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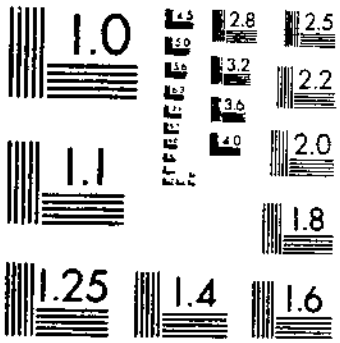

MICROCOPY RESOLUTION TEST CHART
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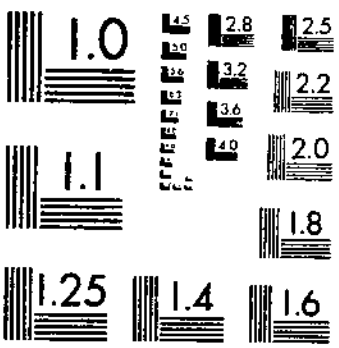

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GRASSHOPPER EGG PODS DESTROYED BY LARVAE OF BEE FLIES, BLISTER BEETLES, AND GROUND BEETLES

By
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CONTENTS

Grasshopper Egg Pods Destroyed by Larvae of Bee Flies, Blister Beetles, and Ground Beetles[1]

By J. R. PARKER,[2] *Entomology Research Division*, and CLAUDE WAKELAND, *Plant Pest Control Division, Agricultural Research Service*

SUMMARY

Data are presented to show the percentage of grasshopper egg pods destroyed by larvae of bee flies (Bombyliidae), blister beetles (Meloidae), and ground beetles (Carabidae).

The data were obtained in annual grasshopper egg surveys made on 16 study areas in 7 States (3 study areas in Arizona, 2 in California, 2 in Kansas, 1 in Minnesota, 4 in Montana, 3 in North Dakota, and 1 in South Dakota), and in grasshopper egg surveys made for use in control work in all the Western and Midwestern States in 1938, 1939, and 1940.

Other data were obtained in annual grasshopper egg surveys of six counties in California and of the major grassland areas in Montana, Nebraska, North Dakota, South Dakota, and Wyoming.

Surveys of the 16 study areas and the 6 California counties were made on cropland and adjacent grassland. In the surveys of the western grassland region, all soil samples taken were remote from crops. Surveys in connection with grasshopper control work were made on cropland, except in a few instances where rangeland immediately adjacent to crops was examined.

The number of sound grasshopper egg pods, destroyed pods, and predators per square foot were determined by sifting soil from a square-foot area through a quarter-inch mesh screen. Approximately 36,000 soil samples were examined in research surveys and 202,000 in control surveys. The percentage of the egg-pod population destroyed by each predator was obtained by dividing the number of pods destroyed by each kind of predator by the number of egg pods per square foot.

The average annual destruction of egg pods for the 16 study areas as a group was 17.87 percent (6.18 percent by bee flies, 8.80 percent by blister beetles, and 2.89 percent by ground beetles). The average total annual predatism, by States, was: North Dakota, 27.62 percent; Montana, 25.30 percent; Minnesota, 21.73 percent; South Dakota, 18.63 percent; California, 16.01 percent; Kansas, 10.49 percent; and Arizona, 5.30 percent. Highest destruction of egg pods in a single area in each State for a single year was as follows: Dickinson, N. Dak., 77.52 percent in 1939; San Luis Obispo, Calif., 60 percent

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[2] Retired June 30, 1954.

1937; Havre, Mont., 55.55 percent in 1940; Mitchell, S. Dak., 32.70 percent in 1939; Hallock, Minn., 30.0 percent in 1941; Hays, Kans., 25.00 percent in 1947; and Tempe, Ariz., 16.67 percent in 1939.

The average annual destruction of egg pods in the 6 counties in California was 27.6 percent; highest predatism in a single county for a single year was 59.50 percent in San Luis Obispo County in 1937.

The average annual destruction of egg pods in the grassland areas of Montana, Nebraska, North Dakota, South Dakota, and Wyoming was 5.10 percent (1.80 percent by bee flies, 2.90 percent by blister beetles, and 0.40 percent by ground beetles). Highest total destruction in a single year was 9.50 percent in 1944. Predatism was considerably lower in the grassland areas than on cropland in study areas in the same States.

Habitat preferences of predators on study areas were sometimes pronounced but were not consistent for all areas or all years.

There was a general tendency toward a high percentage of predatism during years of high egg-pod population, but this did not hold true either for all study areas or for all years.

Grasshopper egg surveys were made annually as a part of the Grasshopper Control Project to help determine the infestation to be expected the following year. Findings from such surveys formed the basis for planning for the next year's control needs. When this study was begun, the expectation was to analyze the data accumulated since the Project was established in 1938. After 1940, however, the survey records lacked data essential to calculating percentages of predatism, so analysis of control survey data was confined to the years 1938, 1939, and 1940.

The average annual destruction of egg pods for the 3 years, as determined by the control project survey, was 15.0 percent (6.9 percent by bee flies, 5.6 percent by blister beetles, and 2.5 percent by ground beetles). The average annual percentage of eggs destroyed by predators in the 5 States where survey was the most complete for all 3 years was as follows: North Dakota, 32.5 percent; Colorado, 23.5 percent; South Dakota, 22.9 percent; Nebraska, 16.4 percent; and Montana, 15.9 percent.

Average predatism was 50 percent or more in many counties in several States each year. Highest destruction of egg pods for each year was as follows:

Arizona—55 percent in Santa Cruz County in 1939.

Colorado—60 percent in Kiowa County in 1938; 55 percent in Bent County in 1940.

Illinois—50 percent in Schuyler County in 1939.

Minnesota—67 percent in Dakota County in 1940.

Montana—59 percent in Richland County in 1939; 50 percent in Hill and Prairie Counties in 1940.

Nebraska—56 percent in Sheridan County in 1938; 50 percent in Scotts Bluff County in 1939; 53 percent in Knox County in 1940.

North Dakota—60 percent in Benson, Foster, and McKenzie counties in 1938; 65 percent in McKenzie County in 1940; 53 percent in Mercer County in 1939.

Oklahoma—59 percent in Cimarron County in 1938.

South Dakota—64 percent in Perkins County in 1938; 63 percent in Bennett County in 1939; and 80 percent in Butte County in 1940.

Texas—52 percent in Carson County in 1938.

Utah—64 percent in Carbon County in 1939.

WASHINGTON—50 percent in Ferry County in 1939.

The most common species of grasshopper egg-pod predators encountered were the following:

Meloidae—Epicauta maculata (Say), *E. puncticollis* (Mann.), and *E. fabricii* (Lec.).

Bombyliidae—Systoechus vulgaris Loew and *Aphoebantus hirsutus* (Coq.).

Carabidae—Amara obesa (Say) and *A. hesperia* (Csy.).

SCOPE OF THE STUDY

Larvae of bee flies (Bombyliidae), blister beetles (Meloidae), and ground beetles (Carabidae) were listed as predators of grasshopper egg pods in the United States by Riley in 1878 and 1880 (*4*, *5*).[3] Since then, many entomologists have mentioned them as important insect enemies of grasshoppers. In most of these references the percentage of the grasshopper egg-pod population destroyed is not stated, but Criddle (*1*), Wilson (*7*), Shotwell (*6*), and Gilbertson and Horsfall (*2*) have published quantitative data showing that these predators are capable of destroying large segments of grasshopper egg-pod populations.

Criddle stated that the combined effects of *Systoechus vulgaris* Loew, several species of blister beetle, and carabid larvae destroyed over 20 percent of the grasshopper egg pods in the entire Province of Manitoba in 1932, and in some areas egg destruction reached fully 90 percent.

Wilson found that bee fly larvae destroyed 44.5 percent of the egg pods in *Camnula pellucida* (Scudd.) egg beds near Tulelake in northern California in 1929. No other predators were found. His records are based on 5 soil samples taken on each of 7 egg beds. The egg beds ranged in size from 2 to 20 acres, and each soil sample was from a 1-square-yard area.

Shotwell published an account of the grasshopper egg-pod predators found in the egg survey conducted as a part of the Grasshopper Control Project in the fall of 1938 by the Entomology Research Division and cooperating States. Records were obtained on a total of 6,277 fields in 11 States. The number of predators per square foot of soil were: Bee fly larvae, 0.31; blister beetle larvae, 0.24; and ground beetle larvae, 0.06. In areas where bee fly larvae were most numerous, from 20 to 70 percent of the egg pods were destroyed.

Gilbertson and Horsfall found 59.3 percent of a *Melanoplus mexicanus mexicanus* (Sauss.) egg population in South Dakota destroyed by predators in 1938 (35.6 percent by bee fly larvae and 23.7 percent by blister beetle larvae). Their findings were based on 100 soil samples (each from a 1-square-foot area) taken at random in 80 acres of wheat stubble.

The Entomology Research Division and the Plant Pest Control Division have not conducted detailed studies of the biology of grasshopper egg-pod predators. However, in the annual grasshopper egg-pod surveys numerous records have been made of the percentage of egg pods destroyed by bee flies, blister beetles, and ground beetles.

[3] Italic numbers in parentheses refer to Literature Cited, p. 28.

Because of the importance of these predators in any study of grasshopper populations and the relatively few previously published quantitative data concerning them, the records, even though most of them are more than 10 years old, have been assembled and are presented in this bulletin.

SOURCES OF DATA

The data collected by the Entomology Research Division were obtained in 7 States on 16 study areas established for the purpose of conducting yearly ecological studies of grasshoppers, including intensive sampling of the egg-pod populations in all the major habitats on each area. The study areas were set up in crop-growing districts subject to grasshopper outbreaks and included crops and range plants representative of those found on surrounding farms. Each area was about 4 miles long and 2 miles wide.

Other research data were obtained by the Entomology Research Division in connection with grasshopper egg-pod surveys of the major grassland areas in several Western States.

The data collected by the Plant Pest Control Division were obtained in annual grasshopper egg-pod surveys of Western and Midwestern States to determine where grasshoppers were numerous enough to indicate they might need to be controlled the following year. In 1938, 1939, and 1940, records for each survey stop showed the number of egg pods found and the number of pods destroyed by bee flies, blister beetles, and ground beetles. From this information in the original field notes it was possible to calculate the percentage of egg pods destroyed by each kind of predator and the total percentage of egg pods each destroyed. Unfortunately, percentage figures could no longer be derived after 1940 because of curtailment of personnel engaged in grasshopper survey work.

METHODS OF OBTAINING AND USING DATA

The number of grasshopper egg pods and the number of predators per square foot were determined by sifting soil from a square-foot area through a quarter-inch mesh screen and recording the number found. The data in this paper were based on approximately 238,000 soil samples (36,000 taken in research studies and 202,000 in control surveys).

A record was made of sound grasshopper egg pods, predator-infested egg pods, and unattached predators found in each soil sample examined. These three items added together represent the total number of egg pods per square foot of soil. The number of predators per square foot was the sum of those found in egg pods and those found free in the soil. A record was made also of the number of bee flies, blister beetles, and ground beetles (larvae and pupae) making up the predator population. Other insect predators were never found in sufficient numbers to affect the egg-pod population materially, and they were disregarded.

The percentage of the egg-pod population destroyed by each predator was obtained by dividing the number per square foot by the total number of egg pods per square foot.

This method of computing the total number of grasshopper egg pods per square foot and the percentage of egg pods destroyed by

each predator is based on three assumptions: (1) One predator-attacked pod contains only one predator; (2) one predator in an egg pod will completely destroy that pod but will not attack another; (3) one predator found free in the soil has already destroyed one egg pod.

The first assumption is not always correct. Sometimes more than one predator is found in an egg pod, but such pods are unusual. Personnel with long experience in grasshopper egg surveys agree that less than 1 percent of predator-attacked pods contain more than one predator.

The second assumption is based on field experience and some experimental results. Spring surveys show nearly complete destruction of all eggs in predator-infested pods as compared with a smaller proportion of eggs destroyed in pods found during surveys in the same location the previous fall. Wilson (*7*) states that unconsumed eggs in *Camnula pellucida* egg pods containing bee fly larvae failed to hatch when held in the laboratory and therefore should be considered destroyed. On the other hand, Horsfall (*3*) has shown that the second assumption is not always correct. He found that several species of blister beetle larvae consumed from 25 to 45 *Melanoplus differentialis* (Thos.) eggs during their entire feeding period when they were allowed to feed to repletion. This indicates that a single blister beetle larva is capable of destroying the entire contents of egg pods of such grasshopper species as *C. pellucida* and *M. mexicanus mexicanus*, which seldom contain more than 30 eggs per pod, but only part of the 75 to 100 eggs usually found in *M. differentialis* and *M. bivittatus* (Say) egg pods. Horsfall apparently assumes that unconsumed eggs in pods attacked by blister beetle larvae hatch normally, but Wilson's results indicate that such may not be the case.

The assumption that a single predator does not attack more than one egg pod may not hold true for ground beetle larvae, which are free moving, but there are no data to show how many eggs one larva can destroy. Bee flies and blister beetles lack functional legs in their late larval stages and cannot move more than a few inches in search of egg pods. Where egg pods are packed closely together it might be possible for one larva to destroy an egg pod and then enter another, but no concrete example of this has been reported during the many years that egg-pod surveys have been conducted.

The third assumption is based on the fact that both bee fly larvae and blister beetle larvae frequently burrow below or to one side of the egg pods after destroying the individual eggs. The remains of egg pods whose contents have been eaten are easily broken in the soil-sifting process and cannot always be recognized as individual pods associated with a particular predator. Therefore, every predator found free in the soil is credited with destroying one egg pod not previously counted. This assumption is also subject to error. Horsfall, as already mentioned, has shown that blister beetle larvae may complete their feeding and leave the egg pods without consuming all the 75 to 100 eggs of such grasshopper species as *Melanoplus differentialis* and *M. bivittatus*. It seems likely that a single bee fly larva would also fail to consume all the eggs in an egg pod of either of these species. This would overemphasize the importance of predators in regions where *M. differentialis* and *M. bivittatus* are dominant.

All the major chances for error in the method used for determining the percentage of egg pods destroyed by predators tend to overrate their importance, but this is more than counterbalanced by the fact

that considerable numbers of predators are overlooked in the soil-sifting process. It is a laborious and painstaking task to recover and count grasshopper egg pods; to find their predators is even more difficult. Early larval stages can be found only by microscopic examination of the soil sample, and this is impracticable in the usual grasshopper egg survey. Late larval stages and pupae are smaller than grasshopper egg pods, and many of them undoubtedly pass through the screen unnoticed. Because of the certainty that considerable numbers of predators are overlooked in soil sampling it is believed that the records presented actually underrate their importance by at least 5 percent.

ANALYSIS OF DATA COLLECTED IN CONNECTION WITH RESEARCH STUDIES

Grasshopper Egg Pods Destroyed in Predominantly Cropland Areas

The quantitative data include records for individual study areas for periods ranging from 2 to 10 years. It would be cumbersome and does not seem worthwhile to present yearly records for all areas. Therefore, they have been summarized and grouped by States. (See table 1.)

Arizona

Records from Arizona are available for study areas at Tempe, Yuma, and Chino Valley (table 1). The Tempe and Yuma areas are in southern Arizona at elevations of 1,159 and 110 feet; they include irrigated cropland and desert; principal crops are alfalfa and cotton at Tempe and alfalfa at Yuma; dominant grasshopper species are *Melanoplus differentialis* and *M. mexicanus mexicanus*. The Chino Valley study area is in northern Arizona at an elevation of about 5,500 feet; it includes cropland surrounded by grassland; principal crops are beans, small grains, and alfalfa; dominant grasshoppers are *M. lakinus* (Scudd.) and *M. mexicanus mexicanus*.

Destruction of grasshopper egg pods by predators was lower on study areas in Arizona than in any other State where records were kept. The average annual destruction of egg pods totaled 5.30 percent (0.4 percent by bee flies, 1.76 percent by blister beetles, and 3.14 percent by ground beetles). Only in Arizona and one other State (Minnesota) was predatism by ground beetle larvae higher than by either bee fly larvae or blister beetle larvae. Highest destruction of egg pods in Arizona in 1 year on 1 study area was 16.67 percent in 1939 on the Tempe study area.

California

California records on grasshopper egg-pod predators include records made on study areas at Sacramento and San Luis Obispo and in 7 counties subject to grasshopper outbreaks (table 1). The Sacramento study area is in the central coastal region and has an elevation of 50 feet; it is in an intensely farmed, irrigated river valley; principal crops are alfalfa, small grains, and truck crops; dominant grasshopper species are *Melanoplus marginatus* (Scudd.) and *M. femur-rubrum* (DeG.). The San Luis Obispo study area is in the southern coastal region at an

elevation of 300 feet; it is composed largely of rangeland but includes some small grains and cultivated crops; dominant grasshopper species are *Camnula pellucida* and *Oedaleonotus enigma* (Scudd.). Records of egg-pod predators were obtained from general surveys in the following counties: Imperial, Sacramento, San Diego, San Luis Obispo, Santa Barbara, and Ventura. Imperial County is in the southeastern corner of the State; all the others are in the southern coastal region. Dominant grasshopper species are *M. mexicanus mexicanus* in Imperial County, *M. marginatus* in Sacramento County, and *C. pellucida* in all other counties.

Average annual destruction of egg pods totaled 16.01 percent (1.71 percent by bee flies, 14.13 percent by blister beetles, and 0.17 percent by ground beetles). On the Sacramento area predatism was highest in 1938 when 26 percent of the egg pods were destroyed by blister beetle larvae, the only predator present. On the San Luis Obispo area predatism was highest in 1937 when 60 percent of the egg pods were destroyed (48.9 percent by blister beetles and 11.1 percent by bee flies). No bee fly larvae were reported for the Sacramento area and only small numbers were reported for the San Luis Obispo area. This is in sharp contrast to the destruction of 44.5 percent of *Camnula pellucida* egg pods by bee fly larvae near Tulelake in northern California in 1929, reported by Wilson (7). Ground beetle larvae were extremely scarce on both study areas.

C. C. Wilson, who made the surveys on the two study areas in California, assisted State personnel in the county grasshopper egg surveys and assembled numerous county records of egg-pod predators. Ground beetle larvae were considered too scarce to be worth recording, and only the combined number of bee fly larvae and blister beetle larvae were listed. These data were not as carefully obtained as the data on the study areas, but they show the combined effects of bee fly and blister beetle larvae over larger areas. Therefore, they are presented in table 2.

The average annual destruction of grasshopper egg pods by bee fly larvae and blister beetle larvae for the group of 6 counties was 22.7 percent. This is 6.7 percent more than were destroyed by these two predators in the Sacramento and San Luis Obispo study areas (table 1). Predatism was highest in San Luis Obispo County with a 3-year average of 38.5 percent. This county also had the highest percentage of egg pods destroyed in a single year—59.5 percent in 1937. Ventura County was second with 43.2 percent in 1934, and San Diego County was a close third with 42.9 percent in 1944. In all the California surveys, egg-pod predators were most abundant where *Camnula pellucida* was the dominant grasshopper.

Kansas

Kansas records on grasshopper egg-pod predators are from study areas at Hays and Garden City (table 1). The Hays area is in central Kansas at an elevation of 2,000 feet; wheat is the main crop; *Melanoplus mexicanus mexicanus* is the dominant grasshopper. The Garden City area is in southwestern Kansas at an elevation of 2,836 feet; small grains, sorghums, and legumes are the main crops; *M. mexicanus mexicanus*, *M. bivittatus*, *M. differentialis*, and *M. femur-rubrum* are the dominant grasshopper species.

Average annual destruction of egg pods totaled 10.49 percent (6.55 percent by bee flies, 3.66 percent by blister beetles, and 0.28 percent

TABLE 1.—*Grasshopper egg pods destroyed by larvae of bee flies, blister beetles, and ground beetles on study areas in Arizona, California, Kansas, Minnesota, Montana, North Dakota, and South Dakota*

State and study area	Surveys		Average samples per year	Average pods per square foot	Average percentage of pods destroyed by—			
					Bee fly larvae	Blister beetle larvae	Ground beetle larvae	All larvae
Arizona:	*Number*	*Years*	*Number*	*Number*	*Percent*	*Percent*	*Percent*	*Percent*
Tempe, Maricopa County	3	1937–39	595	0. 08	0. 46	1. 73	5. 75	7. 94
Yuma, Yuma County	3	1937–39	209	. 25	0	0	. 87	. 87
Chino Valley, Yavapai County	4	1937–39; 1941	328	. 21	. 66	3. 11	2. 89	6. 66
Average (weighted)			372	. 18	. 40	1. 76	3. 14	5. 30
California:								
Sacramento, Sacramento County	6	1936–41	123	. 98	0	17. 30	. 16	17. 46
San Luis Obispo, San Luis Obispo County	10	1936–45	395	2. 23	2. 74	12. 24	. 18	15. 16
Average (weighted)			293	1. 76	1. 71	14. 13	. 17	16. 01
Kansas:								
Hays, Ellis County	5	1942; 1946–49	125	. 05	10. 60	2. 10	. 40	13. 10
Garden City, Finney County	5	1945–49	250	. 19	2. 50	5. 22	. 16	7. 88
Average (weighted)			187	. 12	6. 55	3. 66	. 28	10. 49
Minnesota:								
Hallock, Kittson County	3	1939–41	540	. 57	5. 00	7. 10	9. 63	21. 73

Montana:								
Brinkman, Hill County	7	1939–45	184	.34	3.13	13.33	.76	17.22
Gildford, Hill County	7	1939–45	150	.33	10.27	18.64	1.07	29.98
Havre, Hill County	7	1939–45	186	.62	12.49	20.88	4.44	37.81
Huntley, Yellowstone County	7	1939; 1941–46	269	.19	5.30	9.80	1.14	16.24
Average (weighted)			197	.37	7.79	15.66	1.85	25.30
North Dakota:								
Beach, Golden Valley County	8	1939–46	242	.61	12.59	12.80	3.70	29.09
Dickinson, Stark County	8	1939–46	208	.32	14.22	13.08	.81	28.11
Mandan, Morton County	8	1939–46	283	.36	8.87	14.69	2.13	25.69
Average (weighted)			244	.43	11.89	13.52	2.21	27.62
South Dakota:								
Mitchell, Davison County	9	1938–46	204	.48	9.90	5.79	2.94	18.63
Average (all States)				.56	6.18	8.80	2.89	17.87

TABLE 2.—*Grasshopper egg pods destroyed by bee fly larvae and blister beetle larvae combined, as determined in county grasshopper egg surveys in California*

County	Surveys		Average samples per year	Average pods per square foot	Average percentage of pods destroyed
	Number	*Years*	*Number*	*Number*	*Percent*
Imperial	1	1937	129	1.4	11.2
Sacramento	2	1936–37	185	.45	16.4
San Diego	4	1936–37; 1944–45	182	11.8	23.1
San Luis Obispo	3	1936–37; 1939	424	1.8	38.5
Santa Barbara	2	1936–37	90	1.5	10.8
Ventura	4	1934–37	31	2.2	22.2
Average (weighted)			175	4.2	22.7

by ground beetles). This was the lowest recorded for any State except Arizona. It may possibly be explained by the fact that grasshopper egg-pod populations were extremely low during all the 5 years for which records were kept. Low egg-pod populations not only decrease the actual number of predators but also tend to reduce the percentage of egg pods the predators destroy. The highest record of predatism in Kansas occurred on the Hays study area in 1947 when bee fly larvae, the only predator found, destroyed 25 percent of the egg pods.

Minnesota

Records of the percentage of grasshopper egg pods destroyed by predators were kept for a study area near Hallock (table 1). This area is in northwestern Minnesota at an elevation of 815 feet; wheat and sweetclover are the main crops; *Melanoplus bivittatus, M. mexicanus mexicanus,* and *Camnula pellucida* are the dominant grasshopper species.

Average annual destruction of egg pods totaled 21.73 percent (5.00 percent by bee flies, 7.10 percent by blister beetles, and 9.63 percent by ground beetles). Minnesota was the only State in addition to Arizona in which predatism by ground beetle larvae was higher than by either bee fly larvae or blister beetle larvae. Predatism on the Hallock study area was highest in 1941 when 30.0 percent of the egg pods were destroyed (13.1 percent by ground beetles, 8.0 percent by bee flies, and 8.9 percent by blister beetles).

Montana

Records of grasshopper egg-pod predators are from study areas at Brinkman, Gildford, and Havre in north-central Montana, and at Huntley in south-central Montana (table 1). Havre is 30 miles south of the Canadian border and has an elevation of 2,480 feet; Gildford is 30 miles west of Havre; Brinkman is 20 miles southwest of Gildford; elevations at Brinkman and Gildford are about the same as at Havre. Dryland small grain crops and native prairie vegetation occupy most of the land on the Brinkman, Gildford, and Havre study

areas. Huntley is in the Yellowstone Valley at an elevation of 3,000 feet; principal crops on the study area are irrigated small grains and sugar beets; prairie range vegetation and irrigated pastures are also included. *Melanoplus mexicanus mexicanus* was the dominant grasshopper on all the study areas.

Average annual destruction of grasshopper egg pods totaled 25.30 percent (15.66 percent by blister beetles, 7.79 percent by bee flies, and 1.85 percent by ground beetles). Highest predatism for single years in each study area and the percentage of egg pods destroyed were as follows: Brinkman, 31.2 percent in 1945 (26.7 percent by blister beetles, 4.1 percent by bee flies, and 0.4 percent by ground beetles); Gildford, 53.3 percent in 1943 (27.3 percent by bee flies and 26.0 percent by blister beetles); Havre, 55.55 percent in 1940 (30.41 percent by bee flies, 22.55 percent by blister beetles, and 2.59 percent by ground beetles); and Huntley, 34.6 percent in 1939 (23.5 percent by blister beetles and 11.1 percent by bee flies).

Records of grasshopper egg pods destroyed by predators in the major habitats on the study areas at Brinkman, Gildford, and Havre were obtained for the 6-year period 1941 through 1946. The data have been summarized and are presented in table 3.

TABLE 3.—*Grasshopper egg pods destroyed by larvae of bee flies, blister beetles, and ground beetles in the major habitats included in the study areas in north-central Montana* [1]

Habitat	Average pods per square foot	Average percentage of pods destroyed by—			
		Bee fly larvae	Blister beetle larvae	Ground beetle larvae	All larvae
	Number	*Percent*	*Percent*	*Percent*	*Percent*
Field margins	0. 60	7. 96	9. 18	0. 89	18. 03
Idle land	. 41	5. 08	12. 02	9. 55	12. 65
Small grains	. 24	14. 29	11. 70	0	25. 99
Rangeland	. 25	0	22. 51	. 19	22. 70

[1] Averages for the 6-year period 1941–46 on study areas at Brinkman, Gildford, and Havre.

Predators as a group destroyed considerable numbers of grasshopper egg pods in all major habitats in Montana, but no egg pods destroyed by bee flies were found in rangeland and none destroyed by ground beetles were found in small grains. Bee flies were most effective in small grains, blister beetles in rangeland, and ground beetles in idle land.

The 7 years of continuous records for the study areas in Hill County afford an opportunity to compare the percentage of egg pods destroyed in years when the egg-pod population was low with the percentage destroyed in years when the egg-pod population was high. Comparisons are shown in table 4.

For the Brinkman and Havre study areas and for all areas as a group, the average percentage of predatism was higher in the 3 years of highest egg-pod population than in the 3 years of lowest population.

TABLE 4.—*Grasshopper egg pods destroyed by predators on study areas in Hill County, Mont., in the 3 years of lowest egg-pod population and in the 3 years of highest egg-pod population*

Study area	Years of lowest egg-pod population			Years of highest egg-pod population		
	Year	Pods per square foot	Percentage destroyed	Year	Pods per square foot	Percentage destroyed
		Number	*Percent*		*Number*	*Percent*
Brinkman	1943	0.26	2.30	1941	0.71	16.60
	1944	.22	1.30	1939	.47	28.00
	1945	.11	31.20	1940	.33	21.80
Average	------	.19	11.60	------	.50	22.13
Gildford	1942	.27	17.50	1940	.62	29.90
	1943	.25	53.30	1939	.51	32.50
	1945	.08	34.70	1944	.28	17.00
Average	------	.20	35.16	------	.47	26.46
Havre	1942	.18	41.86	1940	2.66	55.55
	1944	.15	19.61	1939	.87	32.18
	1943	.06	20.20	1941	.21	46.94
Average	------	.13	27.22	------	1.25	44.89
Average (all areas)	------	.17	24.66	------	.74	31.16

This did not hold true for the Gildford study area, where the highest percentage of predatism occurred during the 3 years of lowest egg-pod population, nor was it always true for the Brinkman and Havre study areas when records for only 2 years were compared.

North Dakota

Records of grasshopper egg-pod predators are from study areas at Beach and at Dickinson in southwestern North Dakota and at Mandan in south-central North Dakota (table 1). Beach is 3 miles east of the Montana State line and 62 miles north of the South Dakota border; it has an elevation of 2,759 feet. Dickinson is 64 miles east of Beach, at an elevation of 2,543 feet. Mandan is 100 miles east of Dickinson, at an elevation of 1,750 feet. Dryland small grain crops, legumes, and native prairie vegetation occupy most of the land on all three areas. The dominant grasshopper species on all three areas is usually *Melanoplus mexicanus mexicanus*, but it is sometimes outnumbered at Dickinson by *M. femur-rubrum* and at Mandan by *M. differentialis*.

Average annual destruction of grasshopper egg pods totaled 27.62 percent (13.52 percent by blister beetles, 11.89 percent by bee flies, and 2.21 percent by ground beetles). The total differs only 2.32 percent from the 7-year average of 25.30 percent for the 4 study areas in Montana.

Highest predatism for single years in each study area and the percentage of egg pods destroyed by each predator were as follows:

Beach, 76.16 percent in 1940 (49.74 percent by bee flies, 21.42 percent by blister beetles, and 5.00 percent by ground beetles); Dickinson, 77.52 percent in 1939 (49.08 percent by bee flies and 28.44 percent by blister beetles); and Mandan, 68.69 percent in 1943 (48.95 percent by blister beetles and 19.74 percent by bee flies).

Records of grasshopper egg pods destroyed by predators in the major habitats on study areas at Beach, Dickinson, and Mandan for the 6-year period 1941 through 1946 are summarized in table 5.

TABLE 5.—*Grasshopper egg pods destroyed by larvae of bee flies, blister beetles, and ground beetles in the major habitats included in the study areas in North Dakota* [1]

Habitat	Average pods per square foot	Average percentage of pods destroyed by—			
		Bee fly larvae	Blister beetle larvae	Ground beetle larvae	All larvae
	Number	*Percent*	*Percent*	*Percent*	*Percent*
Field margins	0.76	2.23	3.67	2.71	8.61
Idle land	.70	3.89	5.56	.75	10.20
Small grains	.21	8.97	11.04	4.05	24.51
Legumes	.47	2.48	10.08	6.52	19.08
Rangeland	.08	2.50	20.75	14.44	37.69

[1] Average for the 6-year period 1941–46 on study areas at Beach, Dickinson, and Mandan.

Predators as a group destroyed considerable numbers of grasshopper egg pods in all major habitats. Predatism was greatest in rangeland. Bee flies were most effective in small grains, and both blister beetles and ground beetles were most effective in rangeland.

The 8 years of continuous records for study areas at Beach, Dickinson, and Mandan afford an opportunity to compare the percentage of egg pods destroyed in years when the egg-pod population was low with the percentage destroyed in years when the egg-pod population was high. Comparisons are shown in table 6.

For each study area and for all areas as a group, the average percentage of predatism was much higher for the 4 years of highest egg-pod population than for the 4 years of lowest egg-pod population. However, this did not always hold true within a study area when records for only 2 years were compared, as will be seen in the following comparisons found in table 6:

At Beach, the egg-pod population was 2.24 per square foot in 1939 and predatism was 38.09 percent, whereas the egg-pod population was 0.99 per square foot in 1940 and predatism was 76.16 percent.

At Dickinson, the egg-pod population was 0.05 per square foot in 1945 and predatism was 3.05 percent, whereas the egg-pod population was 0.02 per square foot in 1946 and predatism was 6.25 percent.

At Mandan, the egg-pod population was 0.12 per square foot in 1944 and predatism was 1.86 percent, whereas the egg-pod population was 0.02 per square foot in 1945 and predatism was 8.33 percent.

TABLE 6.—*Grasshopper egg pods destroyed by predators on study areas in North Dakota in the 4 years of lowest egg-pod population and in the 4 years of highest egg-pod population*

Study area	Years of lowest egg-pod population			Years of highest egg-pod population		
	Year	Pods per square foot	Percentage destroyed	Year	Pods per square foot	Percentage destroyed
		Number	*Percent*		*Number*	*Percent*
Beach, Golden Valley County	1942	0. 29	36. 52	1939	2. 24	38. 09
	1944	. 26	11. 62	1940	. 99	76. 16
	1945	. 14	12. 17	1941	. 43	38. 22
	1946	. 11	11. 19	1943	. 41	8. 72
Average	------	. 20	17. 87	------	1. 02	40. 30
Dickinson, Stark County	1943	. 27	25. 29	1940	1. 15	69. 54
	1944	. 05	14. 05	1939	. 43	77. 52
	1945	. 05	3. 05	1942	. 31	14. 87
	1946	. 02	6. 25	1941	. 30	13. 86
Average	------	. 05	12. 25	------	. 55	43. 95
Mandan, Morton County	1941	. 19	13. 47	1940	. 99	46. 66
	1944	. 12	1. 86	1939	. 89	43. 97
	1946	. 03	7. 68	1942	. 38	14. 88
	1945	. 02	8. 33	1943	. 29	68. 69
Average	------	. 09	7. 33	------	. 41	43. 55
Average (all areas)	------	. 11	12. 65	------	. 66	42. 60

South Dakota

Records of grasshopper egg pods destroyed by predators were kept for a study area at Mitchell in Davison County (table 1). Mitchell is in southeastern South Dakota and has an elevation of 1,293 feet; corn, small grains, and legumes are the main crops; *Melanoplus mexicanus mexicanus, M. differentialis,* and *M. femur-rubrum* are the dominant grasshopper species.

Average annual destruction of grasshopper egg pods totaled 18.63 percent (9.90 percent by bee flies, 5.79 percent by blister beetles, and 2.94 percent by ground beetles). This was 8.99 percent lower than the average of 27.62 percent for the 3 study areas in North Dakota.

Highest predatism in a single year on the Mitchell study area was 32.70 percent in 1939. This also was considerably lower than the highest predatism for a single year on the North Dakota study areas.

Records of grasshopper egg pods destroyed by predators in the major habitats of the study area at Mitchell for the 6-year period 1941 through 1946 are shown in table 7.

Bee flies were most effective in small grains and legumes; blister beetles and ground beetles were most effective in legumes. No egg pods destroyed by ground beetles were found in rangeland.

TABLE 7.—*Grasshopper egg pods destroyed by larvae of bee flies, blister beetles, and ground beetles on the major habitats included in the study area at Mitchell, S. Dak.*[1]

Habitat	Average pods per square foot	Average percentage of pods destroyed by—			
		Bee fly larvae	Blister beetle larvae	Ground beetle larvae	All larvae
	Number	*Percent*	*Percent*	*Percent*	*Percent*
Field margins	0. 90	2. 00	1. 78	1. 67	5. 45
Idle land	1. 24	2. 74	3. 22	2. 42	8. 38
Small grains	. 40	9. 00	8. 00	4. 00	21. 00
Legumes	. 90	8. 89	14. 44	6. 66	29. 99
Rangeland	. 44	1. 82	7. 27	----	9. 09

[1] Averages are for the 6-year period 1941–46.

Summary of Predatism by Larvae of Bee Flies, Blister Beetles, and Ground Beetles on Study Areas

Average annual destruction of grasshopper egg pods on the study areas as a group totaled 17.87 percent (8.80 percent by blister beetles, 6.18 percent by bee flies, and 2.89 percent by ground beetles).

The average annual percentage of egg pods destroyed by each kind of predator in the State where it was most effective was as follows: Bee flies, 11.89 percent in North Dakota; blister beetles, 15.66 per-percent in Montana; and ground beetles, 9.63 percent in Minnesota.

The percentage of egg pods destroyed by each kind of predator and by all predators as a group was highest in a solid block of States composed of Montana, North Dakota, Minnesota, and South Dakota. Average annual predatism for this block was 23.07 percent, as compared with a group average of 10.60 percent for Arizona, California, and Kansas.

Arizona and Kansas had the lowest percentage of egg pods destroyed and also the lowest number of egg pods per square foot.

Grasshopper Egg Pods Destroyed in Predominantly Grassland Areas

Records of grasshopper egg pods destroyed by larvae of bee flies, blister beetles, and ground beetles were obtained in 9 annual fall grasshopper egg surveys of the grassland region bounded by the 6,000- and 2,000-foot levels east of the Continental Divide and the 42d and 49th parallels. This region includes large grassland areas in Montana, Wyoming, North Dakota, South Dakota, and Nebraska. Dominant grasshopper species are *Melanoplus mexicanus mexicanus*, *Ageneotettix deorum* (Scudd.), *Amphitornus coloradus* (Thos.), and *Phoetaliotes nebrascensis* (Thos.).

Egg surveys were conducted each fall from 1942 through 1950. Survey stops were distributed as evenly as possible over the region. However, because personnel and time were not available to sample the vast acreage of lightly infested range, stops were made only where 5 or more adults per square yard had been found in earlier surveys.

TABLE 8.—*Grasshopper egg pods destroyed by larvae of bee flies, blister beetles, and ground beetles on grassland areas in Montana, Nebraska, North Dakota, South Dakota, and Wyoming, 1942–50*

Year	Samples	Average pods per square foot	Average percentage of pods destroyed by—			
			Bee fly larvae	Blister beetle larvae	Ground beetle larvae	All larvae
	Number	*Number*	*Percent*	*Percent*	*Percent*	*Percent*
1942	1, 962	0. 26	2. 9	3. 0	0. 4	6. 3
1943	756	. 30	2. 0	2. 5	. 6	5. 1
1944	810	. 31	2. 9	5. 6	1. 0	9. 5
1945	540	. 37	2. 9	5. 2	. 3	8. 4
1946	684	. 32	1. 7	. 3	. 7	2. 7
1947	576	. 21	. 5	5. 6	0	6. 1
1948	466	. 21	1. 1	1. 4	0	2. 5
1949	738	. 56	1. 4	. 8	. 2	2. 4
1950	954	. 41	. 7	2. 2	. 6	3. 5
Average	832	. 33	1. 8	2. 9	. 4	5. 1

Eighteen soil samples (each from a ½-square-foot area) were examined at each stop. The number of egg pods found at survey stops undoubtedly was higher than the number present on other parts of the range where smaller numbers of adults (less than 5) had been found in the earlier surveys.

The average number of egg pods per square foot for the entire grassland region was estimated as follows: First, the average number of egg pods per square foot found during an egg survey was divided by the average number of adults per square yard found at the same stops during the adult surveys. This figure, which represents the number of egg pods per square foot produced by 1 adult per square yard, was then multiplied by the average number of adults per square yard found during the adult surveys for all survey stops in the region to obtain the average number of egg pods per square foot, as shown in table 8.

Total predatism by larvae of bee flies, blister beetles, and ground beetles did not exceed 9.5 percent in any of the 9 years of survey, and averaged only 5.1 percent. This was lower than for any of the 16 study areas. The fact that most species of range grasshoppers scatter their egg pods more widely than species of crop grasshoppers, thus making it more difficult for predators to find them, may be one reason for the lower percentage of egg pods destroyed in grasslands. This is in agreement with the fact that predatism on the study areas was highest during years of greatest egg-pod numbers (table 5).

Another possible explanation of the higher predatism in cropped areas is the fact that bee fly adults frequently gather in large numbers to feed on the blooms of annual plants growing on disturbed ground along roadsides and fencerows, and swarms of blister beetle adults feed on legumes such as alfalfa and sweetclover. Having concentrated in such places for feeding, it seems reasonable to believe they would stay for egg laying.

Predatism in the grassland region averaged about 20 percent less than in the grassland habitats on the study areas in Montana and North Dakota. It should be mentioned that the grasslands on the study areas consisted of small tracts adjacent to crops and cut by many roads and fences. In the regular grassland region, survey stops were generally remote from crops and ground disturbed by roads or fences.

ANALYSIS OF DATA COLLECTED IN CONNECTION WITH CONTROL SURVEYS

Data accumulated in control surveys are so voluminous that it is practicable to publish only a summary, which will be found in table 9. The table shows the number of survey stops made in each State each year and the highest predatism found at a single stop in each State. The table also shows the average percentage of egg pods destroyed by each of the three predators. This is the average for all stops made in all counties in each State, calculated from the number of pods found at each stop and the number that were destroyed by each of the three predators at each stop. The number of pods per square foot is omitted from the table, but the number found at each stop is recorded in the voluminous compilation from which the table is derived.

Key to Abbreviations in Table 9

The abbreviations used in table 9 to indicate dominant species of grasshoppers are as follows:

Species:	*Abbreviation*
Melanoplus bivittatus (Say)	biv
M. devastator Scudd.	dev
M. differentialis (Thos.)	diff
Oedaleonotus enigma (Scudd.)	enig
M. femur-rubrum (DeG.)	f-r
M. mexicanus mexicanus (Sauss.)	mex
M. packardii Scudd.	pack
Trimerotropis pallidipennis pallidipennis (Burm.)	pal
Camnula pellucida (Scudd.)	pell
Arphia pseudonietana (Thos.)	pseu
Aeoloplides turnbulli (Thos.)	turn

TABLE 9.—SUMMARY OF DATA COLLECTED IN CONTROL SURVEYS: *Grasshopper egg pods destroyed by larvae of bee flies, blister beetles, and ground beetles, by States and years*

State and year	Samples	Dominant species [1]		Highest predatism at any survey stop	Average percentage of pods destroyed by—			
					Bee fly larvae	Blister beetle larvae	Ground beetle larvae	All larvae
	Number	*First*	*Second*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Arizona	645							
1938	500	mex	pal	75	3.6	3.1	0.2	6.9
1939	145	mex	diff	55	8.5	17.5	8.2	34.2
Arkansas:								
1939	1,270	diff	mex	40	5.0	3.5	.2	8.7
California	2,406							
1938	215	dev	diff	44	.4	.2	.8	1.4
1940	2,191	dev	enig	75	.6	1.3	1.5	3.4
Colorado	11,058							
1938	3,545	biv	mex	96	7.9	7.2	1.7	16.8
1939	5,596	mex	turn	89	14.2	6.5	1.0	21.7
1940	1,927	turn	mex	91	11.6	18.5	1.8	31.9
Idaho	2,246							
1938	1,453	f-r	mex	50	2.2	.3	3.0	5.5
1939	793	mex	f-r	60	3.8	.2	0	4.0
Illinois	1,117							
1938	630	f-r	diff	48	1.1	12.9	3.3	17.3
1939	487	diff	f-r	79	3.9	17.9	10.0	32.7
Iowa	4,820							
1938	3,357	f-r	diff	91	.6	6.9	1.9	9.4
1939	865	biv	diff	60	.1	10.3	2.6	13.0
1940	598	biv	diff	72	11.7	12.7	7.8	32.2
Kansas	9,201							
1938	4,527	diff	mex	78	2.8	3.9	1.0	7.7
1939	2,171	turn	mex	67	3.3	2.7	.1	6.1
1940	2,503	turn	mex	67	2.3	7.6	.6	10.5
Michigan	3,155							
1938	1,080	mex	pell	78	7.9	.2	5.4	13.5
1939	1,511	mex	f-r	51	3.0	1.2	2.0	6.2
1940	564	mex	pseu	38	1.6	0	.7	2.3
Minnesota	13,074							
1938	3,335	f-r	diff	83	3.4	2.7	1.7	7.8
1939	5,367	diff	f-r	70	7.3	6.8	8.4	22.5
1940	4,372	f-r	biv	88	5.6	5.7	6.9	18.2
Mississippi	195							
1938	105	mex	diff	21	1.4	1.8	0	3.2
1939	90	diff	f-r	40	2.0	4.6	0	6.6
Missouri	4,425							
1938	4,083	mex	diff	100	0	7.1	.3	7.4
1939	342	mex	diff	20	0	2.2	1.5	3.7
Montana	30,905							
1938	9,360	mex	pack	96	9.2	5.8	.3	15.3
1939	15,255	mex	pack	88	9.7	5.2	1.0	15.9
1940	6,290	mex	pack [2]	80	9.8	4.5	2.3	16.6
Nebraska	24,388							
1938	6,026	mex	biv	78	6.6	9.1	2.0	17.7
1939	14,347	diff	mex	76	6.3	9.4	.5	16.2
1940	4,015	diff	biv	86	6.4	7.9	.9	15.2

See footnotes at end of table.

TABLE 9.—SUMMARY OF DATA COLLECTED IN CONTROL SURVEYS: *Grasshopper egg pods destroyed by larvae of bee flies, blister beetles, and ground beetles, by States and years*—Continued

State and year	Samples	Dominant species [1]		Highest predatism at any survey stop	Average percentage of pods destroyed by—			
					Bee fly larvae	Blister beetle larvae	Ground beetle larvae	All larvae
	Number	*First*	*Second*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Nevada	3,076							
1938	623	mex	biv	50	15.9	0.1	0	16.0
1939	1,258	mex	biv	86	9.4	2.2	.1	11.7
1940	1,195	mex	biv	84	14.6	.8	.2	15.6
New Mexico	1,005							
1938	505	mex	biv	66	2.5	3.9	1.6	8.0
1939	500	f-r	diff	82	7.4	3.1	0	10.5
North Dakota	24,518							
1938	6,886	mex	pack	93	30.8	9.5	1.4	41.7
1939	12,730	mex	biv	87	16.8	7.6	3.1	27.5
1940	4,902	mex	biv	95	16.9	8.5	3.0	28.4
Oklahoma	4,371							
1938	2,635	diff	mex	84	8.1	8.6	4.7	21.4
1939	1,361	mex	turn	75	3.3	9.0	.3	12.6
1940	375	mex	turn	66	3.1	3.9	0	7.0
Oregon	744							
1938	180	mex	pell	57	7.5	0	0	7.5
1939	564	mex	f-r	87	19.3	1.8	5.2	26.3
South Dakota	22,585							
1938	8,225	mex	diff	94	12.0	6.6	.9	19.5
1939	9,467	mex	diff	83	11.8	10.5	1.7	24.0
1940	4,893	diff	biv	80	10.3	13.8	1.0	25.1
Texas	7,005							
1938	4,190	diff	pack	83	1.3	5.4	2.0	8.7
1939	1,975	mex	diff	60	2.2	3.2	2.3	7.7
1940	840	mex	turn	67	.9	8.6	.5	10.0
Utah	4,780							
1938	1,550	f-r	mex	69	8.1	3.5	10.8	22.4
1939	3,230	mex	f-r	75	16.4	2.4	12.9	31.7
Washington	453							
1938	240	mex	f-r	67	0	0	17.7	17.7
1939	213	mex	f-r	50	12.6	1.4	2.3	16.3
Wisconsin	20,095							
1938	10,315	f-r	mex	93	3.8	0	5.2	9.0
1939	8,300	f-r	mex	57	.8	.1	.9	1.8
1940	1,480	f-r	mex	50	.4	0	.2	.6
Wyoming	5,204							
1938	2,555	mex	biv	75	9.3	3.7	2.0	15.0
1939	2,308	mex	biv	87	16.2	7.1	2.1	25.4
1940	341	biv	f-r	58	10.3	8.5	.6	19.4

[1] See key to abbreviations, p. 17.

[2] Another species (biv) was equally dominant, but pack was first dominant at 1 stop and biv was not recorded as first dominant.

Several other species of grasshoppers were dominant or second dominant in a few counties but not in any State as a whole. These species and the counties and years in which they were dominant are listed in table 10.

TABLE 10.—*Species of grasshoppers that were dominant or second dominant in individual counties but not throughout the State, by county and year*

Species and year	Collected in—	
	State	County
Ageneotettix deorum (Scudd.):		
1938	Michigan	Montcalm, Osceola, and Wexford.
1939	Michigan	Manistee and Oceana.
	Wisconsin	Wood.
1940	Michigan	Newago and Oceana.
Aulocara elliotti (Thos.):		
1938	Wyoming	Niobrara.
1939	Kansas	Pawnee, Rush, Seward, and Trego.
	Nebraska	Rock.
	North Dakota	Adams.
	Oklahoma	Beaver.
	South Dakota	Harding, Lawrence, Washington, and Ziebach.
	Wyoming	Crook.
1940	Nebraska	Keya Paha.
	Oklahoma	Greer and Kiowa.
	South Dakota	Jackson, Shannon, Todd, Washabaugh, and Washington.
	Texas	Armstrong, Hemphill, and Lipscomb.
Dissosteira carolina (L.):		
1938	South Dakota	Potter.
	Wisconsin	Sheboygan.
1940	Montana	Golden Valley and Hill.
Dissosteira longipennis (Thos.):		
1938	New Mexico	Colfax and Union.
	Oklahoma	Cimarron.
	Texas	Armstrong, Briscoe, Carson, Castro, Deaf Smith, Floyd, Hansford, Hartley, Hemphill, Howard, Hutchinson, Lamb, Lipscomb, Moore, Ochiltree, Oldham, Potter, Randall, Roberts, Sherman, and Swisher.
1939	New Mexico	Quay.
Encoptolophus sordidus sordidus (Burm.):		
1938	Michigan	Presque Isle.
Melanoplus angustipennis (Dodge):		
1938	do	Mecosta.
Melanoplus confusus (Scudd.):		
1938	Texas	Hale.

TABLE 10.—*Species of grasshoppers that were dominant or second dominant in individual counties but not throughout the State, by county and year*—Continued

Species and year	Collected in—	
	State	County
Melanoplus dawsoni (Scudd.):		
1939	Minnesota	Crow Wing and Itaska.
1940	do	Carlton, Itaska, St. Louis, and Stearns.
Melanoplus foedus foedus Scudd.:		
1938	Idaho	Boise.
	Oklahoma	Ellis and Pottawatomie.
	Texas	Fisher.
Melanoplus lakinus (Scudd.):		
1940	California	Sacramento.
Melanoplus marginatus (Scudd.):		
1939	Arizona	Santa Cruz.
Melanoplus rugglesi Gurney:		
1940	Nevada	Lander and Nye.
Schistocerca americana americana (Drury):		
1939	Missouri	Pemiscot.
Mixed range:		
1939	Nebraska	Cherry, Garden, Grant, and Hooker.
1940	South Dakota	Ziebach.

Figures 1, 2, and 3 show the total percentage of grasshopper egg pods destroyed by all predators combined, as determined in the surveys made in connection with control work in the fall of 1938, 1939, and 1940, respectively. The maps show the average percentage of predatism for all survey stops made in each county. For example, 19 survey stops were made in Sheridan County, Nebr., in 1938, and the percentage of egg pods destroyed at each of the 19 stops was 68, 78, 77, 78, 57, 64, 67, 66, 63, 58, 38, 36, 68, 45, 23, 18, 66, 54, and 50 percent, or an average of 56 percent for the 19 stops.

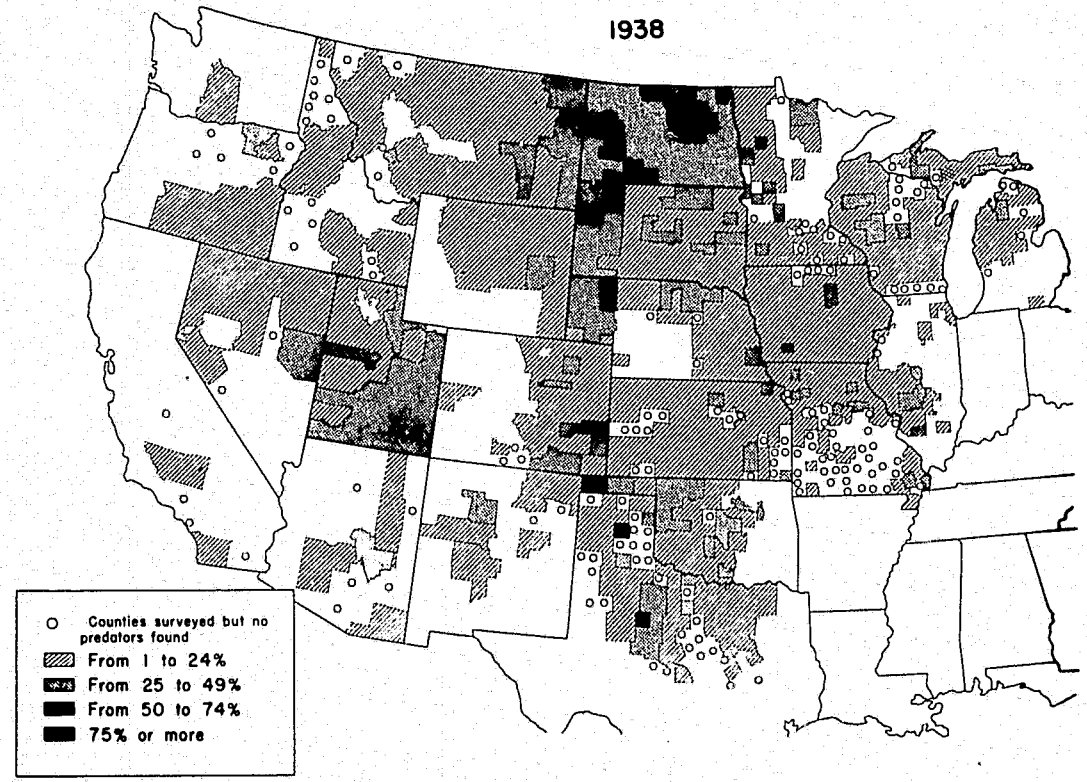

FIGURE 1.—Total percentage of grasshopper egg pods destroyed by larvae of bee flies, blister beetles, and ground beetles, autumn 1938.

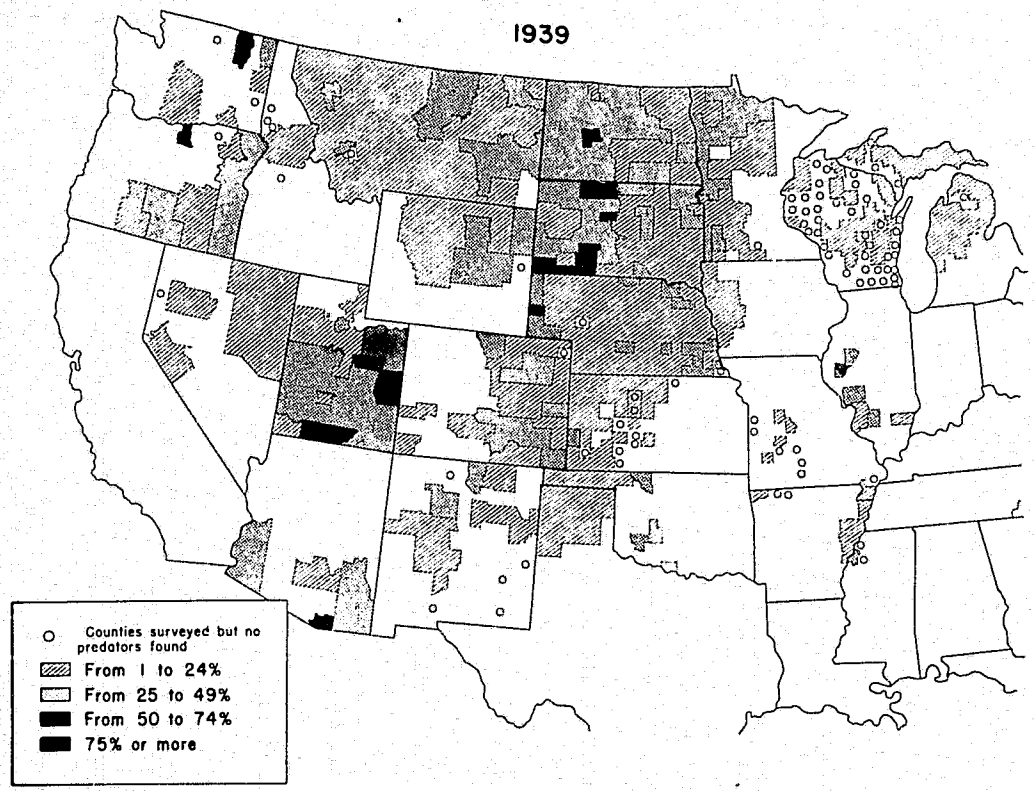

FIGURE 2.—Total percentage of grasshopper egg pods destroyed by larvae of bee flies, blister beetles, and ground beetles, autumn 1939.

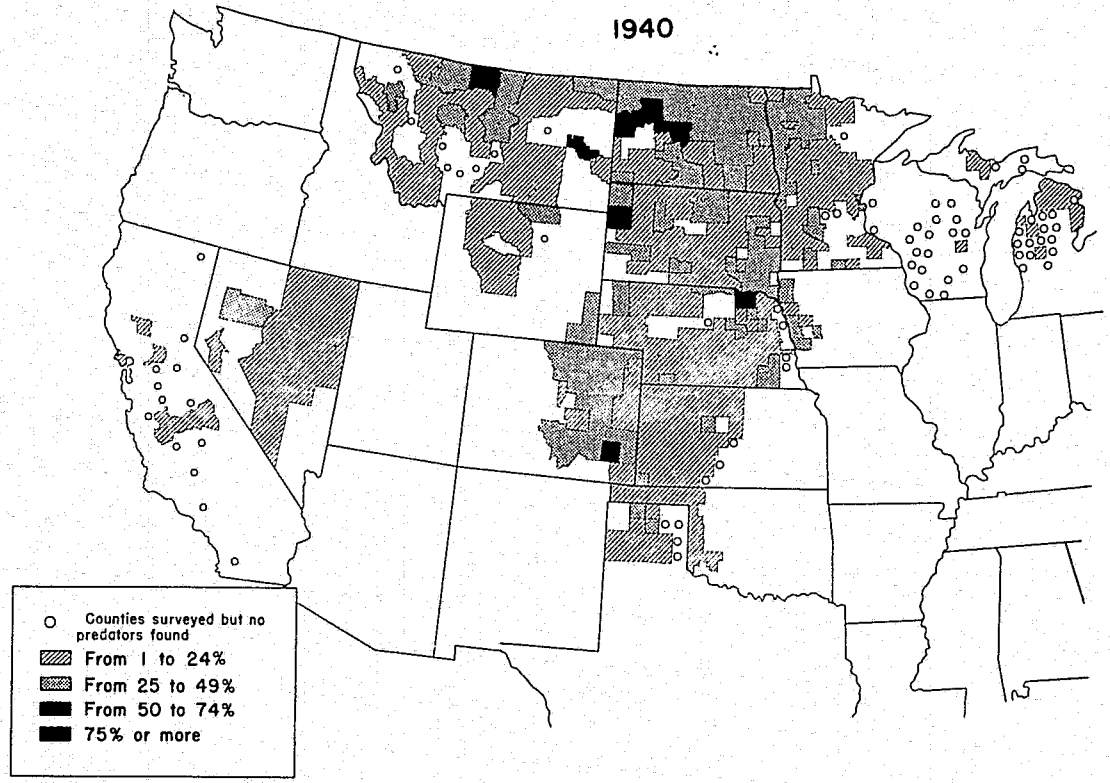

FIGURE 3.—Total percentage of grasshopper egg pods destroyed by larvae of bee flies, blister beetles, and ground beetles, autumn 1940.

PREDATOR SPECIES AND DISTRIBUTION RECORDS

Occasionally, larvae and pupae of bee flies, blister beetles, and ground beetles found in or near grasshopper egg pods were reared to adults and then sent to specialists for identification. Sometimes, adult bee flies and blister beetles associated with adult grasshoppers were collected by personnel making State grasshopper surveys. Some of these predators were identified as species whose grasshopper egg-pod feeding habits were known.

The rearing of larvae or pupae and the collecting of adults were not adequate to establish accurate ratings of abundance or exact limits of distribution, but the records are presented to supplement those of other workers.

Bee Flies (Bombyliidae)

The distribution of species of bee flies that were reared from larvae or pupae found in or near grasshopper egg pods or were collected as adults where grasshoppers were abundant is shown in table 11.

TABLE 11.—*Distribution of species of bee flies, by State and county*

Species	Collected in—	
	State	County [1]
Anastoechus barbatus (Osten Sacken).	Montana	Gallatin* and Hill.*
Aphoebantus hirsutus (Coq.)	California	Siskiyou,* Modoc,* Lassen,* and coastal areas from Monterey County to San Diego County.
	Oregon	Klamath.*
Aphoebantus mus (Osten Sacken).	Oregon	Klamath.*
Aphoebantus n. sp. #1	Colorado	Lincoln.*
Aphoebantus n. sp. #2	Nevada	Lander.*
Systoechus oreas Osten Sacken	Oregon	Klamath.*
Systoechus vulgaris Loew	Michigan	Otsego.
	Minnesota	Kittson* and Traverse.*
	Montana	Fergus,* Hill,* and Richland.
	Nebraska	Howard,* Lincoln,* and Scotts Bluff.*
	North Dakota	Billings, Golden Valley,* Grand Forks, Morton,* Pembina, Renville, and Stark.*
	South Dakota	Davison* and Perkins.

[1] An asterisk following the name of the county indicates that larvae or pupae were collected in or near grasshopper egg pods and held until adults emerged. Adults of species of known grasshopper egg-pod feeding habits were collected in the other counties listed.

Systoechus vulgaris, with records of occurrence in Michigan, Minnesota, Montana, Nebraska, North Dakota, and South Dakota, was the most common and also the most widely distributed species. *Aphoebantus hirsutus* was the next most common species, but its distribution was limited to California and Oregon.

Blister Beetles (Meloidae)

The distribution of species of blister beetles that were reared from larvae or pupae found in or near grasshopper egg pods or were collected as adults where grasshoppers were abundant is shown in table 12.

TABLE 12.—*Distribution of species of blister beetles, by State and county*

Species	Collected in—	
	State	County [1]
Epicauta collosa Lec.	South Dakota	Custer* and Pennington.*
	Wyoming	Park.
Epicauta ferruginea (Say)	Iowa	Dubuque.
	Montana	Hill.
Epicauta lemniscata (F.)	Iowa	Crawford and Pottawattamie.
Epicauta maculata (Say)	Colorado	Pueblo.*
	Iowa	Crawford and Pottawattamie.
	Kansas	Cheyenne,* Greeley, Scott,* Sherman, and Wichita.*
	Montana	Hill* and Pondera.*
	Nebraska	Cheyenne,* Custer, Dawes, Kimball,* and Logan.*
	North Dakota	Golden Valley,* La Moure,* Logan,* Morton, and Ward.*
	South Dakota	Davison.*
	Wyoming	Park.*
Epicauta oregona Horn	Montana	Pondera.*
Epicauta pennsylvanica (DeG.)	Iowa	Pottawattamie.
	Montana	Hill.
	Nebraska	Custer and Thurston.
	Wyoming	Goshen.
Epicauta puncticollis (Mann.)	California	Modoc,* Sacramento,* San Diego,* San Luis Obispo,* and Siskiyou.*
Epicauta sericans Lec.	North Dakota	Logan,* McLean,* and Morton.*
Epicauta albida (Say)	Colorado	Lincoln.*
	Kansas	Greeley.
	New Mexico	Quay.*
Epicauta fabricii (Lec.)	Montana	Fallon,* Fergus,* and Wibaux.*
	Minnesota	Traverse.*
	Nebraska	Banner,* Custer,* Dawson,* Lincoln,* Logan,* Madison,* and Valley.
	North Dakota	Barnes,* La Moure,* McIntosh, and Morton.
	South Dakota	Davison.*
Epicauta subglabra (Fall)	North Dakota	Morton* and Sioux.*

[1] An asterisk following the name of the county indicates that coarctate larvae or pupae were collected in or near grasshopper egg pods and held until adults emerged. Adults of species of known grasshopper egg-pod feeding habits were collected in the other counties listed.

Epicauta maculata, with records of occurrence in Colorado, Iowa, Kansas, Montana, Nebraska, North Dakota, South Dakota, and Wyoming, was the most common and also the most widely distributed species. *E. fabricii* was the next most common species; it was found in Minnesota, Montana, Nebraska, North Dakota, and South Dakota. *E. puncticollis*, found only in California, was the only meloid egg-pod predator found in that State.

Ground Beetles (Carabidae)

Only a few ground beetle larvae and pupae found closely associated with grasshopper egg pods were reared to the adult stage and identified.

L. P. Rockwood of the Grasshopper Research Project reared adults of *Amara obesa* (Say) from larvae found feeding on *Camnula pellucida* egg pods in Klamath County, Oreg. He also observed that adults of the same species dug into *C. pellucida* egg beds and ate large numbers of eggs. Riley (*4*) stated that *A. obesa* larvae destroyed large numbers of grasshopper eggs in Minnesota in 1876 and 1877. As this species is widely distributed throughout the regions where grasshoppers are most abundant, it is perhaps the most important carabid grasshopper egg-pod predator.

C. C. Wilson of the Grasshopper Research Project reared four other species of Carabidae—*Amara impunctiicollis* (Say), *Anisodactylus californicus* (Dej.), *A. nivalis* Horn, and *Pterostichus occidentalis* (Dej.)—from larvae and pupae found in or near grasshopper egg pods in Sacramento County, Calif.

DISCUSSION

The beneficial effects of natural factors in reducing grasshopper infestations is generally recognized. Most farmers and workers engaged in grasshopper control have seen grasshopper populations greatly reduced by parasites and diseases; insect, bird, and animal predators; and weather. Entomologists, including the authors, have been prone to view destruction of grasshopper eggs by larvae of bee flies, blister beetles, and ground beetles as of importance locally but of minor and unpredictable importance in reducing grasshopper populations over sizable geographical areas.

Data obtained by the Plant Pest Control Division in county surveys indicate that destruction of grasshopper egg pods by these predators was high over several extensive areas for the 3 years of survey, and there were few counties in which it did not occur. For example, figure 1 shows that in 1938 from 25 to 49 percent of all egg pods were destroyed in an area that included the eastern part of Montana, nearly all of North Dakota, the western part of South Dakota, the Panhandle of Nebraska, and several counties in Colorado, northern South Dakota, and western Minnesota. Within this extensive area, predatism ranged from 50 to 64 percent in single counties and groups of contiguous counties. In many counties where the average percentage of predators was high, predatism was 80 to 90 percent at individual survey stops and in a few counties, it was as much as 100 percent.

Data obtained by the Entomology Research Division on smaller unit areas, but by more intensive sampling over more years, are in

surprisingly close agreement with data obtained in the same counties by the Plant Pest Control Division (table 13). A comparison of data from the two sources shows that in at least four of the States subject to major grasshopper outbreaks larvae of bee flies, blister beetles, and ground beetles destroy considerable numbers of grasshopper egg pods every year. In the counties listed, average yearly reduction approximates 25 percent of the eggs laid.

Without destruction of grasshopper egg pods by larvae of bee flies, blister beetles, and ground beetles, and by other natural factors, the frequency of major grasshopper outbreaks over extensive areas would be greatly increased. Altogether, natural factors are so important in preventing extensive, explosive outbreaks that control by man, necessary as it is for additional population reduction and crop protection, is directed at only a small part of the potential population.

TABLE 13.—*Egg pods destroyed by larvae of bee flies, blister beetles, and ground beetles in study areas, as determined in research surveys, and in entire counties where study areas were located, as determined in control surveys*

State and county	Survey				Average percentage of egg pods destroyed in—	
	Study area		Entire county		Study area	Entire county
	Number	*Year*	*Number*	*Year*	*Percent*	*Percent*
Minnesota:						
Kittson	3	1939–41	3	1938–40	21	11
Montana:						
Hill	7	1939–45	3	1938–40	28	26
Yellowstone	7	1939; 1941–46	3	1938–40	16	9
North Dakota:						
Golden Valley	8	1939–46	3	1938–40	29	32
Morton	8	1939–46	3	1938–40	27	31
Stark	8	1939–46	3	1938–40	28	33
South Dakota:						
Davison	9	1938–46	3	1938–40	19	17
Average (weighted)					24	24

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