicus Banks	19		2			8					6		2		1					
Corrodentia:																				
Psocidae:																				
Psocus inornatus Aaron	1														1					
Lachesilla pedicularia (Linnaeus)	31	2	2			14			1		5		1	1	3			4		2
Lachesilla sp	1	1				1			1											
Ectopsocus pumilis (Banks)	1	2							2						1					
Peripsocus sp	2										1		1							
Elipsocus sp	3					1					2									
Psocidae, undetermined spp	29	2	1			15			2		6		2		3			1		1
Atropidae:																				
Trogium pulsatorium (Linnaeus)	1																	1		
Troctes divinatorius (Mueller)	1										1									
Troctes sp		1							1											
Total	70	8	3			31			7		15		4	1	8			6		3
Ephemeroptera:																				
Baetidae:																				
Caenis hilaris (Say)	1												1							
Caenis sp	2	3				1			2		1					1				
Ephemeridae:																				
Hexagenia sp	1					1														
Ephemera sp	1												1							
Ephemeroptera, undetermined spp		2										2								
Total	5	5				2			2		1	2	2			1				
Odonata:																				
Libellulidae:																				
Perithemis tenera (Say)	1					1														
Libellula vibrans Fabricius	1					1														
Pachydiplax longipennis (Burmeister)	5					4					1									
Anisoptera, undetermined sp	3					1					2									

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	Day	Night	20 feet (day)	50 feet (day)	100 feet (day)	200 feet (day)	300 feet (day)	400 feet (day)	500 feet (night)	600 feet (day)	1,000 feet Day	1,000 feet Night	2,000 feet Day	2,000 feet Night	3,000 feet Day	3,000 feet Night	4,000 feet (day)	5,000 feet Day	5,000 feet Night	Over 5,000 feet (day)
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Odonata—Continued.																				
Coenagrionidae:																				
Enallagma sp.	1		1																	
Anomalagrion hastatum (Say)	6		1			2					3									
Zygoptera, undetermined spp.	4					3									1					
Total	21		2			12					6				1					
Thysanoptera:																				
Thripidae:																				
Sericothrips, close to *variabilis* Beach	4	1				1					1		1		1				1	
Sericothrips cingulatus Hinds	1										1									
Frankliniella tritici (Fitch)	19	5	1			8			5		4				4			1		1
Frankliniella fusca (Hinds)	6					2					2		2							
Thrips (*Microcephalothrips*) *abdominalis* Crawford	2												2							
Mycterothrips longirostrum (Jones)	1										1									
Phlaeothripidae:																				
Hoplandothrips pergandei (Hinds)	1					1														
Neurothrips magnafemoralis (Hinds)	4					4														
Leptothrips mali (Fitch)	8		1			4					1		2							
Elaphrothrips tuberculatus (Hood)	5					4					1									
Elaphrothrips sp.	1					1														
Liothrips caryae Fitch	12		1			7					4									
Liothrips castaneae Hood ?	1					1														
Liothrips citricornis (Hood)	5					1					3		1							
Liothrips sp.	4					2					2									
Haplothrips graminis Hood	5					1									2			1		1
Tubulifera, undetermined spp.	1					1														
Thysanoptera, undetermined spp.	11	1				6			1		1		2		1			1		
Total	91	7	3			44			6		21		10		8			3	1	2

Heteroptera:																				
Cydnidae:																				
Amnestus pusillus Uhler	42	4	2		16	16			4	1	4				3					
Allocoris (Thyreocoris) pulicaria (Germar)	20		1			9					5		4					1		
Galgupha aterrima Malloch	9		1			7							1							
Cydnidae, undetermined sp.	1					1														
Pentatomidae:																				
Trichopepla semivittata (Say)	1					1														
Mormidea lugens (Fabricius)	1										1									
Solubea pugnax (Fabricius)	1		1																	
Hymenarcys nervosa (Say)	4		1			3														
Banasa dimidiata (Say)	1										1									
Podisus maculiventris (Say)	2										2									
Coreidae:																				
Acanthocephala terminalis (Dallas)	1					1														
Anasa armigera (Say)	1										1									
Harmostes reflexulus (Say)	2					1							1							
Corizus hyalinus (Fabricius)	13	4				5			1		2	2	3		1			2	1	
Corizus sidae (Fabricius)	3			1		2														
Jadera haematoloma (Herrich-Schaeffer)	1					1														
Coreidae (undetermined adults)	3					1							1					1		
Coreidae (undetermined nymphs)	2																	1		1
Aradidae:																				
Aradus falleni Stål	2	1							1		1		1							
Aradus sp.	1					1														
Mezira granulata (Say)	1					1														
Neididae:																				
Aknisus multispinus (Ashmead)	1														1					
Jalysus spinosus (Say)	5	5			1	3			1			3	1			1				
Lygaeidae:																				
Oncopeltus fasciatus (Dallas)	2					1							1							
Lygaeus bicrucis Say	14	4				4			3		6	1	3							1
Ortholomus scolopax (Say)	1					1														
Nysius californicus Stål	18	1	2			8					7	1	1							
Nysius ericae (Schilling)	53	1	1	1		23			1		14		10		4					
Nysius ericae minutus Uhler	19	2				8			1		3		3		2	1		3		
Belonochilus numenius (Say)	4	1									1		1	1	2					
Ischnorhynchus resedae (Panzer)	21					3					3		6		6			3		
Ischnorhynchus championi Distant	7										4		2		1					
Cymus angustatus Stål	3	1	1			2			1											
Cymus virescens (Fabricius) (*breviceps* Stål)	14	1			1	5			1		7		1							
Blissus leucopterus (Say)	24	1	1			17			1		4		1		1					
Geocoris punctipes (Say)	29		3			19					4		2					1		
Geocoris bullatus (Say)	2				1						1									
Geocoris uliginosus (Say)	4					4														
Geocoris spp. (nymphs)	3	1	1								1		1	1						
Heraeus plebejus Stål	6					3					3									
Perigenes constrictus (Say)	2					1					1									
Orthaea bilobata (Say)	12	1			1	7		1	1				1		2					
Orthaea basalis (Dallas)	5					4					1									

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	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Heteroptera—Continued.																				
Lygaeidae—Continued.																				
Orthaea servillei (Guerin)	1					1														
Ptochiomera nodosa Say	17	2		1		8			2		4		2		2					
Antillocoris pallidus (Uhler)	51	19	3		1	24			17		11	1	5		4		1	1	1	1
Antillocoris pallidus (nymphs)	2					2														
Antillocoris spp	2																			
Aphanus umbrosus (Distant)	1					1							1				1			
Eremocoris ferus (Say)	1					1														
Lygaeidae, undetermined spp	2			1		1														
Tingitidae:																				
Piesma cinerea (Say)	1					1														
Corythucha pergandei Heidemann	1					1														
Corythucha spp	25	2	2			13			1		4	1	3		3					
Gargaphia amorphae (Walsh)	2										1		1							
Gargaphia spp	2	1							1		2									
Physatocheila sp	1												1							
Leptoypha sp	1					1														
Tingitidae, undetermined spp	8					3					2		1		2					
Enicocephalidae:																				
Systelloderus biceps (Say)	21	1	2			6			1		7		2		3			1		
Reduviidae:																				
Zelus cervicalus Stål	1					1														
Atrachelus cinereus (Fabricius)	1																			1
Hebridae:																				
Hebrus (Naeogeus) consolidus Uhler	1					1														
Hebrus spp	7					5					1		1							
Mesoveliidae:																				
Mesovelia mulsanti White	1					1														
Nabidae:																				
Nabis sordidus Reuter	1	1							1		1									
Nabis roseipennis Reuter	1	3							2		1			1						
Nabis sp	1										1									
Anthocoridae:																				
Orius (Triphleps) insidiosus (Say)	214	7	13			117			5		48	2	20		11			3		2
Miridae:																				
Trigonotylus breviceps Jokowlef		1							1											
Trigonotylus sp	10	8	2			6			5		1	2		1						1
Platytylellus sp	2					2														

Adelphocoris rapidus (Say)	6	2	2			4			2											
Polymerus basalis (Reuter)	5					2					3									
Polymerus sp.	2					2														
Lygus pabulinus (Linnaeus)	1										1									
Lygus apicalis Fieber	2										1		1							
Lygus pratensis (Linnaeus) (adults)	54	2	8			38			1		5		1	1	1			1		
Lygus pratensis (Linnaeus) (nymphs)	4					4														
Lygus pratensis var. *oblineatus* (Say)	2										1				1					
Lygus spp.	4	6				2			3		1	3			1					
Deraeocoris sp.	1		1																	
Lopidea sp.	1					1														
Psallus seriatus Reuter (adults)	7		2			2					2		1							
Psallus seriatus Reuter (nymphs)	1		1																	
Psallus spp.	4	1				4			1											
Chlamydatus suavis (Reuter)	1												1							
Chlamydatus spp.	6		1			5														
Cyrtopeltis varians (Distant)		2							2											
Ceratocapsus apicalis Knight	1										1									
Plagiognatus sp.	1										1									
Miridae, undetermined spp.	15	4	2			4			4		3		1		3			2		
Hydrometridae:																				
Hydrometra australis Say	1					1														
Gerridae:																				
Gerris marginatus Say	1										1									
Veliidae:																				
Microvelia sp.	2					2														
Saldidae:																				
Micranthis humilis (Say)	4					1					1		2							
Saldidae, undetermined sp.	1					1														
Corixidae:																				
Arctocorixa modesta Abbott	53	58	4			25			42		14	14	6	1	2			2	1	
Heteroptera, undetermined spp.	151	31	24	1		93			8		18	15	11	6	1		1	1	2	1
Heteroptera (undetermined nymphs)	9		1			5					2		1							
Total	1,080	179	83	5	21	555		1	115	1	216	45	107	12	57	2	3	23	5	8
Homoptera:																				
Cicadidae:																				
Tibicen linnei (Smith and Grossbeck)	1					1														
Cercopidae:																				
Tomaspis bicincta (Say)		1							1											
Clastoptera xanthocephala Germar	2					2														
Clastoptera xanthocephala var. *unicolor* Fowler	5		1			2					1		1							
Membracidae:																				
Stictocephala festina (Say)	64	1	6			55					3					1				
Acutalis semicrema (Say)	1	1	1													1				
Micrutalis calva (Say)	18		1			8					6		3							
Micrutalis sp.	1					1														
Entylia sinuata (Fabricius)	1					1														
Membracidae, undetermined sp.	1										1									

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Homoptera—Continued.	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Cicadellidae:																				
Eupteryginae, undetermined sp.	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	1	-----	-----	-----	-----	-----	-----	-----	-----	-----
Agalliopsis novella (Say)	1	-----	-----	-----	-----	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Agallia constricta Van Duzee	38	2	4	-----	-----	27	-----	-----	1	-----	3	-----	-----	-----	3	1	-----	-----	-----	1
Aceratagallia sanguinolenta (Provancher)	8	-----	1	-----	-----	7	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Idiocerus alternatus Fitch	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	1	-----	-----	-----	-----	-----	-----	-----
Idiocerus spp.	35	2	1	-----	-----	10	-----	-----	2	-----	6	-----	2	-----	6	-----	-----	1	-----	-----
Oncopsis sp.	1	-----	-----	-----	-----	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Oncometopia undata (Fabricius)	18	-----	1	-----	-----	13	-----	-----	-----	-----	3	-----	-----	-----	1	-----	-----	-----	-----	-----
Oncometopia lateralis (Fabricius)	3	-----	-----	-----	-----	3	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Homalodisca triquetra (Fabricius)	16	3	-----	-----	-----	13	-----	-----	2	-----	1	1	1	-----	1	-----	-----	-----	-----	-----
Aulacizes irrorata (Fabricius)	1	-----	-----	-----	-----	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Kolla hartii Ball	8	1	1	-----	-----	4	-----	-----	-----	-----	3	1	-----	-----	-----	-----	-----	-----	-----	-----
Graphocephala coccinea (Forster)	12	-----	1	-----	-----	3	-----	-----	-----	-----	5	-----	3	-----	-----	-----	-----	-----	-----	-----
Graphocephala versuta (Say)	67	3	6	-----	-----	26	-----	-----	3	-----	12	-----	12	-----	10	-----	-----	1	-----	-----
Draeculacephala mollipes (Say)	2	-----	-----	-----	-----	2	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Draeculacephala sp.	1	-----	-----	-----	-----	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Carneocephala flaviceps (Riley)	9	4	1	-----	-----	6	-----	1	4	-----	1	-----	-----	-----	-----	-----	-----	-----	-----	-----
Carneocephala spp.	3	1	-----	-----	-----	2	-----	-----	-----	-----	1	1	-----	-----	-----	-----	-----	-----	-----	-----
Xestocephalus pulicarius Van Duzee	28	47	2	-----	-----	14	-----	-----	36	-----	4	10	7	1	-----	-----	-----	-----	-----	1
Xestocephalus spp.	5	12	-----	-----	-----	2	-----	-----	10	-----	2	2	1	-----	-----	-----	-----	-----	-----	-----
Scaphoideus spp.	3	6	-----	-----	-----	2	-----	-----	2	-----	1	3	-----	1	-----	-----	-----	-----	-----	-----
Platymetopius frontalis Van Duzee	3	-----	1	-----	-----	2	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Polyamia weedi (Van Duzee)	5	-----	-----	-----	-----	2	-----	-----	-----	-----	2	-----	1	-----	-----	-----	-----	-----	-----	-----
Deltocephalus flavicostus Stål	3	-----	-----	-----	-----	3	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Deltocephalus sonorus Ball	4	4	-----	-----	-----	1	-----	-----	2	-----	-----	1	-----	-----	1	1	-----	2	-----	-----
Deltocephalus australis DeLong	8	-----	2	-----	-----	1	-----	1	-----	-----	-----	-----	-----	-----	2	-----	-----	-----	-----	2
Deltocephalus spp.	13	5	-----	1	-----	7	-----	-----	1	-----	2	2	1	1	2	1	-----	-----	-----	-----
Exitianus obscurinervis (Stål)	40	18	7	1	-----	13	-----	-----	9	-----	9	4	4	3	5	2	-----	1	-----	-----
Stirellus bicolor (Van Duzee)	10	-----	2	-----	-----	7	-----	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Stirellus obtutus (Van Duzee)	4	1	-----	-----	-----	-----	-----	-----	-----	-----	2	1	2	-----	-----	-----	-----	-----	-----	-----
Phlepsius spp.	1	2	-----	-----	-----	-----	-----	-----	1	-----	-----	-----	-----	-----	1	1	-----	-----	-----	-----
Thamnotettix clitellarius (Say)	-----	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	1	-----	-----	-----	-----	-----	-----	-----	-----
Thamnotettix nigrifrons (Forbes)	53	29	4	-----	-----	29	-----	-----	23	-----	7	3	6	1	7	2	-----	-----	-----	-----
Thamnotettix sp.	1	-----	-----	-----	-----	1	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Chlorotettix viridius Van Duzee	2	3	1	-----	-----	-----	-----	-----	3	-----	1	-----	-----	-----	-----	-----	-----	-----	-----	-----

Macrosteles divisus (Uhler)	40	7	3			28			2		3	3	4	2						2
Macrosteles spp.		1										1								
Balclutha abdominalis (Van Duzee)	6					2					2		1		1					
Eugnathodus spp.	17	11				3			7		1	2	7		2	1		4	1	
Dikraneura maculata Gillette	2	4				2			1			2				1				
Dikraneura carneola Stål		1												1						
Dikraneura sp.		1							1											
Alconeura macra Griffith	5	10				2			7		2	3	1							
Empoasca fabae (Harris)	14	5	2			6			3		2	1	2	1			1			1
Empoasca solana DeLong	2	4				1			4		1									
Empoasca erigeron DeLong	9	14				6			10		1	2	1	2						1
Empoasca bifurcata DeLong	1	1				1			1											
Empoasca n. sp. near *abrupta*		4							3			1								
Empoasca n. spp.	3	1				2			1		1									
Empoasca (*Kybos*) spp.	2	3				2			1			1		1						
Empoasca spp. (females)	39	53				19			26		11	13	3	8	3	3		2	3	1
Typhlocyba gillettei Van Duzee	1														1					
Typhlocyba sp.	1					1														
Hymetta spp.	1	1				1			1											
Erythroneura spp. *comes* group	2					2														
Erythroneura sp. *obliqua* group		2							2											
Erythroneura vulnerata Fitch	2		1			1														
Erythroneura vulnerata var. *nigerrima*	1					1														
Erythroneura vulnerata group	5		1			3					1									
Erythroneura abolla McAtee	1										1									
Erythroneura obria Beamer		1							1											
Erythroneura spp.	20	19	2			11			12		3	7	2							2
Cicadellidae (undetermined nymph)	1					1														
Cicadellidae (undetermined adults)	190	192	5			99			110		33	58	28	16	18	8		7		
Fulgoridae:																				
Catonia bicinctura Van Duzee	1							1												
Oliarus aridus Ball	26	13	1			5			8		3	5	3		12			2		
Oliarus spp.	1	5							5		1									
Pintalia dorsivittatus (Van Duzee)	1	7							4			1		2	1					
Cixius sp.	1										1									
Myndus sp.	1					1														
Otiocerus degeerii Kirby	1		1																	
Stenocranus dorsalis (Fitch)	3												1		2					
Megamelus spp.	47	1		2		10			1		10		10		6		4	4		1
Pissonotus sp.	1					1														
Peregrinus maidis (Ashmead)	2	5				2			3			2								
Stobaera tricarinata (Say)	4	1	1			2						1	1							
Liburniella ornata (Stål)	88	28	1	1		17			8		16	11	18	6	21	2		12	1	2
Delphacodes lateralis (Van Duzee)		1												1						
Delphacodes puella (Van Duzee)	112	27	8			35			19		24	7	19	1	23			3		
Delphacodes basivittata (Van Duzee)	2					1							1							
Delphacodes campestris (Van Duzee)	1	1				1			1											
Delphacodes propinqua (Fieber)	2					1					1									
Sogata furcifera (Horvath)	16	5				3			5		6		5		2					
Sogata spp.	19	3				3			3		4		6		3			3		
Delphacodes spp.	104	17	2			36			11		19	6	19		16		3	6		3
Delphacinae, undetermined spp.	80	19	3			35	2		16		13	3	15		7			5		
Fulgoridae, undetermined spp.	5		2			2					1									

TABLE 9.—*Insects, spiders, and mites collected by airplane, according to altitudes, Tallulah, La., August 1926 to October 1931, inclusive*—Con.

Order, family, genus, and species	Total insects taken		Collected at altitudes of—																	
	Day	Night	20 feet (day)	50 feet (day)	100 feet (day)	200 feet (day)	300 feet (day)	400 feet (day)	500 feet (night)	600 feet (day)	1,000 feet Day	1,000 feet Night	2,000 feet Day	2,000 feet Night	3,000 feet Day	3,000 feet Night	4,000 feet (day)	5,000 feet Day	5,000 feet Night	Over 5,000 feet (day)
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Homoptera—Continued.																				
Psyllidae:																				
Livia maculipennis (Fitch)	1					1														
Livia vernalis (Fitch)	1										1									
Aphalara veaziei Patch	48		17			22					4		2		2			1		
Aphalara sp. (probably *veaziei* var. *metzaria* Crawford)	1																			1
Aphalara spp.	6		3			3														
Trioza diospyri (Ashmead)	31	2				8			1		11		5		6			1	1	
Trioza sp. near *diospyri*	44	2	2			12			1		12		7		10	1		1		
Trioza tripunctata (Fitch)	1										1									
Trioza spp.	7					1	1				3		1		1					
Neotriozellia immaculata (Crawford)	9	1				3							6	1						
Pachypsylla venusta (Osten Sacken)	2			1									1							
Pachypsylla celtidis-mamma Riley	316	5	19			176			2	1	73	1	33	1	12	1		2		
Pachypsylla celtidis-vesiculum Riley		1										1								
Pachypsylla celtidis-gemma Riley	47			2		29					9		5		1					1
Pachypsylla spp.	7					2					2		2					1		
Psylla spp.	32					12					6		5		5			3		1
Psyllidae, undetermined spp.	28	8	1			6			3		8	4	3	1	5			5		
Aphiidae:																				
Chaitophorina sp.	2					1					1									
Sipha flava (Forbes)	1										1									
Aphis gossypii Glover	8	2				1			1		2	1			4					1
Anuraphis sp.	1					1														
Aphis spp.	13					8					1		3							1
Rhopalosiphum pseudobrassicae (Davis)	8					3					2		3							
Rhopalosiphum spp.	3			1		2														
Myzocallis sp.	1					1														
Amphorophora sp. (probably new)	1												1							
Macrosiphum (*Tritogenaphis*) *rudbeckiae* (Fitch)	1					1														
Macrosiphum (*Tritogenaphis*) spp.	2	1				1							1			1				
Macrosiphum (*Illinoia*) *pisi* (Kaltenbach)	17					14					1		1				1			
Macrosiphum (*Illinoia*) spp.	3					3														
Macoura sp.	1					1														

Myzus persicae (Sulzer)	1														1					
Colopha ulmicola (Fitch)	1												1							
Neoprociphilus spp	2										2									
Pemphigus populi-transversus (Riley)	1														1					
Eriosomatinae undetermined spp	5					3					1				1					
Aphididae (undetermined nymphs)	2	3							3		1		1							
Aphididae (undetermined adults)	230	25	3	1	2	92			17		58	3	31	3	33	2	3	5		2
Aleyrodidae:																				
Aleyrodidae, undetermined spp	2					1					1									
Coccidae:																				
Coccidae, undetermined spp	2										2									
Homoptera (undetermined nymphs)	5					3					1		1							
Homoptera (undetermined adults)	800	100	69		1	454	2		116		131	28	58	34	45	4	2	28	8	10
Total	3,079	855	191	10	3	1,497	5	4	521	1	573	198	363	88	284	34	14	100	14	34
Coleoptera:																				
Carabidae:																				
Clivina dentipes Dejean		1										1								
Bembidion affine Say	3	10				3			8			2								
Bembidion variegatum Say	1	1									1	1								
Bembidion sp	3		1	1											1					
Pericompsus ephippiatus (Say)	1					1														
Tachyura sp	5	11				5			8			3								
Tachys laevus (Say)	20	1				13			1		7									
Tachys proximus (Say)		3							2			1								
Tachys corruscus LeConte		5							5											
Tachys sp	71	27	3			35		1	20		17	6	5	1	8			1		1
Micratopus fusciceps Casey	12	46				9			40		2	6	1							
Micratopus sp	3	5				2			4				1						1	
Poecilus chalcites Say	1										1									
Loxandrus sp		2										1		1						
Celia muscula (Say)	2					2														
Circinalia rufipes (Dejean)	1					1														
Circinalia sp	2					2														
Zuphium americanum Dejean		3							2					1						
Lebia viridipennis Dejean	1					1														
Lebia analis Dejean	1					1														
Blechrus pusio LeConte	8		1			3					3									1
Blechrus sp	1					1														
Apenes sinuata (Say)		2							2											
Brachynus sp		1							1											
Harpalus nitidulus Chaudoir	47		3			41					3									
Harpalus sp	1					1														
Selenophorus sp	1					1														
Discoderus sp	2					1							1							
Triplectrus dulcicollis (LaFerté-Sénectère)	2		1			1														
Pseudamphasia sericea (Harris)	1					1														
Stenocellus tantillus (Dejean)	12	4				6			4		2		1		2					1
Amerinus longipennis Casey	1		1																	
Goniolophus lucens Casey	1	2							2				1							
Goniolophus rectangulus (Chaudoir)		3							3											

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	Day	Night	20 feet (day)	50 feet (day)	100 feet (day)	200 feet (day)	300 feet (day)	400 feet (day)	500 feet (night)	600 feet (day)	1,000 feet Day	1,000 feet Night	2,000 feet Day	2,000 feet Night	3,000 feet Day	3,000 feet Night	4,000 feet (day)	5,000 feet Day	5,000 feet Night	Over 5,000 feet (day)
Coleoptera—Continued.	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Carabidae—Continued.																				
Stenolophus ochropezus (Say)	18	4	3			14			2		1	2								
Stenolophus dissimilis Dejean	1					1														
Stenolophus conjunctus (Say)	1					1														
Tachistodes indistinctus (Dejean)	19	4	1			17			2		1	1				1				
Tachistodes testaceus (Dejean)	17	8				16			8		1									
Tachistodes partiarius (Say)	1	1													1	1				
Tachistodes sp.	2	3				1			2				1						1	
Agonoderus pallipes (Fabricius)	10	3	2			8			2			1								
Carabidae, undetermined spp.	35	12	9			23			9		3	2				1				
Haliplidae:																				
Haliplus sp.	2				1								1							
Haliplidae undetermined sp.	1										1									
Dytiscidae:																				
Bidessus pullus (Le Conte)	1					1														
Bidessus granarius (Aubé)	1					1														
Bidessus sp.	1	1				1			1											
Coptotomus interrogatus (Fabricius)	2		1								1									
Copelatus glyphicus (Say)	2	1				2						1								
Dytiscidae, undetermined sp.	1					1														
Hydrophilidae:																				
Ochthebius sp.	1					1														
Hydraena pennsylvanica Kiesenwetter	1					1														
Hydraena marginicollis Kiesenwetter	4		1			2												1		
Helophorus sp.	1					1														
Hydrochus sp.	3	4				2			4				1							
Berosus striatus (Say)	1					1														
Tropisternus striolatus (LeConte)	2	1				1			1		1									
Paracymus subcupreus (Say)	5		1			4														
Paracymus sp.	3					3														
Enochrus sp.	6		1			5														
Cercyon sp.	2					1							1							
Scydmaenidae:																				
Conophron sp.	2	6	1			1			5			1								
Scydmaenidae, undetermined spp.	3		1			1					1									

Staphylinidae:																				
Micropeplus sp.	1					1														
Ocytelinae, undetermined sp.	1														1					
Omaliinae, undetermined spp.	19					17					2									
Omalium sp.	22		2			15					5									
Ephelinus guttatus (LeConte)	7		3			3					1									
Ephelinus notatus (LeConte)	3					3														
Trogophloeus sp.	158	72	8			107			60		22	6	7	3	7	2		7	1	
Apocellus sphaericollis (Say)	2					2														
Apocellus sp.	2					2														
Oxytelus sp.	6		2			1					1		1		1					
Platystethus americanus Erichson	1					1														
Platystethus sp.	4					3									1					
Bledius sp.	104	20	2			86			24		11	5	4					1		
Holotrochus sp.	1					1														
Osorius sp.	1		1																	
Stenus sp.	183		43	1		82		1			41		12		2			1		
Euaesthetus sp.	5	1				4					1	1								
Paederinae, undetermined spp.	23	9	1			21			7			2	1							
Palaminus sp.	5	19				1			16		1		1			3		2		
Lathrobium sp.	25	6	1			19			6		3		1		1					
Medon sp.	11	1	8			2						1						1		
Scopaeus sp.	16	6	2			11			4		2	2						1		
Stilicus sp.	2		1			1														
Astenus discopunctatus (Say)	3		1												2					
Astenus prolixus (Erichson)	1		1																	
Astenus sp.	12	16				9			13		1		2	2					1	
Xantholinini, undetermined spp.	2		2																	
Gyrohypnus sp.	2					2														
Philonthus sp.	5	2				5			2											
Staphylinus cinnamopterus Gravenhorst	2					1					1									
Quedius sp.	2					2														
Tachyporinae, undetermined spp.	10	1				7			1		2		1							
Tachinus limbatus Melsheimer	1					1														
Tachinus sp.	2					2														
Tachyporus sp.	19	1	1			14			1		2		2							
Erchomus sp.	1		1																	
Conosoma sp.	2	4				2			4											
Bolitobius sp.	12	1				5					5	1			2					
Aleocharinae, undetermined spp.	220	19	22		1	135			13		43	3	17	1		1			1	2
Myllaena sp.	3					2							1							
Myrmedonia sp.	3		1			2														
Hoplandria lateralis (Melsheimer)	2	1				2						1								
Atheta sp.	18		4	2		7					2				2					1
Byroporus sp.	18	2	4			10			2		3		1							
Cardiola sp.	1										1									
Aleochara sp.	1			1																
Baryodma sp.	1												1							
Oxypoda sp.	24					20					2		1							1
Staphylinidae, undetermined spp.	219	16	31	2	2	93	4		15		43	1	17		15		1	7		4
Pselaphidae:																				
Pselaphidae, undetermined spp.	21	11	2	5	1	9			10		3	1	1							

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Coleoptera—Continued.	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Trichopterygidae:																				
Trichopterygidae, undetermined spp.	6										4		2							
Histeridae:																				
Hister sp.	1												1							
Acritus sp.	1					1														
Saprinus sp.	2					1					1									
Lycidae:																				
Plateros sp.	3					2					1									
Lampyridae:																				
Pyropyga minuta (LeConte)	1					1														
Lampyridae, undetermined spp.	4					4														
Cantharidae:																				
Chauliognathus marginatus (Fabricius)	28					25					1		2							
Cantharis bilineatus Say	3					2									1					
Cantharis sp.	1										1									
Malachidae:																				
Collops quadrimaculatus (Fabricius)	1					1														
Anthocomus erichsoni LeConte	2		1			1														
Cleridae:																				
Monophylla terminata (Say)	1					1														
Micromalthidae:																				
Micromalthus debilis LeConte	1										1									
Mordellidae:																				
Mordellistena aspera (Melsheimer)	1					1														
Mordellistena pustulata (Melsheimer)	16	1	1			13			1		1		1							
Mordellistena sp.	2					2														
Mordellidae, undetermined sp.	1		1																	
Anthicidae.																				
Notoxus bicolor (Say)	1	4				1			4											
Notoxus monodon (Fabricius)	1	2				1			1			1								
Notoxus sp.	1	1	1						1											
Tomoderus constrictus (Say)		1							1											
Anthicus rejectus LeConte	1												1							
Anthicus vicinus LaFerté-Sénectère	4										1				2					
Anthicus cervinus LaFerté-Sénectère	4	4				3			2		1	1							1	

Anthicus (*Sapintus*) *fulvipes* LaFerté-Sénectère	1					1														
Anthicus sp.	48	30	2			37			22		0	5	1	1	1				2	1
Anthicidae, undetermined sp.	1		1																	
Euglenidae:																				
Zonantes signatus (Haldeman)		1							1											
Zonantes subfasciatus (LeConte)	1	1				1										1				
Zonantes fasciatus (Haldeman)		5							4					1						
Elateridae:																				
Conoderus bellus (Say)	2					2														
Aeolus amabilis (LeConte)	1	1				1			1											
Hypnoidus obliquatulus (Melsheimer)	1					1														
Hypnoidus sp.	3					2									1					
Glyphonyx testaceus (Melsheimer)	3		1			1							1							
Melasidae:																				
Isorhipis ruficornis (Say)	1					1														
Throscidae:																				
Aulonothroscus convergens (Horn)	1														1					
Throscus chevrolati Bonvouloir		1							1											
Buprestidae:																				
Taphrocerus gracilis (Say)	9	2	2			6			2		1									
Heteroceridae:																				
Heterocerus pusillus (Say)	22	11				19			11		1		2							
Heterocerus sp.	8	1	2			4									2				1	
Helodidae:																				
Cyphon variabilis (Thunberg)		1																	1	
Cyphon sp.	7	15	1			5			13		1			2						
Scirtes orbiculatus (Fabricius)	2	1				2			1											
Ptilodactyla serricollis (Say)		2							1			1								
Ptilodactyla sp.	2	9							4		1	4		1				1		
Dermestidae:																				
Trogoderma sp. (undetermined live larva)	1																			1
Dermestidae, undetermined sp.	2					2														
Nitidulidae:																				
Carpophilus sp.	3	1	2						1		1									
Epuraea avara (Randall)	2	1				1					1			1						
Epuraea sp.	5	3				2					2	3	1							
Stelidota strigosa (Gyllenhal)	10	3				5			3		2		3							
Stelidota sp.	4		1										1		2					
Monotomidae:																				
Monotoma americana Aubé	4		1			3														
Hesperobaenus rufipes LeConte	1										1									
Bactridium sp.	2	1				2			1											
Cucujidae:																				
Silvanus imbellis LeConte	1		1																	
Laemophloeus biguttatus (Say)		2							2											
Laemophloeus sp.	1	4							3			1						1		
Erotylidae:																				
Languria mozardi Latreille	1		1																	
Languria angustata (Beauvois)	2					2														
Languria angustata var *pulchra* LeConte	1					1														

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TABLE 9.—*Insects, spiders, and mites collected by airplane, according to altitudes, Tallulah, La., August 1926 to October 1931, inclusive*—Con.

Order, family, genus, and species	Total insects taken		Collected at altitudes of—																	
	Day	Night	20 feet (day)	50 feet (day)	100 feet (day)	200 feet (day)	300 feet (day)	400 feet (day)	500 feet (night)	600 feet (day)	1,000 feet Day	1,000 feet Night	2,000 feet Day	2,000 feet Night	3,000 feet Day	3,000 feet Night	4,000 feet (day)	5,000 feet Day	5,000 feet Night	Over 5,000 feet (day)
Coleoptera—Continued.	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Cryptophagidae:																				
Cryptophilus integer (Heer)		1										1								
Toramus pulchellus (LeConte)	1	2							1		1	1								
Toramus sp.	7	1	1			4					2	1								
Cryptophagus sp.	1	4	1						4											
Atomaria sp.	14	1	8			1					2	1			2			1		
Mycetophagidae:																				
Typhaea stercorea (Linnaeus)	2					2														
Colydiidae:																				
Synchita sp.	1		1																	
Bitoma quadricollis (Horn)		1							1											
Bitoma sp.	1										1									
Lathridiidae:																				
Coninomus constrictus (Gyllenhal)	1												1							
Enicmus sp.	2					2														
Corticaria serrata (Paykull)		1							1											
Corticaria ferruginea Marsham	5					4					1									
Corticaria sp.	50	5	8			20			5		8		3					1		1
Melanophthalma picta (LeConte)	2					1					1									
Melanophthalma distinguenda (Comolli)	5												1		4					
Melanophthalma cavicollis (Mannerheim)	14	1				9					2	1	1		1			1		
Melanophthalma sp.	11	19	1			10			18			1								
Lathridiidae, undetermined spp.	5					5														
Phalacridae:																				
Phalacrus sp.	2					2														
Stilbus sp.	2														1		1			
Phalacridae, undetermined spp.	8	6				5			6		2		1							
Coccinellidae:																				
Scymnus terminatus Say	7					4					1							2		
Scymnus loewi Mulsant	2					2														
Scymus sp.	3			1							1		1							
Psylloboro sp.	1					1														
Naemia seriata (Melsheimer)	12		3			7					1				1					
Coleomegilla fuscilabris (Mulsant)	11		1			10														
Colemoegilla floridana (Leng)	1																			1

Hippodamia convergens Guerin	10	1	5			3						1			1			1		
Coccinella novemnotata Herbst	1										1									
Cycloneda munda (Say)	2	1				1					1	1								
Tenebrionidae:																				
Tribolium castaneum (Herbst)	3					1					1				1					
Tribolium sp	1										1									
Hypophloeus sp		1										1								
Anobiidae:																				
Anobiidae, undetermined sp	1														1					
Bostrichidae:																				
Xylobiops basilare (Say)	1					1														
Scarabaeidae:																				
Aphodius lividus (Olivier)		2							2											
Aphodius sp	3	1	1			2			1											
Ataenius gracilis (Melsheimer)	3					3														
Ataenius sp		5							5											
Cerambycidae:																				
Dectes spinosus (Say)	1					1														
Chrysomelidae:																				
Pachybrachis sp	5		2			3														
Colaspis brunnea (Fabricius)	7					6					1									
Fidia viticida Walsh	1					1														
Metachroma sp	2					2														
Myochrous denticollis (Say)	25		6			18									1					
Myochrous sp		1							1											
Paria canella (Fabricius)	2					1									1					
Paria sp	1					1														
Chrysomela (Lina) scripta Fabricius		1							1											
Diabrotica duodecimpunctata (Fabricius)	18	10	4			10			2		4	5		2		1				
Diabrotica vittata (Fabricius)	6	6	2			2			4		1	2								1
Cerotoma trifurcata (Forster)	2					2														
Oedionychis sexmaculata (Illiger)	1					1														
Disonycha collata (Fabricius)	1					1														
Altica nana Crotch	1					1														
Altica rufa Illiger	3					1	1				1									
Altica scutellaris Olivier	4	1	1			2			1		1									
Altica sp	3	3				2			3				1							
Chalcoides helxines (Linnaeus)	16	1				14			1		2									
Crepidodera atriventris Melsheimer	12					7					3		2							
Crepidodera sp	4			1		2							1							
Epitrix fuscula Crotch		1							1											
Epitrix cucumeris (Harris)	2					2														
Epitrix brevis Schwarz	1					1														
Epitrix parvula (Fabricius)	4					3					1									
Epitrix sp	2		1			1														
Mantura floridana Crotch	7					6					1									
Chaetocnema denticulata (Illiger)	1					1														
Chaetocnema confinis Crotch	3					3														
Chaetocnema pulicaria Melsheimer	19					14					3				1			1		
Chaetocnema sp	73	1	2			56					10	1	5							
Systena frontalis (Fabricius)	1		1																	
Systena taeniata Say	6		2			3					1									

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Order, family, genus, and species	Total insects taken		Collected at altitudes of—																	
	Day	Night	20 feet (day)	50 feet (day)	100 feet (day)	200 feet (day)	300 feet (day)	400 feet (day)	500 feet (night)	600 feet (day)	1,000 feet Day	1,000 feet Night	2,000 feet Day	2,000 feet Night	3,000 feet Day	3,000 feet Night	4,000 feet (day)	5,000 feet Day	5,000 feet Night	Over 5,000 feet (day)
Coleoptera—Continued.	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Chrysomelidae—Continued.																				
Systena sp	3					3														
Longitarsus turbatus Horn	2					1							1							
Longitarsus testaceus Melsheimer	209		32	1		139					28		7		1			1		
Glyptina brunnea Horn	12	1	1			9			1		1				1					
Phyllotreta striolata (Illiger)	3					3														
Phyllotreta bipustulata (Fabricius)	1										1									
Psylliodes punctulata Melsheimer	8					7					1									
Baliosus ruber (Weber)	1					1														
Metriona bivittata (Say)	1					1														
Metriona bicolor (Fabricius)	1										1									
Chrysomelidae, undetermined spp	2			1		1														
Bruchidae:																				
Acanthoscelides alboscutellatus (Horn)	2					1												1		
Acanthoscelides compressicornis (Schaeffer)	2					2														
Acanthoscelides bisignatus (Horn)	1	1				1			1											
Acanthoscelides hibisci (Olivier)	1		1																	
Acanthoscelides submuticus (Sharp)	1										1									
Acanthoscelides sp	2					2														
Megacerus sp. (near *impiger*)	1	1							1		1									
Anthribidae:																				
Brachytarsus vestitus LeConte	1																			1
Brachytarsus sp	2					1					1									
Curculionidae:																				
Apion metallicum Gerstaecker	18		1			12					5									
Apion sp	6		2	1		1	1				1									
Hyperodes sp	2										2									
Smicronyx sp	1	4							4		1									
Stenopelmus rufinasus Gyllenhal	14					8					4		1		1					
Tanysphyrus lemnae (Fabricius)	7	6				4			4		2	2	1							
Thysanocnemis sp	1										1									
Tylopterus pallidus LeConte	2					1					1									
Anthonomus grandis Boheman (females)	12	1	1				6				2	1	3							
Anthonomus grandis Boheman (male)	1						1													
Anthonomus albopilosus Dietz	2					1							1							
Baris aerea (Boheman)	10		4			5					1									

Baris sp.	3					3														
Centrinaspis picumnus (Herbst)	4					4														
Anacentrinus validulus (Casey)	1					1														
Anacentrinus blanditus (Casey)	1										1									
Anacentrinus deplanatus (Casey)	1					1														
Sibariops confusa (Boheman)	1					1														
Barinus curticollis (Casey)	4					2					1							1		
Auleutes nebulosis (LeConte)	1					1														
Ceutorhynchus squamatus LeConte	1										1									
Ceutorhynchus medialis LeConte	4					4														
Ceutorhynchus sp.	2				1						1									
Conotrachelus erinaceus LeConte	9					6					3									
Tyloderma aerea (Say)		1							1											
Platypodidae:																				
Platypus quadridentatus Olivier (male)	1					1														
Platypus compositus Say	3		2			1														
Scolytidae:																				
Leperisinus aculeatus (Say)	5					5														
Hypothenemus sp.	1										1									
Gnathotrichus materiarius Fitch	3					2									1					
Pityophthorus rhois Swaine	1					1														
Ips avulsus (Eichorn)	1					1														
Xyleborus pecanis Hopkins	16	1	4			3					6	1	1		1			1		
Scolytidae, undetermined spp.	33		9	1		3					7		2		6			5		
Coleoptera, undetermined spp.	907	259	128	3		588	3		213	1	114	30	26	9	16	1	2	11	6	15
Total	3, 567	854	431	21	6	2, 232	9	2	680	1	519	120	161	26	98	12	4	51	16	32
Neuroptera:																				
Sympherobiidae:																				
Sympherobius amiculus (Fitch)	1	3									1	2				1				
Hemerobiidae:																				
Micromus sp.	1	3							3						1					
Hemerobiidae, undetermined spp.	1	2									1			1		1				
Chrysopidae:																				
Chrysopa oculata Say	1	2				1			1			1								
Chrysopa oculata var. *albicornis* Fitch	1	4				1			1					3						
Chrysopa chlorophana Burmeister		1							1											
Chrysopa plorabunda Fitch	3	7				3						4				2			1	
Chrysopa sp.	1	3							1			2			1					
Coniopterygidae:																				
Malacomyza westwoodi (Fitch)	1														1					
Neuroptera, undetermined sp.		1							1											
Total	10	26				5			8		2	9		4	3	4			1	
Trichoptera:																				
Leptoceridae:																				
Oecetis sp.	1																	1		
Trichoptera, undetermined spp.	2					2														
Total	3					2												1		

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	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Mecoptera:																				
Panorpidae:																				
Panorpa sp	3																	3		
Lepidoptera:																				
Pieridae:																				
Colias eurytheme Boisduval	1			1																
Nymphalidae:																				
Phyciodes tharos form *marcia* Edwards	1		1																	
Junonia coenia (Huebner)	1					1														
Hesperiidae:																				
Epargyreus tityrus (Fabricius)	1									1										
Antigonus nessus (Edwards)	1		1																	
Hesperia leonardus Harris	1		1																	
Lerema accius (Abbott and Smith)	1					1														
Lerodea eufala (Edwards)	1					1														
Syntomidae:																				
Cisseps fulvicollis (Huebner)	3					1					1		1							
Cisseps fulvicollis (Huebner) female	1												1							
Noctuidae:																				
Heliothis obsoleta (Fabricius)		1							1											
Laphygma frugiperda (Abbott and Smith)	1	5							4			1	1							
Laphygma frugiperda (alive)		1							1											
Eublemma obliqualis (Fabricius)		1							1											
Autographa brassicae (Riley)		1							1											
Alabama argillacea (Huebner)	3	19				1			14		1	5			1					
Tetanolita mynesalis (Walker)		1							1											
Ommatochila mundula Zeller		1							1											
Bomolocha sp		1							1											
Plathypena scabra (Fabricius)		1							1											
Noctuidae, undetermined spp		4							3			1								
Geometridae:																				
Geometridae, undetermined spp		2										2								
Pyralididae:																				
Nomophila noctuella (Denis and Schiffermüller)	1														1					
Loxostege similalis (Guenée)		3							2							1				
Geshna primordalis Dyar		6							2			4								

Pyralis farinalis Linnaeus	1																	1		
Elasmopalpus lignosellus (Zeller)		3							3											
Pyraustinae, undetermined sp.		1																	1	
Pyralidae, undetermined sp.	1									1										
Pterophoridae:																				
Pterophorus tenuidactylus Fitch	1					1														
Pterophorus sp.	1					1														
Pterophoridae, undetermined sp.		1										1								
Cosmoterygidae:																				
Cosmoterygidae, undetermined sp.		1							1											
Lavernidae:																				
Cosmopteryx spp.		2										1							1	
Gelechiidae:																				
Aristotelia sp. *roseosuffusella* Clemens?		2							1			1								
Aristotelia quinquepunctella Busck	1												1							
Gelechia spp.	2					1					1									
Gelechia sp. (larvae)	2	1							1		2									
Stegasta bosquella (Chambers)		1										1								
Dichomeris ligulella Huebner	1												1							
Gelechiidae, undetermined spp.		2							2											
Blastobasidae:																				
Holocera spp.	2	1				1					1	1								
Olethreutidae:																				
Olethreutes cespitana (Huebner)		1										1								
Epiblema strenuana (Walker)		1							1											
Glyphipterygiidae:																				
Glyphipteryx impigritella Clemens	1														1					
Gracilariidae:																				
Neurobathra strigifinitella (Clemens)		1							1											
Scythrididae:																				
Eupermenia sp.		1																	1	
Lyonetiidae:																				
Bedellia somnulentella Zeller?		1												1						
Bucculatrix sp.	1	2				1			2											
Tineidae:																				
Tinea sp.	1												1							
Nepticulidae:																				
Nepticula sp.	2					2														
Lepidopterous larvae	2					2														
Microlepidoptera, undetermined spp.	16	42				4			32		6	6	4	2	2				2	
Lepidoptera (undetermined adults)	23	39	2			18			28			6	2	2	1	1			2	
Total	75	150	5	1		36			105	2	12	31	12	5	6	2		1	7	
Hymenoptera:																				
Braconidae:																				
Microbracon gelechiae (Ashmead)	2					2														
Microbracon pyralidiphagus Muesebeck	1		1																	
Microbracon mellitor (Say)	9	1	1			5					2			1				1		
Microbracon platynotae (Cushman)	3					1									2					
Microbracon punctatus Muesebeck	3					2					1									
Microbracon sp.	10					2					4				2		1			1

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											Day	Night	Day	Night	Day	Night		Day	Night	
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Hymenoptera—Continued.																				
Braconidae—Continued.																				
Microbracon n. sp	1					1														
Zavipio belfragei (Cresson)	1					1														
Allobracon sp		1										1								
Doryctes rufiventris (Brullé)	1										1									
Heterospilus prosopidis Viereck	1		1																	
Heterospilus sp	4	1				3			1		1									
Ecphylus sp	1		1																	
Pambolus americanus (Ashmead)	2	1				2			1											
Hormius sp		2							2											
Hormiopterus n. sp	1					1														
Hormiinae, undetermined sp	1					1														
Lysitermus sp	1					1														
Oncophanes sp		1							1											
Clinocentrus n. sp	1												1							
Rogas nolophanae Ashmead	1	1							1		1									
Rogas sp		2							2											
Polystenidea parksi Viereck	1					1														
Polystenidea sp	1					1														
Triaspis curculionis (Fitch)	3					1							1		1					
Episigalphus minutissimus Ashmead	1					1														
Chelonus albobasilaris Ashmead	1					1														
Chelonus texanus Cresson	22		7			12					1				1			1		
Chelonus sp	8					7					1									
Phanerotoma tibialis (Haldeman)	1												1							
Phanerotoma sp	1	1							1		1									
Mirax texana Muesebeck		1												1						
Adelius coloradensis Muesebeck	1										1									
Microgaster zonaria Say	1										1									
Microplitis feltiae Muesebeck	1					1														
Microplitis varicolor Viereck	1										1									
Microplitis sp	2					2														
Apanteles flaviconchae Riley	1	1				1			1											
Apanteles americanus (Lepeletier)	1														1					
Apanteles marginiventris (Cresson)	6		1			2					1		2							
Apanteles militaris (Walsh)	13	1	1			8			1		4									
Apanteles xylinus (Say)	2		1			1														
Apanteles aristoteliae Viereck	1		1																	

Apanteles forbesi Viereck	3					2									1					
Apanteles hyphantriae Riley	3					2							1							
Apanteles rohweri Muesebeck	1														1					
Apanteles sp.	48	2	2	1		26			2		11		6		1			1		
Microgasterinae, n. gen., n. sp.	2		1			1														
Bassus annulipes (Cresson)	1					1														
Bassus erythrogaster Viereck	1					1														
Bassus sp.	1					1														
Blacus sp.	2	1	1									1					1			
Orgilus sp.	1										1									
Ganychorus sp.	4					4														
Lelophronini, undetermined sp.	1										1									
Diospilus sp.	1										1									
Blacinae, undetermined sp.		1										1								
Macrocentrus delicatus Cresson		1							1											
Zele mellea (Cresson)		1							1											
Zele sp.		1										1								
Opius dimidiatus Ashmead	1					1														
Opius coriaceus Gahan	1										1									
Opius sp.	8	1				3			1		3		2							
Opius n. sp.	6		1			3					1		1							
Gnamptodon nepticulae Rohwer	1					1														
Gnamptodon sp.	1										1									
Meteorus autographae Muesebeck	1										1									
Meteorus vulgaris (Cresson)	11	2				11			1					1						
Perilitus sp.	4					4														
Euphorus sp.	1					1														
Euphorus n. sp.		1							1											
Euphoriella sp.	1	1				1			1											
Aphidius polygonaphis (Fitch)	7					6							1							
Aphidius bicolor Ashmead		1							1											
Aphidius sp.	1										1									
Lysiphlebus testaceipes (Cresson)	17					6					7		1		1			2		
Diaeretus rapae (Curtis)	8					8														
Aphidiinae, undetermined spp.	6					4					2									
Aphaereta muscae Ashmead	6					4					1				1					
Aphaereta sp.	6		1								4							1		
Ischnocarpa sp.	1										1									
Dinotrema sp.	2					1					1									
Delocarpa sp.	1					1														
Spanomeris sp.	1												1							
Alysiinae, undetermined spp.	10					7					2				1					
Rhizarcha sp.	1					1														
New genus, new species	2					1									1					
Dacnusinae, undetermined sp.	1												1							
Braconidae, undetermined spp.	12					5					3		2		1					1
Ichneumonidae:																				
Amblyteles tumidifrons (Cresson)	2					1							1							
Amblyteles sp. near *humilis* (Provancher)	2										2									
Amblyteles sp.	1										1									
Phygadeuon sp.	1										1									
Acrolyta aletiae Ashmead	1												1							

TABLE 9.—*Insects, spiders, and mites collected by airplane, according to altitudes, Tallulah, La., August 1926 to October 1931, inclusive*—Con.

Order, family, genus, and species	Total insects taken		Collected at altitudes of—																	
	Day	Night	20 feet (day)	50 feet (day)	100 feet (day)	200 feet (day)	300 feet (day)	400 feet (day)	500 feet (night)	600 feet (day)	1,000 feet Day	1,000 feet Night	2,000 feet Day	2,000 feet Night	3,000 feet Day	3,000 feet Night	4,000 feet (day)	5,000 feet Day	5,000 feet Night	Over 5,000 feet (day)
Hymenoptera—Continued.	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Ichneumonidae—Continued.																				
Hemiteles sp	4					3									1					
Zamicrotoridea syrphicola (Ashmead)	2					2														
Hemitelini, undetermined spp	4					2					2									
Gelis sp. (male)	1					1														
Hoplocryptus incertulus Cushman	1										1									
Diapetimorpha acadia Cushman	1												1							
Derocentrus macilentus (Cresson)	1														1					
Zaglyptus incompletus (Cresson)	1		1																	
Ephialtes aequalis (Provancher)	3					2									1					
Asphragis n. sp	1										1									
Orthocentrus sp	7	3				6			1					1	1				1	
Orthocentrini, undetermined sp	1					1														
Diplazon laetatorius (Fabricius)	1										1									
Cymodusa eurycreonis (Ashmead)	1										1									
Cymodusa sp	1														1					
Sagaritis provancheri (Dalla Torre)	1					1														
Sagaritis oxylus (Cresson)	4					4														
Pristomerus agilis (Cresson)	1					1														
Neopristomarus melleus Cushman	1					1														
Leptopygus sp	7	2				4			1		2	1						1		
Mesochorus melleus Cresson	1					1														
Mesochorus sp		1							1											
Catastenus sp		1												1						
Proclitus sp	3	1				3								1						
Stenomacrus sp	1												1							
Serphoidea, undetermined spp	8					3					2		2		1					
Diapriidae:																				
Belyta rugosopetiolata (Ashmead)	1					1														
Acilista sp	2												2							
Xenotoma n. sp. near *petiolata* Whittaker		1							1											
Xenotoma n. sp. near *megaplasta* Ashmead	1					1														
Xenotoma sp		1										1								
Belytinae, undetermined spp	2	1				1					1	1								
Phaenopria sp	7					5					1									1
Galesus sp	1										1									

Loxotropa sp.	2					1					1									
Paramesius spinosus Ashmead	4					3					1									
Paramesius sp.	4					4														
Aparamesius sp.	7	1				4			1		2		1							
Trichopria popenoei Ashmead	1					1														
Trichopria sp.	14	1				11			1		1		2							
Ashmeadopria sp.	1					1														
Diapriidae, undetermined spp.	72	3	1			42			2		9	1	6		4		2	7		1
Serphidae:																				
Serphus sp.	4					2					1		1							
Calliceratidae:																				
Calliceras carlylei Girault	13		2			4					6		1							
Calliceras sp.	20		1			9					4		1		1			1		3
Calliceras n. sp.	1										1									
Megaspilus fuscipennis (Ashmead)	1		1																	
Megaspilus sp.	2										2									
Conostigmus sp.	1					1														
Scelionidae:																				
Scelio caloptenti Riley	2					2														
Scelio floridanus Ashmead	3					2					1									
Scelio opacus Provancher	1														1					
Cacellus sp.	1					1														
Ceratoteleia marlattii (Ashmead)	8					5					1		2							
Ceratoteleia rubriclava (Ashmead)	1												1							
Ceratoteleia sp.	5					3												2		
Hadronotus ajax Girault		1							1											
Hadronotus sp.	6		1			5														
Macroteleia sp.	4					3					1									
Opisthacantha sp.	4					3					1									
Paridris brevipennis Fouts	11	1				9					1					1		1		
Psilanteris sp.	1										1									
Prosanteris sp.	1														1					
Hoploteleia floridana (Ashmead)	1					1														
Trimorus bethunei (Saunders)	5					4					1									
Trimorus sp.	53	1	5			36			1		6		6							
Trimorus columbiana (Ashmead)	1					1														
Trimorus n. sp.	3					2					1									
Teleas sp.	1					1														
Trissacantha sp.	7					5					2									
Teleasinae, undetermined spp.	2					1					1									
Ceratobaeus sp.	1					1														
Baeinae, undetermined spp.	2					2														
Trissolcus sp.	4					3					1									
Telenomus podisi (Ashmead)	20	4	2			5			1		7	1	2	1	1	1		3		
Telenomus persimilis (Ashmead)	5		1			2					2									
Telenomus sp.	37	1				17			1		6		4		6			2		2
Scelionidae, undetermined spp.	28	1				20					7	1	1							
Platygasteridae:																				
Leptacis sp.	5					2					2									1
Platygaster errans Fouts	6					4					2									
Platygaster baccharicola Ashmead	1												1							
Platygaster sp.	6										1		3		1					1
Platygasteridae, undetermined spp.	6					3					2							1		

TABLE 9.—*Insects, spiders, and mites collected by airplane, according to altitudes, Tallulah, La., August 1926 to October 1931, inclusive*—Con.

Order, family, genus, and species	Total insects taken		Collected at altitudes of—																	
	Day	Night	20 feet (day)	50 feet (day)	100 feet (day)	200 feet (day)	300 feet (day)	400 feet (day)	500 feet (night)	600 feet (day)	1,000 feet Day	1,000 feet Night	2,000 feet Day	2,000 feet Night	3,000 feet Day	3,000 feet Night	4,000 feet (day)	5,000 feet Day	5,000 feet Night	Over 5,000 feet (day)
Hymenoptera—Continued.	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Platygasteridae—Continued.																				
Trichacis sp.	3					2					1									
Sactogaster anomaliventris Ashmead.	1					1														
Ceratospilus sp.	1					1														
Cynipidae:																				
Anacharis melanoneura Ashmead (female)	1					1														
Anacharis sp.	3	1	2						1				1							
Prosaspicera similis (Ashmead)	15	3				13					1	3	1							
Prosaspicera sp. (females)	3					2									1					
Neralsia hyalinipennis (Ashmead)	2					2														
Neralsia sp.	3		2			1														
Xyalophora sp.	1										1									
Figites sp.	2					2														
Lonchidia sp. (females)	7					6												1		
Cothonaspis sp.	3														1					2
Cothonaspis sp. (*Hexaplasta*) (females)	19					16					2		1							
Eucoila sp. (males)	7	1	2			5														
Psilodora vagabunda (Ashmead)	1					1													1	
Psilodora sp. (female)	1										1									
Kleidotoma sp.	21	1	2			15			1		2				1			1		
Kleidotoma (*Heptameris*) sp.	2					2														
Hexacola sp.	4					4														
Hypodiranchis sp.	2					2														
Eucoilinae, undetermined spp.	5	1	2						1		1		1					1		
Charips brassicae (Ashmead)	4					4														
Charips sp.		2										2								
Alloxysta sp.	4					2					2									
Aulacidea sp.	5					3					2									
Ceroptres sp.	17					15					2									
Synergus sp. (females)	15		1			10					2		1		1					
Periclistus sp.	6		2			2					2									
Neuroterus sp.	10					7							3							
Andricus sp.	3										1				2					
Callirhytis sp.	12		2			10														
Compsodryoxenus sp.	1												1							
Aglaotoma sp.		1							1											

Erisphagia sp	1										1									
Cynipidae, undetermined sp	1																			1
Cynipoidea, undetermined spp	4										2		1		1					
Callimomidae:																				
Callimome advenum Osten Sacken	1					1														
Callimome tubicola Osten Sacken	1										1									
Callimome lividum (Ashmead)	2					1					1									
Callimome sp	12					5					2		1		3		1			
Ormyrus sp	6					2					3				1					
Callimomidae, undetermined sp	1					1														
Monodontomerinae, undetermined spp	2					2														
Podagrion sp	1					1														
Chalcididae:																				
Bracyhmeria sp	1					1														
Spilochalcis delicata (Cresson)	2					1					1									
Spilochalcis longipetiolata (Ashmead)		1										1								
Spilochalcis delira (Cresson)	3					3														
Spilochalcis torvina (Cresson)	1					1														
Spilochalcis sp	3					2									1					
Haltichella sp	1					1														
Haltichella n. sp	2					1							1							
Chalcididae, undetermined sp	3					3														
Chalcidoidea, undetermined spp	20		1			15					3							1		
Eurytomidae:																				
Bruchophagus gibbus (Boheman)	4	1				2			1		2									
Eurytoma succinipedis Ashmead	1												1							
Eurytoma tylodermatis Ashmead	2					1							1							
Eurytoma sp	25	2	2			13			2		7		1					2		
Eurytoma n. sp	1		1																	
Eurytomidae, undetermined sp	1		1																	
Harmolita websteri (Howard)	1										1									
Harmolita sp	1	1				1			1											
Bruchobius laticeps Ashmead	1										1									
Rileya sp	1					1														
Decatoma bicolor Ashmead	1					1														
Decatoma vacciniicola Balduf	1					1														
Decatoma varians Walsh	1					1														
Decatoma sp	4					2							1		1					
Perilampidae:																				
Perilampus bakeri Crawford	1					1														
Perilampus platygaster Say	1												1							
Perilampus granulosis Crawford	1										1									
Perilampus fulvicornis Ashmead	2		1								1									
Perilampus sp	4					1							2		1					
Miscogasteridae:																				
Miscogaster sp	2	1				1			1		1									
Halticoptera aenea Walker	12	1				4					5	1	3							
Lelapinae, undetermined sp	1					1														
Miscogasteridae, undetermined sp	5					3					1				1					
Cleonymidae:																				
Cleonymidae, undetermined sp	1					1														

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											Day	Night	Day	Night	Day	Night		Day	Night	
Hymenoptera—Continued.	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Pteromalidae:																				
Eupteromalus tachinae Gahan	3					3														
Eupteromalus viridescens (Walsh)	1					1														
Eupteromalus sp.	6		1			3					1		1							
Habrocytus langurine Ashmead	3					2					1									
Habrocytus sp.	6					4							1					1		
Zatropis incertus (Ashmead)	30	4	2			15			1		8	2	4					1	1	
Zatropis sp.	4			1		1					1		1							
Merisus sp.	1					1														
Pteromalus archippi Howard	1										1									
Pteromalus sp.	3					2							1							
Pachyceras xylophagorum Ratzeburg	1					1														
Amblymerus sp.	3	1				3						1								
Catolaccus hunteri Crawford	6					5					1									
Coelopisthia forbesi (Dalla Torre)	11		1			7					3									
Coelopisthia sp.	2										2									
Pachyneuron allograptae Ashmead	6	3				3					1	1	2	1					1	
Pachyneuron texanum Girault		1							1											
Pachyneuron siphonophorae Ashmead	9					3					3							2		1
Pachyneuron altiscuta Howard	2	1				1			1		1									
Pachyneuron sp.	13	1		1		5			1		2		1		1			1		2
Heteroschema sp.	1												1							
Psilocera sp.	11					6					3		1		1					
Asaphes sp.	1										1									
Polyscelis sp.	1					1														
Systellogaster sp.	1					1														
Syntomopus americanus Ashmead	1					1														
Sphegigasterinae, undetermined spp.	3	1				3			1											
Pteromalidae, undetermined spp.	73	6	6			42			3		8		10	2	5	1		2		
Eupelmidae:																				
Anastus reduvii (Howard)	1					1														
Anastus sp.	2					2														
Eupelmus sp. near *biguttus* Girault		1							1											
Eupelmus cynipidis Ashmead	1										1									
Eupelmus cyaniceps Ashmead	1					1														
Eupelmus charitopoides Girault	3					3														
Eupelmus auratus Ashmead	1										1									

Eupelmus allynii (French)	1												1							
Eupelmus popa Girault	3					2					1									
Eupelmus rosae Ashmead	4		1			3														
Eupelmus sp	15	2				10					4	1	1	1						
Eupelmus n. sp	1					1														
Eupelminae, undetermined spp	2					1					1									
Encyrtidae:																				
Aphycus sp	4					2					1				1					
Bothriothorax sp. near *insularis* Howard	2					2														
Cheiloneurus albicornis Howard	3					1					2									
Cheiloneurus lineascapus Gahan	3					1					2									
Copidosoma truncatellum (Dalman)	1												1							
Copidosoma sp	1					1														
Aphidencyrtus aphidivorus (Mayr)	1														1					
Blastothrix sericea (Dalman)	2										1				1					
Homalotylus terminalis (Say)	1					1														
Homalotylus flaminius (Dalman)	1					1														
Homalotylus sp	1					1														
Isodromus iceryae Howard	3					1					1				1					
Pentelicus n. sp	1										1									
Chrysopophagus compressicornis Ashmead	6					5					1									
Chrysopophagus sp	1					1														
Microterys sp	1										1									
Psyllaephagus sp	1					1														
Syrphophagus sp	1																			1
Zaomencyrtus sp	1					1														
Encyrtidae, undetermined spp	21	2	2	1		8			1		5	1	2		2					1
Spalangiidae:																				
Spalangia rugosicollis Ashmead	2					1					1									
Spalangia sp	1					1														
Elasmidae:																				
Elasmus setosiscutellatus Crawford	3					1					1		1							
Elasmus sp	2					1					1									
Eulophidae:																				
Chrysocharis sp	1					1														
Cirrospilus sp	1														1					
Closterocerus sp	1																			1
Comedo brevicapitatus (Cook and Davis)	1										1									
Comedo sp		1										1								
Derostenus fullawayi Crawford	1					1														
Pleurotropis sp	1	1				1			1											
Euderus subopaca (Gahan)	3					1					1		1							
Euderus sp	4					2					2									
Euderus n. sp	1										1									
Sympiesis metacomet Crawford	3					1					1		1							
Sympiesis lineaticoxa Girault	3	1				1					1	1	1							
Sympiesis massasoit Crawford	1										1									
Sympiesis guttiventris Girault	2					1					1									
Sympiesis sp	1	1				1								1						
Tetrastichus pulchriventris Girault	1										1									
Tetrastichus chrysopae Crawford	5		1			3					1									

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	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Hymenoptera—Continued.																				
Eulophidae—Continued.																				
Tetrastichus hagenowi (Ratzeburg)	1					1														
Tetrastichus sp.	142	4	7			71			1		31	2	21	1	8			2		2
Tetrastichinae, undetermined sp.	1										1									
Euplectrus comstockii Howard	11	4				7			2		2	2	1		1					
Euplectrus platyhypenae Howard	4	2				3			1			1	1							
Euplectrus sp.	12	1	2			7			1		2		1							
Gyrolasia nigrocyanea Ashmead	5					4							1							
Zagrammosoma multilineatus (Ashmead)		1							1											
Horismenus fraternus (Fitch)	2		1			1														
Horismenus sp.	3					2							1							
Melittobia sp.	3					1					1		1							
Aprostocetus sp.	1					1														
Galeopsomyia n. sp.	1	1				1			1											
Entedoninae, undetermined spp.	2		1			1														
Elachertinae, undetermined spp.	1																	1		
Eulophidae, undetermined spp.	8	1				5					2		1			1				
Mymaridae:																				
Anagrus orijentatus Crosby and Leonard	1																	1		
Anagrus pallidipes Ashmead	1										1									
Gonatocerus sp.	2					2														
Polynema sp.	3												1							2
Mymaridae, undetermined spp.	1												1							
Evaniidae:																				
Evania semaeoda (Bradley)	2					2														
Hyptia floridana Ashmead	1					1														
Psammocharidae:																				
Ceropales longipes Smith	1										1									
Aporinellus fasciatus (Smith)	1												1							
Cryptocheilus pallidipennis Banks	1					1														
Psammochares (Pompiloides) marginatus (Say)	1					1														
Anthoboscidae:																				
Sierolomorpha sp.	1					1														

Tiphiidae:																				
Tiphia sp.	1					1														
Myzine sp.	1		1																	
Mutillidae:																				
Mutillidae, undetermined sp.	1					1														
Formicidae:																				
Ponera opaciceps Mayr (winged queens)	7	2				6			2						1					
Ponera opaciceps Mayr (winged females)	1										1									
Ponera opaciceps Mayr (winged males)	1	1				1						1								
Ponera trigona var. *opacior* Forel (queens)	3		1			2														
Ponera trigona var. *opacior* Forel (workers)	2					2														
Ponera coarctata subsp. *pennsylvanica* Buckley	1					1														
Monomorium minimum Buckley (winged queens)	2										2									
Monomorium minimum (Buckley) (worker)	1					1														
Solenopsis molesta (Say) (winged queen)	1					1														
Solenopsis xyloni McCook (worker)		1							1											
Solenopsis xyloni McCook (winged queens)	5					4					1									
Solenopsis xyloni McCook (winged males)	100		6			94														
Crematogaster sp. (winged males)	148	2				123					13	1	8		3			1	1	
Pheidole dentata Mayr (workers)	2					2														
Pheidole dentata Mayr (winged males)	3		3																	
Pheidole sp. (worker)	1				1															
Leptothorax sp. (winged male)	1					1														
Aphaenogaster sp. (workers)	2					2														
Myrmicinae, undetermined spp. (winged males)	2					1							1							
Tapinoma sessile (Say) (worker)	1					1														
Iridomyrmex pruinosus var. *analis* (André) (worker)	1										1									
Prenolepis (*Nylanderia*) sp. (workers)	4					3							1							
Prenolepis (*Nylanderia*) sp. (winged queens)	2					2														
Prenolepis (*Nylanderia*) sp. (winged males)	1	1				1			1											
Lasius sp. (winged male)	1										1									
Camponotus caryae var. *minuta* Emery (worker)	1																1			
Camponotus sp. (winged male)	1					1														
Formicidae, undetermined spp. (workers)	4					2					2									
Formicidae, undetermined spp. (winged males)	3					1					1							1		

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											1,000 feet		2,000 feet		3,000 feet			5,000 feet		
	Day	Night	20 feet (day)	50 feet (day)	100 feet (day)	200 feet (day)	300 feet (day)	400 feet (day)	500 feet (night)	600 feet (day)	Day	Night	Day	Night	Day	Night	4,000 feet (day)	Day	Night	Over 5,000 feet (day)
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Hymenoptera—Continued.																				
Bethylidae:																				
Perisierola cellularis (Say)	4		1			1					1		1							
Perisierola cellularis punctaticeps Kieffer	2					2														
Perisierola cellularis var. *gracilicornis* Kieffer	1					1														
Perisierola sp	2										1		1							
Goniozus platynotae Ashmead	2					2														
Goniozus sp	4					3							1							
Plastanoxus laevis (Ashmead)	1					1														
Epyris sp	2					1							1							
Psilepyris sp	1					1														
Rhabdepyris sp	2					1												1		
Anisepyris sp	1					1														
Dissomphalus xanthopus Ashmead	1					1														
Dissomphalus sp	6	1	1			5			1											
Aphelopus comesi Fenton	2					2														
Aphelopus sp	9		2			5									2					
Anteon sp	2					2														
Chelogynus sp	1					1														
Laberius longitarsus (Ashmead)	1										1									
Gonatopus sp. (male)	2		1												1					
Anteoninae, undetermined sp	2					1					1									
Bethylidae, undetermined spp	3	1				3			1											
Vespidae:																				
Eumenes sp	1					1														
Polistes fuscatus var. *rubiginosus* Lepeletier	1										1									
Sphecidae:																				
Tachytes sp	1		1																	
Larrinae, undetermined sp	1		1																	
Psen sp	1					1														
Alyson melleus Say	1					1														
Andrenidae:																				
Halictus ligatus Say	1					1														
Halictus coreopsis Robertson	2		1										1							
Halictus rugosus Crawford	7					5					1		1							

Halictus stultus Cresson	2		1			1														
Halictus albitarsis Cresson	2					1					1									
Halictus disparilis Cresson	17		1			14					1		1							
Halictus lepidii Graenicher	1					1														
Halictus (Chloralictus) sp.	13		2			9							1		1					
Augochlorella striata (Provancher)	7	1	2			5			1											
Augochlorella pura (Say)	1					1														
Agapostemon radiatus (Say)	1		1																	
Sphecodes sp.	1					1														
Anthophoridae:																				
Melissodes bimaculata Lepeletier	2		1			1														
Melissodes sp.	9		3			4					1							1		
Bombidae:																				
Bombus americanorum (Fabricius)	1					1														
Apidae:																				
Apis mellifera Linnaeus	13		2			10					1									
Apoidea, undetermined spp.	3					3														
Hymenoptera, undetermined spp.	686	57	47			359	1		35		151	15	71	3	31			17	4	9
Total	2,770	177	161	4	1	1,646	1		101		508	47	235	16	113	4	6	62	9	33
Diptera:																				
Tipulidae:																				
Limonia (Rhipidia) sp.	1				1															
Limonia rara (Osten Sacken)	1										1									
Limonia (Dicranomyia) sp.	6	12				2			11		2			1	1			1		
Erioptera parva Osten Sacken		2							2											
Erioptera sp.		1										1								
Helobia hybrida (Meigen)	187	12	18	2		76	1		9		46	3	27		13		1	3		
Gonomyia sp.	1	1							1				1							
Epiphragma fascipennis (Say)		1												1						
Tipula spp.	25		11			8					6									
Tipulidae, undetermined spp.	72	19	3			26		1	13		18	6	10		11			2		1
Culicidae:																				
Chaborus punctipennis (Say)	22	28				11			19		5	2	6	6		1				
Anopheles quadrimaculatus Say	3	8	1			2			6			2								
Culex spp.	3	2				1						2						2		
Uranotaenia sapphirina (Osten Sacken)	2														2					
Psorophora columbiae (Dyar and Knab)	1	2				1			1			1								
Psorophora (Janthinosoma) sp.	1										1									
Aedes vexans (Meigen)		4							1			1							2	
Aedes spp.	1	1				1						1								
Orthopodomyia signifera Coquillett		1							1											
Culicinae, undetermined spp.	2	3							3		1				1					
Culicidae, undetermined spp.	9	18				5			10		1	4	2	2	1	2				
Psychodidae:																				
Psychoda sp.	1	2				1			1							1				
Psychodidae, undetermined spp.	3	1									3	1								
Chironomidae:																				
Tanypus punctipennis (Meigen)	10	2				8			1		1			1				1		
Tanypus stellatus Coquillett	28	16				21			12		7	2		2						
Tanypus sp.	44	14	2			29			12		8	2	5							

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Order, family, genus, and species	Total insects taken		Collected at altitudes of—																	
	Day	Night	20 feet (day)	50 feet (day)	100 feet (day)	200 feet (day)	300 feet (day)	400 feet (day)	500 feet (night)	600 feet (day)	1,000 feet		2,000 feet		3,000 feet		4,000 feet (day)	5,000 feet		Over 5,000 feet (day)
											Day	Night	Day	Night	Day	Night		Day	Night	
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Diptera—Continued.																				
Chironomidae—Continued.																				
Procladius bellus (Loew)	1										1									
Clinotanypus concinnus (Coquillett)	1					1														
Clinotanypus scapularis (Loew)	1	1				1						1								
Clinotanypus sp.		1							1											
Cricotopus sp.	11					7					2		1		1					
Tanytarsus sp.	1					1														
Chironomus halteralis Coquillett	2	8				1			5			3						1		
Chironomus needhami Johannsen	2										1				1					
Chironomus perpulcher Mitchell	2					1					1									
Chironomus sp.	109	49	5			60			34		14	11	19	3	3			7	1	1
Pentaneura illinoiensis (Malloch)		1										1								
Pentaneura sp.	1	1									1			1						
Spaniotoma sp.	99	1				48					17	1	5		26			2		1
Chironomidae, undetermined spp.	221	74	24	1	2	96	1		51		39	14	29	4	12	2		12	3	5
Ceratopogonidae:																				
Culicoides biguttatus (Coquillett)	1														1					
Culicoides variipennis (Coquillett)		2							1										1	
Culicoides multipunctatus Malloch	1										1									
Culicoides crepuscularis Malloch		1																	1	
Culicoides sp.	30	2				7			1		3		4		2	1		5		9
Ceratopogon sp.	1														1					
Ceratopogoninae, undetermined spp.	57	1	15	1	1	12	3	2	1		3		7		4		2	5		2
Forcipomyia pergandei (Coquillett)		2							2											
Forcipomyia squamipes (Coquillett)	2	5				2			4			1								
Forcipomyia sp.	8	8				5			5		1	2	2						1	
Palpomyia subasper (Coquillett)	6	2				2					3	1		1	1					
Palpomyia sp.	1	1				1			1											
Stilobezzia coquilletti Kieffer	5	10				3			8			2	2							
Alluaudomyia splendida Winnertz		1							1											
Atrichopogon levis (Coquillett)	43	35	2			15			20		7	10	11	5	1			7		
Atrichopogon sp.	21	12	2			12			11		3	1	2		2					
Dasyhelea grisea (Coquillett)	25	8	5			15			4		1	1	3	3	1					
Dasyhelea sp.	7					7														
Cecidomyiidae:																				
Ceratomyia sp.	3					2					1									
Colpodia sp.	1	1				1			1											
Dasyneura sp.		2							1					1						

Asphondylia sp.		3							2					1						
Diplosid sp. (group Bifili)		1							1											
Diplosid sp. (group Trifili)	4	1				3							1						1	
Diplosid sp.		3							1			1		1						
Cecidomyiidae, undetermined spp.	59	9	10	1		30			7		7	2	6		3			1		1
Mycetophilidae:																				
Cordyla sp.	1										1									
Exechia sp.		1														1				
Mycetophilidae, undetermined spp.	94	22	8			55		1	10		14	4	4	4	3	2		7	2	2
Sciaridae:																				
Eugnoriste occidentalis Coquillett	35	1	6			12			1		9		6		2					
Eugnoriste sp.	2		2																	
Sciara jucunda Johannsen	60		3			46					6				4			1		
Sciara coprophila Lintner	1												1							
Sciara sp.	268	27	7			125			15		70	6	30	2	23	2		11	2	2
Sciaridae, undetermined spp.	63	6	2			29			2		17		6	1	7	3		1		1
Bibionidae:																				
Bibio sp.	1		1																	
Dilophus breviceps Loew	21					8					3		7		3					
Dilophus sp.	50		2			20					17		7		3					1
Bibionidae, undetermined spp.	26					6					7		11		2					
Scatopsidae:																				
Reichertella sp.	1					1														
Scatopsidae, undetermined spp.	1																	1		
Simuliidae:																				
Simulium meridonale Riley	3					2					1									
Simulium occidentale Townsend	42		2			25					5		5		3			2		
Simulium sp.	2										1				1					
Simuliidae, undetermined spp.	1					1														
Stratiomyiidae:																				
Odontomyia sp.	4		1		1						2									
Nemotelus sp.	2					2														
Stratiomyiidae, undetermined spp.	1					1														
Tabanidae:																				
Tabanus mularis Stone	1										1									
Tabanus sp.	1					1														
Bombyliidae:																				
Anthrax sp.	1					1														
Systoechus sp.	1					1														
Sparnopolius sp.	1		1																	
Threvidae:																				
Psilocephala sp.	1					1														
Scenopinidae:																				
Scenopinus sp.	1																	1		
Scenopinidae, undetermined spp.	62	15	6			29			12		13	3	5		9					
Asilidae:																				
Atomosia sp.	1		1																	
Dolichopodidae:																				
Sciapus sp.	20	1	1			6					6		4	1	3					
Chrysotus sp.	1										1									
Argyra sp.	1														1					
Raphium sp.	1																	1		
Nothosympycnus sp.		2										1		1						

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	Day	Night	20 feet (day)	50 feet (day)	100 feet (day)	200 feet (day)	300 feet (day)	400 feet (day)	500 feet (night)	600 feet (day)	1,000 feet Day	1,000 feet Night	2,000 feet Day	2,000 feet Night	3,000 feet Day	3,000 feet Night	4,000 feet (day)	5,000 feet Day	5,000 feet Night	Over 5,000 feet (day)
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Diptera—Continued.																				
Dolichopodidae—Continued.																				
Thrypticus sp	1										1									
Hydrophorus sp	1					1														
Gymnopternus sp	53	21	2			23			9		16	3	9	5	3	3			1	
Pelastoneurus vagans Loew	2					2														
Pelastoneurus sp	7	1				1					4			1	1			1		
Dolichopodidae, undetermined spp	204	20	1			86	1		9		40	7	31		25	2	1	8	2	2
Empididae:																				
Hybos sp	4					1					2		1							
Empis sp	1					1														
Drapetis sp	10					7							3							
Empididae, undetermined spp	7					4					2				1					
Lonchopteridae:																				
Lonchopteridae, undetermined spp	1														1					
Phoridae:																				
Megaselia sp	94	14	8	3	2	24			8		23	2	14	3	6	1		12		2
Phora sp	1					1														
Phoridae, undetermined spp	12				2	1	1	1		1	2		1		2			1		
Platypezidae:																				
Platypeza sp	2					1					1									
Pipunculidae:																				
Pipunculus sp	1												1							
Pipunculidae, undetermined spp	34	1	12			20			1		1		1							
Syrphidae:																				
Chrysogaster sp	1					1														
Paragus bicolor Fabricius	1										1									
Baccha fascipennis Wiedemann	1												1							
Baccha sp	1					1														
Syrphus americanus Wiedemann	5		2			2									1					
Xanthogramma sp	1																	1		
Toxomerus politus Say	33		1			14					6		4		3			5		
Toxomerus marginatus Say	25	2				14			1		8		2			1		1		
Toxomerus sp	118	3	4			59			1		23	1	14	1	10			8		
Allograpta sp	2					2														
Sphaerophoria sp	2					2														
Eristalis tenax (Linnaeus)	1					1														
Eristalis sp	3					2					1									
Syrphidae, undetermined spp	52		5			26					9		6		2			4		

Tachinidae:																				
Doryphorophaga doryphorae (Riley)		1							1											
Sturmia sp.	3					3														
Myophasia sp.	3	1				3			1											
Gonia texana Rondani		1										1								
Cuphocera sp.	1					1														
Alophora sp.	1		1																	
Tachinidae, undetermined spp.	13		1			6					5		1							
Sarcophagidae:																				
Sarcophaga opifera Coquillett	1					1														
Sarcophaga sulca Aldrich	1																	1		
Sarcophaga australis Aldrich	1					1														
Sarcophaga quadrisetosa Coquillett	1												1							
Sarcophaga rapax Walker	8		1			6					1									
Sarcophaga lherminieri Robineau-Desvoidy	1		1																	
Sarcophaga laakei Hall	3					2					1									
Sarcophaga tenuiventris Van der Wulp	2					1									1					
Sarcophaga sp.	10		1			5					1				1		1	1		
Macronichia sp.	1		1																	
Miltogramminae, undetermined sp.	1					1														
Sarcophagidae, undetermined sp.	1										1									
Calliphoridae:																				
Cochliomyia macellaria (Fabricius)	5					3									1			1		
Muscidae:																				
Stomoxys calcitrans (Linnaeus)	1														1					
Morellia sp.	3					2							1							
Muscina sp.	2					1					1									
Muscidae, undetermined spp.	2		1										1							
Anthomyiidae:																				
Lispa sp.	3					3														
Hylemyia sp.	36	1	6			18			1		1		3		5			3		
Lispinae, undetermined sp.	1					1														
Fanniinae, undetermined spp.	25		7			10					3		3		2					
Anthomyiinae, undetermined spp.	41	1	4			24					7		3	1	2			1		
Anthomyiidae, undetermined spp.	172	13	19	1		95			4		21	3	20	2	10	4		6		
Scatophagidae:																				
Scatophagidae, undetermined spp.	7					6					1									
Helomyzidae:																				
Helomyzidae, undetermined spp.	2					2														
Borboridae:																				
Sphaerocera spp.	5		1			1					2		1							
Leptocera frontinalis (Fallen)	1														1					
Leptocera sp.	413	16	13	2	2	210	3		8		96	2	51	4	30	1	1	4	1	1
Borboridae, undetermined spp.	99	3	15			49			1		17		9	2	7			2		
Sciomyzidae:																				
Tetanocera sp.	1										1									
Sciomyzidae, undetermined spp.	26	3	1			16			1		4	1	3		2	1				
Sapromyzidae:																				
Sapromyzidae, undetermined spp.	28	2	3			14			1		7	1			4					

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Diptera—Continued.	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Otitidae:																				
Rivellia sp.	1					1														
Euxesta notata Wiedemann	1					1														
Euxesta sp.	5					3							2							
Otitidae, undetermined spp.	2		1								1									
Trypetidae:																				
Paracantha culta Wiedemann	2					2														
Tomoplagia sp.	2					2														
Neaspilota sp.	1					1														
Trypanea daphne Wiedemann	15	1				11							3	1	1					
Trypanea bisetosa (Coquillett)	7					5					1				1					
Trypanea mevarna Walker	1					1														
Trypanea sp.	13	3				4			1		4	2	5							
Tephritis sp.	3	1				1			1				1					1		
Trypetidae, undetermined spp.	3					1							1		1					
Sepsidae:																				
Sepsis violacea Meigen	12					7					2		2					1		
Sepsis sp.	51	4		1		32			1		7	3	6		4		1			
Nemopoda sp.	1					1														
Piophilidae:																				
Piophilia sp.	2					2														
Psilidae:																				
Psilidae, undetermined sp.	1		1																	
Ephydridae:																				
Dichaeta sp.	9	3				4			1		2		3	2						
Scutella sp.	5	2				1	2		2				1							1
Ephydridae, undetermined spp.	655	53	38		2	336	2		25		131	14	79	8	54	5		12	1	1
Chloropidae:																				
Meromyza sp.	2					2														
Chloropisca sp.	3	2							1		2	1	1							
Chlorops sp.	112	15	8			56			10		25	4	12	1	9			2		
Hippelates texanus Aldrich	1					1														
Hippelates pallipes Loew	45		1			15					15		10		3					1
Hippelates sp.	43	1	4			17			1		12		5		3			2		
Madiza sp.	5					2					1				1					1
Oscinella coxendix (Fitch)	2																			2
Oscinella sp.	25	1	2			14			1		6		3							
Oscinis sp.	828	39	98			407			26		170	8	83	4	43	1		24		3

Elachiptera nigricornis (Loew)	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1
Elachiptera sp.	82	7	6	--	--	44	--	--	4	--	16	--	6	3	6	--	--	3	--	1
Chloropidae, undetermined sp.	978	31	122	5	4	452	2	--	17	--	212	5	92	5	39	2	3	43	2	4
Drosophilidae:																				
Chymomyza amoena Loew	--	1	--	--	--	--	--	--	--	--	--	--	--	1	--	--	--	--	--	--
Leucophenga varia Walker	1	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Drosophila melanogaster Meigen	1	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Drosophila sp.	3	--	--	--	--	1	--	--	--	--	2	--	--	--	--	--	--	--	--	--
Scaptomyza adusta Loew	7	2	--	--	--	5	--	--	1	--	2	--	--	--	--	1	--	--	--	--
Scaptomyza sp.	7	4	--	--	--	5	--	--	--	--	--	3	1	1	1	--	--	--	--	--
Drosophilidae, undetermined spp.	12	4	--	--	--	10	--	--	3	--	--	--	1	1	1	--	--	--	--	--
Milichiidae:																				
Desmometopa m-nigrum Zetterstedt	1	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Ochthiphilidae:																				
Leucopis sp.	1	1	--	--	--	--	--	--	1	--	1	--	--	--	--	--	--	--	--	--
Agromyzidae:																				
Agromyza virens Loew	4	2	--	--	--	1	--	--	--	--	1	--	1	1	1	1	--	--	--	--
Agromyza sp.	9	--	--	--	--	3	--	--	--	--	4	--	--	--	1	--	--	1	--	--
Agromyzidae, undetermined spp.	3	--	--	--	1	--	--	--	--	--	1	--	--	--	--	--	--	1	--	--
Diptera, unrecognizable spp.	3,478	579	239	4	--	2,040	--	1	339	--	662	159	292	41	143	24	7	55	16	35
Total	9,973	1,331	773	21	18	5,172	16	6	788	1	1,979	314	1,024	130	586	62	17	279	37	81
Siphonaptera:																				
Pulicidae:																				
Pulex irritans Linnaeus	1	--	--	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Unrecognizable insects	2,500	292	207	1	--	1,444	1	1	181	1	494	68	196	20	95	10	5	41	13	15
Grand total	24,559	3,955	1,860	61	51	13,396	34	14	2,548	7	4,749	853	2,357	314	1,364	136	54	612	104	225
Total time flying, minutes	51,178	6,790	721	79	63	10,277	92	40	1,664	23	10,101	1,488	9,767	1,248	10,102	1,225	291	9,622	1,165	2,455

TABLE 10.—*Insects and spiders collected by airplane at altitudes over 5,000 feet, Tallulah, La., 1926–31*

Order and species	Collected at altitude of—									
	6,000 feet	7,000 feet	8,000 feet	9,000 feet	10,000 feet	11,000 feet	12,000 feet	13,000 feet	14,000 feet	15,000 feet
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Araneida:										
Linyphiidae, undetermined sp.				2						
Thomisidae, undetermined sp.							1			
Salticidae, undetermined sp.			1							
Araneida, unrecognizable spp.	1	1		2	2	3				1
Thysanura:										
Lepisma sp.			1							
Collembola:										
Bourletiella sp.		1				1				
Corrodentia:										
Psocidae, undetermined sp.			1							
Lachesilla pedicularis			1		1					
Thysanoptera:										
Frankliniella tritici					1					
Haplothrips graminis						1				
Heteroptera:										
Coreidae, (undetermined nymph)				1						
Lygaeus bicrucis		1								
Antillocoris pallidus		1								
Atrachelus cinereus			1							
Orius insidiosus	1		1							
Trigonotylus sp.						1				
Heteroptera, undetermined sp.					1					
Homoptera:										
Agallia constricta					1					
Xestocephalus pulicarius	1									
Deltocephalus australis		2								
Macrosteles divisus								2		
Empoasca fabae		1								
Empoasca erigeron	1									
Empoasca sp. (female)	1									
Erythroneura spp.							1		1	
Megamelus sp.							1			
Liburniella ornata		1					1			
Delphacodes spp.		1					1		1	
Aphalara sp. (probably *veaziei* var. *metzaria*)			1							
Pachypsylla celtidis-gemma								1		
Psylla sp.					1					
Aphis gossypii								1		
Aphid, undetermined sp.						1				
Aphididae (undetermined adults)		1			1					
Homoptera (undetermined adults)		2	1		3			1	3	
Coleoptera:										
Tachys sp.			1							
Blechrus pusio					1					
Stenocellus tantillus	1									
Aleocharinae, undetermined spp.		1		1						
Atheta sp.				1						
Oxypoda sp.					1					
Staphylinidae, undetermined spp.				3		1				
Anthicus sp.	1									
Trogoderma sp. (live larva)				1						
Corticaria sp.		1								
Coleomegilla floridana	1									
Diabrotica vittata						1				
Brachytarsus vestitus					1					
Coleoptera, undetermined sp.	2	2	1		4	2	4			
Hymenoptera:										
Microbracon sp.	1									
Braconidae, undetermined sp.			1							
Phaenopria sp.					1					
Diapriidae, undetermined sp.			1							
Calliceras sp.					1			1	1	
Telenomus sp.	1							1		
Leptacis sp.			1							
Platygaster sp.	1									
Cothonaspis sp.		1			1					
Cynipidae, undetermined sp.						1				
Pachyneuron siphonophorae	1									
Pachyneuron sp.				1	1					
Syrphophagus sp.							1			
Encyrtidae, undetermined sp.		1								
Closterocerus sp.				1						
Tetrastichus sp.					1		1			
Polynema sp.						1	1			
Hymenoptera, undetermined sp.	2	1			4			1	1	

TABLE 10.—*Insects and spiders collected by airplane at altitudes over 5,000 feet Tallulah, La., 1926–31*—Continued

Order and species	Collected at altitude of—									
	6,000 feet	7,000 feet	8,000 feet	9,000 feet	10,000 feet	11,000 feet	12,000 feet	13,000 feet	14,000 feet	15,000 feet
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Diptera:										
Tipulidae, undetermined sp.									1	
Culicoides sp.		3		1		2	2	1		
Ceratopogoninae, undetermined sp.		2								
Chironomus sp.		1								
Spaniotoma sp.		1								
Chironomidae, undetermined spp.		1		2	1			1		
Cecidomyiidae, undetermined sp.									1	
Mycetophilidae, undetermined spp.		1			1					
Sciara sp.	1				1					
Sciaridae, undetermined sp.			1							
Dilophus sp.					1					
Dolichopodidae, undetermined spp.					1				1	
Megaselia sp.		1	1							
Leptocera sp.						1				
Scatella sp.					1					
Ephydridae, undetermined sp.					1					
Hippelates pallipes Lw.						1				
Madiza sp.				1						
Oscinella coxendix		1						1		
Oscinis sp.	1	1			1					
Elachiptera nigricornis						1				
Elachiptera sp.		1								
Chloropidae, undetermined spp.	1	1			2					
Diptera, undetermined spp.	6	11	7		7	1		3		
Unrecognizable insects	5	2	3		2	1	1	1		
Total	30	46	25	17	45	21	14	16	10	1
Total flying time, minutes	321	355	335	270	399	224	204	171	118	20

WINGED FORMS

ORTHOPTERA

Of the order Orthoptera 13 were taken in the day flights and 3 at night. They were found scatteringly from May to November, inclusive. In the day collections two specimens of a cricket (*Tridactylus minutus* Scudd.) were taken in June and July 1929 at altitudes of 200 and 1,000 feet, respectively. Four specimens of the red-legged grasshopper (*Melanoplus femur-rubrum* (Deg.)) were collected in September and October at altitudes of from near the surface to 1,000 feet. This species is very destructive, causing serious damage to crops. The other species of grasshoppers taken in the upper air were one specimen of *Tettigidea acuta* Morse at 2,000 feet, and three specimens of *T. lateralis* (Say), two at 1,000 feet and one at 2,000 feet. Two undetermined species of Orthoptera were taken at 200 and 2,000 feet. At night one cricket, *Nemobius carolinus* Scudd., was taken at 1,000 and two at 2,000 feet.

CORRODENTIA

There were 78 specimens belonging to the order Corrodentia taken in the upper air. Seventy specimens were represented in the day collections and eight in the night. The families Psocidae and Atropidae and six determined species were represented. Corrodentia appeared in every month of the year, but were more abundant in April, May, and November. The family Psocidae included the majority of the specimens taken. Several species belonging to this order are of economic importance and are known as booklice, being pests in libraries and museums. One particularly annoying species, the booklouse (*Troctes divinatorius* (Mull.)), was taken in the upper air at 1,000 feet. One *Trogium pulsatorium* (L.) was taken at 5,000 feet. One *Psocus inornatus* Aaron was taken at 3,000 feet. Thirty-one specimens of *Lachesilla pedicularia* (L.) were taken in the day flights at from near the surface to 10,000 feet. Two were found at night at altitudes of 500 and 2,000 feet.

ISOPTERA

The order Isoptera, or termites, was represented in the day collections only. There were 19 specimens taken in the upper air at altitudes ranging from near the surface to 3,000 feet. *Reticulitermes virginicus* Banks was the only species taken, with 13 specimens in April and 6 in May. On the dates of these collections great numbers of termites were visible in the air. It is not appropriate to refer to these swarms as "nuptial flights" since the sudden appearances of termites in the air are merely colonizing flights, or a means of dispersal (*68*). It is only on these flights that termites come out into the sunlight and above ground. The wings are shed before the adult termites are sexually mature, and mating does not take place at the time of swarming. The females form new colonies, never returning to the colonies from which they came. Unless carried by the wind, termites do not fly very far. The great majority of the colonizing adults of the genus *Recticulitermes*, after a short vacillating flight, alight or fall to the ground and lose their wings. Species of this genus always swarm during the daytime. The dates of swarming vary with the species, the geographical location, and the season. The actual dates of the month are of no importance, as there may be swarms from one colony distributed over a period of several weeks. Termites were collected in the upper air from April 3 to 22 in 1930, and on May 21 and 22 in 1931.

EPHEMEROPTERA

The order Ephemeroptera was represented by 10 specimens taken at altitudes ranging from 200 to 3,000 feet in the spring and summer months, with equal numbers for the day and night collections. One specimen of *Caenis hilaris* (Say) was found at 2,000 feet in the daytime, and one specimen of *Caenis* sp. was taken in the day at 200, and one at 1,000 feet, and two at night at 500 and one at 3,000 feet. A species of *Hexagenia* was collected at 200 feet, and one of *Ephemera* at 2,000 feet in the daytime. Two undetermined species of Ephemeroptera were collected at 1,000 feet at night. The Ephemeroptera are quite important as food for fishes, as the nymphs feeding on living or dead aquatic vegetation in lakes and bayous are very abundant. Often great numbers of Mayflies, especially species belonging to the genera *Caenis* and *Hexagenia*, were seen under street lights in Tallulah, and by morning the walks and pavements would be covered to the depth of an inch with the dead bodies of these fragile and short-lived adults. Although they were often so thick in the air that they became a general nuisance in stores and on the streets, comparatively few were taken in the higher atmosphere.

ODONATA

The order Odonata appeared only in the day collections, 21 specimens being collected belonging to this order. Odonata were taken in the spring and summer months and two specimens in October at altitudes of from 20 to 3,000 feet. The dragonflies taken at 200 feet were one specimen of *Perithemis tenera* (Say), one *Libellula vibrans* F., four *Pachydiplax longipennis* (Burm.), and one undetermined species. At 1,000 feet there were collected one specimen of *P. longipennis* and two undetermined species of dragonflies. Damsel flies were collected at 20 to 3,000 feet, with one *Enallagma* sp. near the surface and one *Anomalagrion hastatum* (Say) at 20 feet, two at 200 feet, and three at 1,000 feet. Dr. Needham, who determined the species of Odonata collected in the upper air, stated that he was surprised in studying them to find that the most abundant species was one of the smallest weaklings in the whole order, *Anomalagrion hastatum*. Airplane collecting explains the wide distribution of this species, which ranges from Canada to Argentina and which is always very local in its distribution. Dr. Needham stated that he had never seen one flying higher than the tops of the spikerush in the seepage pools that are its home. Three undetermined species of Zygoptera were collected at 200 feet and one at 3,000 feet.

During the summer and early in the fall the writer has seen dragonflies flying at altitudes as high as 7,000 feet. Dragonflies are very rapid fliers, and the writer has observed these gauzy-winged insects keeping up with the airplane or even darting ahead at times when the airplane was flying at 90 miles or more an hour. The species, as nearly as could be determined from the cockpit, was the big green darner, *Anax junius* (Dru.). Thus it is to be expected that very few specimens would be taken in the upper air, because of their rapid flight and their ability to dodge the on-coming airplane. Dragonflies are considered useful insects, as they destroy many injurious insects, especially mosquitoes. They may be seen in great numbers flying at dusk, when mosquitoes and nightflying insects are especially active in the air. The nymphs also furnish a food supply for fishes, and on the other hand it is known that the larger dragonfly nymphs habitually eat very young fishes.

THYSANOPTERA

The order Thysanoptera was represented by 98 specimens, of which 91 were collected in the upper air during the day and 7 at night. They were collected from March to October inclusive, and were most abundant in June. Thysanoptera were taken at altitudes ranging from near the surface to 11,000 feet. The families represented were Thripidae, in which six determined species were taken, and the family Phlaeothripidae, of which there were eight determined species. Of the Thripidae, the flower thrips (*Frankliniella tritici* (Fitch)) was the most abundant species taken, 19 being collected in the daytime and 5 at night. Specimens of this species were collected as high as 10,000 feet. This is a very important economic species which does much damage to young cotton and other crops. Two specimens of the tobacco thrips (*F. fusca* (Hinds)) were taken at 200 feet, two at 1,000 and two at 2,000 feet. This species of thrips occurs on seedling cotton, and has been very destructive in South Carolina and no doubt is responsible for a large percentage of the thrips damage to cotton (*20*). Of the Phlaeothripidae, *Liothrips caryae* (Fitch) was most abundant, 12 specimens having been collected, 3 in June and 8 in July, from near the surface to 1,000 feet. This species occurs in phylloxera galls on hickory and is probably predacious. Eight specimens of *Leptothrips mali* (Fitch) were taken in the day flights in June, July, August, and October at 20 to 2,000 feet. This species is known as the "black hunter" and is predacious on thrips, lice, etc. Five specimens of *Haplothrips graminis* Hood were collected, one at 200 feet, two at 2,000, one at 5,000, and one at 11,000 feet. Many species of Thysanoptera are very serious pests of fruit, vegetables, flowers, and field crops.

HETEROPTERA

The order Heteroptera was represented in the collections of insects of the upper air by a total of 1,259 specimens. Of this number 1,080 were collected in the day flights and 179 at night. Heteroptera were found in every month of the year, with the greatest numbers in October and the next largest in May. Specimens were collected at every altitude up to 11,000 feet. Nineteen families, 63 genera, and 69 determined species were represented.

Twenty specimens of the negro bug, (*Allocoris* (*Thyreocoris*) *pulicaria* (Germ.) (Cydnidae)), were collected in the day flights. They were taken at 20 to 5,000 feet, from March to August, inclusive, with the largest numbers in March and June. These small shiny black bugs, similar to beetles in appearance, are known to attack ripe fruits of raspberry and blackberry. Two specimens of the spined soldier bug (*Podisus maculiventris* (Say)) (Pentatomidae) were taken, one each in March and April, at 1,000 feet in the day flights. This is a beneficial predacious insect. One *Anasa armiger* (Say) (Coreidae) was caught in June in the daytime at 1,000 feet. This is an injurious species. Thirteen specimens of *Corizus hyalinus* (F.) (Coreidae) were collected at 200 to 5,000 feet in the day flights, and four at night at 500 to 5,000 feet. Fourteen specimens of *Lygaeus kiernеis* Say (Lygaeidae) were taken in the daytime at 200 to 7,000 feet and four at night, three at 500 feet and one at 1,000 feet. Eighteen specimens of *Nysius californicus* Stål (Lygaeidae) were collected in the day flights at 20 to 2,000 feet, and one at night at 1,000 feet. This species is very injurious, especially to beets. Fifty-three specimens of *Nysius ericae* (Schill.) were collected from near the surface to 3,000 feet, with the greatest numbers taken in July and October. One specimen was found at night at 500 feet. This species is of economic importance. Specimens of *Ischnorhynchus resedae* (Panz.) (Lygaeidae) were collected mostly at the higher altitudes, with three specimens at 200 feet, three at 1,000, six each at 2,000 and 3,000 feet, and three at 5,000 feet, all having been taken in the day flights and mostly in the winter and spring months. This species often causes damage to plants, especially to azaleas.

Twenty-four specimens of *Blissus leucopterus* (Say) (Lygaeidae) were collected in the day flights at altitudes of 20 to 3,000 feet, and the species appeared from April to November, inclusive. One specimen was taken at night at 500 feet in August. This species is the destructive chinch bug, which causes enormous damage and loss to wheat and corn. The writer, while flying on September 29, 1930, observed great numbers of chinch bugs at the height of 2,000 feet. The wind was from the north at this altitude, and as nearly as could be determined the insects were flying in a southerly direction. The late Elmer Johnson, senior agricultural engineer, formerly of the Delta Laboratory at Tallulah, La., related to the writer that at one time while he was flying in Arkansas, he saw great numbers of insects in the air at an altitude of 5,000 feet and detected the peculiar and characteristic odor of chinch bugs. No specimens were captured yet he was quite positive in his determination of the species.

Twenty-nine specimens of *Geocoris punctipes* (Say) (Lygaeidae) were taken in the daytime in the months of April to December from near the surface to 5,000 feet. This lygaeid is commonly found on cotton and is predacious on many insects. *Antillocoris pallidus* (Uhler) (Lygaeidae) was taken in considerable numbers, with 51 in the day collections and 19 at night. These were collected at from near the surface to as high as 7,000 feet and at night up to the height of 5,000 feet. Specimens were taken throughout the year. This species is of no economic importance. One specimen of *Corythucha gossypii* Heid. (Tingitidae) was taken at 200 feet in the month of May. This species is thought to transmit mosaic diseases. Twenty-one specimens of *Systelloderus biceps* (Say) (Enicocephalidae) were collected from near the surface to 5,000 feet. The greatest numbers of specimens were found in September. This is a most interesting insect, being very odd in appearance and quite different in structure from other Heteroptera. It is a predacious species, and the front legs are fitted for grasping prey. One specimen of *Atrachelus cinereus* (F.) (Reduviidae) was collected at 8,000 feet in June.

The most abundant of the species of Heteroptera taken was (*Triphleps*) *Orius insidiosus* (Say) (Anthocoridae). There were 214 specimens of this in the day collections and 7 at night. Specimens were collected in every month with the greatest numbers in May. They were taken at most altitudes, with 117 specimens at 200 feet, 48 at 1,000, 20 at 2,000, 11 at 3,000, 3 at 5,000, and one each at 6,000 and 8,000 feet. At night five were collected at 500 feet and two at 1,000 feet. This species is known as the insidiuous flower bug and is predacious on thrips, plant lice, the chinch bug, the grape phylloxera, and other pests. *Orius insidiosus* is also known to attack and destroy the eggs and small larvae of the corn earworm (*79*). Eight specimens of the rapid plant bug (*Adelphocoris rapidus* (Say)) (Miridae) were collected, six in the day flights and two at night. This species is known to damage cotton. Five specimens of *Polymerus basalis* (Reut.) (Miridae) were collected in the upper air, two specimens at 200 feet and three at 1,000 feet. Fifty-four specimens of the tarnished plant bug (*Lygus pratensis* (L.)) (Miridae) were taken during the daytime. They were captured in every month of the year with the exception of November. There were 38 specimens collected at 200 feet, 5 at 1,000, and 1 each at 2,000, 3,000, and 5,000 feet. Two were found at night at altitudes of 500 and 2,000 feet, respectively. This insect is of considerable economic importance, causing damage to cotton, orchard trees, nursery stock, and many species of flowers.

Seven specimens of the cotton flea hopper (*Psallus seriatus* (Reut.)) (Miridae) were collected in the daytime; two each at the altitudes of 20, 200, and 1,000 feet, and one at 2,000 feet. They were taken in the months of April to June and from August to October. This species does considerable damage to cotton. There were 53 specimens of *Arctocorixa modesta* Abbott (Corixidae) taken in the day flights and 58 in the night flights. Specimens were found in every month of the year, but they were most abundant in September.

They were taken at altitudes up to 5,000 feet in both day and night collections. This is an aquatic species that often appears in immense numbers around street lights at night, and by morning the walks and pavements under the lights are covered with the dead insects.

HOMOPTERA

The order Homoptera was third in numbers taken as compared with the other orders of insects collected in the upper air. There were 3,934 specimens collected of which 3,081 were taken in the day collections and 855 at night (tables 9 and 10). The order appeared in every month of the year.

For the day collections the largest number per 10 minutes' flight were taken in October and November, with more in November. At night Homoptera were collected in largest numbers in May, September, and October, and in smallest numbers in July, after which they increased, reaching their maximum in October. In the daytime fewest appeared in January, the numbers increasing until May, dropping off considerably in June and July, then greatly increasing in August and until November, with over three times as many specimens taken in November as in August.

Homoptera were collected in the day flights at almost every altitude up to 14,000 feet, and were taken at night at every altitude flown up to 5,000 feet.

There were 9 families, 74 genera, 79 determined species, and 3 new species represented. Of these numbers, 9 families were represented in the daytime and 6 at night, with 71 determined species in the day collections and 38 at night (table 9).

The greatest numbers of specimens taken belonged to the families Cicadellidae, of which family 773 were collected in the day flights and 479 at night; Chermidae, with 581 in the day and 19 at night; Fulgoridae, with 518 in the day and 133 at night; Membracidae, with 86 in the day and 2 at night; and Aphiidae, with 304 specimens taken in the day flights and 31 at night.

The largest homopteron taken was a *Tibicen linnei* (Sm. and Grosb.) taken at the altitude of 200 feet. The family Membracidae was represented principally by the three-cornered alfalfa hopper (*Stictocephala festina* (Say)), of which 64 specimens were taken in the day flights from near the surface to the altitude of 1,000 feet. These specimens were collected from May to November, with the greatest numbers in June. Only one specimen of this species was taken at night, and this at 3,000 feet.

The Cicadellidae were found at nearly every altitude flown. Specimens were taken up to the height of 14,000 feet during the day flights. One of the most abundant of the species taken was *Graphocephala versuta* (Say), 67 being caught in the day flights and 3 at night. They were taken up to the height of 5,000 feet. In the day collections 12 specimens were taken at 1,000, 12 at 2,000, and 10 at 3,000 feet. This species was most abundant in October and November. There were 38 specimens of *Agallia constricta* Van D., an important pest of alfalfa, collected in the day flights in March, and in May to October inclusive. This species was taken mostly at the altitude of 200 feet, with several at 3,000, and one specimen at 10,000 feet. Two specimens were taken at night, one at 500 feet and one at 3,000 feet. Seven specimens of *Aceratagallia sanguinolenta* (Prov.) were taken at the altitude of 200 feet. This is a serious pest of a number of legumes in the Eastern States. Two specimens of *Draeculacephala mollipes* (Say) were taken at 200 feet, one each in April and November. This species is recorded as being of importance as a grass feeder. Three specimens of *Deltocephalus flavicostus* Stål were collected at 200 feet, one each in May, June, and September, in the day flights. It is probably of considerably importance as a grass feeder.

The most abundant of the species of Cicadellidae taken was *Thamnotettix nigrifrons* (Forbes), which was caught in almost every month. Fifty-three specimens were collected in the daytime at altitudes up to 3,000 feet. In the night flights 29 were taken at altitudes of 500 to 3,000 feet, mostly in June and September. This is a common pest in the Eastern States. The largest species of Cicadellidae taken in the upper air were the sharpshooters *Oncometopia undata* (F.), *O. lateralis* (F.), and *Homalodisca triquetra* (F.). These species were taken throughout the year at altitudes of 200 to 3,000 feet. *H. triquetra* was taken at night also, two specimens at 500 feet and one at 1,000 feet. Forty specimens of the leafhopper *Macrosteles divisus* (Uhl.) were collected in the daytime from March to October. This species was taken mostly at the altitude of 200 feet, although four specimens were found at 2,000 feet and two at 13,000 feet. Seven specimens were collected at night during the summer months at altitudes of 500 to 2,000 feet. This species attacks some grains and grasses and is reported as transmitting certain mosaic diseases. The potato leafhopper (*Empoasca fabae* (Harr.)) was represented by 19 specimens taken in April, August, September, and October, from near the surface to the height of 7,000 feet. Five of these were taken at night. Two specimens of *Empoasca solana* DeLong were collected in February and September in the daytime, at 200 feet and 1,000 feet, respectively. Four were taken in the night flights in October at 500 feet. This cicadellid occurs on potatoes. Two specimens of *Erythroneura vulnerata* Fitch were taken in the daytime, one in July near the surface and one in November at 200 feet. This species is a common pest of grapes. The Cicadellidae were most abundant in September and October, although they occurred in great numbers throughout the spring, summer, and fall months.

The family Fulgoridae was represented by 14 genera and 14 determined species of which 13 species were taken in the day flights and 9 at night. They were taken in the daytime at almost every altitude up to 14,000 feet. The Fulgoridae were taken mostly in September and October, with fewest in the spring, late in the fall, and in winter. Two specimens of *Peregrinus maidis* (Ashm.) were taken in the daytime, in September and October, at 200 feet. Five were taken at night in October; three at 500 feet, and two at 1,000 feet. This species is the transmitter of corn stripe in Cuba, a virus disease similar to the mosaic disease of sugarcane. There were 116 specimens of *Liburniella ornata* (Stål) taken in the upper air with 88 in the day collections and 28 at night. This species is of no special interest economically, but it was very abundant late in the summer at most altitudes, 12 having been taken at 5,000 feet in the daytime and one each at 7,000 and 12,000 feet. At night this species was taken as high as 5,000 feet. *Delphacodes puella* (Van D.) was the most abundant species of Fulgoridae taken. There were 112 specimens taken at altitudes up to 5,000 feet in the daytime and at night there were 27 specimens taken

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at altitudes up to 2,000 feet. This species appeared mostly in August, September, and October.

The family Psyllidae was represented by 6 genera and 10 determined species. The most abundant species of all the Homoptera taken in the upper air belong to this family, namely, *Pachypsylla celtidis-mamma* Riley, of which 321 specimens were taken from near the surface up to 5,000 feet. Of this number only five were taken at night, these at the altitudes of 500, and 1,000 to 3,000 feet. This species appeared in greatest numbers in March and November. There were 47 specimens of *P. celtidis-gemma* Riley taken in the daytime at altitudes from near the surface to 3,000 feet, and one specimen at the altitude of 13,000 feet. This species is the common hackberry twig gall psyllid. The family Psyllidae appeared mostly in the spring and late fall months.

The family Aphiidae appeared in considerable numbers in the upper air, species having been taken up to the height of 13,000 feet. There were 14 determined genera represented, 8 determined species, and 1 new species. Though specimens were collected in every month of the year, they were taken mostly in April, May, and June. Fewest were taken in the winter months. One specimen of *Sipha flava* (Forbes) was collected at 1,000 feet during the daytime in May. This species, known as the yellow aphid and found on sugarcane in Puerto Rico and the Tropics, has caused serious damage to broomcorn and sorghum in Illinois (*33*). Specimens of the cotton aphid or melon aphid (*Aphis gossypii* Glover) were taken in the day collections at altitudes from 200 to 3,000 feet and one specimen at 13,000 feet. Two specimens were taken at night at 500 and 1,000 feet. This species was taken in the spring months only. It is a well known economic species, being destructive in the South especially to cotton and cucurbits.

The most abundant aphid collected was the pea aphid (*Macrosiphum (Illinoia) pisi* (Kalt.)). There were 17 specimens collected at altitudes of 200 to 4,000 feet and they were collected mostly in May. This is a very injurious species, often serious on peas, clovers, and other legumes. One specimen of the green peach aphid (*Myzus persicae* (Sulzer)) was taken at 3,000 feet in May 1930. This species is of considerable economic importance, attacking truck crops, garden flowers, and fruit trees.

The family Aleyrodidae was represented by two specimens taken at 200 and 1,000 feet, respectively, in the day collections in September 1930. The whiteflies are often very destructive to various cultivated plants.

Two specimens of the family Coccidae (scale insects) were taken at 1,000 feet in July 1930.

In comparing the day and night collections of the species of Homoptera it was found that there was a similar trend in the monthly maximum and minimum occurrences. The spring peak was in May, with a minimum for the summer in July. Both day and night collections increased similarly in the number of specimens taken, with the exception that the peak of abundance for night was reached in October, whereas that for the day collections was in November. This may be accounted for by the fact that Cicadellidae were more active at night in October than in November, because of meteorological conditions that limited the activity of night-flying insects in the latter month.

It is evident that many of the species belonging to certain families are more active in the upper air either in the daytime or at night. The families especially represented in the day collections are those of Membracidae, Psyllidae, and Aphiidae. The families Cicadellidae and Fulgoridae were collected in great numbers both in the daytime and at night. However, as estimated on the amount of time flown, more than five times as many Cicadellidae were taken at night as during the day. This would indicate that Cicadellidae were more active at night in the upper air than during the daytime. Almost twice the numbers of Fulgoridae were taken at night as during the day, as estimated on the amount of time flown. Species of Homoptera of which more were taken in 10 minutes of flight in the day than at night are *Stictocephala festina* (Say), *Micrutalis calva* (Say), *Agallia constricta* Van D., *Graphocephala versuta* (Say), *Macrosteles divisus* (Uhl.), *Liburniella ornata* (Stål), *Delphacodes puella* (Van D.), *Aphalara veazici* Patch, *Trioza diospyri* (Ashm.), *Pachypsylla celtidis-mamma* Riley, and *Macrosiphum* (*Illinoia*) *pisi* (Kalt.). Species which are apparently more active at night than during the daytime are *Xestocephalus pulicarius* (Van D.) and those belonging to the genus *Empoasca*.

COLEOPTERA

The order Coleoptera was second to Diptera in the numbers of insects taken in the upper air. The order appeared in every month of the year, and in the day collections the specimens were most abundant in March and November, with more in March. They were found at every altitude flown up to 12,000 feet. At night Coleoptera appeared in the collections in greatest numbers in May and October, with more in May. Nearly twice as many were taken at night per unit of flying time as in the day flights. The Coleoptera collected in the upper air were represented by 46 families, 191 genera, and 175 determined species. There were 4,420 specimens taken, of which 3,566 were collected in the daytime and 854 at night (tables 9 and 10).

More than half the Coleoptera taken belonged to the families Carabidae, Staphylinidae, Chrysomelidae, and Curculionidae.

The family Carabidae was third in the number of specimens taken. The greatest numbers were found in March, May, and June, with the greatest number collected in May. Fewest specimens were found in January and, for the summer, in August. They were collected from near the surface to the height of 10,000 feet. Species belonging to the genus *Bembidion* were taken mostly at night at altitudes of 500 and 1,000 feet. Twelve specimens of *Micratopus fusciceps* Csy. were collected in the day flights, and 46 at night. These were collected from May to December, at altitudes of 200 to 2,000 feet. Forty-seven specimens of *Harpalus nitidulus* Chd. were taken in the day flights, mostly at 200 feet, but three at 1,000 feet. This species was found from February to May, with the most taken in March and the fewest in May. Thirteen specimens of *Agonoderus pallipes* F., were collected, 10 in the daytime and 3 at night, at from near the surface to 1,000 feet. This species sometimes attacks seeds of corn, although it feeds mainly on insects or insect remains. Species of Carabidae taken at high altitudes were one specimen of *Blechrus pusio* Lec. at 10,000 feet, one *Stenocellus tantillus* Dej. at 6,000 feet, and one *Tachys* sp. at 8,000 feet.

Members of the family Staphylinidae include more specimens than any other family of Coleoptera taken in the upper air, and are among the most abundant of insects. There were 1,188 specimens collected in the daytime and 206 at night. Specimens were taken at nearly every altitude up to 11,000 feet. In the day collections staphylinids were more abundant in the months of March, May, and November than in other months, with the peak of abundance in March, but at night they appeared mostly in October. Based on the amount of time flown, the Staphylinidae were more abundant at night, when they were probably the most active of the Coleoptera, at times the air being filled with these minute insects, especially around lights. As these insects feed in decaying animal and vegetable matter where they are predacious on other insects, they may be classed as beneficial.

One interesting family represented in the collections of the upper air was the Trichopterygidae, of which six specimens were taken. They were collected in the summer months, four at 1,000 feet and two at 2,000 feet. This family includes the smallest beetles known. They are minute insects, the wings being long and slender, fringed with long hairs, and featherlike in apearance.

Five specimens belonging to the Lampyridae, or firefly family, were collected. One specimen of *Pyropyga minuta* (Lec.) was taken at 200 feet in April and four undetermined specimens at the same altitude, one in April and three in September. Fireflies do not fly high at night, as the writer never observed any "flashes" of these insects while flying very high at night. While they are rather sluggish by day, a few are active, as all specimens were collected between 8 and 10 a. m.

One specimen of *Micromalthus debilis* Lec. (Micromalthidae) was taken in September at 1,000 feet. This is a most interesting species, having a very remarkable life history. It has been found by Barber (4) that most of its larvae give birth to living larvae (viviparous paedogenesis) whereas some lay single eggs (oviparous paedogenesis). This egg produces a male beetle through larval forms that are different from those producing the female beetle. The adult female lays two eggs that are not like the egg of the oviparous larva. Most of the larvae burrow in and feed upon decaying wood, but those that produce males remain quiet, each in the cell of its mother larva, which latter supplies its own nutriment.

The family Dermestidae includes three specimens taken in the day flights. One dermestid larva, a species of *Trogoderma*, was caught alive in March at the altitude of 9,000 feet. Two undetermined species of adults were collected in June at 200 feet. This family includes many species destructive to foodstuffs, household goods, and clothing.

One specimen of the clover stemborer *Languria mozardi* Latr. (Erotylidae) was taken near the surface in April.

The family Coccinellidae (ladybeetles) was represented by 50 specimens taken in the day flights and 2 at night. Specimens were taken in every month except January and December. Eight determined species were collected from near the surface to the height of 6,000 feet. Seven specimens of *Scymnus terminatus* Say were found in the day flights, with four at 200 feet, one at 1,000 feet, and two at 5,000 feet. Two specimens of *S. loewi* Muls. were caught at 200 feet. One *Coleomegilla floridana* (Leng.) was taken at the altitude of

6,000 feet in August. Ten specimens of *C. fuscilabris* (Muls.) were taken at 200 feet in the summer months. Eleven specimens of *Hippodamia convergens* Guér. were found from near the surface to the height of 5,000 feet. One *Coccinella novemnotata* Hbst. was found at 1,000 feet. Two specimens of *Cycloneda munda* (Say) were collected in the day at altitudes of 200 and 1,000 feet and one at night at 1,000 feet. The species of Coccinellidae represented in the collections of the upper air may be considered as beneficial, being predacious and feeding on aphids and other small insects.

Three specimens of the red flour beetle (*Tribolium castaneum* (Herbst)) (Tenebrionidae) were taken in the daytime, one each in January, April, and September, at the altitudes of 200, 1,000, and 3,000 feet, respectively. This species causes damage to stored flour and other products.

One specimen of *Xylobiops basilare* (Say) (Bostrichidae) was taken in March at the altitude of 200 feet. This species is one of the shot-hole borers and causes damage to wood products.

The family Scarabaeidae was represented by six specimens collected in the day flights, and eight at night. They appeared in the winter, summer, and fall months. Two specimens of a dung beetle, *Aphodius lividus* (Oliv.), were found at night, one each in July and October at 500 feet.

The family Chrysomelidae was second in the numbers taken, there being 475 specimens in the day collections and 26 at night. The greatest numbers were taken in March and April. For the months in which flights were made at night the larger numbers of Chrysomelidae were found in May and October. There were 24 genera and 34 determined species taken at altitudes ranging from near the surface to 11,000 feet. Seven specimens of *Colaspis brunnea* (F.) were collected in the summer months, six at 200 feet and one at 1,000 feet. This species is of economic importance, feeding on corn and clover and being destructive to grapes. It has also caused some injury to growing cotton. A specimen of the grape rootworm (*Fidia viticida* Walsh) was taken in June at the altitude of 200 feet. Twenty-five specimens of *Myochrous denticollis* (Say) were taken, 6 at 20 feet, 18 at 200, and 1 at 3,000 feet. They were found in the spring, summer, and fall months. This chrysomelid causes injury to young corn plants. Two specimens of the strawberry rootworm (*Paria canella* (F.)) were found in March at 200 and 3,000 feet, respectively. This is a pest on many plants, eating leaves and buds and feeding on the small roots. One willow leaf beetle, *Chrysomela* (=*Lina*) *scripta* F., was taken at night at 500 feet.

The spotted cucumber beetle (*Diabrotica duodecimpunctata* (F.)) was caught in the upper air, with 18 specimens found in the day collections and 10 at night. They appeared in nearly every month from February to December, although the greatest number were taken in May. They were captured in the daytime from near the surface to 1,000 feet, and at night from 500 to 3,000 feet. There were 12 specimens of the striped cucumber beetle (*Diabrotica vittata* (F.)) collected, 6 each in the day and night flights. They were taken from June to October, from near the surface to 1,000 feet, and one specimen at 11,000 feet. Two adults of the bean leaf beetle (*Cerotoma trifurcata* (Forst.)) were found in September at the altitude of 200 feet.

Twelve specimens of *Crepidodera atriventris* Melsh. were collected in the day flights in April and May and from September to November, at altitudes of from 200 to 2,000 feet. This species has caused severe injury to *Acalypha* in gardens in Illinois and in Washington, D. C. (*3*). The flea beetles were taken mostly in the summer months at altitudes of 200 to 1,000 feet. The species of flea beetles collected in the upper air included the eggplant flea beetle (*Epitrix fuscula* Cr.); potato flea beetle (*E. cucumeris* (Harr.)); *E. brevis* Schwartz; and the tobacco flea beetle (*E. parvula* (F.)); seven specimens of *Mantura floridana* Cr. taken in April, six at 200 feet, and one at 1,000 feet; the sweetpotato flea beetle (*Chaetocnema confinis* Cr.), and the toothed flea beetle (*C. denticulata* Ill.) at 200 feet; 19 specimens of the corn flea beetle (*C. pulicaria* Melsh.) from 200 to 5,000 feet; the pale-striped flea beetle (*Systena taeniata* Say) from near the surface to 1,000 feet; and many undetermined specimens. *Chaetocnema pulicaria* has often been reported as a corn pest of first importance. It has been known for many years to be a vector of bacterial wilt of corn. However, it is only more or less recently that it was learned that *Aplanobacter stewarti*, the organism which causes bacterial wilt of corn, was found passing the winter in a virulent condition in the bodies of the hibernating adult beetles (*60*). New corn plants are inoculated with the wilt organism in the spring by the feeding of these beetles, and this appears to be the chief means by which disease is spread each year in cornfields. *Chaetocnema denticulata* is also a vector of bacterial wilt of corn, as it will transmit the bacterial wilt organism from infected to healthy corn for a considerable period of time, but it has not been found to harbor the organism over the winter.

Longitarsus testaceus (Melsh.) was found in every month, although it was taken mostly in March and April. Two hundred and nine specimens were collected in the daytime from near the surface to as high as 5,000 feet. Three specimens of the striped cabbage flea beetle (*Phyllotreta striolata* (Ill.)) were found at 200 feet in April. The hop flea beetle (*Psylliodes punctulata* Melsh.) was taken late in the spring and early in the summer at 200 and 1,000 feet. A small leaf miner, *Baliosus ruber* Web., was collected at 200 feet in May. The larva of this species mines in the leaves of apple and basswood. One specimen each of the striped sweetpotato beetle (*Metriona bivittata* (Say)), and the golden tortoise beetle (*M. bicolor* (F.)) were found in October and November, respectively, at 200 and 1,000 feet.

The family Curculionidae was fourth in the numbers of specimens collected. There were 108 taken in the day flights and 12 at night. Seventeen genera and 18 described species were represented, and they were collected in every month, although mostly in spring, being most abundant in May. They were found from near the surface to the altitude of 5,000 feet. Fourteen specimens of the cotton boll weevil (*Anthonomus grandis* Boh.) were collected from May to October. One specimen was collected at 20 feet, seven at 200 feet, three at 1,000, and three at 2,000 feet. Only one specimen was found at night, this at the altitude of 1,000 feet. This beetle is the major pest of cotton.

Of the family Platypodidae one specimen of *Platypus quadridentatus* Oliv. was taken at 200 feet in October. Two adults of another similar ambrosia beetle (*P. compositus* Say) were collected near the surface and one at 200 feet. These beetles are destructive to dying, recently felled, and wind-blown trees, especially to cypress throughout the range of this tree.

Of the family Scolytidae five specimens of *Leperisinus aculeatus* (Say) were taken in the winter and spring at 200 feet. One *Pityophthorus rhois* Sw. beetle was found in August at 200 feet.

NEUROPTERA

The order Neuroptera was represented by 36 specimens taken in the upper air, of which 10 were found in the day flights and 26 at night. The specimens were collected from April to November, with the greatest number taken in October, at 200 to 5,000 feet. Four families and six determined species were represented (table 9).

Four specimens of *Sympherobius amiculus* (Fitch) (Sympherobiidae) were found in the upper air, two at night in August, at 1,000 and 3,000 feet, and two in September, one each at 1,000 feet in the day and the night collections.

Seven specimens of the family Hemerobiidae were taken at 500 to 3,000 feet, with two specimens in the daytime and five at night.

The family Chrysopidae was represented by 6 specimens caught in the day flights and 17 in the night. One specimen of *Chrysopa oculata* Say was found at 200 feet in the day, and one each at 500 and 1,000 feet at night. Five specimens of *C. oculata* var. *albicornis* Fitch were collected, one at 200 feet in the daytime and one at 500 feet and three at 2,000 feet, at night. One *C. oculata* var. *chlorophana* Burm. was found at 500 feet at night. Three *C. plorabunda* Fitch were taken in the day collections at 200 feet, and seven at night, with four at 1,000, two at 3,000, and one at 5,000 feet. Four *Chrysopa* species were collected at altitudes of 500 to 3,000 feet. Species belonging to this family are the well known lacewing flies, and as the larvae are predacious on aphids and other small insects they may be classed as beneficial.

One *Malacomyza westwoodi* (Fitch) (Coniopterygidae) was taken in the daytime in October at 3,000 feet.

TRICHOPTERA

Three specimens belonging to the order Trichoptera (caddisflies) were collected in the upper air in the day flights (table 9). One specimen of *Oecetis* sp. was found in July at 5,000 feet. Two undetermined species of Trichoptera were collected at 200 feet in October. The Trichoptera are important as food for fishes, the larvae being abundant in the bottom of lakes or streams.

MECOPTERA

The order Mecoptera was represented by three specimens of scorpionflies of the genus *Panorpa* (Panorpidae), collected in the daytime at 5,000 feet on September 15, 1926. The order Mecoptera includes insects of little, if any, economic importance.

LEPIDOPTERA

There were 225 specimens of Lepidoptera collected in the airplane insect traps, of which 217 belonged to the Heterocera and 8 to the Rhopalocera.

SUBORDER HETEROCERA

The Heterocera, or moths, caught belonged to 16 families and 30 genera, in which 24 species were determined. They were taken in every month of the year, although mostly in September and October. There were 67 specimens caught in the day flights and 150 at night. At night the greatest numbers appeared in October. They were collected at altitudes ranging from near the surface to the height of 5,000 feet (table 9).

Forty specimens belonging to the family Noctuidae (cutworms, etc.) were taken, of which 4 were found in the daytime and 36 at night. One specimen of the cotton bollworm or corn earworm moth (*Heliothis obsoleta* (F.)) was found at night in October at 500 feet. Seven adults of the fall armyworm moth (*Laphygma frugiperda* (A. and S.)) were collected, one in a day flight at the altitude of 2,000 feet, and five at 500 and one at 1,000 feet, at night. Larvae of this species are a serious pest of field and vegetable crops. One specimen of the cabbage looper (*Autographa brassicae* (Riley)) was taken in October at 500 feet at night. The larvae are serious pests of plants of the cabbage family as well as of many other vegetables and of flowers.

The cotton leafworm moth (*Alabama argillacea* (Hbn.)) was represented by 22 specimens of which 3 were taken in the daytime and 19 at night. They were collected in August, September, and October, from 200 to 3,000 feet in the daytime and from 500 to 1,000 feet at night. The larva of this moth is one of the important cotton pests, and the moths often cause injury to fruit in the North. There is a mystery about the advance of the cotton leafworm from year to year. An infestation will appear in one locality and then suddenly in a place far distant. The moth is a well-known migrant, flying from the Cotton Belt of the South and appearing in great swarms in the Northern States and Canada. There is no known record of this species overwintering in the United States, yet each year it appears usually first in the cotton fields of the extreme South and then advances toward the North.

Doubtless temperature is the controlling factor in the appearance or disappearance of the cotton leafworm moth, for it seems to stimulate or retard the migrations. The migrations of *Alabama* in South America are southward from the Tropics in December and January, the caterpillars disappearing in May and June with the advance of colder weather. In the United States the migrations are northward as the season advances. In some years the moths reach the most Northern and Northeastern States very early, and at times are reported in the North within a few days after their first appearance in Louisiana. In 1929 the first moth found at Tallulah was one taken in the airplane insect trap on August 5 at the altitude of 500 feet. This specimen was probably a migrant, since eggs or larvae had not been reported in Louisiana previously. On August 24 a moth was taken in Wisconsin. In 1920 the first eggs and larvae were found on cotton at Tallulah on July 22. On August 1 adults were found at Columbia, Mo. Comparing the records of 7 years it was found to take from 40 to 58 days, or an average of 56 days, for the moth to appear in northern Louisiana after its initial appearance in southern Texas near Brownsville. From the first record of the moth near Brownsville to the first record of the moth reported from Wisconsin there was an average of 107 days, with 121 days for Minnesota and 113 days for Michigan.

The pink bollworm (*Pectinophora gossypiella* (Saund.)) was not taken in the flights over Louisiana, but a few specimens were captured in Mexico, as discussed under another heading.

One moth of the green clover worm (*Plathypena scabra* (F.)) was found at night in October at 500 feet. The larvae of this species are very destructive to clover, alfalfa, and leguminous crops.

One moth of the celery stalk worm (*Nomophila noctuella* (D. and S.)) (Pyralididae) was taken in September at 3,000 feet in the daytime. This species has a world-wide distribution, but as a rule is not of much economic importance. The larvae attack celery, bluegrass, and legumes. Three adults of the garden webworm (*Loxostege similalis* (Guen.)) were taken at night, two at 500 feet and one at 3,000 feet. The garden webworm attacks truck crops, feeding on the foliage. It may seriously injure alfalfa. Six specimens of *Geshna primordalis* Dyar were taken at night in July and September, two at 500 feet and four at 1,000 feet. This is a widely distributed species, the larvae feeding on semiaquatic plants. One specimen of the meal moth (*Pyralis farinalis* L.) was found in September at 5,000 feet in the daytime. The larvae feed upon cereals of all kinds and do considerable damage. Three adults of the lesser cornstalk borer (*Elasmopalpus lignosellus* (Zell.)) were collected at night in September and October, at 500 feet. This is a very destructive species that causes injury to young sugarcane in Cuba and to young corn and other crops in the United States.

SUBORDER RHOPALOCERA

Eight species of butterflies were taken in the day flights in April, August, September, and October, all at the lower altitudes. A specimen of the alfalfa caterpillar butterfly (*Colias eurytheme* Bdv.) was taken at 50 feet. Other species of butterflies collected at altitudes from near the surface to 600 feet were *Phyciodes tharos* form *marcia* Edw., *Junonia coenia* (Hbn.), *Epargyreus tityrus* (F.), *Antigonus nessus* (Edw.), *Hesperia leonardus* Harr., *Lerema accius* A. and S., and *Lerodea eufala* (Edw.) (table 9).

HYMENOPTERA

The order Hymenoptera was fourth in the number of specimens taken. There were 2,947 specimens collected of which 177 were caught at night. Hymenoptera appeared in every month of the year, with the greatest numbers for the day flights taken in May and July and the smallest in January and February. At night most specimens were found in October. They were collected at nearly all altitudes flown up to the height of 14,000 feet. There were represented 33 families, 244 determined genera, and 195 determined species, with 3 new genera and 20 new species. More than half of the Hymenoptera belonged to seven families, these being Braconidae, Diapriidae, Scelionidae, Cynipidae, Eulophidae, Pteromalidae, and Formicidae (tables 9 and 10).

The family Braconidae included the greatest number of specimens collected of any of the families of Hymenoptera. There were 325 specimens taken, of which 298 appeared in the day collections and 27 at night. There were 44 genera, 44 determined species, 2 new genera, and 7 new species represented in this family. Specimens were found throughout the year and were more or less evenly distributed, but with fewest specimens taken in the winter months. They were found at all altitudes flown up to the height of 8,000 feet. The genus *Microbracon* was represented by five determined species and one new species. Two of *M. gelechiae* (Ashm.) were collected at 200 feet, in April and May. It is a species parasitic on many lepidopterous larvae of the families Pyralididae, Tortricidae, and Gelechiidae. It is known as a parasite of the apple and grape leaf rollers, oriental fruit moth, and grape berry moth. Ten specimens of *M. mellitor* (Say) were taken in the spring and summer at altitudes from near the surface to 5,000 feet. This species is exceedingly important as a parasite of the boll weevil and the pink bollworm.

Three *Triaspis curculionis* (Fitch) were collected at 200, 2,000, and 3,000 feet. This is a widely distributed parasite of the plum curculio and frequently parasitic on the boll weevil. Twenty-two specimens of *Chelonus texanus* Cress. were found, mostly in August and September, at altitudes from 200 to 5,000 feet. This species is a parasite of the fall armyworm and the bollworm. One *Microplitis varicolor* Vier. was found at 1,000 feet. This is a parasite of the armyworm (*Cirphis unipuncta* (Haw.)) and the green clover worm (*Plathypena scabra* (F.)). The genus *Apanteles* was represented by 83 specimens, of which only 4 were taken at night. There were nine determined species collected in the spring, summer, and fall at altitudes from near the surface to 5,000 feet. Six *Apanteles marginiventris* (Cress.) were found at from near the surface to 2,000 feet. This is known as a parasite of the corn earworm, fall armyworm, etc. Fourteen of *A. militaris* (Walsh) were found at altitudes up to 1,000 feet. This is a gregarious parasite of the armyworm (*Cirphis unipuncta*). Three of *A. forbesi* Vier. were found at 200 and 3,000 feet. This is also a parasite of cutworms. One *Opius dimidiatus* (Ashm.) was caught at 200 feet. It is a common parasite of the serpentine leaf miner (*Agromyza pusilla* Meig.). Thirteen of *Meteorus vulgaris* (Cress.) were found, mostly in May, at altitudes of from 200 to 2,000 feet. This is an abundant parasite of noctuid larvae of the cutworm type. Seventeen specimens of *Lysiphlebus testaceipes* (Cress.) were taken in the spring and summer at altitudes up to 5,000 feet. This is an important parasite of the cotton aphid and other aphids. Six adults of *Aphaereta muscae* Ashm., parasitic on various Diptera, were taken at 200 to 3,000 feet.

There were 64 specimens belonging to the family Ichneumonidae taken in the day flights, and 8 at night. The specimens collected comprised 23 genera, 16 determined species, and 1 new species. They were found throughout the year at altitudes from near the surface to the height of 5,000 feet. Three *Ephialtes aequalis* (Prov.) were collected at the altitudes of 200 and 3,000 feet, and one *Acrolyta aletiae* Ashm. at 2,000 feet. The former species is parasitic on the cotton leaf worm and the bollworm, and the latter is a secondary parasite. A specimen of *Diplazon laetatorius* (F.) was caught at 1,000 feet. This is a parasite of syrphid flies. One *Sagaritis provancheri* (D. T.), parasitic on the fall armyworm, European corn borer, bollworm, and other lepidopterous larvae, was found at 200 feet. Four of *S. oxylus* (Cress.) were collected at 200 feet in the months of March and April. This is also a parasite of the fall armyworm (*Laphygma frugiperda*), and the armyworm (*Cirphis unipuncta*).

One hundred and twenty-seven specimens belonging to the family Diapriidae were collected, of which eight were taken at night. They were taken mostly late in the spring, in the summer, and early in the fall, and were found at altitudes up to 10,000 feet. There were 10 genera, 3 determined species, and 2 new species represented in the collections.

The family Scelionidae was fourth in the number of specimens taken, with 227 specimens, of which 9 were found at night. They appeared from March to November, but chiefly in May and September (based on the amount of time flown). They were taken at from near the surface to the height of 13,000 feet. Eighteen genera, 12 determined species, and 1 new species were represented. Members of this family are egg parasites, infesting the eggs of nearly all orders of insects and the eggs of spiders. Twenty-four specimens of *Telenomus podisi* (Ashm.) were collected up to the height of 5,000 feet. This is an egg parasite of pentatomid bugs.

The family Cynipidae comprised 195 specimens taken, of which 10 were found at night, and included 25 genera and 5 determined species. Specimens were taken at altitudes up to 11,000 feet, appeared in every month except February, and were most abundant in April and August with more in August. Members of this family are mostly minute insects. Many species produce galls, some are parasites, and others are inquilines or guests in galls produced by other species. Eighteen *Prosaspicera similis* (Ashm.) were found at 200 to 2,000 feet. This species is parasitic on Diptera. Four specimens of *Charips brassicae* (Ashm.), parasitic on the cabbage aphid, were taken at 200 feet. Fifteen females of the genus *Synergus* were collected from near the surface to 3,000 feet. Species of this genus are guest flies in cynipid galls on oak.

The 37 specimens of the family Chalcididae taken at altitudes up to 5,000 feet included 3 genera, 4 determined species, and 1 new species. This family comprises species which are mostly parasitic on lepidopterous larvae or pupae, although a few are parasitic on other insects.

The family Eurytomidae was represented by 49 specimens, of which 4 were taken at night. There were six genera, eight determined species, and one new species collected from near the surface to the height of 5,000 feet, from March to October. Four specimens of the clover-seed chalcid (*Bruchophagus gibbus* (Boheman)) were taken at altitudes of 200 and 1,000 feet in the daytime, and one at night at 500 feet. This is a serious pest of red and crimson clovers and alfalfa, infesting the seeds. One *Bruchobius laticeps* Ashm. was collected at 1,000 feet in October. This species is a larval parasite of bean weevils (Bruchidae).

The specimens collected of the family Pteromalidae comprised 222 individuals of which 18 were collected at night. The collected material included 16 genera and 13 determined species found at altitudes from near the surface to 10,000 feet. The greatest numbers of specimens appeared in September and October. Thirty-four specimens of *Zatropis incertus* (Ashm.) were taken at altitudes up to 5,000 feet. This species is parasitic on the boll weevil and pink bollworm. Six of *Catolaccus hunteri* Cwfd. were collected at altitudes of 200 and 1,000 feet. This is also a parasite of the boll weevil and the pink bollworm. Four species belonging to the genus *Pachyneuron* were found at altitudes of from 50 to 10,000 feet. Nine specimens of P. *siphonophorae* (Ashm.) were taken at from 200 to 6,000 feet and were found mostly in the spring months. This is an important parasite of the cotton aphid (*Aphis gossypii*).

The family Eupelmidae contributed 38 specimens, of which 3 were taken at night. There were two genera, nine determined species, and one new species represented, taken from near the surface to 2,000 feet. They were found mostly in the summer months.

The family Encyrtidae was represented by 58 specimens, 2 of which were taken at night. Fourteen genera, 10 determined species, and 1 new species were taken at altitudes from near the surface to 12,000 feet. One *Homalotylus terminalis* (Say), a parasite of coccinellid larvae, was taken at 200 feet.

There were 245 specimens belonging to the family Eulophidae, 17 of which were taken at night. There were 16 genera, 15 determined species, and 2 new species represented in the collections. This family ranked third in the numbers taken. The insects appeared from March to December and were mostly found in May and October, with more in May. Specimens were collected from near the surface to the height of 13,000 feet. There were 153 specimens belonging to the genus *Testrastichus* collected at altitudes up to 11,000 and 13,000 feet. Some are egg parasites, but members of this genus show a great diversity in host relations. Many are larval parasites of Coleoptera and Lepidoptera, and many are secondary. Fifteen specimens of *Euplectrus comstockii* How. were found at 200 to 3,000 feet. This species is known as a parasite of the bollworm and cotton leaf worm. Six of *E. platyhypenae* How. were collected at 200 and 2,000 feet. This species is parasitic on the corn earworm.

One *Anagrus orijentatus* C. and L. of the family Mymaridae was taken at 5,000 feet in May. This is an egg parasite of the tarnished plant bug.

The family Formicidae contributed 309 specimens, of which 7 were found at night, and the material included 12 genera and 10 determined species. They were taken from near the surface to the height of 5,000 feet, and appeared in March to November, with the greatest numbers collected in July.

Great swarms of winged ants are often seen in the air in the spring, summer, and fall. These are the newly matured males and females that have emerged from their nests. The pairing of the males and females from different nests prevents too close interbreeding. The factors that determine the occurrence of the nuptial flights at the same time in one locality are not understood.

Several of the species of ants collected are of special interest and economic importance. Some are known to occur in houses, being more or less destructive and of major importance. These are *Solenopsis molesta* (Say), *S. xyloni* McCook, *Pheidole dentata* Mayr, *Iridomyrmex pruinosus* var. *analis* (André), *Prenolepis* (*Nylanderia*) sp., *Tapinoma sessile* (Say), and *Monomorium minimum* (Buckley). The genus *Crematogaster* also includes some of the most common species of ants in the South, a few of which are house-infesting forms. Of the 150 specimens of *Crematogaster* sp. collected in the upper air, most were taken in the morning, with the majority at from 10 to 11 a. m. They appeared in greatest numbers at the temperature range of 85° to 89° F., and were mostly taken on partly cloudy days. *Solenopsis xyloni* is considered to be the most destructive species in the Southern States, poultry, quail, clothing, seeds, citrus, and nuts being attacked by it.

In comparing the morning and afternoon collections of these fire ants it was found that of the 106 specimens taken, 101 were found between 1 and 6 p. m., with the majority at 2 to 4 p. m. From a limited number of records on this species by M. R. Smith, it appears that the nuptial flights of fire ants take place in the afternoon, usually between 1 and 6 p. m. The greatest numbers were taken in the temperature range of 80° to 89° F., with the majority at 85° to 89°. More specimens of the fire ant were taken when the sky was overcast than when it was clear.

The family Bethylidae was represented by 53 specimens, 2 of which were taken at night. There were 13 genera and 8 determined species collected from near the surface to 5,000 feet, mostly in the summer months. This is a very large family of parasitic wasps, many species being known to prey upon either coleopterous or lepidopterous larvae.

Of the family Andrenidae, 56 specimens were collected in the upper air, only one of which was taken at night. There were 5 genera, and 11 determined species taken from near the surface to 3,000 feet, mostly in the spring and summer. This family contains the andrenid bees, which are solitary nest-building bees, and members of the genus *Halictus*, the mining bees, of which seven species were found.

One specimen of *Bombus americanorum* (F.) (Bombidae) was taken at 200 feet. This is a well known species of bumblebee.

Thirteen specimens of the honeybee (*Apis mellifera* L.) (Apidae) were collected, 2 at 20 feet, 10 at 200 feet, and 1 at 1,000 feet.

DIPTERA

The material of the order Diptera comprised the greatest number of specimens collected. There were 11,304 specimens of which 9,973 were taken in the daytime, and 1,331 at night. They appeared in every month of the year. In the daytime Diptera were most abundant in May and June, with more taken in May. At night the greatest numbers were collected in May and October, with nearly twice as many taken in October as in May. Specimens were found at every altitude flown in the daytime up to 14,000 feet, and at every altitude flown at night. Diptera were slightly more abundant at night than in the daytime per unit of flying time. In comparing the number of specimens collected at the altitude of 200 feet in the daytime with those at 500 feet flown at night, it was found that curves representing the maximum and minimum collections of Diptera for each month follow each other closely. There was a decided increase in number of specimens collected at night in May, and for the day collections the maximum numbers were also found at this time. In October there was but a slight increase in the number of specimens found at 200 feet; but at night, at 500 feet, nearly twice as many were collected as in the daytime. Calculated on the basis of 10 minutes of flying time, in May more specimens were collected at 200 feet in the daytime than at 500 feet at night, but at 1,000 feet there were fewer specimens taken in the daytime than at night. In October the numbers at 1,000 feet in both day and night collections were similar to those for 200 and 500 feet. At 3,000 feet in May and October, Diptera were more numerous at night than in the daytime, but at 5,000 feet there were many differences, as at this high altitude other factors contribute to offset any natural tendencies of insect flight. In the daytime fewest Diptera were collected in January and December with about equal numbers in each of those months These estimates are all based on the 10-minute unit of collecting time.

Nearly three times as many Diptera were collected as of the second largest order, Coleoptera.

Many species of Diptera taken in the upper air were of economic importance, and comprise some of the most dangerous pests. Those species affecting the health of man and animals are discussed separately.

There were 293 specimens belonging to the family Tipulidae taken in the day flights and 48 at night. Of four determined species collected, *Helobia hybrida* (Meig.) was the most abundant, with 187 in the daytime and 12 at night. They were found mostly in March and April. This species is one of the very common crane flies and is widely distributed. One species was collected at 14,000 feet in June.

Seven specimens of the family Psychodidae were taken, with one *Psychoda* sp. in the daytime at 200 feet in July, one at 500 feet at night in June, and one at 3,000 feet in October. Three other species of the family were taken at 1,000 feet in July and November, with one at night in October. Species of this family are mothlike in appearance.

The family Cecidomyiidae was represented by 64 specimens taken in the daytime and 20 at night. They were collected at all altitudes from near the surface to 5,000 feet and one undetermined species was taken at 14,000 feet in August. The cecidomyiids were collected throughout the year, principally in February and October. These are very minute flies, many species producing galls on vegetation.

One undetermined specimen belonging to the family Psilidae was taken at 20 feet in March. Some larvae of this family feed or carrots, celery, and parsnips and are often quite destructive.

There were 669 specimens taken in the daytime and 58 at night belonging to the family Ephydridae. They were taken at most altitudes near the surface to 5,000 feet and one *Scatella* sp. and one undetermined species of Ephydridae were taken at 10,000 feet in September. They occurred throughout the year, although more specimens were collected in April. This family is of no special economic importance, except in the far West and in Mexico, where the larvae occur in great numbers in the alkaline lakes, and are gathered, dried, and used for food by the Indians (*17, p. 859*).

Thirty-one specimens of the family Drosophilidae were taken in the day flights and 11 at night. Four species were represented, *Chymomyza amoena* Loew, *Leucophenga varia* Walk., *Drosophila melanogaster* Meig., and *Scaptomyza adjusta* Loew. They were collected at altitudes from 200 to 3,000 feet. Specimens were found in the collections throughout the year, but principally in September. Those of the genus *Drosophila* are known as fruitflies or pomace flies, as they feed on ripe and decaying fruit. The adult flies are widely used in experimental research in genetics.

Two specimens of the genus *Leucopis* (Ochthiphilidae) were taken, one in the daytime in February at 1,000 feet and one at night in October at 500 feet. The larvae of this genus prey upon aphids and coccids, and thus may be considered as beneficial.

One hundred and eighteen specimens of the fungus gnats (Mycetophilidae) were taken, 95 in the day flights and 23 at night. They were collected at most altitudes flown. One specimen was taken at 7,000 feet in July and one at 10,000 feet in June. They were found in every month of the year except January, the greatest numbers in May. These flies are usually abundant, the larvae feeding on fungi and on decaying vegetable matter.

The Sciaridae were represented by 463 specimens, of which 34 were taken at night. They were collected at most altitudes and appeared throughout the year, with the greatest numbers taken in May. Thirty-six specimens of *Eugnoriste occidentalis* Coq. were collected, including one at night; they were taken mostly in June and September. Sixty specimens of *Sciara jucunda* Joh. were collected in the day flights at altitudes up to 5,000 feet. One specimen of *S. coprophila* Lint. was taken at 2,000 feet in June. There were also 268 *Sciara* sp. collected in the day flights and 27 at night, with the greatest numbers taken in May. One *Sciara* sp. was collected at 6,000 feet in August, one at 10,000 feet in June, and one undetermined species of Sciaridae was taken at 8,000 feet in May. The larvae of the genus *Sciara* are particularly interesting in that they have a characteristic habit of congregating in dense numbers under the bark of trees. Just before time for pupation they become very active, marching over the surface of the ground in a serpentlike column, and accordingly have been termed the sciara armyworm.

Ninety-eight specimens belonging to the family Bibionidae were taken in the day flights. They were collected from March to October, with the greater numbers appearing in June and July. Twenty-one specimens of *Dilophus breviceps* Loew and 49 of *Dilophus* sp. were taken from near the surface to 3,000 feet. One *Dilophus* sp. was also taken at 10,000 feet in June. The larvae of the bibionids, or March flies, feed on decaying vegetable matter, although some species attack the roots of grass and growing plants.

Two specimens were taken belonging to the family Scatopsidae, with one, *Reichertella* sp., taken at 200 feet in April and one undetermined species of Scatopsidae at 5,000 feet in September.

Seven specimens belonging to the family Stratiomyiidae were taken, all in the day flights. Two genera were represented with four *Odontomyia* sp. at altitudes of 20 to 1,000 feet, and two *Nemotelus* sp. at 200 feet. The stratomyiids, or soldier flies, were collected from April to July. The larvae of some of the species are aquatic, others living in the earth or decaying wood and vegetable matter, and a few are carnivorous.

Three specimens of the family Bombyliidae were collected in the daytime, with a species of *Anthrax* and one of *Systoechus* at 200 feet in November, and one of *Sparnopolius* at 20 feet in October. The adult flies, known as bee flies, are strongly built and rapid fliers, and may be seen hovering over flowers as they feed on the nectar. The larvae are parasitic on the larvae of Hymenoptera and Lepidoptera, and on egg sacks of Orthoptera, and may be classed as beneficial.

Only one specimen was taken belonging to the family Therevidae, a species of *Psilocephala* at the altitude of 200 feet in May. The larvae of this family are usually predacious but sometimes feed on decaying animal and vegetable matter. The adult flies likewise are predacious.

Seventy-eight specimens of the Scenopinidae were collected, 15 being taken at night. They were found at most altitudes up to 5,000 feet, occurring almost throughout the year, with more taken in April, May, and June. The adult flies are commonly seen on windows and for this reason are known as the window flies. The larvae are predacious and often found in houses, under carpets, etc. Others are found in decaying wood.

The family Asilidae or robber flies was represented by one specimen, a species of *Atomosia* taken at 20 feet in October. The adults of this family are strong fliers and are mostly beneficial. They prey on almost any insect they are able to catch.

The family Dolichopodidae was represented by 336 specimens, of which 45 were collected at night. They were found at most altitudes. One undetermined species was taken at 10,000 feet and one at 14,000 feet in September. The Dolichopodidae were taken throughout the year, although more specimens were found in June and September. This family is of some importance economically; it is a very large group containing several hundred species. The larvae of some species are predators in galleries of other insects, and some are aquatic or semiaquatic.

Twenty-two specimens of the Empididae were taken in the day flights. They were collected at altitudes of 200 to 3,000 feet. Specimens appeared scatteringly throughout the year. The empids or dance flies are often seen in swarms, and are predacious. The larvae live in decaying vegetable matter, some being carnivorous.

One undetermined specimen of Lonchopteridae was caught in the daytime at 3,000 feet on November 5, 1926. The adults of this family are very minute flies. The larva has a very peculiar form and has been reared from cabbage in England.

The family Platypezidae was represented by the genus *Platypeza*, two specimens of which were taken. One was taken at 200 feet in February and one at 1,000 feet in October. Members of this family, called flat-footed flies, are somewhat like the housefly in appearance, although smaller, and may often be seen flying rapidly in circles. The larvae are found in decaying mushrooms.

Thirty-six specimens of the family Pipunculidae were taken, one at night. This family, the members of which are commonly known as the big-eyed flies may be considered as beneficial, as the larvae are parasitic on leafhoppers. The specimens collected were found throughout the year.

Of the family Syrphidae 246 specimens were taken in the day flights, and 5 at night. Thirty-three specimens of *Toxomerus polita* Say were taken at altitudes up to 5,000 feet. This is one of the very common syrphids, the larvae preying mostly on plant lice, although adults have been known to be pollen feeders on cotton and corn, but causing little injury (*26, p. 162–163*). The Syrphidae were taken mostly in August and September, although specimens were collected in every month.

Twenty specimens were collected belonging to the family Tachinidae, of which two determined species were taken at night, one *Doryphorophaga doryphorae* (Riley) at 500 feet in August, and one *Gonia texana* Rond. at 1,000 feet in July. The tachinids were collected mostly in the summer months. Species of this family are beneficial, as they are parasitic chiefly within lepidopterous larvae, and are extremely important in checking the increase of many insect pests.

The family Anthomyiidae was represented by 278 specimens in the day flights and 15 at night. They were found at altitudes near the surface to 5,000 feet, and were taken throughout the year with the greater numbers in April. The anthomyiids are very common flies, the larvae living mostly in decaying vegetable matter. Some are parasitic on other insects, while a few species are very destructive garden pests.

Seven undetermined specimens of the family Scatophagidae were collected in the day flights, six at 200 feet and one at 1,000 feet. Five were taken in June and one each in May and August. The scatophagids are commonly known as dung flies.

Two undetermined specimens of the family Helomyzidae were caught at 200 feet in February and December. The adult flies are found in shady or damp places, the larvae feeding on decaying wood and mushrooms.

Of the family Borboridae 518 specimens were taken in the daytime, and 19 at night. They were collected at most altitudes flown under and including 5,000 feet, and one at 11,000 feet in August. They appeared throughout the year, although mostly in the spring and fall months. They are also called dung flies, and are of little importance, as the larvae live in excrement.

Thirty specimens of the family Sciomyzidae were in the collections. One, of the genus *Tetanocera*, was taken at 1,000 feet in March. Twenty-six undetermined specimens were taken in the daytime at altitudes up to 3,000 feet. Three were caught at night. The specimens were found scatteringly throughout the year. The larvae are aquatic.

Thirty undetermined specimens of the family Sapromyzidae were collected, of which two were found at night. They were taken at altitudes up to 3,000 feet and were distributed throughout the year. The larvae are aquatic.

Nine specimens belonging to the family Otitidae were taken in the day flights. They were collected in the summer months up to 2,000 feet.

The family Trypetidae was represented by 47 specimens taken in the daytime, and 5 at night. They were found in the day at the altitudes, 200 feet (28), 1,000 (5), 2,000 (10), 3,000 (3), and 5,000 feet (1); at night, 500 feet (2), 1,000 (2), and 1 at 2,000 feet. They were collected in every month of the year with a few more in September and October than in other months. The Trypetidae include many species which are well known gall makers.

The Sepsidae collected comprised 64 specimens taken in the day flights and 4 at night. Twelve specimens of *Sepsis violacea* Meig. were collected at altitudes up to 5,000 feet. This species, widely distributed throughout North America, was found scatteringly throughout the year, but chiefly in May. Fifty-five undetermined specimens of the same genus were taken at altitudes up to 4,000 feet, mostly in May. This family includes small slender flies which are so commonly met with that they have been largely shunned by the systematists (*50, p. 7*). They are of economic importance, being principally scavengers, feeding and breeding in filth, sewage, excrement, carrion, and other decomposing vegetable and animal matter (*50, p. 8*).

Two specimens of the genus *Piophila* (Piophilidae) were caught at 200 feet in April and November. The family Piophilidae is similar in habits to the Sepsidae, and is considered of economic importance, since the flies are principally scavengers (*50, p. 3*).

The family Agromyzidae was represented by 18 specimens, of which 2 were caught at night. They were taken at altitudes up to 5,000 feet, and throughout the year. The agromyzids are very small flies. Many are stem and leaf miners, and a few species live in plant galls.

DIPTERA AFFECTING MAN AND ANIMALS

Many of the species of Diptera taken directly affect man and animals. These are included in the families Culicidae, Chironomidae, Simuliidae, Tabanidae, Phoridae, Syrphidae, Sarcophagidae, Calliphoridae, Muscidae, Anthomyiidae, and Chloropidae.

There were 111 specimens taken belonging to the family Culicidae, comprising 7 genera and 6 determined species, with 44 specimens found in the daytime and 67 at night. These mosquitoes are usually active at dusk and at night, although, if disturbed, may be seen flying about during the day. Fifty *Chaoborus punctipennis* (Say) were taken, with 22 in the day flights at the following altitudes: 200 feet (11), 1,000 (5), and 2,000 (6). 28 were taken at night, at 500 feet (19), at 1,000 (2), at 2,000 (6), and at 3,000 feet (1). They were found from April to October. Eleven *Anopheles quadrimaculatus* Say were taken, three in the daytime and eight at night, at altitudes up to 1,000 feet, in May, June, and August. Five females and six males were taken. This species is the well known carrier of malaria. Five *Culex* sp. were taken, three in the daytime, one at 200 feet, and two at 5,000 feet. Two *Uranotaenia sapphirina* (O. S.) were found at 3,000 feet in the daytime on July 1, 1929. One specimen of *Psorophora columbiae* D. and K. was taken at 200 feet in the daytime, and one each at 500 and 1,000 feet at night. This mosquito is quite important, and may become serious to livestock by its great numbers (*8*). Two females of *Aedes vexans* (Meig.) were collected at night at 5,000 feet, one specimen at 500 feet in October, and one at 1,000 feet in May. This mosquito is annoying but it is not known to be a carrier of any disease of man. Two undetermined species of *Aedes* were taken at 200 and 1,000 feet, respectively. There were 32 undetermined specimens of mosquitoes, 11 of which were taken in the day flights at altitudes of 200 to 3,000 feet, and 21 at night at 500 to 3,000 feet.

The family Chironomidae was represented by 701 specimens, comprising 8 genera and 9 determined species. They were found throughout the year, with more in the months of June and July in the daytime. Nearly twice as many were taken at night as in the day in proportion to the time flown. Chironomids were found as high as 13,000 feet. One *Chironomus* sp. was taken at 7,000 feet. Five undetermined specimens of Chironomidae were collected at 7,000 (1), 9,000 (2), 10,000 (1), and 13,000 (1) feet.

There were 298 specimens taken belonging to the family Ceratopogonidae, of which 90 were collected at night. Thirty-two undetermined specimens of *Culicoides* were collected at altitudes from 200 to 13,000 feet. One specimen of *Culicoides variipennis* (Coq.) and one *C. crepuscularis* Mall., were taken in the same flight at 5,000 feet at night in October. Members of this genus are often mistaken for mosquitoes; they are known as punkies, "no-see-ums," or sand flies, and are bloodsucking midges. Their bite is very annoying, and where they occur in sufficient numbers they become almost unbearable. The larvae are aquatic, and thrive in great numbers in the swamps, lakes, or ponds. No species of this genus are known as disease carriers in the United States.

The family Simuliidae was represented by 48 specimens taken, all in the daytime, in May and June. Three turkey gnats (*Simulium meridionale* Riley) were found in May 1929, two at 200 and one at 1,000 feet. Forty-two *S. occidentale* Town. were collected at altitudes of 20 (2), 200 (25), 1,000 (5), 2,000 (5), 3,000 (3), and 5,000 feet (2). Two undetermined species of *Simulium* were taken, one at 1,000 and one at 3,000 feet. The species of *Simulium* are known as black flies, buffalo gnats, or turkey gnats, and constitute one of the major pests of our country. They viciously attack both man and animals, inflicting a most painful bite. They are at times responsible for heavy losses of livestock, especially in Mississippi, Louisiana, and Arkansas, where mules occasionally are killed in great numbers when they are most needed to put in the cotton crop.

Two specimens belonging to the family Tabanidae were taken, one *Tabanus mularis* Stone at 1,000 feet and one undetermined *Tabanus* at 200 feet. Members of this family, commonly termed horseflies, are quite important economically, and cause considerable annoyance to both man and livestock. They are known to be active agents in the transmission of the deadly anthrax. Members of this genus are strong and rapid fliers, which may account for so few specimens being taken.

There were 107 specimens belonging to the family Phoridae taken in the daytime, and 14 at night. They were collected from near the surface to 8,000 feet. These small flies, commonly known as "humpbacked" flies, are often seen dancing up and down in the air. The larvae feed mostly on decaying vegetable matter, although a few are known to be parasitic on other insects. The genus *Megaselia* was represented by 45 specimens. Species of this genus have been known to survive the action of gastric juice, and thus have been included in the field and study of animal myiasis.

The family Syrphidae was represented by 251 specimens, of which only 5 were taken at night. One specimen of *Eristalis tenax* (L.) was taken at 200 feet in February. The larvae of this species, called rat-tailed maggots, have been indicted in cases of intestinal myiasis in man (*19; 49, pp. 398–400*). *Syrphus* larvae have also been reported as causing intestinal myiasis, although they are mostly predacious. Three *Eristalis* sp. were collected, one each in February and July at 200 feet and one at 1,000 feet in October.

There were two genera and eight identified species collected belonging to the family Sarcophagidae. Thirty-one specimens were taken, all in the day flights, at altitudes from near the surface to 5,000 feet. The sarcophagids are quite important in that they may be either beneficial insects or dangerous pests of man and animals. Some species have been credited as causing intestinal myiasis in man. Others have been found in necrotic tissues of wounds in man and may be regarded as saprophytic or beneficial (*19*). *Sarcophaga quadrisetosa* Coq. was taken at 2,000 feet in July. This is one of the very common excrement-feeding species (*2*). *S. rapax* Walk. was collected at 20 feet (1), 200 (6), and 1,000 feet (1). The larvae of this species are scavengers on meats and parasitic on some insects.

The family Calliphoridae was represented by one species, *Cochliomyia macellaria* (F.), three of which were taken at 200 feet and one each at 3,000 and 5,000 feet. This species is known as the secondary screw-worm fly; the larvae are often found in old wounds.

One stablefly (*Stomoxys calcitrans* (L.)) (Muscidae) was taken at 3,000 feet in September 1929. This fly is a definite menace to the farmer, causing heavy losses in practically all types of livestock. Two specimens of the genus *Morellia* were taken at 200 feet and one at 2,000 feet. Two specimens of *Muscina* were collected at 200 and 1,000 feet and two of the family Muscidae at 20 and 2,000 feet.

Two hundred and seventy-eight specimens belonging to the family Anthomyiidae were taken in the daytime and 15 at night. They were found as high as 5,000 feet. The subfamily Fanniinae was represented by 25 specimens taken at 20 feet (7), 200 (10), 1,000 (3), 2,000 (3), and 3,000 feet (2). This group has been associated with intestinal myiasis of man, although in some cases it was considered as accidental.

The Chloropidae were represented by the largest numbers of specimens taken of any family of Diptera. There were 2,227 collected, of which only 97 were taken at night. *Hippelates texanus* Ald. and *H. pallipes* Loew are included in this family, one specimen of the former being taken at 200 feet in April. Forty-five specimens of *H. pallipes* were collected in the daytime as follows: 20 feet (1), 200 (15), 1,000 (15), 2,000 (10), 3,000 (3) and at 11,000 feet (1). They were found practically throughout the year. Forty-four undetermined *Hippelates* were also collected, one at night, in about the same numbers and at the same altitudes as *H. pallipes*, excepting the 11,000-foot collection of *H. pallipes*. Species of this genus have been associated with the transmission of pink eye (*49, p. 361*). Often the air seems filled with the tiny insects of the genus *Hippelates*, which become extremely annoying to man and animals. They are usually excessively abundant after a rain following a dry period.

SIZE, WEIGHT, AND BUOYANCY

The size and weight, and therefore the buoyancy, of an insect determine the height to which it may be carried by air currents. This relationship may be expressed in terms of the aerostatic or lighter-than-air coefficient. The aerostatic coefficient varies directly with the area of the insect which is exposed perpendicular to the pull of gravitation and inversely with the weight of the insect per unit of exposed area. This is represented by the equation

$$Ac=K\frac{R}{W}$$

in which Ac is the aerostatic coefficient, R equals the area in metric units exposed perpendicular to gravity, W represents the weight in milligrams of the insect, and K equals a constant; therefore the lighter the insect the greater the aerostatic coefficient, and the heavier the insect the less the aerostatic coefficient or actual buoyancy.

The insects collected in the high altitudes, especially from 6,000 to 14,000 feet, occurred there because of their relative size and weight, or buoyancy. Under the same given conditions of wind velocity and convection, a heavily built insect with small wing expanse will not be carried up so high as a very light insect with relatively greater wing expanse.

There is, of course, a wide range of values for the ratio of weight to wing surface among insects. According to Piéron (*59*), this weight ranges from 0.04 to 5.93 kg per square meter. Portier and de Rorthays (*61*) determined the weight supported during flight by wings in 20 species of butterflies and moths, a dragonfly (*Aeshna grandis* (L.)), and two bees (*Xylocopa violacea* and *Bombus terrestris*) and found it to be much less than in birds and airplanes. The weight sustained in butterflies is 0.1 to 0.15 kg per square meter; in certain hawk-moths, 10 times as much; in *Bombus*, 25 times, or 2.5 kg. In biplanes the weight supported by the wings was equal to 8 to 22 kg, and for monoplanes 13 to 23 kg per square meter.

It is probable that after insects are on the wing little muscular exertion is necessary to sustain the rate of speed. Insects on entering strong vertical air currents may attempt to resist them by flying through these currents; otherwise they will be carried up from one level to another.

Most butterflies find it difficult to fly in a strong wind, as the wings offer a broad surface to the air. A few butterflies, such as hesperiids, have a jerky flight which seemingly offers less resistance to air currents. One butterfly, *Catophaga galena*, in Ceylon, is especially noteworthy in its method of flight. It is a migratory species and usually flies directly against the wind, and the stronger the wind blows the more rapid the flight. Tutt (*72, p. 72*) comments on this peculiar butterfly and states—

> The action of the wings of these butterflies is not horizontal like that of the Admiral or the Tortoiseshell, nor is the flight even and continuous, but they are propelled in jerks, with the wings vertically closed and opened alternately, so as to offer the sharpest edge to the resistance of the wind. Thus the butterfly does not appear to propel itself, but to be driven forward by the action of the wind eddying round against the under surface of the wing presented to it, but how this is done it is not easy to demonstrate.

Among the Homoptera *Stictocephala festina* was collected mostly at the lower altitudes, with several at 1,000 and 3,000 feet. This is a very strong flier, heavily built, and able to resist the rough currents of air. The larger cicadellids, such as *Oncometopia undata* and *Homalodisca triquetra*, were taken mostly at 200 feet and very few above 1,000 to 3,000 feet. More specimens of the smaller species of cicadellids were taken at high altitudes than at the 200-foot level. More specimens of several species of Fulgoridae were taken at 1,000 feet and above than at 200 feet. Most of the Fulgoridae have a large wing expanse in proportion to their body size, which accounts for their appearance in the higher altitudes. The Aphiidae, although weak fliers, and the Psyllidae, which also have a large wing expanse in comparison with their small bodies, were taken in considerable numbers at as high altitudes as 13,000 feet.

The Heteroptera showed some correlation between size, weight, and buoyancy and the heights at which they were found. Lygaeidae appeared in considerable numbers above 1,000 feet and were taken as high as 7,000 feet. Species of this family are generally strong fliers, yet with a wing expanse greater than average in proportion to their size and weight. The Tingididae, Anthocoridae, Miridae, and Corixidae were also found in considerable numbers in the higher altitudes. In most species of these families the insects are light, with comparatively good wing expanse. On the other hand, compactly built Heteroptera, such as the pentatomids, were not found above 1,000 feet, and very few were taken. Pentatomidae are abundant on the ground, but do not fly high, apparently because of their weight.

Coleoptera offer less resistance to the wind than do Lepidoptera, being bulky, with less wing expanse in relation to their size. Many of them are strong fliers, however, and must depend mostly on their muscular power for propulsion, as they lack the ability of the butterflies to drift with the wind. The horny elytra of beetles are concave and act more or less as vanes, and the wind blowing against them makes it difficult for the beetles to regulate their flight, putting them at the mercy of a strong wind. Thus the lowland species of beetles are carried up by ascending currents of air, and probably travel great distances at high elevations.

There are many records of the occurrence of species of Coccinellidae at high altitudes. These ladybird beetles are often migratory. It is not known why ladybird beetles fly to high mountains, especially during the midsummer days. The writer once observed (August 1920) a great swarm of ladybird beetles at the altitude of 12,680 feet, near the Arapahoe Pass in the Rocky Mountains, in Colorado. The beetles had congregated by millions on the talus slope and were crawling over the rocks projecting out of snow and ice adjacent to the Arapahoe Glacier. Many beetles could be seen flying over the ridge of the Pass. There was a strong ascending current of air on the windward side of the mountain, which doubtless aided the beetles in their upward flight. The air on the other, or leeward, side was found to be more quiet, and as soon as the beetles passed the summit of the ridge they settled down immediately. A few minutes after these coccinellids were first seen a severe thunderstorm came up, causing the beetles to disappear. They probably found shelter beneath the great rocks.

Coleoptera were collected at all altitudes up to 12,000 feet. More specimens per 10 minutes' flight were collected at 10,000 feet than at other high altitudes above 5,000 feet. The Coleoptera taken at altitudes above 6,000 feet belonged mostly to the families Carabidae and Staphylinidae. A few Coccinellidae were taken at very high altitudes, with two specimens of *Scymnus terminatus*, at 5,000 feet, and one *Ceratomegilla floridana* at 6,000 feet. One chrysomelid beetle, *Diabrotica vittata*, was found at 11,000 feet.

Lepidoptera were not taken at heights above 5,000 feet. The specimens taken at 3,000 to 5,000 feet were small microlepidoptera, with great wing expanse in proportion to their weight and thus with more buoyancy. These tiny moths are weak fliers and accordingly would be almost entirely subject to air currents in their distribution in the upper air. The Noctuidae, however, were found mostly at the lower altitudes, from 200 to 2,000 feet, with one at 3,000 feet, but with the majority of the specimens at 500 and 1,000 feet. The noctuids are strong fliers, but with less wing expanse as compared with their body weight, which would cause them to fly or to be found closer to the surface.

Hymenoptera were well represented, with 33 specimens taken at the altitudes of 6,000 to 14,000 feet. The specimens found were very small species and included 11 families. These small Hymenoptera have considerable wing expanse, with light bodies. Winged males of ants were taken as high as 5,000 feet, while the winged queens were found mostly at 200 and 1,000 feet. The queen ants are much heavier than the males and accordingly would not fly very high. The workers are the smallest of the ant forms.

More Diptera were taken at the high levels than of any other order. There were 81 specimens taken at 6,000 to 13,000 feet, mostly very small species. The Diptera taken were weak fliers, with great wing expanse as compared with their size and body weight, thus having considerable buoyancy.

WINGLESS INSECTS

Numbers of wingless insects, belonging to the orders Thysanura, Collembola, and Siphonaptera; also nymphs of Heteroptera, Homoptera, and Orthoptera, larvae of Coleoptera, Lepidoptera, and Diptera, great numbers of wingless ants, and spiders and mites, were collected in the upper air, from near the surface to as high as 15,000 feet. These adult wingless insects, as well as the nymphs, larvae, spiders, and mites, were all at the mercy of the air currents. It is most likely that the wingless forms found above 5,000 feet did not originally come directly from the territory over which the flights were made, but were picked up at distant places and carried in the upper air currents, perhaps for hundreds of miles. By means of these avenues of travel insects have been distributed to far countries, to remote islands, over mountain barriers, and across stretches of hot, barren deserts and waste lands (tables 1, 2, and 3).

ARANEIDA

There were 1,461 spiders taken in the upper air, and of this number only 60 were collected at night. There were determined 15 families and 30 species, and there was 1 new species. The greatest number of specimens taken in any one family (192) belonged to the Linyphiidae, with the next highest numbers (83) in the Lycosidae. They were found at nearly every altitude flown from 20 to 15,000 feet, and appeared mostly in November to January, with fewest in August.

AERONAUTICAL SPIDERS

The dispersal habits of spiders provide opportunity for an absorbing investigation. There were 1,461 spiders taken in the upper air at altitudes from near the surface to 15,000 feet. They were taken in greatest numbers in November, December, and January. The specimen taken at the highest altitude of all was a spider, and this is probably the highest elevation at which any specimen has ever been taken above the surface of the earth.

A species of spider has been found in crevices in ice on Mount Everest at an altitude of 22,000 feet (*18*). Savory (*64*) states that

> Far above the highest plant which grew at an altitude of 18,000 feet, small black spiders belonging to the family of jumping-spiders were found, hopping among the rocks and hiding under the stones in such places as were swept bare of snow by the wind. They reached a height of 22,000 feet, at which altitude they were not only in proud position of being the highest permanent inhabitants of the earth, but seemed to be alone in their isolation. No other living thing has been found to share their loneliness. There is nothing but rock, snow, and ice. What they get to feed on is a mystery.

Dr. Ewing of the Division of Insect Identification has observed dead insects in crevices at 14,000 feet, blown up while alive by surface air currents, and believes that these dead (or dying) insects furnish the food for spiders inhabiting the icy tops of high mountains.

At times while flying, the writer observed numbers of white silken filaments of webs floating through the air, even as high as 11,000 feet or more, and often when landing the struts would be almost white with the silken webs wrapped around them. It is chiefly the immature stage of a spider, known as a spiderling, that uses the air as a means of dispersal, and it is probable that the young of most spiders are more or less addicted to this mode of transportation. McCook (*46, v. 2, p. 268*) states that the huntsman spider (*Heterapoda venatorius*) on account of its aeronautic habits, might well have circumnavigated the globe with the aid of trade winds, basing his calculations on localities where the spider is known to occur and on the direction of the winds. It is interesting to note the method the young spiders have of "taking off" on their journeys. The spiderling climbs to the top of some object such as a fence, twig, or any other elevated projection, lifts its abdomen to an angle of about 45°, with legs stiffened, thus pushing the body upward, spins out a thread, lets go, and is carried off into the air and away. Fields have often been seen covered with a gauze of silk, blown down when the wind was too strong. Howard (*34*) states that these remarkable sheets of gossamer are yearly found on the sides of the Yosemite Valley and are of great extent. Comstock (*16, p. 216*) states that showers of gossamer have been met by ships at sea hundreds of miles from land. Ballooning spiders are carried long distances in this way and are stopped only by striking against some elevated object or by the subsidence of the breeze. It has even been noted that it appears to be within the spider's own volition to regulate its flight, for it can draw in with its claws the forward ray and gather it in a white roll within the mandibles, thus causing either a gradual or sudden descent.

The families of spiders which seem to have a strongly fixed aeronautical habit are the orb weavers, epeiroid spiders just out of the cocoons, and the subfamily Erigoninae of the Linyphiidae. These families were well represented in the airplane collections, as were also the families including the crab spiders, lynx spiders, wolf spiders, and sheet-web weavers.

ACARINA

The order Acarina, or mites, was represented by 44 specimens taken in the upper air during the day flights, and 2 at night. In the day they were found at altitudes ranging from near the surface to the height of 3,000 feet and were taken mostly in February, March, and April. The family Parasitidae was represented by 33 specimens collected at altitudes of 200 to 3,000 feet, with 2 specimens in February, 16 in March, 13 in April, and 1 in November. During March, April, and May large numbers of Tipulidae were usually in the air, and Carabidae were taken in the upper air in greatest numbers in March. Acarina were especially found on these two families of insects.

The nymphs of Acarina are mostly attached to insects, a habit known as phoresy. They are not dependent directly on the air currents, but are carried upward as riders on the insects. This affords an effective means for their dissemination. The specimens were taken, however, when the surface wind velocity was from 3 to 14 miles an hour.

One undetermined species was taken alive at 3,000 feet attached to a species of Tipulidae. The two specimens collected at night were one *Dameosoma* sp., taken September 18, 1929, and one undetermined species of Acarina in August at 500 feet. Species of the genus *Dameosoma* are known as moss mites. The record of the specimen taken in the upper air is interesting in that the species of the genus are not found on beetles but are beetlelike in appearance, occurring under rotten logs and in moist places, in ground litter, or under loose bark. At the time the specimen was taken the surface wind velocity was 3 miles an hour and the air was slightly rough.

THYSANURA

Forty specimens of Thysanura were taken in the upper air, representing two families, five genera, and one determined species. Thysanura are the most primitive of insects. These insects, known as bristletails, are found under stones and various objects lying on the ground and in cool and shady places. Some species of the family Lepismatidae, which were represented in the upper-air collections, are commonly found in houses, libraries, and museums, attacking starched clothes, book bindings, etc.

In the airplane collections Thysanura appeared in every month except February and July (table 4). Three specimens of a lepismatid were taken at 3,000 feet and one at 8,000. They were collected at times when the wind ranged in velocity from calm to 16 miles per hour, althougr the majority were taken when the surface wind velocities were from 3 to 10 miles an hour.

COLLEMBOLA

The Collembola, or springtails, are similar to Thysanura in being primitively wingless insects. Specimens were taken in the upper air in every month except January and September (table 4), and when the surface wind velocity was from calm to 13 miles per hour, principally 9 to 10 miles per hour. Twenty-six specimens were caught representing three families, seven genera, and four determined species. They were found at altitudes up to 11,000 feet, the genus *Bourletiella* being represented by one specimen each at 5,000, 7,000, and 11,000 feet. The species *Sira nigromaculata* Lubb., which is often found in houses, was taken at several levels up to 3,000 feet (table 9).

HYMENOPTERA

Worker ants were the only wingless Hymenoptera found in the air. Of the 309 ants collected there were found to be 23 winged queens, 265 winged males, 20 workers, and 1 not distinguished (table 9). It appears that worker ants are carried into the upper air with a wind velocity of 3 to 6 miles per hour, whether the air is smooth, slightly rough, or rough. A typical colony of most species of ants consists of workers, queens, and males. The queens are winged until they become fertilized. Workers were taken at altitudes of 100 to 4,000 feet. One specimen of the genus *Pheidole* was taken at 100 feet; at 200 feet there were collected two specimens of *Ponera trigona* var. *opacior*, one *Monomorium minimum*, two *Pheidole dentata*, two *Aphaenogaster* spp., one *Tapinoma sessile*, three *Prenolepis* (*Ny-*

landeria) sp., and two undetermined species of ants; one *Solenopsis xyloni* was found at night at 500 feet; at 1,000 feet were found one *Iridomyrmex pruinosus* var. *analis* and two undetermined species of Formicidae; at 2,000 feet one specimen of *Prenolepis* (*Nylanderia*) sp. was taken; and at 4,000 feet one specimen of *Camponotus caryae* var. *minuta* was taken.

SIPHONAPTERA

One specimen of *Pulex irritans* L. (Pulicidae) was taken at 200 feet (table 9), on July 1, 1929, at 2:16 p. m. The surface wind velocity was 7 miles an hour, and the air slightly rough at 200 feet. Fleas are jumping insects, and probably the wind was strong enough to pick up this small wingless insect and carry it along.

IMMATURE STAGES

ORTHOPTERA

One nymph of a species belonging to the family Phasmidae (walkingsticks) was taken at the altitude of 200 feet in September. The wind velocity was 10 miles an hour at the time, with considerable convection.

HOMOPTERA

The immature Homoptera were represented by one cicadellid nymph taken at 200 feet, and five nymphs of the Aphiidae, three at 500 feet at night, and one each in the daytime at 1,000 and 2,000 feet. There were also five undetermined homopteran nymphs taken, three at 200, and one each at 1,000 and 2,000 feet, respectively. The aphid nymphs were taken when the surface wind velocities ranged from 3 to 6 miles an hour, and when the convection was fairly strong (table 9).

HETEROPTERA

Among the Heteroptera, nymphs were collected in the upper air as high as 9,000 feet. They were taken in the spring when nymphs were most abundant in the field, and when the surface wind velocities were from 6 to 10 miles per hour, with the air rough and the convection strong.

Two nymphs of the family Coreidae were taken at 5,000 and 9,000 feet, respectively. Four nymphs of *Geocoris* were found, with one each at 20, 1,000, and 2,000 feet, in the daytime, and one at night at 2,000 feet. Two nymphs of *Antillocoris pallidus* and four of *Lygus pratensis* were taken at 200 feet. One nymph of *Psallus seriatus* was taken at 20 feet. Nine undetermined nymphs of Heteroptera were found at the altitudes shown in table 9.

COLEOPTERA

One small and very hairy dermestid larva, *Trogoderma* sp., was taken alive at 9,000 feet. It was caught on March 24, 1931, when the wind velocity was 11 miles per hour at the surface and 42 miles an hour at 9,000 feet, and the air slightly rough to rough at all altitudes. Considering the hairy covering of this small larva, with the long hairs offering a great surface area, it is not surprising that it was found at such a height.

LEPIDOPTERA

Three larvae of the genus *Gelechia* were taken in the upper air, one at 500 feet at night and two at 1,000 feet early in the morning. The two specimens at 1,000 feet were taken on the same screen on September 9, 1930. The surface wind velocity was 4 miles per hour and the air was slightly rough. The one at 500 feet was caught on the morning of the following day at 4 a. m. The lower air was calm, but at 500 feet there was a wind velocity of 9 miles an hour and the air was slightly rough. Doubtless the small caterpillar taken at 500 feet had been in the air for some time, as convection is not present at night, and the air was calm on the surface. The larvae of *Gelechia* are often seen dangling from limbs of trees, each by a silken thread. The wind blows these unprotected larvae loose from their silken ropes and carries them through the air. There were also two unidentified lepidopterous larvae taken at 200 feet in October when the surface wind velocity was 5 and 6 miles per hour (table 9).

It is well know that caterpillars of many of the Lepidoptera are carried by the wind. Important investigations have been made in determining the extent to which larvae of the gypsy moth (*Porthetria dispar* (L.)) are carried by the wind. Burgess (*10*) released newly hatched first-instar larvae that had spun silk in front of an electric fan, and found that they drifted from 20 to 30 feet. Later Collins (*13*) in 1915 caught larvae on specially constructed screens covered with a sticky substance, the larvae having drifted from the mainland to the Isle of Shoals, off the coast of New Hampshire, for distances as much as 13½ miles. Continued experiments by Collins (*14*) showed that the wind carried gypsy moth larvae from 19 to 30 miles inland from across Cape Cod Bay off the coast of Massachusetts. The most outstanding work done in connection with the study of the dispersal of the gypsy moth larvae was that in 1932–33 by Collins and Baker (*15*), who used traps made at the Tallulah laboratory on an airplane, with which three newly hatched gypsy moth larvae were taken, one at an elevation between 300 and 500 feet and two at 1,000 feet, and later one larva was taken at an altitude of 2,000 feet above sea level. Studies have also been made by Felt (*24*) on the possible drift of insects.

DIPTERA

One small dipterous larva was found at 200 feet on October 16, 1930; the surface wind velocity was 5 miles per hour, and at 200 feet the wind velocity was 12 miles per hour, with the air slightly rough.

The larvae of Diptera, Coleoptera, and Lepidoptera were taken when the temperatures were from 67° to 86° F.

INSECTS TAKEN ALIVE

There may be a question as to whether insects taken at heights of 5,000 to 14,000 feet are still alive.

It has been suggested that the oxygen content of the atmosphere at 14,000 feet would not be sufficient to support insect life. The writer, however, collected insects on the summit of Longs Peak, Colo., at 14,255 feet above sea level, and other collectors have recorded insects from mountains at altitudes of 15,000 to 16,500. In a letter to the author, C. F. Marvin, former Chief of the United States Weather Bureau, states:

To the best of our knowledge, no difference in this quantity [of oxygen] has been observed as between free air and mountain surface air. In fact the continuous and great movements of air-winds, thermal convection, turbulance—and also molecular diffusion would quickly smooth out any appreciable difference in the percentage of oxygen between places mentioned if for any reason it should occur.

At the very high altitudes of 14,000 feet and above, there is less barometric pressure. Lutz (*44*) conducted experiments with barometric pressure and its effect on insects in relation to their chance of life at high altitudes and their future ability to reproduce. He placed numbers of flies in a bell jar together with a dish of water to keep them from drying up in the vacuums to which they would be subjected, and pumped out the air. Lutz, in describing this most interesting experiment, said:

The barometer showed a pressure of about 22 mm but it was the water-vapor that was keeping it there. This pressure represented a height of more than seventeen miles above sea-level, and the flies were taken there from approximately sea-level in ninety seconds. The flies stopped moving, possibly because they were chilled by excessive evaporation from their bodies.

Then the valves in the apparatus were opened wide and the pressure instantly returned to normal. Within four minutes all ten flies were walking about as though nothing had happened. The same procedure was repeated again and again. After the eighth trip from a pressure of that at approximate sea-level to one of that more than seventeen miles up in a minute and a half, and return trips in less time than it takes to say it, one fly did not walk within seven minutes after reaching ground pressure and I did not wait for him but went on with the one- to three-minute swings from normal pressures to practically no air and back again. After the twentieth trial only 6 of the 10 stalwarts were walking * * *

Human endurance would fall so far below that of insects in such a test that no comparison can be made. An express elevator in the Empire State Building or the dropping of a cage in a deep mine are slow coaches going a short block compared to the rides these flies took twenty-four times in four hours, * * *.

Lutz later took the two surviving flies and kept them in a cage, and found that they reproduced normally, and the following generations failed to show indications that anything unusual had happened in the life of these flies.

Minimum temperature is another factor affecting the possibility of insects remaining alive in the upper air and being able to reproduce their kind in new or distant localities. Noble (*53*) conducted experiments with the pink bollworm moth, using a temperature of 60° F. This was the average temperature at which specimens were taken in the upper air (6,700 feet above sea level) by the writer in Mexico in 1928. Noble concluded that after 7 days' isolation female moths were able to begin or to resume oviposition of fertile eggs.

With the oxygen content of the air sufficient to support insect life, and with an adequate barometric pressure for their existence, there can be no apparent reason to believe that insects could not live, for a while at least, in the upper atmosphere above the troposphere (convection region) and approaching the stratosphere.

From the collection of insects by airplane much evidence can be drawn to support the conclusion that many of the insects are alive in the very high altitudes. Considerable numbers of the specimens taken, belonging to many orders, were found to be alive when removed from the screens. It is also evident that the majority of the 28,739 specimens collected in the upper air were alive when caught, since the specimens when removed from the screens were soft and pliable, even an hour or more after the flights. Insects were found alive at altitudes of 200 to 9,000 feet. Naturally, at the altitudes of 200 to 1,000 feet or more it is to be expected that the majority of the insects would be alive. It is more important for the migration and dissemination of insects that they be alive at the altitudes of 3,000 feet and above, for at that height prevailing winds are blowing and at a greater velocity, and the insects would have a better chance of being carried over long distances. A few of the more important records are given.

At 3,000 feet several unidentified Diptera and a Mayfly (*Caenis hilaris*) were taken alive. At 5,000 feet even more of the insects taken were found to be alive. These included one specimen each of *Graphocephala versuta*, *Aedes vexans*, an aphid, one unidentified lepidopteron, and also numbers of Diptera, including two trypetid flies. At 6,000 feet one coccinellid (*Coleomegilla floridana*) was found alive. At 7,000 feet an aphid was found alive. The highest altitude at which a specimen was taken alive was 9,000 feet, at which height a small dermestid larva (*Trogoderma* sp.) was taken. This small hairy larva was alive and wriggled considerably when placed in a vial of alcohol.

A few specimens of importance taken alive at the lower altitudes were two boll weevils, one each at 1,000 and 2,000 feet; and a moth (*Cisseps fulvicollis*) at 2,000 feet. Numbers of *Stictocephala festina*, honeybees, one *Melanoplus femur-rubrum*, one *Anopheles quadrimaculatus*, several chironomids, crane flies, a bumblebee, and 15 specimens of the family Lampyridae were collected alive at altitudes of 200, 500, and 1,000 feet.

METEOROLOGICAL DATA

In the field of ecology of insects it is most essential carefully to observe and study the complex meteorological factors associated with the interactions of insects. The numbers of insects taken in the air at any given time depended directly on the condition of the weather preceding and at the time the collections were made.

Insects naturally are far less abundant in the winter than in the warmer months of the year. There were times, however, at the peak of their abundance when very few or no insects were taken on flights. Often it was difficult to single out any specific condition of the weather which contributed to these differences in the numbers of specimens taken. At times when the weather appeared to be ideal for insects, only a few or none would be taken. Again, when weather conditions were "bad," insects were taken in considerable numbers.

Meteorological observations were made and carefully recorded for every flight (fig. 2), but not until the last 2 years of flying were any records made of the wind movements in the upper air. During the 5 years of collecting, certain meteorological conditions were found which influenced either favorably or unfavorably the numbers of insects taken. These are considered as to their influence on the activity of insects in the air, and in their relation to the numbers collected, in the following sections.

TEMPERATURE

There is no doubt that temperature is one of the most important meteorological factors in the control and distribution of insects. Wherever and whenever the temperature conditions are favorable, insect life is usually abundant.

TB 673 (1939) USDA TECHNICAL BULLETINS UPDATA
THE DISTRIBUTION OF INSECTS, SPIDERS, AND MITES IN THE AIR
GLICK, P.A. 2 OF 2

The airplane collections show that temperature plays the dominant role in the seasonal distribution of insects, and, combined with various other meteorological conditions, was the most important controlling factor affecting the distribution of insects both on the surface and in the upper air. At a given locality vapor pressure, dew point, and absolute humidity usually vary more or less directly with temperature.

SURFACE TEMPERATURE

The numbers of insects in the upper air depend, of course, on the surface conditions; and the number caught at 200 feet serves as a nearly accurate index of their abundance. If the temperature is favorable at the surface, and the other conditions are more or less equal, insects will be active.

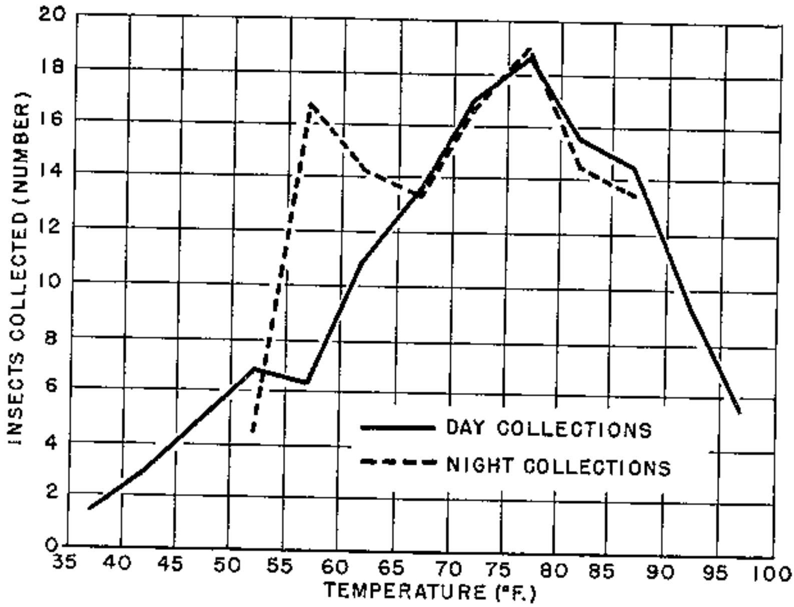


FIGURE 5.—Comparative numbers of insects collected by airplane in 10 minutes of flying at the altitudes of 200 feet by day and 500 feet by night, as related to the surface temperatures, Tallulah, La., 1926–31.

In the collection of insects from the upper air during the day flights at the altitude of 200 feet, it was found that in general the numbers taken increased rapidly from low temperatures of approximately 35° F., reached a definite peak between 75° and 79°, then dropped off suddenly and continued to decrease as the temperature increased from 79° to 100° (fig. 5).

Considering the orders of insects separately, there was found to be some variation in the optimum surface temperatures. Homoptera were taken in greatest numbers between temperatures of 70° and 74° F.; Heteroptera, Coleoptera, and Diptera in the range 75° to 79°; and Hymenoptera at 85° to 89°. The order of spiders, or Araneida, was collected in largest numbers at ground temperatures from 50° to 54°, this low temperature range being partially explained by their being found mostly in November, December, and January.

At the altitudes from 1,000 to 3,000 feet, insects were taken in greatest numbers when the surface temperatures were from 80° to 84° F. It appears that as the air became warmer, convection became stronger, and carried insects into the higher levels. With the surface temperatures higher than 84°, insects in general dropped off in numbers at all altitudes.

Among the 1,162 flights made during the daytime in Louisiana, there were many cases in which temperature appeared to be the controlling factor in the numbers of insects collected. During the winter and early spring months insects were taken in greater numbers when days were warm. On very cold days few specimens were collected. During the summer the collections dropped off most decidedly when the days were excessively hot, especially with temperatures of 95° F. and above. As the temperature increased from before sunrise and until it reached about 90° insects became more active and were collected in great numbers. There were times, however, when other conditions entered, such as severe winds, rain, cloudiness, or drought that offset the temperature effect and limited the numbers of specimens taken.

A few of the many examples are given in table 11 to show how temperature appeared to be the dominant factor, as indicated by the numbers of insects collected. For each flight the traps were exposed at 200, 1,000, 2,000, 3,000, and 5,000 feet for 10 minutes each, the entire flight being usually accomplished in a little over 1 hour.

TABLE 11.—*Meteorological data showing effect of temperature on the numbers of insects taken in airplane traps, Tallulah, La.*

Date of flight	Time of start	Surface temperature	Wind velocity	Sky	Insects taken in traps
		° F.	*Miles per hour*		*Number*
Feb. 28, 1930	9:21 a. m.	53	6	Clear	7
	1:40 p. m.	67	2	do	37
	3:15 p. m.	68	0	do	44
Mar. 20, 1930	9:13 a. m.	56	7	do	19
	11:05 a. m.	62	5	Part cloudy	30
	1:30 p. m.	70	8	Overcast	68
Nov. 18, 1930	8:32 a. m.	58	0	Clear	9
	10:45 a. m.	71	5	do	17
	2:30 p. m.	82	10	do	45
June 17, 1929	9:06 a. m.	83	5	Part cloudy	43
	2:03 p. m.	89	3	Clear	25
	3:48 p. m.	90	7	do	16
July 1, 1929	8:13 a. m.	81	9	do	41
	9:59 a. m.	90	8	Part cloudy	29
	1:32 p. m.	94	7	do	24
Aug. 1, 1930	8:14 a. m.	84	7	Clear	31
	9:44 a. m.	89	11	do	12
	3:42 p. m.	96	7	do	3

On November 18, 1930, insects were taken only at 200 feet on the 8:32 a. m. flight. On the second flight, made at 10:45 a. m., insects were collected at both 200 and 1,000 feet, and on the 2:30 p. m. flight they were taken up to 2,000 feet When the temperature was 58° F., the air was smooth, with little convection and no wind. Then as the temperature rose, reaching 82° for the afternoon, the air became slightly rough with considerable wind, and insects reached the higher altitudes. Furthermore, the low temperature of 58° is below the range of maximum activity, while 82° is still within the optimum range.

On days when the temperatures were within or slightly above the range of maximum activity of insects, the numbers of insects taken usually decreased as the temperature rose. Examples of this rise in temperature and its effect are seen in the flights of June 17 and July 1, 1929, and of August 1, 1930 (table 11). When the temperatures were not extreme for the first flights of the day, insects were taken at the higher altitudes, but as the temperatures increased to 90° F. and above, few insects or none were taken above 2,000 feet.

Among many species of insects, sudden changes in temperature cause noticeable reactions. It was often observed that after a drop in the temperature, following a long period of hot weather, insects became very active and abundant in the upper air. If such changes occur in the fall, especially after there has been a frost, many insects will start their migration flights. At such times the boll weevils become more active and fly out of the cottonfields to seek hibernation quarters.

In the spring a reverse reaction takes place, in that as the mean temperature increases, hibernating insects come forth, and many species start their flights northward. There is also a general emergence of pupating insects, and hatching of eggs. The increase in activity of insects in spring due to the rise in temperature accounts for the maximum numbers taken in the upper air in the spring months, especially May.

To tabulate the numerous species of insects collected in the upper air according to the temperatures at which they were taken would be too great an undertaking. Some species will be found when the days are cold in winter, as well as on extremely hot days in the summer and fall. Sudden drops or rises in temperatures will cause insects to be scarce or abundant, respectively. Generally speaking, however, insects have their optimum temperatures for activity, below or above which they will decrease in numbers or disappear from the upper air.

NIGHT TEMPERATURES IN THE UPPER AIR

With respect to convection, night conditions are the reverse of daytime conditions. There is commonly a "temperature inversion," that is, the temperature of the lower layers of air usually increases with increase in height; and even when there is sufficient wind to prevent this temperature inversion, the lower atmosphere still is colder than it otherwise normally would be (*35, p. 42*). During the night the ground is slightly colder than the air in winter and slightly warmer in summer. The ground at night cools rapidly, and the air loses heat by radiation both to the open sky and to the cooling ground. Conduction cools the air in immediate contact with the earth's surface, and unless the wind is strong this layer is not mixed with the air above. Convection is usually not operative at night, and the marked cooling must take place very near the earth's surface (*52, p. 57*).

The amount of time spent in flight at night was scarcely sufficient to compare the results with those of the day flights, except for flights made on the same day. It was found, however, that the greatest numbers of insects were collected in the night flights at the altitude of 500 feet when the surface temperatures were from 75° to 79° F. The temperature range from 55° to 59°, gave the next highest numbers. These lower night temperatures were recorded mostly late in the fall, when insects usually were abundant (fig. 5).

FREE AIR TEMPERATURE

Temperatures were recorded at every altitude at which collections were made (fig. 2).

The average vertical temperature gradient is subject to much variation from various causes.

At the altitude of 200 feet most insects were collected when the temperature ranged from 75° to 79° F., surface temperatures being the same. At the altitude of 1,000 feet the greatest numbers of insects were taken when the temperatures recorded at this altitude were from 70° to 74°, the surface temperatures ranging from 80° to 84°. At 2,000 feet insects were most abundant at temperatures of 65° to 69°, with the surface temperature at 80° to 84°. Above 2,000 feet there was much variation, since other meteorological conditions entered in.

Homoptera, Coleoptera, and Diptera were collected in greatest numbers at the altitude of 200 feet when the temperatures recorded at that altitude were from 75° to 79° F., Hymenoptera at 85° to 89°, Heteroptera at 80° to 84°, and Araneida were collected in greatest numbers at 200 feet in the temperature range of 60° to 64°.

In the day collections at 1,000 feet, more Diptera and Hymenoptera were taken when the temperatures at that altitude were 70° to 74° F. Homoptera, Heteroptera, and Coleoptera were found in greatest numbers when the temperature ranged from 65° to 69°. Spiders were found in greatest numbers at temperatures of from 60° to 64°.

At the altitude of 2,000 feet, Diptera, Homoptera, Heteroptera, and Hymenoptera were taken in greater numbers when the temperature ranged from 65° to 69° F. Coleoptera varied considerably. Araneida were collected in largest numbers at temperatures of 45° to 49°.

Above the altitude of 2,000 feet, the orders varied considerably in respect to optimum temperature ranges.

The high-altitude flights at 6,000 to 16,000 feet were made during the spring, summer, and fall months. For the altitude of 10,000 feet temperatures were recorded in March as low as 27° F.; the minimum for April was 32°; for May, 42°; for June, 45°; for July and August, 49°; for September, 42°; and for October, 45°. The highest altitude was attained on August 13, 1931, when 16,100 feet was reached. The temperature and other meteorological conditions recorded on this flight and on one on March 11, 1931, are given in table 12.

TABLE 12.—*Meteorological data, and insects collected on the highest collecting flights made at Tallulah, La.*

MARCH 11, 1931

Traps (letters) and trays (numbers)	Altitude	Time of exposure (a. m.)	Length of time exposed	Dry bulb	Wet bulb	Relative humidity	Wind velocity	Direction of wind	Air condition	Cloud condition	Insects taken
	Feet		*Minutes*	*°F.*	*°F.*	*Per cent*	*Miles per hr*				*Number*
A:											
1	200	9 16	10	57	51	75	9	WSW.	Slightly rough	Clear	4
2	1,000	9 27	10	52	48	75	10	WSW.	do	Hazy	1
3	2,000	9 38	10	51	46	66	15	WSW.	do	do	0
4	3,000	9 49	10	51	43	50	19	WSW.	Smooth	do	0
5	5,000	10.03	10	40	31	57	22	WS.	do	do	0
B:											
1	7,000	10.16	10	40	27	17	23	SSW.	do	do	0
2	9,000	10.31	10	30	[1] 32		28	SSW.	do	do	0
3	11,000	10 46	10	24	[1] 32		30	S.	do	do	0
4	13,000	11.04	10	19	[1] 25		37	SSW.	do	do	0
5	15,000	11.24	10	11					do	do	0

[1] Wet bulb covered with ice.

TABLE 12.—*Meteorological data, and insects collected on the highest collecting flights made at Tallulah, La.*—Continued

AUGUST 13, 1931

Traps (letters) and trays (numbers)	Altitude	Time of exposure (a. m.)	Length of time exposed	Dry bulb	Wet bulb	Relative humidity	Wind velocity	Direction of wind	Air condition	Cloud condition	Insects taken
	Feet		*Minutes*	*°F.*	*°F.*	*Percent*	*Miles per hr.*				*Number*
A:											
1	200	8.11	10	72	63	61	5	NE.	Smooth	Hazy	14
2	1,000	8.22	10	71	59	49	9	NE.	do	do	4
3	6,000	8.44	10	54	35	7	15	NNE.	do	do	1
4	8,000	9.03	10	53	33	3	14	N.	do	Very hazy.	1
5	10,000	9.20	10	47	30	5	18	NNW.	do	do	1
B:											
1	12,000	9.35	10	39	26	14	18	NNW.	do	do	0
2	13,000	9.50	10	33	------	------	13	NNW.	do	do	0
3	14,000	10.02	13	30	24	48	21	NNW.	do	do	0
4	15,000	10.19	10	27	17	8	21	NNW.	do	do	[1] 1
5	16,100	10.31	5	23	14	6	21	NNE.	do	do	0

[1] A spider.

Few insects were taken at the high altitudes in the early spring months, since the surface air had not reached a temperature at which insects are abundant in the air.

DEW POINT

In the collection of insects in the upper air, their distribution appeared to be correlated with the dew point, which is the temperature at which the quantity of water vapor present would at the same pressure produce saturation. If the temperature of a quantity of humid air is lowered, a temperature will finally be reached at which any further reduction must result in the condensation of some of the moisture in the form of dew, frost, fog, cloud, or precipitation (*52, p. 196*).

The surface dew point was recorded at the time each flight was made. At the altitude of 200 feet fewest insects were taken at the low dew point of 25° to 29° F., represented in figure 6 by the middle point of the range, but the numbers of specimens then rapidly increased and reached a decided peak at 60° to 64°, suddenly dropping off as the surface dew point continued to increase (fig. 6).

There was some variation in this, Heteroptera being collected in greater numbers at dew points of from 55° to 59°, Diptera and Homoptera at 60° to 64°, Coleoptera at 65° to 69°, and Hymenoptera at 70° to 74° F. Spiders were taken in greater numbers at dew points of from 35° to 39°, and decreased in numbers as the dew point was raised, which was the reverse of the reaction on insects (fig. 7). A further discussion of dew points and spiders is given in the section on barometric pressure.

At the altitude of 1,000 feet there was still an indication that surface dew point contributed in some measure to the numbers of insects collected. Homoptera, Diptera, and Hymenoptera were more abundant when the surface dew points were 60° to 64° F.; Heteroptera were taken mostly at dew points of from 55° to 59°; Coleoptera at 45° to 49°, although this order fluctuated much. Spiders continued to be most abundant at 35° to 39°.

For the altitudes above 1,000 feet, the variation was too great to show a decided relation, since other meteorological factors entered in to offset the effect of surface dew point.

Dew points were also calculated from readings taken in the upper air at the various altitudes, and some relation of dew points at higher altitude to numbers of insects is apparent. Homoptera varied much

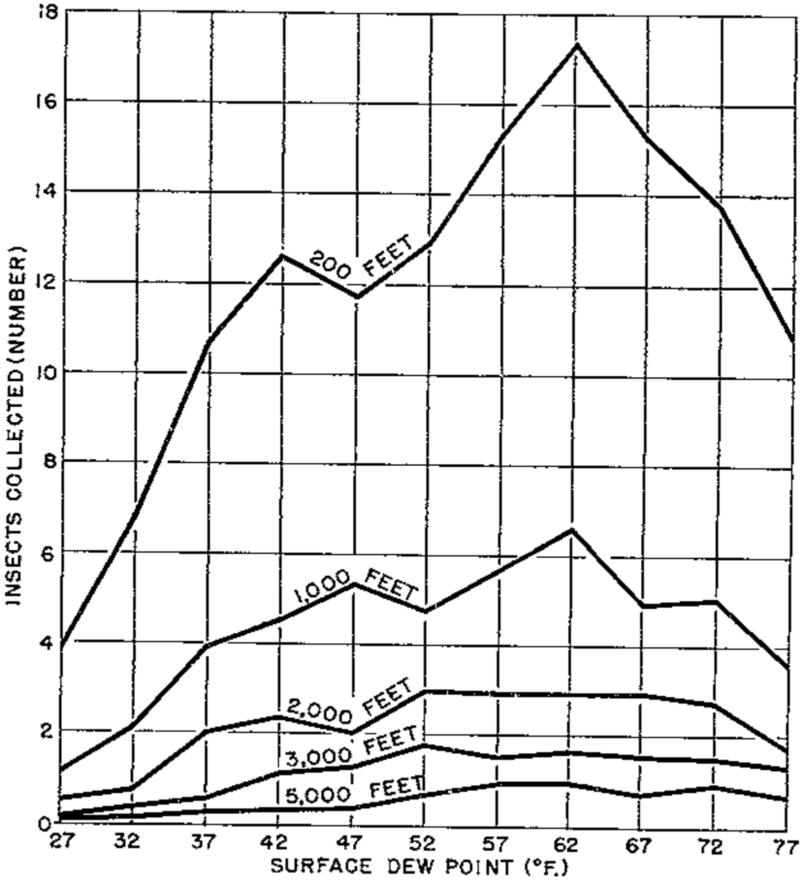


FIGURE 6.—Comparative numbers of insects collected by airplane in 10 minutes of daylight flying at altitudes of 200, 1,000, 2,000, 3,000, and 5,000 feet in relation to the surface dew point, Tallulah, La.

in numbers at the altitude of 200 feet. At 1,000 feet, the greatest numbers of Homoptera were found in the dew point range at that altitude of 45° to 49° F., the numbers dropping off decidedly as the dew point increased. At 5,000 feet a peak was reached at 60° to 64°.

Heteroptera showed a relation to the dew point only at 200 feet, with a sudden rising in numbers to a maximum abundance at 55° to 59° F., gradually dropping off to 65° to 69°, and then decreasing rapidly thereafter.

More Coleoptera were taken at the altitude of 200 feet when the dew point at that altitude was 60° to 64° F. For the higher altitudes no relation was evident.

Hymenoptera appeared to be directly affected by dew point at the altitude where collected. At 200 feet they reached a peak at 70° to 74°, but at the altitude of 1,000 feet considerably more Hymenoptera were collected when the dew points were 55° to 59°.

Diptera showed a general tendency to react to dew point for most altitudes from 200 to 3,000 feet. At 200 feet a peak was reached in the dew point range of 65° to 69° F. At 1,000 feet there were two

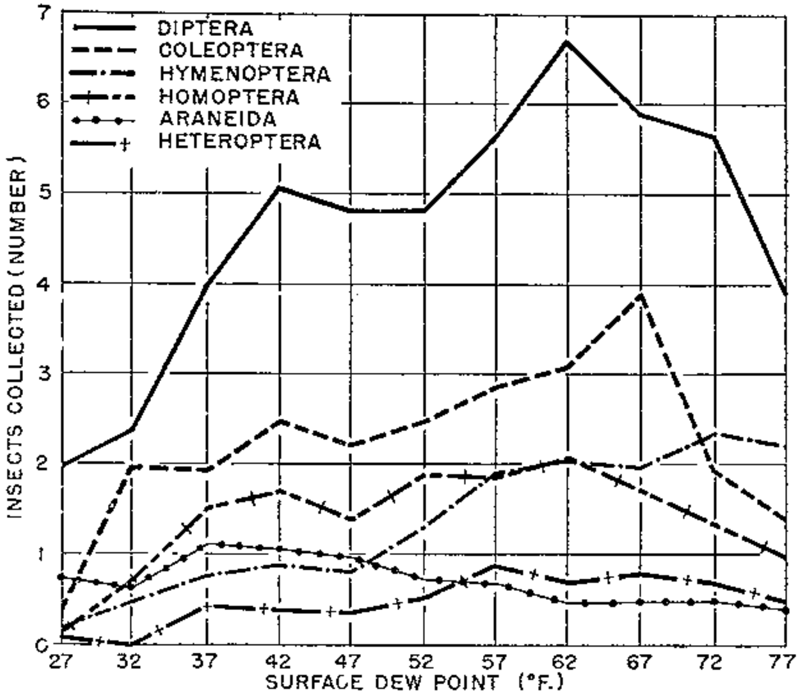


FIGURE 7.—Average number of insects of the important orders collected by airplane in 10 minutes of daytime flying at the altitude of 200 feet, showing the effect of the surface dew point on the abundance of the insects in the air at that height, Tallulah, La.

peaks, a minor at 45° to 49°, and a major peak at 55° to 59°. For the altitude of 2,000 feet most Diptera were taken with dew points reading from 55° to 59°; at 3,000 feet most specimens were collected with dew points from 50° to 54°.

Dew point, next to barometric pressure, seemed to be the most important contributing factor to increase the numbers of spiders taken and limit the numbers of insects in the upper air.

RELATIVE HUMIDITY

Relative humidity is the ratio of the actual amount of water vapor present at any one time to the quantity that would be present if the air were saturated, and is expressed as a percentage of the latter quantity. Relative humidity is more or less regular in its daily fluctuation. During a hot sunny day it usually is low but with the approach of sunset, when the air usually becomes more quiet and the temperature drops, the relative humidity increases rapidly and remains high during the night. After sunrise, with the rise of temperature and the increase in wind and convection, there is a gradual decrease in relative humidity. Thus with the more or less regular daily increase and decrease in the relative humidity, there would seem to be a considerable probability that insect activity would be closely associated with and affected by such changes.

It has been stated that certain insects are more active at night, since they require a high degree of humidity, and are inactive during the day, remaining in dark places to avoid excessive evaporation. While this is correct to a certain degree, Uvarov (*74 p. 103*) considers that humidity is not the only factor that affects the daily cycle of insect activities, since a damp rainy day does not bring out the nocturnal insects from their hiding places.

The number of insects in the upper air did not appear to show any relation to the relative humidity for the investigation as a whole, or at any given time. The reason for this may be that relative humidity is so irregular and variable under all temperatures throughout the year. It may be 95 percent or 20 percent at any given temperature, but insects will be abundant or scarce according to temperature and other factors rather than according to relative humidity.

Relative humidity appears, therefore, to have no direct influence on the numbers of insects collected, since they were taken indiscriminately under widely varying conditions of humidity in both day and night collections.

ABSOLUTE HUMIDITY

Absolute humidity is the actual quantity of water vapor per unit volume of air. For every flight, absolute humidity was calculated from the records of temperature and relative humidity, both on the surface and at each altitude.

A correlation was found between the number of insects taken and the actual amount of water vapor (absolute humidity) at the surface. There was a tendency for the numbers of insects to increase as the absolute humidity rose from low to high values, with fewest at absolute readings of 1.5 to 2 grains per cubic foot, and nearly seven times as many at readings of 6 to 6.5 grains. From this point the numbers of specimens taken dropped off considerably as the amount of water vapor increased. The orders Diptera, Hymenoptera, and Coleoptera showed the closest relationship between numbers collected and the amount of water vapor in the air. Homoptera and Heteroptera fluctuated considerably in this relation.

For the absolute-humidity records at the altitude of 200 feet, the relation was considerably more evident. The numbers of insects collected increased rapidly as the amount of water vapor increased, with the minimum numbers taken at the readings of 0.5 to 1 grain, and the peak at 6 to 6.5 grains per cubic foot. There were more than five times as many insects taken at the latter readings than at 0.5 to 1. The numbers dropped off greatly after the 6 to 6.5 range was passed.

The numbers of Diptera showed the closest relationship to the amount of water vapor in the air. Spiders were taken in greater numbers at the lower absolute-humidity readings, the numbers of specimens decreasing as the amount of water vapor increased. Apparently the greater moisture content of the atmosphere, the greater the tendency of water to collect on the webs, causing the silk to become heavier.

At the altitude of 1,000 feet the greatest numbers of insects were taken when the amount of water vapor was from 6.5 to 7 grains per cubic foot. At the altitudes of 2,000 to 5,000 feet the relationship was not significant, since other conditions appeared to offset any effect of the amount of water vapor.

As mentioned in the discussion of temperature, the amount of water vapor in the air is in general connected with the temperature. With high temperatures there were correspondingly high absolute-humidity readings. At temperatures of from 75° to 85° F., which were found to constitute the most favorable range for insect activity in the air, the absolute-humidity readings averaged from 5.5 to 6.5, i. e., the larger

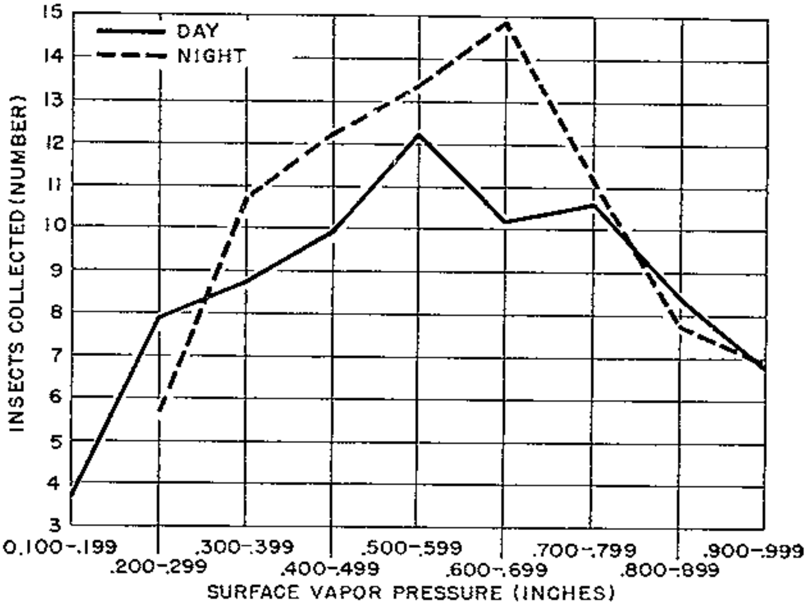


FIGURE 8.—Average number of insects collected by airplane in 10 minutes flying, in relation to the surface vapor pressure, the flying being done at 200 to 1,000 feet altitude in the daytime and from 500 to 1,000 feet at night, Tallulah, La.

quantities of water vapor were correlated with the largest catches of insects.

However, where favorable temperatures for insects were found accompanied by low absolute humidities, as occasionally occurred, there was found no apparent diminution in the average numbers of insects taken, other conditions being equal.

This would indicate that the effective factor in operation was temperature rather than absolute humidity, and that the close correspondence in the slope of the temperature-insect and absolute humidity-insect curves is due primarily to the close correlation between absolute humidity and temperature rather than to any marked effect of absolute humidity on insect abundance.

VAPOR PRESSURE

Absolute humidity has been stated to be the actual quantity of water vapor per unit volume of air. The total possible amount, that is, the amount that would produce saturation, increases rapidly with temperature. Absolute humidity is often expressed in terms of the expansive force that the vapor exerts, which is referred to as vapor pressure and is measured in the same units as employed for barometric pressure (*28, p. 28*).

Vapor pressure was calculated from the records of temperature and the depression of the wet bulb, both at the surface of the ground and at each altitude when the flights were made. Surface vapor pressures were not considered for the collections of insects made above the altitude of 1,000 feet, as the relation was not important.

It is evident (fig. 8) that the numbers of insects taken were related closely to the surface vapor pressure. For the day collections at the altitudes of 200 and 1,000 feet, the numbers of insects increased rapidly from the vapor-pressure minimum range of 0.100 to 0.199 inch to the maximum of 0.500 to 0.599 inch, there being more than three times as many insects taken at the latter as at the former. However, from the surface vapor-pressure readings of 0.500 to 0.599, the numbers collected dropped off rapidly as the surface vapor pressures increased.

An even more decided effect was shown in the night collections at the altitudes of 500 to 1,000 feet, with a minimum at vapor pressures of 0.200 to 0.299 inch and a definite peak at 0.600 to 0.699. The numbers of insects taken were much less after this peak had been reached (fig. 8).

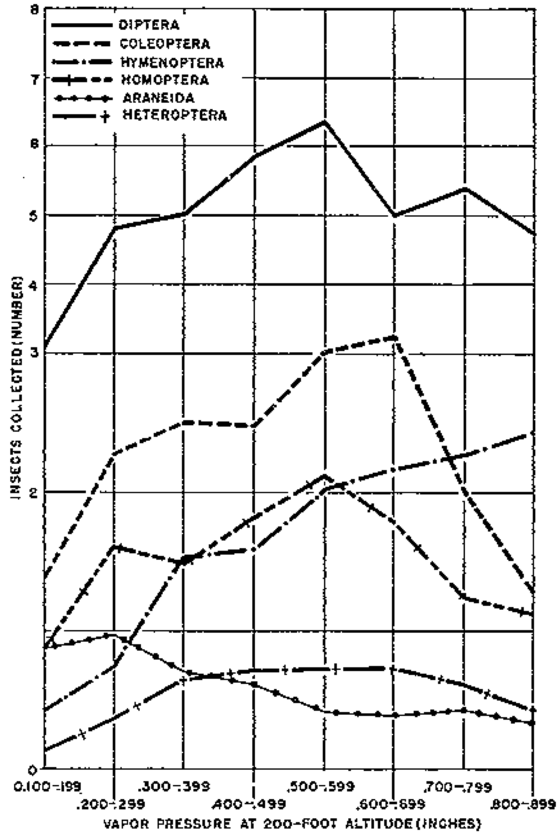


FIGURE 9.—Average number of insects of the important orders collected by airplane in 10 minutes of daylight flying at 200 feet altitude as related to the vapor pressure at that height, Tallulah, La.

There was not a great variation in the maximum numbers of specimens of the different orders of insects taken, either at 200 or at 1,000 feet. Diptera, Coleoptera, and Homoptera were taken in greatest numbers in the surface-vapor-pressure range of 0.500 to 0.599, and Hymenoptera at 0.700 to 0.799 inch.

Spiders were affected to some degree by vapor pressure, with the greatest numbers found at the lower readings of 0.200 to 0.299 inch, and they decreased more or less in numbers as the vapor pressures increased (fig. 9).

The effects of vapor pressures as calculated for each altitude were similar to those of surface vapor pressures as related to the numbers of insects taken. The peaks, however, were more evident. Most insects were taken at the altitude of 200 feet at vapor pressures of 0.500 to 0.599, and at 1,000 feet at 0.300 to 0.399 inch.

Vapor pressure and the number of insects caught both vary with temperature and in the same direction. The apparent vapor-pressure effect is undoubtedly due not to vapor pressure itself, but to the temperature effect upon the insects, which varies to a definite degree and in the same direction as does the temperature effect upon vapor pressure.

Vapor pressure by its effect on dew point has a direct relation to the occurrence of spiders; and, as affected by temperature, an indirect relation to the occurrence of insects.

BAROMETRIC PRESSURE

Experiments and observations in both the laboratory and the field have shown that there is a more or less direct relation between atmospheric pressure and the behavior of insects. Some observers have reported rather definite reactions, while others have considered that they may be dealing only with coincidences in which other conditions may be the controlling factors.

There are several factors which produce changes in barometric pressure: There is, for example, a small regular daily variation, in which, among other things, temperature has an important effect. Both the afternoon barometric minimum and the forenoon maximum are to be regarded as effects, in part at least, of temperature increase; the minimum as due to expansion and consequent overflow, the maximum as caused by vertical convection and consequent interference with the free circulation of the atmosphere. In general, convection increases most rapidly during the forenoon, is most active at 10 to 11 a. m., and reaches its greatest elevation at about 4 p. m. This produces a damming up of the atmosphere, due to the vertical convection, and the resulting increase of barometric pressure must take place most rapidly during the forenoon and come to a maximum at about 10 a. m. After this, the convectional interference decreases while at the same time the amount of air in a vertical column of fixed cross-section diminishes, as a result of expansion and overflow; until, at about 4 p. m., the barometric pressure, as already explained, has reached a minimum (*38, p. 235*).

The amount of evaporation is influenced slightly by barometric pressure—the higher the pressure the slower the rate of evaporation. Of course, the amount of evaporation depends upon a great variety of things, such as the nature of the surface from which the evaporation is taking place, the quantity of water vapor already in the atmosphere, the temperature, and the velocity of the wind. The amount of evaporation is greater during the day than at night, and greater during the summer than in winter (*52, pp. 192–194*).

The greatest changes are produced by the passage of the barometric highs and lows that are responsible in the main for weather changes; and there are many examples in which the changes in barometric pressure are shown to have had an important bearing on the reaction of insects. As far back as 1897 it was pointed out by Sajo (*63, p. 230*) that insects became unusually active during barometric depressions. Parman (*57*) found that in some flies the mortality increased considerably with a falling barometer. He collected data on the effects of a severe storm at Corpus Christi, Tex., in 1916. A few days before the storm *Stomoxys calcitrans* was very abundant, but after the storm the flies had practically disappeared. *Musca domestica L.* and *Cochliomyia macellaria* were also abundant before the storm, but all species of Diptera diminished appreciably in numbers with the storm, although *Lucilia* sp. was least affected. With the rapidly falling barometer at the approach of the storm, the muscids became nervously active and showed a tendency to seek places of protection, where they went into a state of partial coma. The great destruction of the flies may have been due to the heavy rains following the chilling effect of the storm, and to the action of the wind and sea spray. Parman also made observations at lights at night, and found insects to be more active during high barometric periods and especially while the barometer was rising. He also observed that migrations of *Libythea bachmanni* Kirt. took place after storms, which indicated that the flights were made during periods of high barometric pressure.

Williams (*76*) reports that in 1915 there was an invasion of migratory locusts (*Schistocerca gregaria* (Forsk.)) into Egypt, and all the waves of the invasion were preceded by barometric depressions; also that some butterflies, as *Vanessa cardui* (L.), have been occasionally noted to follow areas of depression during their migrations. According to Pictet (*58*) Lepidoptera tend to emerge from the pupal stage during a fall in atmospheric pressure, a sudden drop in pressure, even of a small magnitude, after a long-continued rise, resulting in a considerable emergence of insects.

It is said by some that the swarming of some insects in the evening is due to the usual slight (not over 0.1 mm) increase in barometric pressure which occurs every evening between 9 and 10 p. m. It is suggested, however, that swarming begins at dusk under natural conditions, keeping pace with the change in the time of sunset, and being related to a definite intensity of light, or degree of darkness, rather than to a difference in barometric pressure (*74, pp. 99, 100*).

Felt (*22, p. 65*) states:

> Since winds blow towards lows, a lowering of the barometer would be favorable for the drifting of insects toward the center. It hardly seems as though changes in pressure alone would have a determining influence upon the movement of insects, although it can be easily understood how the conditions near the center of a storm area would very likely have a profound influence upon insect life, as well as upon larger animals.

There is no doubt that insects would gradually drift toward the center of a low, since air has a component of flow from high-pressure areas to low-pressure areas. But as to there being a profound influence upon insect life near the center of a storm area, it is somewhat questionable. While winds do blow toward the center of a low, they do not blow directly into the center, but spirally inward around the center. Just what the effect, then, would be on insects in the center of a storm is not certain.

Steinberg (*70*), in his studies of the sugar-beet web worm in the Union of Soviet Socialist Republics, states that the migrations are always connected with cyclonic depressions, and that it is most probable that the moths are swept in from every quarter to the center of the cyclonic depressions. In the southeastern steppes they will remain in large numbers and deposit their eggs. Here will remain a mass stock of hibernating larvae, and the moths emerging the following spring may immediately threaten the cultivated areas bordering the steppes and cause a mass outbreak of the pest in them.

There is little chance of a satisfactory explanation of the phenomena observed, if pressure alone is considered as a factor affecting the behavior of insects in the air, since changes in barometric pressure are also associated with changes in the weather. It is possible to understand how sudden drops or rises in barometric pressure can and do influence the behavior of insects, since the weather is correspondingly variable.

The collections of insects in the upper air indicate that one or more factors have an important correlation with barometric pressure.

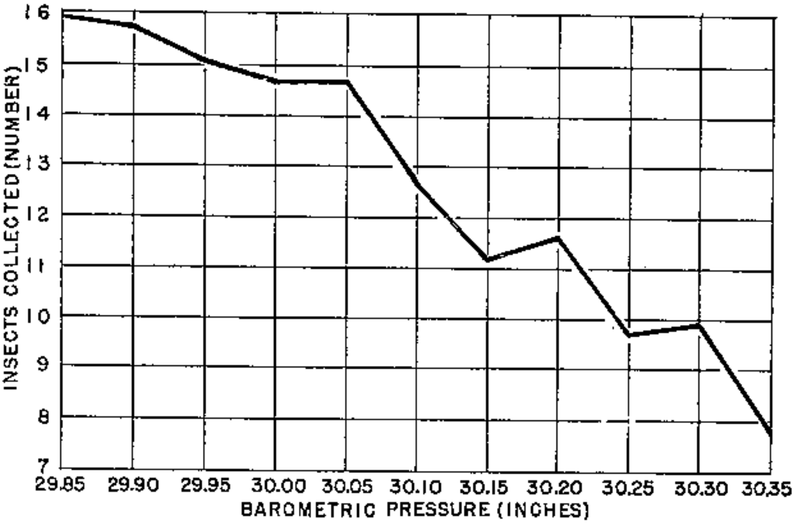


FIGURE 10.—Average number of insects collected by airplane in 10 minutes of daylight flying at 200 feet altitude, as related to the surface barometric pressure, Tallulah, La.

There is no marked relation in the numbers of insects in the upper air to barometric pressure and temperature, but there is an evident tendency for temperature to be the controlling factor. Barometric pressure generally varies inversely with temperature; i. e., with high pressures there are low temperatures, and with low pressures, high temperatures. The same tendency is shown in correlating dew point with barometric pressure, for the latter also varies inversely with the dew point. There is no evidence that the relation of vapor pressure to barometric pressure affects the number of insects in the upper air.

Only the collections at 200 feet will be considered, as at 1,000 feet and above there is very little or no correlation with barometric pressure. At the high altitudes pressure is only secondary, since other factors which overweigh or interfere with this influence regulate the distribution of insects at these heights.

The greatest numbers of insects were taken in the daytime when the barometer was at 29.85 inches; and the numbers decreased more or less rapidly as the pressure increased. (The normal barometric pressure for Tallulah, is from 30.00 to 30.15 inches.) More than twice as many insects were taken at pressures of from 29.85 to 29.89, than at 30.35 to 30.39. From 29.85 to 30.05 there was only a small and gradual decrease in number of specimens taken, but from 30.05 and on the numbers fell off decidedly (fig. 10).

The orders Coleoptera, Hymenoptera, and Diptera, the three orders with the most highly developed nervous systems, showed the closest relationship to barometric pressure, as the largest numbers were in

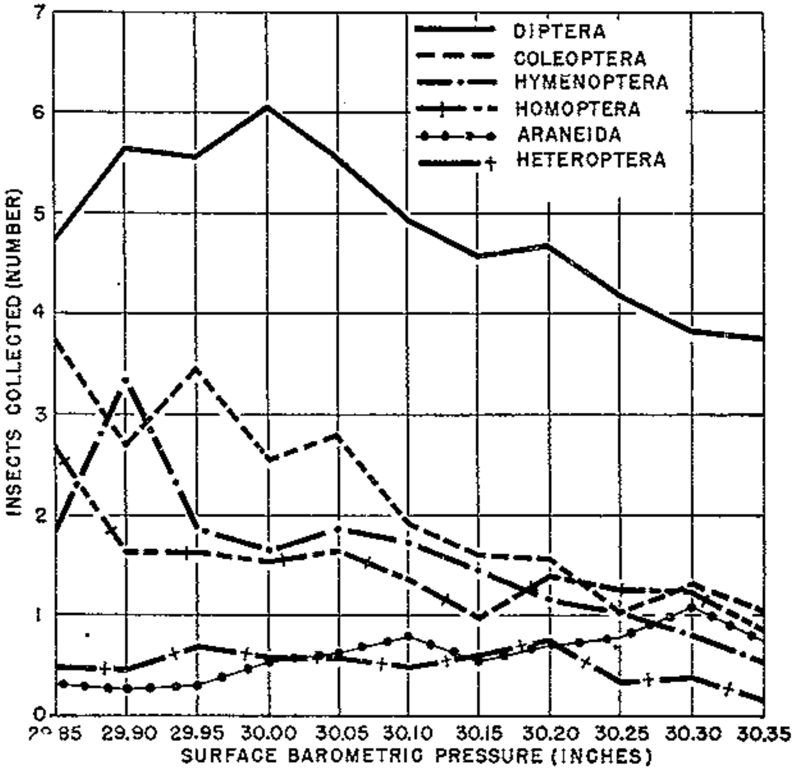


FIGURE 11.—Average number of the insects of the important orders collected by airplane in 10 minutes of daylight flying at 200 feet altitude, as related to the surface barometric pressure, Tallulah, La.

the air mostly at the readings of 29.90 to 30.00, and thereafter decreased rapidly as the barometer rose. There was also a tendency for Homoptera to decrease in numbers as the pressure increased, but the Heteroptera showed little effect of the various pressure readings (fig. 11).

There was a distinct and exactly opposite reaction in spiders as compared with insects. This same trend was evident at the altitudes of 200, 1,000, 2,000, and 3,000 feet, with the fewest specimens taken at the readings of 29.90 and the numbers greatly increasing with increase in the pressure from 29.90 to 30.10 inches. At the altitude of 200 feet there were more than twice the number of spiders taken at the pressure reading of 30.10 as were collected at 29.90 or 29.94. Then at 30.10 the numbers of spiders taken dropped off considerably, but greatly increased thereafter from 30.15, reaching a maximum at

30.30, with nearly twice as many as were collected on flights when the readings were 30.15, and almost four times as many as at 29.90 (fig. 11).

High barometric pressures from 30.15 to 30.30 inches were recorded mostly in the winter months. Since the spiders were taken in greatest numbers in November, December, and January, it appears that the occurrence of spiders is correlated with the seasonal change in barometric pressure.

It is important to know what meteorological condition contributed the controlling factor along with barometric pressure, in order to cause such a reverse reaction of spiders in comparison with insects. Surface vapor pressure and absolute humidity did not show any direct relation with the abundance of spiders in the upper air. Dew point, however, appeared to be the outstanding factor in correlation with barometric pressure, to which spiders showed the most definite reaction. This is quite understandable when one considers the role that dew point plays in the movements of aircraft. Dew point means simply that temperature at which, without change of pressure, saturation is just reached. It might be defined as the temperature at which the saturation pressure is the same as the existing vapor pressure (*35, p. 11*).

Airplane wings offer a wide surface for the condensation of water vapor. When a plane passes through fog or clouds, or an area of saturation, a drop in temperature from a given dew point may result in the collection of moisture or ice on the surface of the wings. Accordingly it is most essential that the pilot know the dew point, especially in freezing weather, as the collection of ice on the wings may result in a forced landing.

The silky webs of spiders may be compared to the wings of an airplane, since the spider floats on these webs as an airplane remains in the air on its wings, and if the dew point changes and moisture collects on the webs, this excess liquid weight will bring the web and its rider down toward the earth.

AIR CURRENTS

It has long been suggested that wind has played a considerable part in the distribution and dispersal of insects over the earth. There are numerous references in entomological literature to the importance of the wind as an agency in the migration and diffusion of insects. Its effects are seen everywhere in the sudden invasion of certain insect pests, when wind of sufficient velocity has brought them from distant localities; or in their sudden disappearance with the change of the wind direction.

It is important to know what effect the intensity of the wind, strong convectional currents, and the direction of the wind have on insect movement in the upper air. Wind plays numerous roles in its effect on insects. It influences the evaporative power of the air; and the mechanical action can directly destroy insects by driving them into large bodies of water or carrying them to places unsuitable for life and reproduction, or by destroying the immature stages, such as mosquito pupae in water. Winds of great intensity, such as are found in tornadoes, destroy insects in great numbers instead of aiding them much in their flight. If the wind becomes too strong, insects have a tendency to remain close to the ground, clinging to vegetation;

or if flying, they may be carried along by the wind. On the other hand many insects fly against, and not with, the wind.

To understand and properly account for the distribution of insects in the upper air it is essential to have some knowledge of the action of winds, eddies, and disturbances.

An important type of wind that has a definite effect on disturbing and distributing insects is that which usually accompanies a thunderstorm. The air becomes agitated, blowing directly toward the nearest portion of the storm front. As the rain is about to fall, the wind often suddenly changes to violent gusts, blowing away from the storm center and in the same direction in which the storm is traveling, which is usually different from that of the original surface wind. After the storm the wind may resume the same general direction as the original surface wind.

Intense heating of the surface of the earth often causes vertical currents of air, by which insects are carried upward. The writer once observed on Longs Peak, Colo., at the altitude of 14,265 feet, various species of butterflies and dragonflies flying briskly up the sides of the great walls of this mountain and over snowbanks until the insects reached the very summit. Strong ascending surface currents of air were evident and these aided or carried the insects upward and over the mountain barriers.

These mountain air currents have been a great aid in the migration of the enormous swarms of grasshoppers which have been so destructive in past years. There is unmistakable evidence that numerous flights of grasshoppers were made at remote times. Speer (*69*) mentions a visit of Professor Ruggles of the University of Minnesota several years ago to Grasshopper Glacier, near Cook City, Mont. This glacier lies in a valley in the Rocky Mountains some 12,000 feet above sea level, near Yellowstone National Park. Here Professor Ruggles found decaying heaps of locusts lying at the melting foot of the ice sheet of the terminal moraine. Successive layers of locusts were imbedded in the ice from the bottom to the top of the face of the glacier. Each layer was evidence of an individual flight. The bottom layers had been deposited hundreds of thousands of years ago.

Guppy (*30*) records that in 1897 numerous wings of butterflies were found on the top of Mauna Loa in the Hawaiian Islands, at the altitude of 13,600 feet where life was scarcely bearable for man. Muir, according to Williams (*77*), in writing on the Hawaiian Islands, states:

> Only such [insects, plants, and animals] as could come on the wing, be carried by the wind through the air, carried on bodies or in the crops of birds, or be borne on floating logs, etc., could reach the Islands. Even today we can state that in a broad sense, the native fauna and flora are mainly composed of forms that could travel in these ways, or of descendents of such.

Guppy (*30*), however, doubts that butterflies could be transported 2,000 miles from California.

There are cases on record which illustrate the importance of winds in carrying insects over unexpectedly long distances. Elton (*21*) gives an example of the appearance of winged spruce aphids on the snow at Spitzbergen, where they could have been brought only by the wind from the Kola Peninsula, a distance of over 800 miles.

McAtee (*45*) has assembled a number of records of the fall of insects during storms. In one instance numbers of living larvae of *Tenebroides mauritanicus* were found on the snow following a storm in

Haute-Savoie. The insects had probably been carried there to a height of 3,500 feet from central or southern France.

The cosmopolitan butterfly *Danaus menippe* (Hbn.) (*Anosia plexippus* of authors) has been seen in the South Pacific, 500 miles from land. Tutt (*72 p. 15*) reports a record that a swarm of migratory locusts (*Schistocerca gregaria* (Forsk.)) invaded a ship which was making a voyage from Bordeaux to Boston, the nearest land being some 1,500 miles distant.

Hardy and Milne (*31*) conducted experiments on the drift of insects over the North Sea by flying collecting nets either from the masthead or from kites flown from the ship. Altogether 730 insects were collected 120 to 150 miles from the nearest land, some being taken with kites at heights of from 200 to 400 feet. Considering the small size of the nets used, the number of insects collected indicates a very large population of "aerial plankton" drifting across the sea. They concluded:

> It appears likely that the study of insect drift over the sea, in giving definite evidence of the distances (minimum when measured from the nearest land) travelled by insects, may be of value in understanding the spread of insect pests over the land, in addition to indicating the infestation of Great Britain from the Continent and throwing light on the origin of the insect faunas of islands.

WIND VELOCITY

In the collection of insects by airplane there is much evidence to show to what degree wind velocity influences insect abundance in the air. The numbers of insects taken do not imply that the wind was the most important factor but indicate the comparative numbers of insects that may be found in the air under given wind velocities.

At the altitudes of 200 to 5,000 feet insects were more often taken in the daytime when the surface wind velocity was from 5 to 8 miles per hour, and the greatest number was taken at from 5 to 6 miles an hour. Fewest were collected at 15 to 16 miles per hour, above which velocity few flights were made. As compared with the velocities of 1 to 14 miles per hour, fewer insects were taken when the air was calm.

At the altitude of 200 feet the greatest numbers of insects were collected when the wind was blowing at 5 to 6 miles per hour, and fewest at 15 to 16 miles. At the altitudes of 1,000 and 2,000 feet the greatest numbers were collected in the daytime when the surface wind velocity was from 7 to 8 miles per hour, indicating a slightly stronger wind as necessary for insects to reach the higher altitudes (fig. 12). At night very few flights were made when the wind velocity was over 5 to 6 miles an hour on the surface, and fewest insects were taken when the air was calm, the numbers collected continuing to increase rapidly up to velocities of 5 or 6 miles per hour.

As regards the orders, there was much variation. Heteroptera were collected in greater numbers at the altitude of 200 feet, with the wind on the surface recording from 1 to 8 miles per hour.

The Homoptera collected at 200 feet were at their maximum numbers when the surface wind velocity was from 7 to 8 miles an hour, and for the higher altitudes there was a considerable fluctuation in the numbers, with apparently little reference to surface wind velocity.

The Coleoptera were collected in greatest numbers at 200 feet when the wind velocity was between 5 and 6 miles per hour. The spotted cucumber beetle (*Diabrotica duodecimpunctata*) was taken when the wind was calm or when it was strong. The boll weevil was collected in the upper air when the average wind velocity ranged from calm to 5 or 6 miles an hour. The boll weevil is governed in flight by the wind. If there is no wind, or only a light one, a weevil is as likely to fly in one direction as another (*36*).

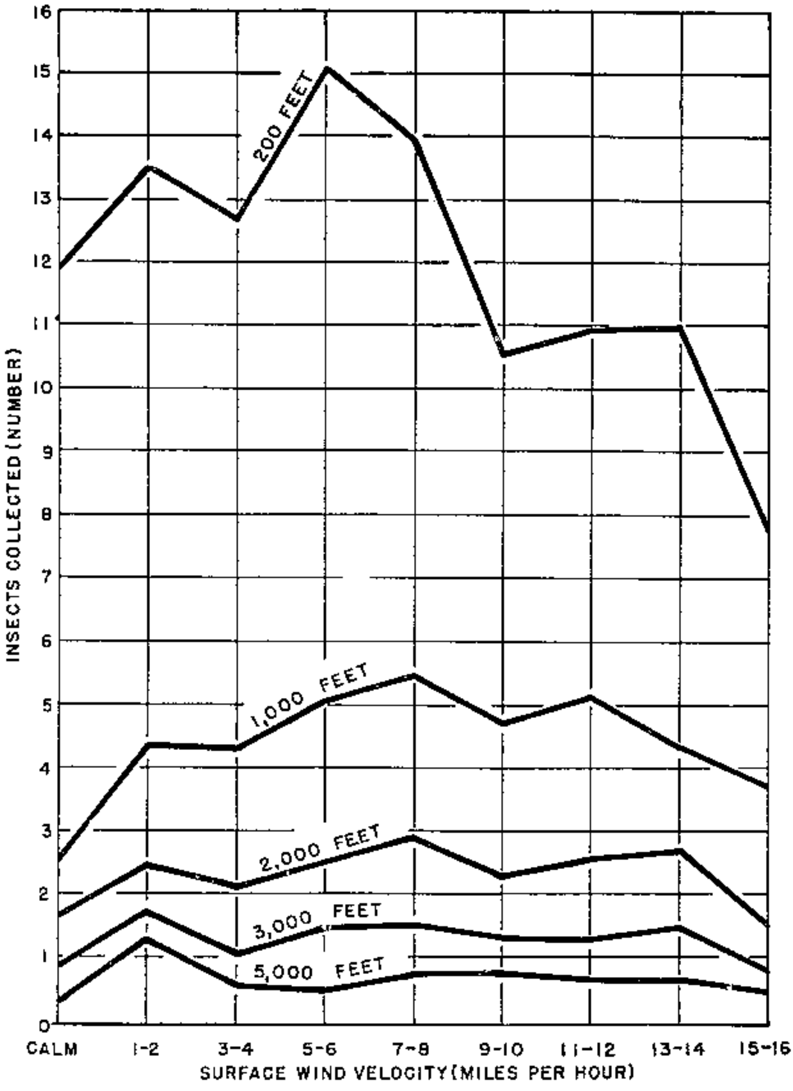


FIGURE 12.—Average number of insects collected by airplane in 10 minutes of daylight flying, as related to surface wind velocity, Tallulah, La.

The species of Hymenoptera taken at 200 feet were about equal in numbers when the surface wind velocity was from 1 to 2 and 5 to 6 miles per hour. The greatest numbers of ants were collected at velocities of from 5 to 6 miles an hour, with the next largest number at 7 to 8 miles per hour. Especially was this evident at the altitude of 200 feet. For the higher altitudes there was no apparent relation between velocities and insects taken, except at the altitude of 1,000 feet, when most ants were found when the surface wind velocity was from 7 to 8 miles per hour.

The Diptera showed a stronger reaction to the wind than any of the other orders. Their numbers taken increased from calm air, reaching a peak when the surface wind velocity was 5 to 6 miles per hour, and dropping off as the surface wind increased in velocity. At the altitude of 1,000 feet there was a rapid rise in the numbers collected, from the fewest at calm to most at the velocity of 5 to 10 miles per hour. At 2,000 feet more specimens were collected when the surface wind velocity was from 13 to 14 miles per hour.

Too few specimens of Lepidoptera were taken to show much relation to surface wind velocity. *Alabama argillacea* was taken at night during calm evenings and at wind velocities of 1 to 4 miles per hour.

Spiders were taken in greater numbers when the velocity of the wind was from 3 to 4 and from 7 to 8 miles per hour, with most specimens at 3 to 4 miles per hour. When the velocity of the wind in the upper air was observed (theodolite readings), it was found that at the altitudes of 200, 1,000 and 2,000 feet most spiders were collected when the velocity was from 1 to 2 miles per hour.

At the high altitudes of 6,000 to 16,000 feet many insects were taken when the upper-air wind velocities were as high as 45 miles per hour. The velocities at these high altitudes are significant, for when insects reach heights beyond 6,000 feet they are carried upward and doubtless great distances by the usually high winds.

WIND DIRECTION

The direction of the wind has, it is believed, determined to a great extent the course of the migrations of insects. Certain prevailing winds have been definitely used in the migratory movements of insects during various seasons of the year. Not only have birds taken advantage of seasonal wind direction, but insects as well, for many insects, as suggested long ago by various entomologists, are now known to follow the migratory routes of birds. Such avenues of travel have been mapped out both in this country and in other parts of the world. Some lines have followed a coastwise route, extending from the New England States, through Long Island, Charleston Harbor, S. C., and southward. Shannon (*66*) has brought evidence in support of a western route along the northern shores of Lake Ontario and Lake Erie, which has been followed especially by "monarchs" in their flights to the South. Another great route has been indicated along the west shore of Lake Michigan through Chicago, central and eastern Illinois, and southward to the Tropics. Routes have been suggested through the wide highways of the Great Plains and West Central States, as Minnesota, Iowa, Kansas, Oklahoma, and eastern Texas. Vast armies of monarch butterflies and dragonflies travel southward over given routes, starting in August and September at times when the general wind direction is from the north. Appearances of insects such as Lepidoptera and Odonata over the ocean have indicated to seamen the approach of the pampero of South America, a southwest wind often very violent (*65*).

It is believed that the destructive grasshopper (*Schistocerca*) which often descends in vast swarms from Montana to as far as Missouri takes all possible advantage of air currents. Hurd (*38*) states that on fair days, when the prevailing winds are from the southeast, the grasshoppers have been known to fly over the prairie for a distance of 200 to 300 miles. It has been shown that nearly all grasshoppers apparently prefer to fly with the wind. According to Tutt (*72, p. 21*) locusts, or grasshoppers, have been observed from mountains at elevations of 13,000 to 15,000 feet going in opposite directions with the differing air currents. Complete destruction of vegetation and crops from plagues of locusts are known to have been averted by the sudden change or start of the wind.

Whether grasshoppers definitely take advantage of certain air currents, especially those favorable to their migration, it is difficult to determine. However, a sudden brisk or steady wind would serve, perhaps, as a stimulus or an aid in their dispersal movements.

Bishopp and Laake (*9*) found that a blowfly, *Cochliomyia macellaria*, and the housefly (*Musca domestica*) appeared to have a tendency to go with the wind in greatest numbers, although they were found to travel also against the wind and at right angles to it. Many insects of the South are migrants and are dependent for distribution on meteorological conditions, usually being carried along by southerly winds that carry the insects northward. Often insects are swept by hurricanes from one island to another, or to a mainland where they had not previously appeared. After the southwestern gales of August 26, 1901, numbers of the "blue page" moth of Trinidad were found to have been blown to the Barbados, a distance of 160 miles, and some to Dominica, still more remote (*58*). Summer resorts along the Gulf coast have been invaded by great swarms of mosquitoes, blowing in with the winds. As soon as the wind changed its direction, the mosquitoes disappeared.

In August 1932 there was over 15 inches of rainfall in the Everglades, causing a considerable area to be flooded. A low-pressure center was moving in, with the barometer at 29.84 inches on September 4, dropping to 29.67 by September 6. Great numbers of mosquitoes (*Psorophora columbiae*) were blown in from the Everglades by the west wind which followed a tropical storm threat. These mosquitoes caused great annoyance and made it necessary to take measures to protect cattle and horses. Complete relief from this mosquito invasion came only when an east wind started blowing on September 15. Swarms of buffalo gnats, which cause tremendous destruction to livestock in the Mississippi Delta States, have been blown into various sections from the swamps of lower Louisiana, when strong winds swept the area, carrying the gnats before them, and then suddenly have been blown away with the change of the wind. Wadley according to Chapman (*11, p. 138*) considered it probable that the green bug (*Toxoptera graminum* Rond.), found so abundant in Minnesota in 1926, was carried from Oklahoma by the southerly winds in the spring of that year.

Melnichenko (*51*) found that the movement of the migrating moths of the sugar-beet webworm coincides almost entirely with the direction and speed of the air currents at the time of their migration.

Lutz conducted experiments with light traps to determine insect preference in relation to wind direction. He concluded from his collections that at least the night-flying Diptera and Lepidoptera tend to stop their flight on the leeward side of a light, and that this somewhat favors the idea that, in general, they tend to fly against the wind (*43*).

When the author was discussing the subject of insect flight and wind direction with Dr. Williams of the Rothamsted Experimental Station, England, Dr. Williams offered the suggestion that it may be possible for an insect to find it easier to land against the wind than with it, just as it is important for a pilot to fly his airplane against the wind in making a landing.

The altitude studies of 1931 substantiated those of 1930 as regards the movement of insects with or against the wind. More insects were collected on the north side of screens, or the leeward side, since the prevailing wind during this period was from the south and southeast.

Revolving screens were placed in the field so made that the screen would turn to face the wind. Most of the boll weevils caught were found on the leeward side of these revolving screens, showing that the weevils flew into or against the wind.

It is evident that most insects can fly better against a moderate wind than with it. With the wind at 5 to 6 miles an hour, insects are able to fly against the wind, for more were found in the upper air at such velocities. At higher wind velocities insects will be carried along with the air currents, even though they may be flying into the wind, since the angle of attack makes it easier for the insect to keep itself oriented. Bees make little progress against a wind having a velocity as great as 15 miles per hour (*55*). As has been previously noted, Tutt (*72, p. 72*) records that many butterflies have been observed to fly against a stiff wind, so strong are their migratory instincts.

In the airplane flights it was found that the greatest numbers of insects were taken at 200 feet when the surface wind direction was from north-northeast, south-southeast, and southwest. This appears to correspond with what is known respecting insect migration in general, i. e., that insects fly with the wind during the spring and summer when the surface prevailing winds are from a southerly direction, and from a northerly direction in the fall. When the wind directions were recorded by means of theodolite readings, it was found that most insects were collected at 200, 1,000, 2,000, and 3,000 feet when the wind was from the northeast, and at various directions for the next highest numbers of insects taken.

The spotted cucumber beetle (*Diabrotica duodecimpunctata*) is known to be migratory. Smith and Allen (*67*) have studied its habits and have found that this destructive chrysomelid migrates northward regularly during the spring and early summer and that the offspring migrate back to the South in the fall. The migration of this beetle seems to be an established habit, and certain climatic factors are taken advantage of in its accomplishment. Of these, surface wind, upper air currents, and temperature are probably the more important, the migration occurring during periods of favorable winds, that is, with southerly winds during spring and northerly winds during the fall. A temperature of 60° to 65° F. or above is also necessary. In the airplane collections the general tendency appeared to bear this out, in that in the spring months most of the beetles collected were taken at times when the wind was in a southerly direction, and in the fall when the wind was in a northerly direction. *Longitarsus testaceus*, a chrysomelid beetle of which 209 specimens were taken, was collected in greatest numbers in the spring months when the wind was from the south. This beetle, however, is not known to be migratory.

Many species collected had probably been carried in the upper air currents from distant localities. The late J. M. Aldrich stated that a small fly, *Hippelates texanus*, (Oscinidae) taken at 200 feet, is known only in the distant Southwest, and has never been collected in the Mississippi Valley. The late J. W. Folsom determined a collembolan, a species of *Entomobrya*, taken at 3,000 feet, as being probably *cubensis* Fols., known as yet only from Cuba. One of the ants collected, determined by W. M. Mann as *Ponera coarctata* subsp. *pennsylvanica* Buckley, is northern and eastern in distribution and barely extends into a number of the Southern States. M. R. Smith states that in his many years of collecting ants he has taken the species very rarely in the central and southern sections of Mississippi.

Thus it appears that the upper air currents and the direction of the wind have much to do with many serious and sudden outbreaks of insects. It is advantageous to the migration of insects from the south in the spring and for their return in the fall months. On the other hand, the direction of the wind may be a disadvantage to insects by blowing them into regions of unsuitable habitat where their food plants are not available, or where temperatures are too low or too high for them to exist. If blown out to sea they may eventually be destroyed.

CONVECTION

Convection plays an important role in the limitation of insect population in the upper air. When convection is very strong, insects flying near the surface may be quickly carried upward to enter the horizontal wind currents of the upper strata of air. Convection in the atmosphere may be divided into two classes: (1) Mechanically forced convection, as the rise of air on the windward side of a mountain, or other obstruction, and its fall on the leeward side; (2) thermal convection, involving both warming and cooling, which is by far the more important of the two; in fact, it either constitutes or is associated with all natural air movements. In reality thermal convection is only a gravitational phenomenon, consisting in the sinking of relatively cold air and the consequent forcing up of air which, volume for volume and under the same pressure, is relatively lighter (*35, p. 97*).

During the winter the temperature decreases with elevation less rapidly than it does in the summer. The temperature of the atmosphere, however, is dependent on the same factors in the winter as in the summer, including radiation, conduction, and convection, principally from the surface of the earth and the lower altitudes. Thermal convection is the spottiest, in that it is much more dependent on local surface conditions, such as plowed fields, meadows, forests, deserts, and bodies of water. Clusters of trees may create local convection currents in the air, owing to their coolness as compared with open country. The effects from water, as over lakes, swamps, and rivers, are sometimes felt up to a great height. Eddies are found over white roads, moving trains, and chimney stacks.

Mosquitoes and small Diptera have occasionally been observed swarming over treetops, steeples, and similar objects. This rising column of air is often of great importance to certain insects, as termites, by aiding in their dispersal, and to ants and bees in mating. Theodore Roosevelt, Jr., reported that at one time while making a balloon ascension he passed through a cloud of gnats drifting at a height of some 500 or 600 feet. The warm vertical currents of air thus carry upward numerous light bodies and insects even to the tops of mountains. Whenever atmospheric disturbances occur suddenly, as by convection, great numbers of insects are lifted and may be removed to distant places.

F. C. Meier of the Extension Service, United States Department of Agriculture, who made an extensive study and collection of plant spores, pollen, and microorganisms of the atmosphere and stratosphere, related that on one of his flights he met with a swarm of beetles at an altitude of 4,000 feet. The airplane was making a speed of 100 miles or more per hour, and for more than a minute he encountered these beetles. The air was exceedingly turbulent.

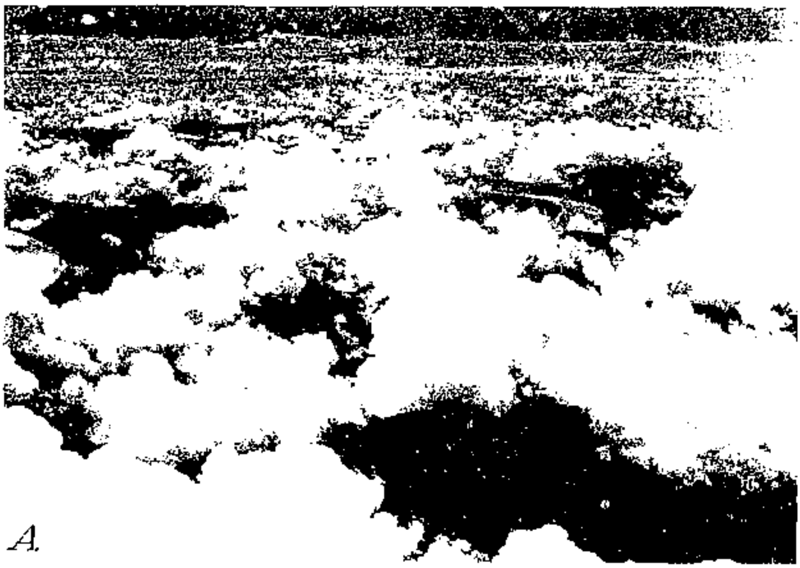
The importance of thermal convection as an aid not only to insects but to man as well may be illustrated by the interesting account of how a famous Austrian glider was guided by a flock of butterflies to the winning of a coveted prize (*1*). Many pilots of motorless planes had tried unsuccessfully to accomplish the feat of gliding from the top of the Puy-de-Dome in France to the mountain Banne d'Ordanche, lying on the other side of a wide valley. Kronfeld himself, in spite of his skill and experience, was not at all sure he could win the prize, because the conditions required that the winner hop from one peak to a height of exactly the same altitude over a valley free from such obstructions as are likely to form upgoing currents.

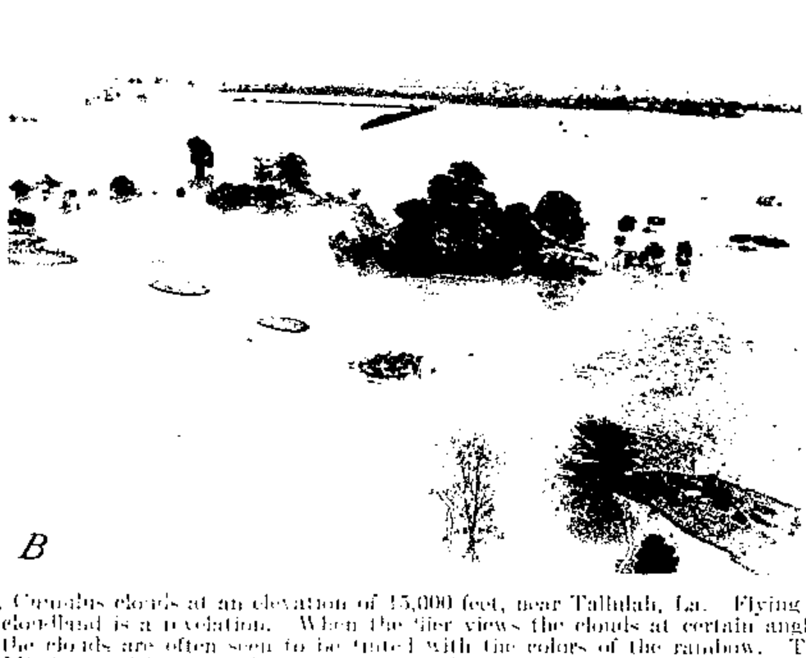
Describing his achievement afterward, Kronfeld said he was catapulted off the Puy-de-Dome at a height of 1,440 meters (about 4,500 feet) and got into the air successfully but immediately found that he could not maintain his altitude. There was no strong wind to buoy him up, and no thermal streams rising toward the sky. As he neared the foothills of the mountain on which he was to land he began to sink again. For nearly an hour he sailed about over the woods, descending ever lower and lower until he was not more than a dozen meters above the treetops. It was then, on looking about, that he saw little white butterflies standing out sharply against the dark pine forest. They were gliding, as he was, but were slowly rising. They had found the current he was looking for. So he followed them and glided into a warm stream of air that carried him upward. His courage returned, his speed increased above the trees, and he sailed out over a smooth grass sward 1,400 meters high and landed, winning the prize.

Later, in a letter to the author, Kronfeld added the following information:

> It might interest you to hear that I previously made observations about insects and the influence air currents have on their flight. Any time you see insects at greater heights, say between 6,000 or 10,000 feet or more, you can be certain that they got there through up-currents and nearly always against their will. I saw millions of insects stranded on glaciers on the Swiss and Austrian Alps at a height of about 10,000 feet. What happens is that they get carried up by currents of warm air. By the influence of the ice and snow the air gets cooled, an up-current is converted into a down draught and the insects die in the cold.

With the air calm at the surface, convection may be exceedingly strong, causing insects to be carried to great heights. The air is often rough high above, and smooth below most clouds. In the case of convection (cumulus) clouds (pl. 5, *A*), however, the air is generally smooth above and rough below. This is caused by the constant flow of air up and down. This difference in air currents was frequently observed by the writer while flying among the clouds.





A, Cumulus clouds at an elevation of 15,000 feet, near Tallulah, La. Flying in cloudland is a revelation. When the flier views the clouds at certain angles the clouds are often seen to be tinted with the colors of the rainbow. The Mississippi River may be seen in its winding course far below. *B*, Scene of the flood of 1927, caused by the overflow of the Mississippi River. The Indian mounds shown in the picture are not uncommon in the Delta region, and served as places of refuge not only for people and stock, but also for numerous insects, in their escape from the swirling flood waters.

The heat-radiating and absorbing power of green fields and plowed fields may differ markedly. Differences in surface topography contribute to differences in the amount of convection over valleys, canyons, or even bayous as in Louisiana.

The bayous there were made by the Mississippi River and form drainage canals, as it were, winding in and out of the swamps and cultivated areas. The writer vividly recalls that on a certain flight the pilot nearly lost control of the plane because of meeting a sudden downward current of air while flying over a bayou. The plane was saved from a terrific crash only by a sudden lift caused by an ascending current at the edge of a hot dry meadow which bordered the bayou. Gregg (*28, p. 46*), in discussing flying in gusty air, says:

> The resulting changes in air density give rise to vigorous convection which produces a bodily uplift or drop of an aircraft, with changes in the angle of attack as the column of ascending or descending air is entered or left. If, as sometimes happens, only a portion of the aircraft is affected by such a column, e. g., one wing is in rising air and the other is not, a decided tilting of the machine is produced. If, for instance, on entering a column of rising air, the angle of attack is so changed as to keep the machine at a constant level, an abrupt drop (popularly known as "air pocket" or "hole in the air") will occur as the column of rising air is left.

Convection is more rapid in the morning and reaches its greatest height late in the afternoon. Melnichenko (*51*), in his studies of the migration of the sugar-beet webworm (*Loxostege sticticalis* (L.)), shows that the diurnal rises and departures of the moths are always in connection with convection currents in the air, and that the diurnal flights of the moths are associated with heat convection in the air about noon. Convection usually reaches its limit at about 5,000 feet and is strongest in the lower strata. Usually the atmosphere becomes more stable and an airplane runs smoother above 1,000 feet.

It is very difficult to measure the convection in the air, owing to the difference in the air movements. During each airplane flight to collect insects, the amount of convection was judged by the "feel" of the plane in the air. The amount of vertical motion in the atmosphere was estimated in the following terms: (1) Smooth air, where the plane ran evenly with no vibration felt; (2) slightly rough, when the plane began to tilt from side to side, with slight sudden lifting and falling; (3) rough, when the machine was thrown about considerably, making it somewhat difficult to keep it adjusted (flying then became hazardous at very low altitudes, and very few "hedge-hopping" flights were ever made under these conditions, since the danger of crashing was greater); and (4) very rough, when the plane was thrown violently about, making it very difficult to control at times. Often these strong ascending air currents resulted in a sudden drop of the machine for as much as 100 feet or more. Few flights were made below 1,000 feet when the air was very rough, and even at that altitude some risk was run.

The insects taken were separated into divisions for each altitude according to the amount of convection as estimated by the pilot and the person making the meteorological records and controlling the trap. Since most of the flights were made by J. M. Yeates and the writer as observers, the convection was recorded and sufficient flights were made to compare records and reach a relatively uniform standard of measurement, with the air conditions classed as smooth, slightly rough, rough, and very rough.

At the altitude of 200 feet more insects were taken when the air was smooth than when it was slightly rough or rough. The supposition is that when the air was smooth, more insects were in the air from

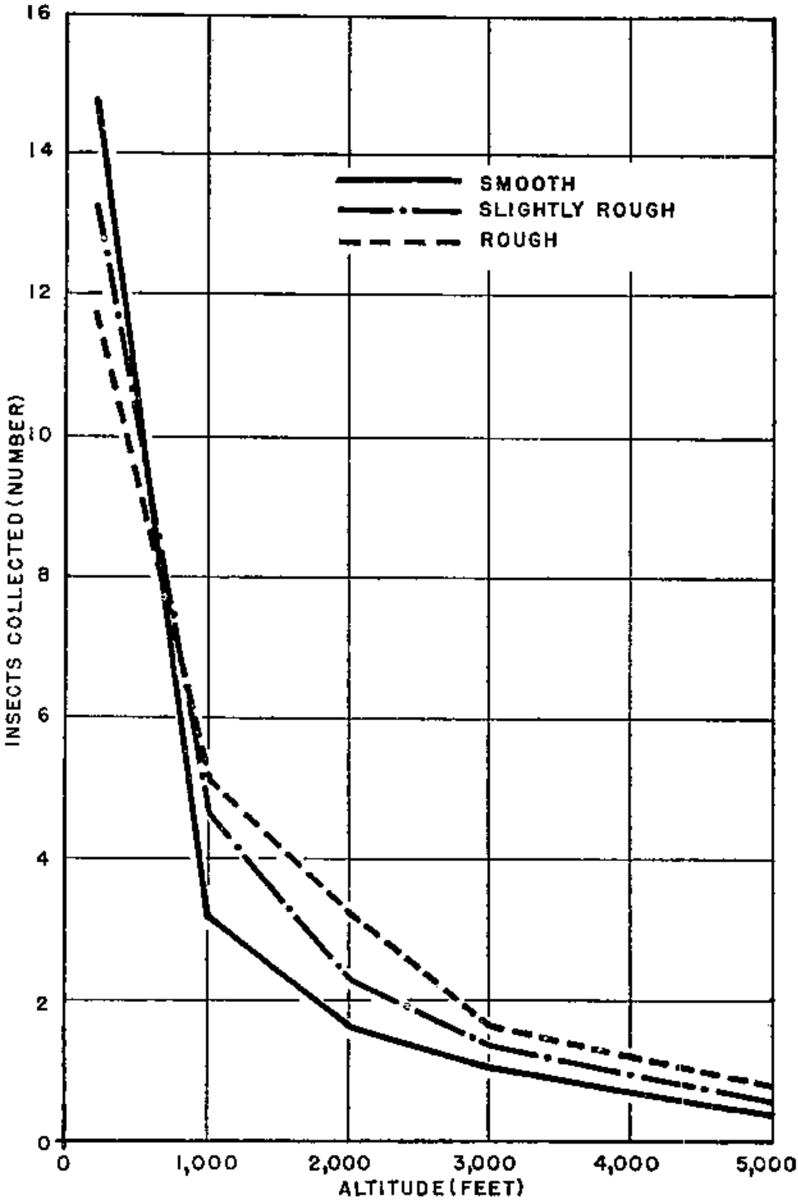


FIGURE 13.—Average number of insects collected by airplane in 10 minutes of daylight flying, showing the relation between the altitude reached by the insects and the condition of the air, Tallulah, La.

their own volition from near the surface to 200 feet, since they were flying about undisturbed with less chance of interference by air currents. At the altitudes of 1,000 to 5,000 feet, however, fewer insects were found when it was smooth, and the greatest numbers were collected when the air was rough (fig. 13).

The evident interpretation of these data is that under disturbed conditions of the atmosphere weak-flying forms, such as aphids, small Diptera, Hymenoptera, and insects of this character, of which thousands were taken, are unable to remain close to the ground but are carried up in convection currents into regions above the altitudes where they would be expected, thus giving an increase in insect population in the air. The rougher the air, the greater the numbers of insects that were found at higher levels. At lower altitudes there was a considerable modification of chance distribution, since the strong-flying insects were better able to remain close to the ground, or cling to vegetation. Under rough conditions many of the stronger flying insects doubtless did not take wing at all, and the insect population under these conditions at altitudes above 3,000 feet was found to consist primarily of the very weak fliers such as aphids. Many insects are able to regulate their flight activities to a considerable extent and are not always at the mercy of air currents unless the air is very rough and wind velocities considerable.

Chance distribution varies inversely as the square of the distance from the earth's surface. Under slightly rough and rough conditions, at somewhere between the 500 and 1,000 foot levels distribution is equal to that expected according to the laws of chance, with fewer insects than expected below 500 feet and more than would be expected above 1,000 feet. The greater the atmospheric disturbance from calm to slightly rough and rough, the greater the variation from the expected chance distribution.

Among the records of the 1,356 flights made to collect insects in the upper air, examples are numerous in which convection played a very direct part in the distribution of the insects. With the air smooth, and a breeze of 3 to 4 miles per hour, there was a greater number of insects in the air and a closer approach to the theoretical chance distribution. A wind of this strength is not sufficient to interfere with normal insect flight. It is not to be inferred, however, that because the air is smooth there is no convection, as often it was very strong. Especially was this noted during clear summer days when thermal convection and attending movement so mixed the surface layers of the air with those next above as to bring both to a more or less common velocity, which was greater than the undisturbed or night surface velocity, and less than that of the undisturbed upper layers before their mixture with the lower layers (*35, p. 137*).

After insects are up in the smooth air and then are caught in strong ascending and horizontal currents of air, they will be carried upward from elevation to elevation. A few of the more outstanding and interesting examples are given in table 13, in which convection was the apparent cause of the distribution of the insects in the upper air.

Often when it was slightly rough at 200 feet and smooth above, insects would be taken in abundance at the lower altitudes and few or none taken above 1,000 feet. An example of this is shown in the flight of July 2, 1930 (table 13). On this flight 57 ants of the species *Solenopsis xyloni* were taken at 200 feet and one at 1,000 feet.

There were many flights when the air was slightly rough at 200 feet, and as altitude increased either convection or wind velocity increased, or both, and insects were carried upward and taken in greater numbers. The flights of September 18, 1929, represent this condition (table 13).

TABLE 13.—*Examples of interesting cases of distribution of insects in the upper air in relation to air currents, Tallulah, La.*

Date	Time	Sky condition	Elevation	Temperature	Wind		Air condition	Insects taken
					Velocity	Direction		
			Feet	*° F.*	*Miles per hr.*			*Number*
Aug. 5, 1929	3:25 p. m.	Partly cloudy	Surface	89	5	E.	------	------
			200	89	5	E.	Smooth	18
			1,000	86	6	E.	do	7
			2,000	81	5	NE.	Slightly rough	6
			3,000	79	4	ENE.	do	7
			5,000	72	5	ENE.	Smooth	10
Sept. 18, 1929	11:35 a. m.	Clear	Surface	78	11	NE.	------	------
			200	80	15	NE.	Slightly rough	17
			1,000	78	18	NE.	Rough	10
			2,000	73	23	NE.	do	10
			3,000	68	29	NE.	do	2
			5,000	64	27	NNE.	do	8
Do	1:19 p. m.	do	Surface	85	12	N.	------	------
			200	85	16	NNE.	Slightly rough	8
			1,000	79	19	NNE.	Rough	13
			2,000	76	23	NNE.	do	8
			3,000	70	20	NNE.	do	4
			5,000	63	34	NNE.	do	2
Oct. 21, 1929	2:42 p. m.	Partly cloudy	Surface	71	13	NW.	------	------
			200	74	13	NNW.	Rough	35
			1,000	71	13	NNW.	do	20
			2,000	66	18	NNW.	do	42
			3,000	59	20	NNW.	Slightly rough	19
			5,000	50	21	NNW.	do	0
Nov. 7, 1929	1:45 p. m.	Clear	Surface	70	8	N.	------	------
			200	72	9	N.	Rough	55
			1,000	67	9	NE.	do	51
			2,000	62	13	NE.	do	11
			3,000	58	8	NE.	Smooth	3
			5,000	54	6	SSE.	do	1
May 15, 1930	9:25 a. m.	do	Surface	78	4	S.	------	------
			200	81	5	S.	Smooth	38
			1,000	79	10	S.	Slightly rough	23
			2,000	69	15	SSW.	do	12
			3,000	67	13	SSW.	Smooth	10
			5,000	59	12	WSW.	do	1
July 2, 1930	4:05 p. m.	Very cloudy	Surface	85	6	NW.	------	------
			200	88	6	WNW.	Slightly rough	69
			1,000	86	6	NNW.	Smooth	11
			2,000	81	7	NNW.	do	2
			3,000	70	8	NNE.	do	1
			5,000	71	11	N.	do	0
Aug. 11, 1931	2:05 p. m.	Partly cloudy	Surface	82	10	N.	------	------
			200	81	12	NNW.	Rough	16
			1,000	76	15	NNW.	do	11
			2,000	70	16	NNW.	do	4
			3,000	65	17	NNW.	do	3
			5,000	55	13	NNW.	do	13
Aug. 31, 1931	2:35 p. m.	do	Surface	86	7	NNE.	------	------
			200	84	11	N.	Rough	26
			1,000	81	15	N.	Slightly rough	6
			2,000	76	15	N.	Rough	18
			3,000	69	14	N.	do	6
			5,000	63	11	NNE.	do	2
Oct. 16, 1931	2:10 p. m.	Clear	Surface	76	6	N.	------	------
			200	74	7	NNW.	Rough	60
			1,000	70	9	NNW.	do	20
			2,000	66	10	NNW.	do	24
			3,000	62	10	NNW.	do	31
			5,000	51	10	NNW.	do	0

When the air was slightly rough or very rough, insects were usually taken in greater numbers in the higher altitudes. Examples of this are found in the flights of October 21 and November 7, 1929, and August 11 and 31 and October 16, 1931 (table 13). In the collections on the first two of these dates a great variety of insects of all sizes were caught at the lower altitudes.

At 2,000 feet there were taken *Orius* (*Triphleps*) *insidiosus* and *Stirellus obtutus*, which are small Hemiptera but with good wing expanse. Spiders were abundant at 200 to 3,000 feet.

The species of Heteroptera collected at 5,000 feet in the flight of August 11, 1931, are especially interesting. These were *Lygus pratensis*, *Geocoris punctipes*, *Nysius ericae minutus*, and *Allocoris* (*Thyreocoris*) *pulicaria*. The first three species are comparatively strong fliers, with correspondingly good wing expanse in proportion to their body weight, giving added buoyancy. The negro bug *Allocoris pulicaria* is a small, hard-shelled, shiny-black bug, which resembles a beetle. While this species is a strong flier, it does not have much wing expanse in comparison with its body weight. The rough air at all altitudes, with wind velocities of 10 to 17 miles per hour, probably accounts for its occurring at this height.

The species collected in the flight of August 31, 1931, varied in size, weight, and buoyancy. At the altitude of 200 feet the Heteroptera taken were *Orthea basalis*, a light insect with considerable wing expanse, and *Trichopepla semivittata*, a rather large and heavy pentatomid. The Homoptera included four specimens of *Delphacodes puella*, a very small fulgorid having considerable buoyancy. *Liburniella ornata*, a small fulgorid with a great wing expanse in comparison with its very small body, was taken at the altitudes of 2,000, 3,000, and 5,000 feet.

At the time the flight of October 16, 1931, was made great numbers of insects were out, primarily owing to a good rain in the morning after a long dry spell. The day cleared up, insects appeared in great abundance, and as convection was very strong they were carried upward. Many strong fliers were collected, such as the large sharpshooter *Oncometopia undata*, taken at 200 and 1,000 feet, and a female red-legged grasshopper (*Melanoplus femur-rubrum*). *Graphocephala versuta* was taken at all altitudes, with 2 at 200 feet, 1 at 1,000, 11 at 2,000, and 7 at 3,000 feet. The psyllids *Pachypsylla celtidis-mamma* and *P. celtidis-gemma* were also abundant at all altitudes up to 3,000 feet. One butterfly, *Junonia coenia*, was caught at 200 feet, and numbers of spiders were taken at all altitudes.

INSECT ACTIVITY AT NIGHT

The atmospheric conditions at night are the reverse of the daytime conditions. Relatively calm air generally prevails in the lower strata at night; there is little thermal convection, and the surface friction holds the lower air levels comparatively quiet at the time of a light to moderate wind. In general, the maximum wind velocity in the daytime is reached between noon and 3 p. m., and the minimum at night between midnight and 6 a. m. At sunset the ground begins to cool, and, being a much better radiator than the atmosphere, it often cools, especially during clear nights, to a decidedly lower temperature than the air at some distance above it. Hence, late at night when the sky is clear and the wind light, the temperature of the lower layers of air usually increases with increase in height, and even when there is sufficient wind to prevent this temperature inversion, as it is called, the lower atmosphere still is colder than it would be without this radiation. The amount of surface cooling depends jointly upon the rates of radiation to and from the sky and the time involved (*35, p. 42*).

Insects that are in the higher levels (above 3,000 feet) during the day tend to be brought down toward the surface at night, with the descending cool air currents, or because of failure of upward convection currents, while those on the surface are carried upward in the ascending warm air. In this way there is apparently a concentration of night-flying insects from the surface and the diurnal insects which have been left in the upper air from the day. On many flights insects were collected in greater numbers at the higher altitudes than they were at the lower levels.

The data from three flights which are outstanding examples are given in table 14 to show the relative distribution of insects in the upper air at night.

TABLE 14.—*Examples of the distribution of insects at night (air smooth) under various types of weather conditions, Tallulah, La.*

Date	Time	Sky condition	Elevation	Temperature	Wind		Insects taken
					Velocity	Direction	
			Feet	*°F.*	*Miles per hour*		*Number*
Oct. 14, 1929	10:55 p. m.	Clear, very bright moonlight.	Surface	58	5	NE.	----
			500	58	----	----	59
			1,000	77	----	----	9
			2,000	70	----	----	2
			3,000	65	----	----	1
			5,000	58	----	----	10
Oct. 13, 1930	10:34 p. m.	Calm, half moon, clear.	Surface	60	0	----	----
			500	75	6	NE.	33
			1,000	74	12	ENE.	16
			2,000	69	12	E.	15
			3,000	65	15	ENE.	3
			5,000	58	17	ENE.	2
Oct. 25, 1930	8:09 p. m.	Calm, very dark, clear.	Surface	72	0	Calm	----
			500	84	0	Calm	12
			1,000	83	15	E.	8
			2,000	79	13	E.	4
			3,000	72	15	E.	4
			5,000	62	14	E.	18

On the flight of October 13, 1930, one microlepidopteran belonging to the family Pterophoridae was taken at the altitude of 1,000 feet. August Busck, who determined the species of microlepidoptera taken in the upper air, made the following comment:

> An interesting collection. All of these are minute, weak-flying species, which voluntarily would not go more than a few yards from the place they hatched out. Air currents are solely responsible for their being taken in the upper air. The wide distribution of some species of *Pterophorus* is accounted for in this manner.

On the same flight two mosquitoes, females of *Aedes vexans*, were taken at the altitude of 5,000 feet.

In general it may be said that at night insects were in greater numbers in the upper air at all altitudes when the air was smooth. In most instances, however, there was considerable wind in the upper air even at times when the air was calm at the surface. Insects were often taken in greater numbers at 1,000 feet and above than at the lower altitude of 500 feet, during the same flight.

LIGHT INTENSITY

The numbers of insects appearing during the time from daybreak to dark varies considerably. The actual hour or period when insects are most abundant in the air depends upon the amount of light and the meteorological conditions most favorable for their activity.

Insects which require considerable moisture or high humidity are not usually found flying during the daytime, as they prefer deep shade or dark places.

It has been suggested that the time of activity of certain crepuscular insects, such as mosquitoes, depends on the light being of a definite intensity. There are, however, other conditions which point to the intensity of light as secondary. Light and heat are inseparable in their effects, for with less light, as on very cloudy days, mosquitoes become active, since evaporation is not in general so great as on sunny and hot days.

Insects react positively or negatively to light and their activity varies according to the amount of light. Thus great numbers of insects fly by day; other species, not until late in the evening or after dark. Sunshine has a stimulating effect on most insects, but if the rays of the sun are too nearly direct and intense, many insects, especially the immature stages, will be killed.

The distribution of insects is influenced by the intensity of light. Grevillius (*29*) has shown that some insects will concentrate in the best illuminated part of a cage, even if that part is kept cooler than the others. In other words, within the limits from 60° to 71° F. temperature is less important than light. One controlling factor in the oviposition of the codling moth is the intensity of light, as, according to laboratory experiments, the moth usually deposits its eggs in the evening, or at night (*39*).

Marcovitch (*48*) has shown in experiments with *Aphis sorbi* that just as the short days of the fall stimulate the production of fall migrants, so the lengthening days of spring stimulate the production of spring migrants. The length of day in relation to the time of hatching appears to be an important factor influencing the early or late production of migratory forms.

Light seems to be the principal factor in the activity of bees. In one instance, after a storm, though the temperature remained low, honeybees resumed their activities (*42*).

There are many meteorological factors which contribute to the maximum activity of insects during the daytime; the more important of these, other than light intensity, are temperature, humidity, convection or air currents, and wind velocity. The surface wind velocity at night is usually less than during the day. Convection starts at sunrise and reaches its maximum intensity at 4 p. m.

Temperature and light are inseparable in their effects. Melnichenko (*51*) has shown that the influence of light upon the flight activity of the sugar beet webworm was extremely interesting in that the moths were negatively phototropic when the temperature was not lower than 24° or 22° C. and positively phototropic when the air temperature at the flight level of the moths fell to 20° or 19° C.

In another study of the numbers and species of insects collected in the upper air, the day flight periods were divided into four major groups. These were: (1) Daybreak to sunrise and shortly after, or the hours from 5 to 7 a. m.; (2) morning flights from 8 a. m. to noon; (3) afternoon flights from 1 to 5 p. m.; and (4) sunset or late evening before dark, from 6 to 8 p. m.

It was found that at the altitudes of 200 to 5,000 feet a few more insects were collected during the time from daybreak to sunrise than during the morning flights at the same altitudes. At this time of the day, or early in the morning, there is a concentration of night-flying insects at all altitudes; these insects are added to the day-flying insects which begin activity at the break of dawn and continue to increase in numbers as the light increases or the temperature rises.

In the afternoon, when convection is strongest, the upper air usually becomes slightly rough to rough, wind increases in velocity, and insects are carried upward in greater numbers. At the altitudes of 3,000 and 5,000 feet, however, fewer insects were taken than for the same altitudes at daybreak.

At sunset the maximum numbers of insects are found. Many night-flying insects are starting to fly, and together with the day forms there is an accumulation of insects. At 3,000 feet, however, the number began to drop off, but at 5,000 feet more insects were collected than during the morning and afternoon flights. Thermal convection has practically ceased at this time, and insects which were carried to altitudes above 5,000 feet are beginning to descend only to meet with many night-flying insects.

The orders Heteroptera, Homoptera, Coleoptera, Hymenoptera, and Diptera were taken in greatest numbers in the daytime between 5:30 and 6:30 p. m.

At night more Diptera were collected at 11 p. m., while Coleoptera, Homoptera, and Heteroptera were in greater numbers earlier in the evening, or from 8 to 9 p. m.

During 1929 and 1930, 19 days were given to flights to determine at what hour of the day insects were most abundant. Nine days of flying were made from March to October in 1929, and 10 days from March to August in 1930. An average of six flights were made for each day, and on several days seven or eight flights were made. The flights usually started at or before sunrise, were begun every other hour, and ended from 5 to 6 p. m. In the 120 flights there was found to be no direct relation between the maximum numbers of insects caught and any particular hour of the day. On some days the greatest numbers were taken early in the morning, at 6, or at 8, or 11 a. m. Sometimes the maximum numbers were taken in the afternoon from 1 to 5 p. m. These results simply show that the time of day had little relation to the maximum or minimum numbers of insects collected. It was found that the greatest numbers of insects were taken when the sky was clear, when the air was smooth at the ground surface, and when the temperature ranged from 64° to 90°, with a peak activity at 75° F.

The numbers of insects collected had a close relationship to temperature. In March, with low temperatures early in the morning, few insects were taken, but the numbers increased with the rise in temperature. It was undoubtedly the temperature increase from 40° to 81° F. which caused the increase in the numbers of insects found in the air.

During the summer months temperature had the same effect, since insects were at times just as abundant early in the morning as at any other time of the day, regardless of light. For the 120 flights from March to October, the results show a temperature correlation, with fewest insects collected in ranges of from 36° to 58° F. Insects begin to be active at a minimum temperature of approximately 60°, becoming increasingly active and reaching their peak in the range from 76° to 86°, then gradually dropping off from 87° to 92°, with a minimum activity beyond 94°. Therefore, with a later time for sunrise in the winter and spring months insects do not begin activity until temperatures increase as the day advances. In the summer and fall months, with the sunrise earlier in the morning, and correspondingly higher temperatures, insects start flying at sunrise.

COLLECTIONS BEFORE AND AFTER DARK

It is generally thought that some insects are more active as twilight approaches than at any other time, while others cease to be active or are never seen. As darkness arrives some species are seen which were not observed at twilight. At first it may be considered that this decrease or increase in the numbers and species of insects flying at this time is in direct proportion to the intensity of light. But, as stated, light may be secondary in its effect on insect movement, for the conditions of light and heat are inseparable in their effects. Evaporation is retarded and relative humidity increases at night, and many insects are more active under the conditions of high humidity and lower temperatures of night.

In order to determine to some extent the exact numbers of insects that were flying before and after dark, flights were made a few minutes before dark and then immediately after dark. Each flight was so timed that 10 minutes were flown at the altitude of 500 feet during a period of considerable light, immediately after sunset or twilight. Then 10 minutes of flying time was made at 1,000 feet after dark. The airplane then descended to the altitude of 500 feet to fly another 10 minutes in complete darkness. The flights were made each year during August to November in 1929, 1930, and 1931. In this way collections were made showing the numbers and species of insects which were in the air before and after dark at the time of each flight.

Nearly twice the number of insects were taken before dark as after dark. The orders of insects that showed considerably larger numbers taken before dark than after dark were Homoptera, Coleoptera, and Diptera.

The Homoptera were represented mostly by Cicadellidae, and more than twice the number of these were taken before dark than after dark. Although more Heteroptera were taken before dark, a few species were taken in greater numbers after dark, and a few species appeared only after dark. Nearly twice as many *Arctocorixa modesta* were found after dark as before dark.

The Coleoptera comprised mostly specimens belonging to the families Staphylinidae and Carabidae, and were taken mostly before dark.

The Lepidoptera were slightly more abundant after dark, the Noctuidae especially. Nine specimens of the cotton leaf worm moth (*Alabama argillacea*) were taken after dark at 500 feet, and only one specimen before dark. The fall armyworm moth (*Laphygma frugiperda*) was taken mostly after dark.

The Neuroptera were represented by species of *Chrysopa* or lacewing flies taken before dark.

The Hymenoptera appeared to be mostly day-flying insects, although several species were found at 500 feet after dark. Among the species taken after dark were one clover-seed chalcis, *Bruchophagus gibbus*, *Meteorus vulgaris*, *Euplectrus comstockii*, and *E. platyhypenae*.

Approximately one-third more Diptera were taken at 500 feet before dark than were found after dark. Mosquitoes appeared in about equal numbers before and after dark. *Culicoides varipennis* and *C. crepuscularis*, or "punkies," were taken after dark.

MOONLIGHT

It was of interest to determine how the activity of insects in the upper air was affected by moonlight. Hora (*32*) noted in India that swarms of Mayflies appeared usually about the period of full moon. He studied the dates of swarming of Mayflies in other countries and found with each species that the appearance of swarms coincided with a definite moon phase.

In order to have comparable data, flights at 500 feet from May to September, inclusive, when the moon was half full to full, were compared with collections made on nights with no moonlight, and there appeared to be a tendency for insects to be more abundant in the air on nights when there was considerable moonlight. Considering individual flights made during the several years of collecting, it was found that the maximum numbers were taken mostly on nights of bright moonlight. Moonlight nights when only a few insects were collected were usually characterized by relatively low temperatures.

Coleoptera, Hymenoptera, and Diptera were taken in greater numbers on moonlight nights than on dark nights. A few more Heteroptera, Homoptera, and Lepidoptera were taken on dark nights than on moonlight nights.

The presence or absence of moonlight made no apparent difference in the height at which insects were collected, for insects were taken up to 5,000 feet about as many times when it was dark as when it was moonlight.

CLOUD CONDITIONS

The intensity of light, the temperature, the humidity, evaporation, and other meteorological factors are directly affected by the cloudiness of the sky. Insects are sensitive to the atmospheric changes resulting from the degree of cloudiness from a clear to an overcast sky. When clouds obscure the sun, cutting out the direct rays and lessening the amount of light, the temperature drops, and the rate of evaporation is lowered. Many insects prefer clear and sunny days, whereas others are more active when the sky is partly cloudy or overcast.

Uvarov (*73, p. 33*) and Parker (*56, p. 65*) report that nymphs of *Melanoplus mexicanus* and *Camnula pellucida* stop their march even when the sun is obscured by a small passing cloud. This is due, apparently, to the sudden change in the intensity of light or to the drop in temperature. In the cases of nocturnal Lepidoptera, cloudiness increases the number of insects coming to light, but this is probably due to the increase in air humidity caused by cloudiness (*62*). The activity of honeybees during cloudy intervals on sunny days is lowered. One bee visits on the average from six to nine flowers in a minute when the sun shines, and only five or six when there are clouds. The actual cause of this difference remains unknown (*78*).

The beautiful underwing moths of the genus *Catocala* remain in the deep woods, at the bases of trees or under an overhanging bank of a stream, during hot sunny days. They prefer these dark, wooded places where they are hidden from direct sunlight, and remain there quiet and motionless unless disturbed. During a very cloudy day, however, they become restless and may be seen flying about in the woods from tree to tree and even flying out into the open spaces. Mosquitoes usually become more active on a cloudy day.

Clouds have a direct relation to sudden changes in air temperature, causing strong air currents, eddies, and gustiness. Clouds are associated with vertical convection, resulting from the local application of heat, and the consequent forming of strong horizontal temperature variations, which may often be observed in the rapid boiling and rolling motions of the upper portions of large cumulus clouds. These conditions were frequently met with when flying on days when the sky was partly cloudy, the air usually being rough because of these strong vertical convectional currents of air, and the plane was sometimes difficult to control.

For every flight made, both day and night, the cloud condition was recorded. When the sky had a few scattering clouds or was less than three-tenths covered, this was considered as a clear day, as these few clouds could have no effect on insect activity. When the sky was from four- to seven-tenths covered with clouds, this was considered as partly cloudy; beyond this the sky was recorded as very cloudy or overcast.

The greatest numbers of insects were taken on days and nights when the sky was partly cloudy. For the day collections the difference was small between sunny and partly cloudy days, but there appeared to be a tendency for more insects to be found on partly cloudy days. On days when the sky was overcast there was usually an appreciable drop in the numbers of insects taken. At night nearly twice as many insects were collected on partly cloudy nights as on clear nights; more insects were also collected on nights when the sky was overcast than on clear nights.

The orders of insects showed some relation, in the numbers taken, to cloud conditions. Homoptera, in general, indicated only a slight relation to the degree of cloudiness in the daytime. At 200 feet more specimens were collected on partly cloudy days, but at 1,000 feet more were taken on clear days.

Heteroptera were collected at 200 feet in greatest numbers on partly cloudy days, with fewest when the sky was overcast. For the altitudes above 200 feet for the day collection the differences were not appreciable. At night, however, the numbers taken were fewest on clear nights, increasing to their maximum on very cloudy nights.

More Coleoptera were taken at 200 feet on clear days, the numbers gradually dropping off as the sky increased in cloudiness.

So few Lepidoptera were taken in the day flights that no comparisons are possible. At night more than twice as many specimens were found on partly cloudy nights as on clear or overcast nights.

Diptera and Hymenoptera did not show a very definite relationship to cloudiness in general, although more were taken on partly cloudy days.

Spiders were collected in considerably greater numbers on clear days. This may be owing to the decrease in humidity in the air, for when it is partly cloudy and overcast the relative humidity is generally greater, and thus moisture would collect on the gossamer webs, making them less buoyant.

Doubtless the reason that a more definite relationship between the number of insects taken in the upper air and the cloud conditions was not evident is that when the flights were made the sky may have been from four- to six-tenths cloudy, but not immediately over the territory where the plane flew, or vice versa. The sky may have become cloudy within a very short time, or the sky may have been partly cloudy, or almost overcast, when the plane left the ground, but clear before the end of the flight. Accordingly the collections were subject to these variations in cloud conditions.

PRECIPITATION

Precipitation had a definite effect on the numbers and species of insects found in the upper air. It is scarcely possible to estimate the effects of excessive rainfall on the numbers of insects by exact observation; yet when a period of drought is followed by sudden rains, one is able to observe an increase in the insect population. Excessive rainfall checks the flight of many insects, reduces their progeny, especially of subterranean species, by drowning, or causes fungus growths on many insects such as aphids. Hunter and Pierce (*37, p. 113*) found that a moderately cold winter, with temperatures frequently near the fatal zone, and excessive precipitation, is very unfavorable for the boll weevil, but that a winter with little precipitation and a temperature within the zone of fatal temperatures is much more unfavorable. Frequent rains late in the spring and in summer are conducive to an increase in the boll weevil population.

On the other hand, deficient rainfall checks aquatic insects, and the lack of rain kills food plants, making it difficult for larvae or nymphs to mature. A long period of drought causes the ground to become dry, making it difficult for ground insects to emerge through the hard soil, or greatly delaying the emergence of certain species. But if this is followed by a sudden rain, the insects in the soil often emerge in great swarms. J. C. Bridwell has stated that in various excessively arid regions, such, for instance, as the Kalihari Desert of west-central South Africa, the normal dry condition is interrupted at intervals of perhaps 10 years by seasons of excessive rainfall. With such wet seasons there appear in vast numbers the strange insects peculiar to that region but not apparent during the long intervening dry period. Similar mass emergence of dormant drought-sealed insects has been noted in various arid regions, and sometimes in the Sonoran region of the United States.

On various occasions the effects of drought, excessive precipitation, or sudden rains were observed while insects were being collected by airplane. A few examples are given to represent these conditions.

In April 1930 less than one-half inch of rain fell, and there was no rain of any importance until May 7, when one-half inch was recorded. On this day insects increased greatly in numbers in the upper-air collections, averaging 58 insects per flight, with a maximum of 79 insects in one flight. The families Aphiidae and Psyllidae predominated in the collections. During May the precipitation amounted to nearly 10 inches, and insects were taken in greater numbers than in any other month of the year.

During June 1930 no rain was recorded. On the morning of July 2 the first rain fell. Insects became exceedingly abundant immediately after this first light rain. Seven flights were made on this day, with an average catch of 35 insects per flight and a maximum of 83 specimens in one flight. Ants appeared in swarms in the air, and 76 ants were collected up to 3,000 feet, including specimens of *Monomorium* *minimum*, *Crematogaster* sp., *Solenopsis xyloni*, and *Aphaenogaster* sp. Aphids and thrips were also abundant. Very little rain fell in July, and scarcely enough in August, September, and October to relieve the drought. Then from November 11 to 14 more than 2 inches of rain fell, ending at noon on November 14. The sky became clear and the afternoon was very warm and sunny. Insects were unusually numerous in the air. A flight was made between 1:40 and 3:08 p. m., at the altitudes of 200 to 5,000 feet, and 189 insects were taken. This was the largest number of specimens collected on any single day flight. The predominating insects taken belonged to the families Cicadellidae, Psyllidae, Chrysomelidae, and Carabidae, and there were 23 specimens of ants, winged males of *Crematogaster* sp.

During September 1931 and up to October 16 there was scarcely any precipitation, and few insects were taken in the flights made during the daytime. On the morning of October 16 nearly 1 inch of rain fell. A flight was made in the afternoon, on which 136 insects were taken at altitudes of from 200 to 5,000 feet, with 31 specimens at 3,000 feet. This was the second largest number of specimens taken on any flight. The insects belonged mostly to the families Cicadellidae, Psyllidae, Mycetophilidae, Eulophidae, and Pteromalidae. Many spiders were also taken up to 3,000 feet.

Many other examples might be given to illustrate the effect of precipitation as a controlling factor in the increase or decrease of numbers of insects in the upper air. During the months when precipitation was excessive and temperatures low, however, insects dropped off to a minimum.

ELECTRICAL STATE OF THE ATMOSPHERE

On the approach of a thunderstorm insects are unusually active. Dragonflies have been seen in great abundance just before thunderstorms. Collectors of moths in Europe are also in general agreement that on heavy, still nights, with thunder in the air, moths are much more active and numerous than at other times. Certain insects migrate just before or immediately after thunderstorms.

The movements of air currents in and preceding a thunderstorm are often very rapid, with the wind blowing outward in front of and in the general direction of the travel of the storm. Descending currents in a thunderstorm may stir up insects to a considerable degree.

Kestner (*40*) observed that in man a nervous depression is usually found during a decline of the barometer on sultry days preceding thunderstorms. He raises the question about the possible existence of substances in the higher air levels, formed by the radiation of the sun and driven down by the descending air currents, which may be responsible for lower blood pressure in man and cause his depressed feeling. What effect such a condition would have on insects has never been determined, little being known regarding this subject.

It has been suggested that the increase in numbers of nocturnal insects flying before a thunderstorm is due to the electric state of the atmosphere, or to some meteorological factor such as pressure or humidity. That the ozonization of the atmosphere during a thunderstorm causes insects to remain inactive for a long time after the storm, owing to the stupor produced by the ozone, has been held by Gourdon (*27*). Ozone is present in only very small quantities in the lower atmosphere, since in the presence of moisture at ordinary temperatures

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ozone soon reverts to ordinary oxygen. Ozone is present in the stratosphere, since the extreme ultraviolet radiation, such as there is every reason to believe is emitted by the sun, in passing through cold dry oxygen converts much of it into ozone; and it has long appeared exceedingly probable that this substance must exist in appreciable quantities in the outer air (*35, p. 88*). The peculiar odor often noted after a storm is not that of ozone, but is due to nitrogen peroxide according to Humphreys. The quantity of ozone in the atmosphere is extremely small, usually 1 part in 1,000,000, and there is much more during the winter than during the summer (*52, p. 13*).

Since ozone is practically absent in the lower atmosphere and since its amount is greater in winter than in summer, ozone could bear no relation to the behavior of insects.

Only a few flights were made at times when thunderstorms were approaching, since flying conditions were unfavorable, in fact it was dangerous to fly. The air was never smooth on the surface, and was slightly rough to rough at all altitudes. Observations were made on these occasions to determine what effect lightning and thunder might have on the activity of insects in the air. It was found that the numbers of insects collected under such conditions were usually above the average. Insects were taken at all altitudes, from 200 to 5,000 feet. Those especially abundant were aphids and leafhoppers. Among the Coleoptera, staphylinids were noticeably abundant.

It would be difficult to determine what effect lightning and thunder have in the activity of insects. It is doubtful whether there is any direct relation between the numbers of insects taken in the upper air and the electric state of the atmosphere when thunderstorms are imminent, since other conditions, as wind, humidity, barometric pressure, and temperature, disturb insects.

EFFECTS OF THE MISSISSIPPI RIVER FLOOD OF 1927 ON THE INSECT POPULATION OF THE AIR

The extensive and destructive floods in the Mississippi Valley during the spring and summer of 1927 are well remembered. The flooded area included an almost continuous strip in some places 30 miles in width along the Mississippi River reaching from New Madrid, Mo., to the Gulf of Mexico.

The flood at Tallulah, was caused by the breaking of Cabin Teal levee some 8 miles northeast of the town, on May 3, 1927, and the water covered the territory in and about Tallulah to a depth of from 1 to 15 feet (pl. 5, *B*). A part of the country opposite Tallulah on the Mississippi side of the river was not flooded, since the land is much higher, especially at Vicksburg. On the Louisiana side there was considerable territory at Lake Providence, 28 miles north of Tallulah, which was not overflowed. Most of the water had receded by August 1, although the lowlands and swamps were covered for several months longer.

It is of importance to know what effect these flood conditions had on the insect life within the territory covered with water. One of the most conspicuous effects was the migration of vast numbers of ants. Trees, shrubbery, and even houses that protruded above the rushing currents of water formed places of refuge for ants. Often the ants, bringing along their eggs, formed in a ball at the top of a plant, only to be destroyed as the waters washed them away.

Practically everything in the path of the overflow was directly or indirectly affected. Considerable vegetation was destroyed, and much of it was covered with water for several months. Probably the majority of the adult winged insects escaped, but may species were prevented from feeding or depositing their eggs, and immature stages undoubtedly were killed, especially those forms near the ground.

Many species became more abundant after the overflow, probably because of the destruction of their parasitic and predacious enemies. It has been observed by Coad (*12*) that certain insects became abnormally abundant and injurious, and that in some cases this increase in numbers and abnormal injury was noticed almost immediately after the water receded, while in others the effect was slower and lasted for several years. The larvae of the fall armyworm (*Laphygma frugiperda*) and the bollworm (*Heliothis obsoleta*) were exceedingly abundant and caused considerable damage, becoming injurious immediately after the water receded.

Other insects which were formerly injurious, such as the cotton aphid (*Aphis gossypii*) and the cotton flea hopper (*Psallus seriatus*), were afterward extremely scarce. The cotton aphid was scarce especially during 1928. The wild host plants of the cotton flea hopper were killed, and until these plants were again established this cotton pest did negligible damage.

The boll weevil was practically destroyed in the flooded area, but on small patches of isolated cotton on protected places or high ridges the boll weevils found refuge, and those places served as nuclei of reinfestation. The flood had no effect on the cotton leaf worm, since this insect migrates into the cotton territory.

A number of flights were made over a nonflooded area at Mansfield, La., about 165 miles west of Tallulah. This territory was not comparable with that of Tallulah, as it had a somewhat different type of vegetation. It had been quite dry there during the summer and insects were accordingly scarce.

For an exact comparison seven flights each were made over the flooded and nonflooded territory at Tallulah during September 1927. The flooded territory consisted of an area adjacent to the Mississippi River and was comparatively narrow. It was therefore possible for great numbers of native insects to escape the rushing waters.

At the altitude of 200 feet over eight times as many insects were taken over the nonflooded area as were collected over the flooded territory. At altitudes of 1,000 to 5,000 feet, however, the usually expected numbers were collected. Over the flooded area eight times as many insects were taken at 1,000 feet as at 200 feet. This definitely shows a drift in of insects from nonflooded region.

The insects represented in the collections at 200 feet over the flooded area were mostly those of the families Chloropidae, Dolichopodidae, and Ceratopogonidae of the Diptera. A very few leafhoppers and plant lice were also taken.

The collections made over the territory which had not been flooded showed a definite increase in the numbers of families and species taken. Many more leafhoppers were collected and larger species of Diptera were represented. Microlepidoptera, parasitic Hymenoptera, Staphylinidae, and a few Heteroptera were also taken.

In the flights made over the flooded area in the following October, the numbers taken greatly increased at the 200-foot altitude.

As the water receded, vegetation grew again, and the difference in the collections became less noticeable in both numbers and species taken over these localities.

SEEDS COLLECTED IN THE UPPER AIR

Numbers of seeds were caught on the collecting screens. Unfortunately these were saved only during the last year (1931) of collecting, and accordingly the collection is rather small. It shows, however, the comparative sizes of the few species of seeds represented and the height at which they were found. A list of the seeds caught on the screens and the altitude at which they were drifting is given in table 15.

TABLE 15.—*Plant seeds caught by the collecting screens and the altitude at which found, Tallulah, La., 1931*

Family and species	Collected at altitudes of—						Total seeds
	200 feet	500 feet	1,000 feet	2,000 feet	3,000 feet	5,000 feet	
Compositae:	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Eupatorium sp.		1					1
Erigeron sp.	2		1	1	3		7
Circium sp (pappus only)	1						1
Sonchus asper (Linnaeus)				1			1
Salicaceae:							
Populus sp.	5		5	3	1		14
Gramineae:							
Paspalum dilatatum Poir	1		3	1	2	1	8
Paspalum urvillei Steud.	3	1	7	3	1	1	16
Paspalum pubiflorum Rupr.					1	1	2
Panicum urvillei Steud.						1	1
Setaria probably *geniculata* (Lam.) Beauv.	1						1
Hordeum pusillum Nutt.					1		1

The seeds of *Populus* sp. were taken in June; *Paspalum dilatatum, P. urvillei*, and *P. pubiflorum*, from July to October; and the seeds of *Erigeron* sp. were collected throughout the year. The height to which seeds of *Populus* sp. were taken is, of course, to be attributed to their light weight, and their "parachute" attachment in the shape of a pappus. Seeds are subject to much the same conditions as insects, in so far as their size, weight, and buoyancy are concerned.

The late A. S. Hitchcock of the Bureau of Plant Industry, who identified the seeds of the grasses, considered the list to be rather surprising. He added:

> One would expect to find fluffy seeds like those of *Andropogon virginicus*. The two species of *Paspalum, P. dilatatum* and *P. urvillei*, are ciliate-margined, but are rather heavy for such high flights. The abundance of *P. urvillei* is noteworthy. This is an introduced species common in some localities of Louisiana and adjacent States, but not widely distributed. That the seeds were all gathered in the region of Tallulah would be a fact coordinated with the presence of *Paspalum urvillei* there.

P. urvillei is a native of Brazil, Uruguay, and Argentina, having been introduced into the United States some 40 years ago. This species was collected at altitudes of 200 to 5,000 feet.

Most of the seeds were taken when the upper air was slightly rough to rough and when convection currents were rather strong. For example, on September 29, 1931, the air was from slightly rough to rough, and seeds of *Paspalum urvillei* and *P. dilatatum* were taken at all altitudes up to 5,000 feet.

Plants, like insects, have become established in remote islands of the sea and in continents far distant from their original homes. Seeds are transported by birds and by water, but the majority are probably carried in the upper air currents by the prevailing winds.

COLLECTION OF INSECTS IN MEXICO

In August 1928 a trip was made to Mexico under the direction of B. R. Coad, and F. A. Fenton, formerly of the Bureau of Entomology, to investigate the possibility of the migration of the pink bollworm by flight. Two airplanes, equipped with insect traps, were flown from Tallulah via El Paso, Tex. After a week at El Paso, and at Juarez, Mexico, in making the necessary customs arrangements to transfer the planes and equipment across the border, the planes landed in Tlahualilo, Durango, Mexico, on August 22, 1928. The pilots were accompanied by Lieut. Eduard Aldorsoro, Mexican escort pilot, and, through the courtesy of the Mexican Government Manuel Alcazar accompanied this entomological expedition as interpreter and official representative.

The territory in which the flights and studies were made is situated some 500 miles southeast of El Paso and 200 miles south of the Big Bend section of Texas. The headquarters for this investigation were established on the hacienda of the Tlahualilo Agricultural & Colonization Co., situated in the Laguna district of Durango and Coahuila. The Laguna district was ideally located for the study of pink bollworm migration flights, since it is a desert reclaimed by irrigation and completely surrounded by barren desert and equally barren mountains. Vegetation other than that grown by means of irrigation and cultivation is scarce. Cotton is the principal crop and normally 75,000 to 100,000 bales are produced annually. The pink bollworm has been present in this section since 1911, and the infestation and damage here are the highest on the North American Continent.

It had been found that the fluctuations in the infestations of the pink bollworm in the Big Bend section of Texas were in proportion to the increase or decrease of infestation in the Laguna district, and it had been suggested that the moths from the Laguna district flew with the aid of the prevailing winds to the Big Bend section. In order to test the possibility of this source of infestation, a series of airplane flights were made over the Laguna district to determine whether any pink bollworm moths were actually present in the upper air.

Forty-four flights were made between August 27 and September 17, 1928, at altitudes from near the surface to the height of 4,000 feet. No night flying was done except on a few occasions when the plane landed late in the evening. Thirty-one hours and twenty minutes were used in the actual collecting, in which time 1,294 insects were taken. Ten orders of insects were represented, including Ephemeroptera, Odonata, Thysanoptera, Heteroptera, Homoptera, Coleoptera, Neuroptera, Lepidoptera, Hymenoptera, and Diptera (table 16).

TABLE 16.—*Insects collected by airplane in Tlahualilo, Durango, Mexico, in August and September 1928, according to altitudes*

Order, family, genus, and species	Total insects taken	Collected at altitudes of— 20 feet	100 feet	500 feet	1,000 feet	2,000 feet	3,000 feet	4,000 feet
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Ephemeroptera:								
Baetidae:								
Cloeon sp.	1	1						
Odonata:								
Undetermined species of the suborder Anisoptera.	2				2			
Thysanoptera:								
Aeolothripidae:								
Stomatothrips flavus Hood	4				1	2		1
Thripidae:								
Heliothrips phaseola Hood	15	1	4	2	3	1	2	2
Heteroptera:								
Cydnidae:								
Amnestus sp.	2	1	1					
Pentatomidae:								
Mecidea longula Stål	1	1						
Coreidae:								
Aufeius impressicollis Stål	3	2	1					
Neididae:								
Aknisus multispinus (Ashmead)	1	1						
Lygaeidae:								
Nysius californicus Stål	3		2	1				
Nysius ericae (Schilling)	17	4	6	5		1	1	
Heraeus plebjus Stål	1	1						
Exptochiomera fusicornis (Stål)	1	1						
Tingididae:								
Piesma cinerea (Say)	1		1					
Corythucha sp.	2		1	1				
Gargaphia iridescens Champion	5		3	1		1		
Miridae:								
Trigonotylus breviceps Jakowlef (adults)	11	3	3	3	2			
Trigonotylus breviceps Jakowlef (nymphs)	8	2	4	2				
Polymerus basalis (Reuter)	1				1			
Adelphocoris rapidus (Say)	12	6	2	2	2			
Plagionathus sp.	1	1						
Chlamydatus sp.	6	1	2	1	1	1		
Leucopoecila albofasciata Reuter	1		1					
Miridae (undetermined nymph)	1						1	
Miridae (undetermined adults)	7	3	2	2				
Total	85	27	20	18	6	3	2	
Homoptera:								
Membracidae:								
Stictocephala festina (Say)	1			1				
Cicadellidae:								
Cicadella hieroglyphica (Say)	1			1				
Draeculacephala sp.	1				1			
Carneocephala nuda Nottingham	17	8	2	6	1			
Xestocephalus pulicarius Van Duzee	17	8	2	5			1	1
Platymetopius acutus (Say)	1		1					
Deltocephalus sonorus Ball	10	3	4	1	1	1		
Deltocephalus sp.	4	1	1	1			1	
Exitianus obscurinervis (Stål)	4		1	1	1		1	
Phlepsius sp.	1					1		
Acinopterus angulatus Lawson	1		1					
Acinopterus sp.	1	1						
Macrosteles divisus (Uhler)	3	1	1	1				
Nesosteles neglectus (DeLong and Davidson)	12	5	4	2	1			
Nesosteles sp.	1	1						
Erythroneura sp.	8	2	4	1	1			
Cicadellidae, (undetermined adults)	19	5	2	3	1	4	4	
Cicadellidae, (undetermined nymphs)	4	1	2	1				
Fulgoridae:								
Oliarus aridus Ball	10	5	3	1	1			
Microledria asperata Fowler	4	1		2			1	
Delphacodes consimilis (Van Duzee)	4	1			2		1	
Delphacodes sp.	1			1				
Psyllidae:								
Heteropsylla texana Crawford	2	1		1				
Triozinae, undetermined sp.	18	1	3	4	5	5		
Paratrioza cockerelli (Sulc)	102	9	23	17	20	23	6	4
Paratrioza sp.	2			1		1		
Trioza sp.	1	1						
Total	250	55	54	51	35	36	15	6

TABLE 16.—*Insects collected by airplane in Tlahualilo, Durango, Mexico, in August and September 1928, according to altitudes*—Continued

Order, family, genus, and species	Total insects taken	Collected at altitudes of—						
		20 feet	100 feet	500 feet	1,000 feet	2,000 feet	3,000 feet	4,000 feet
Coleoptera:	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Carabidae:								
Micratopus sp.	1	-	-	1	-	-	-	-
Discoderus sp.	1	1	-	-	-	-	-	-
Bradycellus sp.	2	2	-	-	-	-	-	-
Staphylinidae:								
Platystethus americanus Erichson	7	4	1	1	-	1	-	-
Platystethus obscurus Sharp	6	2	2	-	2	-	-	-
Stenus sp.	1	-	1	-	-	-	-	-
Lathrobium sp.	1	1	-	-	-	-	-	-
Aderocharis sp.	1	-	-	1	-	-	-	-
Astenus sp.	1	1	-	-	-	-	-	-
Atheta sp.	2	1	-	-	1	-	-	-
Melyridae:								
Collops punctulatus LeConte	35	12	7	16	-	-	-	-
Anthicidae:								
Notoxus sp.	2	2	-	-	-	-	-	-
Anthicus sp.	5	2	2	1	-	-	-	-
Elateridae:								
Conoderus sp.	3	2	-	1	-	-	-	-
Elateridae, undetermined sp.	1	-	-	-	-	1	-	-
Throscidae:								
Throscus sp.	3	-	1	-	1	-	1	-
Mycetophagidae:								
Typhaea stercorea (Linnaeus)	2	2	-	-	-	-	-	-
Lathridiidae:								
Melanophthalma subfusca Sharp	1	-	-	1	-	-	-	-
Phalacrididae:								
Phalacrus sp.	1	-	-	1	-	-	-	-
Tenebrionidae:								
Uloma sp.	2	-	2	-	-	-	-	-
Melandrydidae:								
Canifa sp.	10	1	-	1	3	-	4	1
Anobiidae:								
Lasioderma serricorne (Fabricius)	1	-	1	-	-	-	-	-
Catorama sp.	1	-	-	1	-	-	-	-
Chrysomelidae:								
Babia sp.	1	-	1	-	-	-	-	-
Pachybrachis sp.	1	-	1	-	-	-	-	-
Monoxia sp.	1	1	-	-	-	-	-	-
Diabrotica vittata var.	1	-	-	-	1	-	-	-
Diabrotica sp.	1	1	-	-	-	-	-	-
Epitrix parvula auctorum	6	2	-	1	2	-	1	-
Epitrix sp.	1	-	-	-	-	-	1	-
Chaetocnema sp.	1	1	-	-	-	-	-	-
Longitarsus sp.	12	7	3	-	1	-	1	-
Mylabridae:								
Acanthoscelides prosopis (LeConte)	12	3	4	4	-	1	-	-
Curculionidae:								
Smicronyx sp.	7	3	1	1	-	1	1	-
Endalus sp.	2	2	-	-	-	-	-	-
Total	136	53	27	31	11	4	9	1
Neuroptera:								
Chrysopidae:								
Chrysopa externa Hagen	1	1	-	-	-	-	-	-
Chrysopa sp.	1	-	-	-	-	1	-	-
Eremochrysa punctinervis (McLachlan)	6	2	1	3	-	-	-	-
Lepidoptera:								
Gracilariidae:								
Gracilariidae, undetermined sp.	1	-	-	-	-	1	-	-
Gelechiidae:								
Pectinophora gossypiella (Saunders)	7	4	1	-	1	-	1	-
Gnorimoschema sp.	1	-	-	-	-	1	-	-
Scythridae:								
Scythris sp.	1	-	1	-	-	-	-	-
Heliodinidae:								
Heliodinidae, undetermined sp.	2	-	-	1	1	-	-	-
Olethreutidae:								
Epiblema sosana (Kearfott)	1	-	1	-	-	-	-	-
Pterophoridae:								
Pterophoridae, undetermined sp.	1	1	-	-	-	-	-	-
Lycaenidae:								
Hemiargus isola (Reakirt)	1	-	-	-	1	-	-	-
Satyridae:								
Satyridae, undetermined sp.	1	1	-	-	-	-	-	-
Macrolepidoptera, undetermined sp.	1	1	-	-	-	-	-	-
Lepidoptera, undetermined sp.	1	1	-	-	-	-	-	-
Total	18	8	3	1	3	2	1	-

Table 16.—*Insects collected by airplane in Tlahualilo, Durango, Mexico, in August and September 1928, according to altitudes*—Continued

Order, family, genus, and species	Total insects taken	Collected at altitudes of—						
		20 feet	100 feet	500 feet	1,000 feet	2,000 feet	3,000 feet	4,000 feet
Hymenoptera:								
Argidae:								
Sterictiphora (Leston) zabriskiei Webster and Mally (females)	*Number* 18	*Number* 6	*Number* 7	*Number* 4	*Number* 1	*Number*	*Number*	*Number*
Sterictiphora (Leston) zabriskiei Webster and Mally (male)	1	1						
Braconidae:								
Microbracon nuperus (Cresson)	8	3			1	2	2	
Microbracon sp.	4	2	1	1				
Chelonus albobasilaris Ashmead	1							1
Chelonus sp.	1	1						
Apanteles sp.	3	2			1			
Bassus sp.	1				1			
Euphoriana uniformes Gahan	1				1			
Vipio sp.	1		1					
Braconidae, undetermined sp.	1		1					
Ichneumonidae:								
Mesochorus sp.	1		1					
Scelionidae:								
Telenomus sp.	1		1					
Scelionidae, undetermined sp.	1				1			
Platygasteridae:								
Platygaster sp.	1						1	
Cynipidae:								
Cynipidae, undetermined sp.	2		2					
Callimonidae:								
Microdontomerus sp.	1		1					
Chalcididae:								
Chalcididae, undetermined sp.	1				1			
Spilochalcis sp.	2		1					1
Eurytomidae:								
Rileya sp.	1				1			
Eurytoma sp.	1			1				
Encyrtidae:								
Bothriothorax sp.	1		1					
Pteromalidae:								
Cyrtogaster sp.	1		1					
Zatropis sp.	2		1	1				
Pteromalidae, undetermined sp.	7	2	1	2	2			
Eulophidae:								
Tetrastichus sp.	3		1		1		1	
Eulophidae, undetermined sp.	3		1	1	1			
Tiphiidae:								
Tiphia sp.	1	1						
Formicidae:								
Ponera sp. (males)	4	1	2			1		
Ponera sp. (females)	3		1	1		1		
Monomorium sp.	1	1						
Bethylidae:								
Bethylidae, undetermined sp.	3	1				1	1	
Sphecidae:								
Trypoxylon carinifrons Fox (female)	1		1					
Andrenidae:								
Halictus ligatus Say (female)	3	1	1	1				
Halictus pseudotegularis Cockerell (females)	8	1	2	4	1			
Halictus pruinosiformis Crawford	5	1	2	2				
Halictus (Chloralictus) sp.	1		1					
Sphecodes sp.	1				1			
Melissodes pallidicincta Cockerell	1	1						
Andrenidae, undetermined sp.	1		1					
Apidae:								
Apis mellifera Linnaeus	1	1						
Apoidea, undetermined sp.	1		1					
Total	104	26	34	18	14	5	5	2
Diptera:								
Culicidae:								
Sayomyia sp.	3	1			1	1		
Chironomidae:								
Culicoides sp.	49	8	21	6	11	2	1	
Chironomus sp.	5	1		2	2			
Chironomidae, undetermined sp.	25	3	4	4	5	2	4	3
Cecidomyiidae:								
Cecidomyiidae, undetermined sp.	2		2					

TABLE 16.—*Insects collected by airplane in Tlahualilo, Durango, Mexico, in August and September 1928, according to altitudes*—Continued

Order, family, genus, and species	Total insects taken	Collected at altitudes of—						
		20 feet	100 feet	500 feet	1,000 feet	2,000 feet	3,000 feet	4,000 feet
Diptera—Continued.	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Bombyliidae:								
Phthiria sp.	1		1					
Geron sp.	2			1		1		
Scenopinidae:								
Scenopinus sp.	11	1	2	7	1			
Dolichopodidae:								
Dolichopodidae, undetermined sp.	3	1				2		
Empididae:								
Empididae, undetermined sp.	1						1	
Phoridae:								
Phoridae, undetermined sp.	3	1	2					
Pipunculidae:								
Pipunculus sp.	2	1	1					
Syrphidae:								
Syrphus sp.	1	1						
Allograpta sp.	1			1				
Toxomerus sp.	7	2	4		1			
Mesogramma polita Say	1	1						
Mesogramma sp.	3		2	1				
Syrphidae, undetermined sp.	1	1						
Tachinidae:								
Phorocera sp.	2	2						
Sarcophagidae:								
Sarcophagula occidula (Fabricius)	4	1		1	1	1		
Muscidae:								
Haematobia irritans (Linnaeus)	5	3		1		1		
Musca domestica Linnaeus	1	1						
Anthomyiidae:								
Anthomyiidae, undetermined sp.	1		1					
Helomyzidae:								
Trixoscelis frontalis (Fallen)	1	1						
Trixoscelis sp.	1				1			
Borboridae:								
Limosina sp.	1		1					
Borboridae, undetermined sp.	6		3	1		1	1	
Chyromyidae:								
Spilochroa ornata Johnson	3	1	2					
Sapromyzidae:								
Camptoprosopella vulgaris (Fitch)	3	1	1			1		
Camptoprosopella sp.	1		1					
Otitidae:								
Euxesta notata Wiedemann	1	1						
Chaetopsis sp.	2	1		1				
Trypetidae:								
Spilographa vittigera Coquillett	2			2				
Tephritis sp.	4		1	1	1	1		
Trypanea bisetosa (Coquillett)	74	19	17	19	11	2	5	1
Sepsidae:								
Sepsis sp.	2	2						
Ephydridae:								
Psilopa compta (Meigen)	1			1				
Philygria fusicornis Loew	9	4	1	3	1			
Typopsilopa atra Loew	4	4						
Ephydridae, undetermined sp.	1				1			
Chloropidae:								
Hippelates sp.	5	1	2	1	1			
Oscinella coxendix (Fitch)	2		2					
Oscinella sp.	1					1		
Chloropidae, undetermined sp.	3		2		1			
Drosophilidae:								
Drosophila sp.	2	2						
Agromyzidae:								
Agromyza sp.	6	1	2		1	1	1	
Cerodonta sp.	2			1	1			
Diptera, undetermined sp.	3	1	1		1			
Total	274	68	76	54	42	17	13	4
Unrecognizable insects	397	176	104	78	32	7		
Grand total	1,294	418	332	256	149	77	47	15
Total flying time, minutes	2,120	350	330	430	410	340	150	110

The Thysanoptera comprised four of *Stomatothrips flavus* Hood and 15 of *Heliothrips phaseola* Hood. Both species were collected at altitudes up to 4,000 feet.

There were 85 Heteroptera taken, representing 7 families, 16 genera, and 13 determined species. They were found at altitudes up to 3,000 feet. The species taken were of more or less general distribution.

The Homoptera comprised 250 specimens of 4 families, Membracidae, Cicadellidae, Fulgoridae, and Psyllidae; 19 genera; and 14 determined species.

There were 136 Coleoptera found representing 15 families, 31 genera, and 9 determined species. One striped cucumber beetle (*Diabrotica vittata*) was taken at 1,000 feet and six tobacco flea beetles (*Epitrix parvula*) were found at altitudes of from 20 to 3,000 feet. Twelve *Acanthoscelides prosopis* (Lec.) (Mylabridae) were found at altitudes of 20 to 2,000 feet. This beetle is destructive to seeds of mesquite, both in Mexico and in the United States.

The Lepidoptera were represented by 18 specimens, including 8 families and 3 determined species. Seven specimens of the pink bollworm moth (*Pectinophora gossypiella* (Saund.)) were taken; four at 20 feet, one at 100 feet, one at 1,000 feet, and one at 3,000 feet.

There were 104 specimens of Hymenoptera found, including 18 families and 10 determined species. One *Euphoriana uniformis* Gahan was taken at 1,000 feet. This braconid is recorded in the United States National Museum collections from nymphs and adults of *Lygus pratensis*.

The Diptera comprised 274 specimens, representing 23 families, 33 genera, and 14 determined species. There were 79 specimens of Chironomidae taken. Owing to the extensive irrigation system the chironomids found breeding places. Five horn flies (*Haematobia irritans* L.) were taken at altitudes up to 2,000 feet. This fly was especially troublesome to the cattle and was abundant everywhere. One fly especially abundant in the collections was *Trypanea bisetosa* (Coq.) (Trypetidae), of which 74 specimens were taken, some at all altitudes flown.

As a whole the families and species represented in the upper-air collections in Mexico were found to be much the same as those taken at Tallulah. There were, however, some decided differences in the numbers of specimens taken with reference to altitude and time of day. As was stated, the Laguna district is surrounded by mountains and a desert region, and the insects collected were those which for the most part came directly from this district.

In order to make a more definite study of the insect population of the upper air, the flights were divided into the following four divisions: Flights made at daybreak, in the morning, in the afternoon, and at sunset. The collections made at daybreak showed a very heavy population at the lower altitudes, with a decided decrease at altitudes above 500 feet.

The morning flights, made between 8 a. m. and noon, showed a decrease in the numbers taken at 20 and 100 feet, but for altitudes above 100 feet the numbers increased greatly, with nearly twice the number taken at 500 feet as at 20 feet, and more were taken at 1,000 feet than at 20 feet.

In the afternoon the numbers of insects taken dropped off appreciably for all the altitudes.

At sunset the greatest numbers of insects collected during the day were taken at 20 feet. Insects were scarce at 500 and 1,000 feet, and no specimens were collected above 1,000 feet.

Early in the morning or at daybreak, when the insects were very active, especially at the lower altitudes, the average temperature was 67° F., and convection had ceased. Later in the morning convection began, and the temperature increased to an average of 79°, the air becoming turbulent. The insects found close to the ground were carried upward, showing a great increase in the upper air at altitudes of 500 feet and above. Convection was decidedly strong during the morning hours, and made flying difficult and hazardous at the very low altitudes. In the afternoon convection was not so strong, the temperature rising to 84° on an average, and the numbers of insects decreasing rapidly, especially at the higher altitudes. At sundown there were almost no insects at the high altitudes, but there was a concentration of insects near the surface, when nocturnal insects became active. These changes in the insect population of the upper air were presented day after day with remarkable regularity. In the airplane collections, two pink bollworm moths were taken at 20 and 100 feet, respectively, at daybreak; two were found in the morning collections at 1,000 and 3,000 feet, respectively; and three specimens were taken at 20 feet at sunset. These few specimens were collected at daybreak and sunset close to the ground, in the absence of convection, and at high altitudes in the morning when convection is greatest.

In this section of Mexico the prevailing winds are from the south or southeast, and any strong ground wind will also be from that direction. Regardless of the direction of the ground wind the airplane at 1,000 feet would always encounter winds from the south or southeast, becoming very strong at the altitude of 3,000 feet. This same wind was encountered as a strong head wind by the pilots when flying to Tlahualilo, although it greatly aided the return flight. Thus it can be seen that insects caught up by the violent convectional currents of the morning to the heights of 3,000 and 4,000 feet will be caught in the horizontal wind currents.

It was also found, when collecting north or west of the Tlahualilo property, either at the edge of the cultivated area or over the desert, that insects were as abundant in the upper air as they were found to be directly over the irrigated area, although, of course, there was no such concentration of insects close to the ground as was found over the cultivated area. When flying east of the extreme southern area of the Laguna, however, where the prevailing wind was out of the desert few insects were taken at the higher altitudes. This is in contrast to the conditions in Louisiana, where insects are abundant in all directions within the area flown. In the Laguna few insects were found above 3,000 feet, whereas at Tallulah insects continued to be taken up to the height of 14,000 feet, and no doubt many of those found in the upper air directly over Tallulah had been brought in from distant localities.

The flights made at Tlahualilo, and all other observations (*41, 47, 54*), bear out the idea that flight with the aid of air currents has been a dominant factor in the distribution of the pink bollworm in the United States.

SOURCES OF INSECTS AND ROUTES OF MIGRATION

One of the difficult things connected with a study of insects collected at some distance above the ground is the determination of the probable sources of the insects. Those taken at altitudes above 10,000 feet may have been in the air for days, carried in the prevailing winds and strong air currents from places hundreds of miles away. The record of a collembolan *Entomobyra cubensis* Fols., taken at 3,000 feet, known only from Cuba, points to evidence of insects carried by air currents from distant points. However, where the territory over which flights are made is of a more or less homogeneous nature it is impossible to determine whether the specimens taken in any flight have had their origin in the territory immediately beneath or whether they have been carried in for great distances by winds. There are fortunately certain areas in the United States where such studies might well be carried on. The insect fauna of irrigated lands with their imported plants are usually accompanied by no inconsiderable populations of the pests and insects associated with those plants. These insects are often actual immigrants into the area and differ markedly from the native desert fauna of insects. Studies in such areas, then, both inside the cultivated area and outside it, to find the extent of movement of desert forms into, and emigrant forms out of, the irrigated area might be of marked value.

A project which should yield information of interest as well as of economic importance on this subject is the tracing of the flight of the cotton leaf worm moth (*Alabama argillacea*). It is known that *argillacea* does not overwinter in this country and that the moths migrate each season from the countries to the south, but no serious attempt has ever been made to find the actual source of infestation or to trace the routes of flight taken. Airplane collecting flights made during the probable time of migration would be of special interest. These flights should be made along the Gulf coast with the chance of collecting any moths in flight from the Tropics. Flights should be made along the coastal region of Central America and in the Caribbean Sea between the West Indies and the northern coast line of South America. Not only could important records of the flight of the cotton leaf worm moth be taken but also records of other tropical economic insects such as the Mediterranean fruitfly, Mexican fruitfly, and pink bollworm moth.

In further studies of the flight and migration of insects in general it would be of considerable interest to collect insects in the upper air over bodies of water hundreds or thousands of miles from shore. When transoceanic air-passenger routes are established and regular schedules flown from continent to continent, an excellent opportunity to make these collections may be offered.

Workers in other fields of science have become much interested in the study of upper air zones. On November 12, 1937, a group of scientists met under the auspices of the National Research Council to consider these matters. From this meeting there resulted a committee on aerobiology. It is hoped that this meeting marks the beginning of an important step in the advancement of research in the study of aerial dissemination of micro-organisms, viruses (insect transmitted), pollen, insects, and other objects. The National Research Council interdivisional committee on aerobiology hopes to establish a central laboratory which will assist in the fields of human, veterinary, and plant pathology, industrial mycology, economic entomology, plant breeding, and meteorology.

Fred C. Meier, senior scientist, Division of Cooperative Extension, Extension Service, United States Department of Agriculture, was appointed chairman of this committee. Meier's work in collecting spores and micro-organisms with the cooperation of Charles A. Lindbergh and Albert W. Stevens, of the stratosphere flights, was outstanding and fitted him most advantageously for directing the activities in this new field of research.[5]

AIRCRAFT AS INSECT CARRIERS

With the great numbers of airplanes in use throughout the civilized world, numerous ways are offered for insects to find shelter in the cockpit, fuselage, or cabin of an airplane.

Quarantine stations have been established for a number of years at the international airports in the United States under the direction of the Bureau of Entomology and Plant Quarantine, cooperating with the Customs Bureau and the Public Health Service of the United States Treasury Department. During the fiscal year 1935, 3,150 airplanes arriving from foreign countries and from Hawaii were inspected (*71*). A total of 916 interceptions of prohibited and restricted plant material were taken from airplanes.

Immediately after a passenger airliner arrives, the passengers' baggage and the express are unloaded, and inspectors search for quarantined material, and at some ports clean the airplane with a light portable machine, very much like a vacuum cleaner, to get any insects that might be in the dark corners or around the window jambs.

During the 5 years of collecting insects in the upper air there were many times when insects were found in the cockpit or cabin of the airplane used. This was particularly noticeable during the spring and early fall months when insects were at their maximum abundance. Insects would fly into the lighted hangar at night and would often fall into the cockpit underneath the lights. The next morning, when the airplane was taken out and flown, many of these insects still remained in the cockpit or back in the rear fuselage. Often, when the airplane was high in the air, and at a considerable distance from the landing field, these insects would be seen flying out of the cockpit.

To have kept a collection of the insects found in the cockpits and cabins of the several airplanes used would have been a laborious undertaking. Often numerous microlepidoptera, Noctuidae, even *Alabama argillacea*, *Heliothis obsoleta*, and *Laphygma frugiperda*, would fly out when the motor was started, or be seen crawling into the parts of the fuselage where the draft from the propeller could not disturb them. Many beetles, as carabids and staphylinids, were always to be found. Leafhoppers were common stowaways. Wasps were always to be feared, for often they built nests in the fuselage behind the seat; in fact, mechanics working on the planes were often annoyed by wasps as the latter flew in and out, and at one time the writer was stung on the ankle by a wasp while the airplane was flying at a 5,000-foot altitude. It became an accepted part of the daily

[5] Meier's tragic death in the ill-fated Hawaii Clipper on July 29, 1938, will be a great loss to science. Accompanying him on this flight was Earl B. McKinley, dean of the School of Medicine, George Washington University, Washington, D. C. Both were collecting pathogens and allergens with a special device invented by Lindbergh. The writer hopes that the work and study in this field of aerobiology will be carried on as first planned by Meier and his committee, and that the interest and activities in aeroentomology will continue and further advance ways and means to study the dissemination of insects in the air.

routine to clean a mud dauber's nest out of the air-speed tube, which projected underneath the wing. Invariably every day a mud dauber wasp filled this small air-speed tube with mud, which if not thoroughly cleaned would interfere with the registering of the speed of the airplane.

Mosquitoes find an excellent hiding place in the dark cockpit, and unless driven out by the air blast from the propeller, or by the pilot, remain therein while the airplane is in flight.

It is not always easy for insects to fly out of the cockpit while the airplane is in flight, since the great pressure of the air when the plane is flying upward forces them down on the floor of the cockpit.

On several occasions insects flew into the airplane while it was flying. A specimen of *Stictocephala festina* flew into the cockpit at the altitude of 2,000 feet and one at 4,000 feet. On one flight the writer flew through a swarm of chinch bugs at 2,000 feet, and several flew into the cockpit.

With the new means for the dispersal and distribution of diseases and dangerous insect pests offered by modern air transportation, it is urgent that physicians, health officers, and medical and economic entomologists be ever ready and alert to cope with this situation.

COLLECTING INSECTS IN THE UPPER AIR

The actual work of collecting insects in the upper air in this country and abroad has been very limited. The following references given of such work are the only other ones which have come under the attention of the writer. While the data of collections made from forest-lookout stations, mountaintops, and roofs of high buildings are of great interest and importance, only those collections that have been made in the free air high above the surface of the earth are given herewith.

E. P. Felt made several flights using an insect trap attached to the lower wings of an airplane. A number of insects were taken in flights on August 30 and 31, 1926. (*22*, *23*.)

In 1927 Felt and Chamberlain (*25*) used traps on various types of kites for the purpose of demonstrating possibilities of capturing insects in the upper air.

In 1931 and 1932 T. T. Terrell, of the Division of Forest Insect Investigations, of this Bureau, made collections using airplane insect traps as designed by the writer. Exposures were made as high as 13,000 feet, but without results at the very high altitudes. Diptera and Hymenoptera were taken up to 9,600 feet. The flights were made to study the flight activities of the mountain pine beetle (*Dendroctonus monticolae* Hopk.). In 1933 the standard Weather Bureau kites were used in Montana, 7 miles southwest of Dillon, in the open plains between the Beaverhead and Madison National Forests. Eight successful kite flights were made as high as 8,000 feet above the ground. Several bark beetles were taken, but none of the mountain pine beetle.

Flights were made by Collins and Baker (*15*), of the Bureau of Entomology, at Melrose Highlands, over a section of southeastern Massachusetts that was heavily infested with the gypsy moth. In 1932 the airplane insect traps as designed by the writer, with certain modifications by Collins and Baker, were used for the flights. In 1933 a different type of airplane insect trap was used designed by

Karl O. Lange, and installed on an airplane (*15, p. 325*). The flights were made to study the distribution of the gypsy moth larvae, as discussed on page 91.

In June 1932 several flights were made in Honolulu, using the airplane insect traps, with a modification to accommodate them for the type of airplane used. The flights consisted of 6 hours' flying time, and were made at elevations from 50 to 1,800 feet. No mosquitoes were taken, and the conclusion of the Honolulu health authorities was that mosquitoes do not fly over the mountains into the city of Honolulu. Obviously it is not good science to make such a conclusion in view of the brief time given to the work. Also the three species of mosquitoes represented in Honolulu are essentially domestic or house mosquitoes, and are not migratory species, and thus are not expected to make extensive flights or be caught in the upper air.

Lucien Berland, of the Museum National D'Historie Naturelle, Paris, was the first European entomologist to have used an airplane to collect insects in the upper air. The collections were made in 1934 with specially devised nets attached to the wings and controlled from the cockpit. Dr. Berland made many flights collecting considerable material, representing the orders Collembola, Thysanoptera, Hemiptera, Homoptera, Psocoptera, Coleoptera, Hymenoptera, and Diptera. Collembola were taken as high as 2,000 m, and Hemiptera, Homoptera, and Diptera at 2,500 m. The flights were made near Paris (*5, 6, 7*).

Jean Larribere, accoucheur à l'Hôpital d'Oran, made a number of flights at Oran, Algeria (north Africa), using the Berland airplane insect nets. He collected a number of insects.

Father Le P. Poidebard used nets on airplanes to collect insects while making archaeological surveys in Beymouth, Asia Minor.

J. A. Freeman of London, who was a student in Cornell University during 1937, made collections of insects in the upper air using kites. This work was done along the Great Lakes in Canada.

In England Freeman worked under the direction of A. C. Hardy, of the Department of Zoology and Oceanography, University College, Hull, making a special study of insect drift. Nets were used on the 300-foot masts of a large wireless station. This work was done between 1932 and 1935. Freeman also used specially constructed kites for collecting, whereby samples could be obtained at given altitudes.

Hardy and Milne (*31*) studied the drift of insects over the North Sea in 1936. They used collecting nets flown either from the masthead or kites flown from the ship. Considerable data were collected as discussed on page 110.

SUMMARY

Collecting insects in the air by means of special traps fitted to the wings of various types of airplanes was accomplished during the 5-year period from August 1926 to October 1931. During this period the traps were in operation for 1,007 hours in 1,314 flights at Tallulah, La., and 44 flights at Tlahualilo, Durango, Mexico.

There were 30,033 specimens of insects and spiders taken at altitudes ranging from 20 to 15,000 feet. Specimens were taken in every month of the year. They were caught most abundantly in May, per

10 minutes of flying time, and in fewest numbers in January and December.

Eighteen orders of insects and the orders of spiders and mites were collected. There were represented in the Louisiana collections, 216 families, 824 genera, 4 new genera, 700 species, and 24 new species. The order Diptera was the most abundant order in the air, and nearly three times as many specimens were taken as of any other order. Coleoptera followed next after Diptera in the numbers taken.

Homoptera and Hymenoptera were taken at 14,000 feet, the highest altitude at which insects were found. The highest altitude at which any specimen was taken was 15,000 feet, at which a spider was caught.

The numbers of insects taken at different altitudes in 10 minutes of collecting in the daytime were as follows: At 200 feet, 13.03 specimens; 1,000 feet, 4.70; 2,000 feet, 2.41; 3,000 feet, 1.35; and 5,000 feet, 0.64 specimens. For the night collections the figures are: At 500 feet, 15.31 specimens; 1,000 feet, 5.73; 2,000 feet, 2.52; 3,000 feet, 1.11; and 5,000 feet, 0.89 specimens.

Of the Araneida, 1,461 specimens were taken, chiefly in November and up to 15,000 feet altitude. The Heteroptera were taken up to 11,000 feet, with the greatest number in October, 1,259 in all being captured. There were 3,934 Homoptera caught, chiefly in November and as high as 14,000 feet. The Coleoptera were most abundant in March, and 4,420 were caught, the greatest altitude at which any were taken being 12,000 feet. The Hymenoptera and Diptera were most abundant in May and both were taken as high as 14,000 feet, and 2,947 Hymenoptera and 11,304 Diptera were taken during the airplane flights.

The size, weight, and buoyancy of an insect contributes directly to the height to which it may be carried by air currents. Of the Homoptera, numbers of the small species of Cicadellidae, Fulgoridae, Psyllidae, and Aphiidae were taken up to 14,000 feet. These are weaker fliers of small size but of comparatively large wing expanse. Many species of the other orders represented at high altitudes were also small insects

Numbers of adults, nymphs, and larvae of wingless forms of insects and mites were collected in the upper air at altitudes as high as 14,000 feet and a spider at 15,000 feet. These wingless forms are all at the complete mercy of the upper air currents.

There is much evidence to support the conclusion that many of the insects taken in the upper air were alive at the time they were collected. Many specimens were alive when removed from the screens. Among the most interesting of these was one mosquito, *Aedes vexans*, and a cicadellid, *Graphocephala versuta*, taken alive at 5,000 feet; a coccinellid, *Coleomegilla floridana*, at 6,000 feet; an aphid at 7,000 feet; and a small dermestid larva, *Trogoderma* sp., at 9,000 feet.

The relative distribution and abundance of insects in the air depend on the weather conditions preceding and at the time of observation.

Temperature was undoubtedly the most important factor regulating the numbers of insects to be found in the air at any given time. The optimum range was from 75° to 79° F., surface temperature. Dew point and vapor pressure were found to be more convenient criteria than relative humidity or absolute humidity for expressing the relation of moisture in the air to the number of insects collected. Most insects were collected when the surface dew point was from 60° to 64°. Spiders were taken in greater numbers at the lower dew points of 35° to 39°.

The numbers of insects taken followed closely the differences in the surface vapor pressure. The apparent vapor-pressure effect is undoubtedly not due to vapor pressure itself, but to the temperature effect upon the insects, which varies to a definite degree with and in the same direction as does in general its effect upon vapor pressure.

Barometric pressure showed some possible relation to the numbers of insects in the upper air. More insects were taken at pressures of 29.85 to 29.89 inches, the numbers collected decreasing with variation therefrom. Spiders were collected mostly at the high barometric pressure of 30.30. (The usual normal barometric pressure at Tallulah, La., is from 30.00 to 30.15 inches.)

The intensity of air currents is a great factor in the distribution and dispersal of insects. Most insects were taken at the lower altitudes when the surface wind velocity was from 5 to 6 miles per hour, and fewest when it was calm.

The direction of the wind has influenced to a great extent the migrations of insects. In the airplane flights at Tallulah it was found that the greatest numbers of insects were taken when the surface wind direction was from the north-northeast, southeast, or southwest. Some insects were apparently moving with the wind during the spring and summer when the surface prevailing winds were from a southerly direction, and again with the wind from a northerly direction in the fall.

Convection and turbulence play an important role in determining the insect population in the upper air. At the altitude of 200 feet more insects were taken when the air was smooth. At 1,000 feet and up to 5,000 feet more insects were taken when the air was rough or slightly rough. As the air became rougher greater numbers of insects were found proportionately at the higher levels. When insects are in smooth air and caught in strong ascending and horizontal currents of air they will be carried upward.

It was found that from 200 to 5,000 feet more insects were collected during the time from daybreak to sunrise than during the hours from 8 a. m. to noon. At sunset the maximum numbers of insects are found. At that time many crepuscular and night-flying insects are becoming active, and together with the day forms there is an accumulation of insects.

The intensity of the light, with temperature, humidity, and evaporation, as well as other meteorological factors, are directly affected by the cloudiness of the sky. The greatest numbers of insects were taken on days and nights when the sky was partly cloudy. Spiders were taken in greater numbers on clear days, the numbers diminishing as the sky increased in cloudiness.

When flights for collecting insects were made shortly before and after dark, it was found that almost twice as many insects were taken before dark as after dark.

When the collections were made on moonlight nights and very dark nights, it was found that more insects were taken on moonlight nights than on nights when the moon was not shining. While the difference was not great, yet there appeared to be a tendency for insects to be

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more active in the upper air on nights when there was considerable moonlight.

Precipitation had a definite effect on the numbers and species of insects found in the air. A rain after a long period of drought caused an increase in insect activity, and insects were taken in greater numbers in the upper air at such times. At times when precipitation was excessive and temperatures low, insects dropped to minimum numbers.

It was noted that the electric state of the atmosphere at times of thunderstorms apparently increased the numbers of insects collected to above the average.

Numbers of seeds were found in the upper air at altitudes of 200 to 5,000 feet. They belonged to the families Compositae, Salicaceae, and Gramineae. The seeds were usually taken on flights when the upper air was slightly rough to rough from convection currents. Seeds are subject to the same conditions as insects in so far as their size, weight, and buoyancy are concerned.

Flights made over the flooded area of 1927 at Tallulah showed definitely that fewer insects were in the air at the lower altitudes. However the numbers taken at 1,000 feet and above were approximately the same as over nonflooded territory, indicating that insects flew or drifted in.

In the airplane collections of insects in Mexico the pink bollworm moth was found as high as 3,000 feet. This and other studies all indicate that the pink bollworm moths are carried in the upper air currents for considerable distances.

Modern aircraft offer a new source of danger in the dispersal and distribution of diseases and dangerous insect pests. During the 5 years of flying to collect insects, many insects were found in the cockpits of the planes used, even during flight.

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