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Demographic Studies of Sagebrush Insects as Functions of Various Environmental Factors

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DEMOGRAPHIC STUDIES OF SAGEBRUSH INSECTS AS FUNCTIONS OF VARIOUS ENVIRONMENTAL FACTORS

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ABSTRACT

This report summarizes findings of the 1975 season and discusses some of the findings of previous reports. Two major objectives were pursued in 1975: 1) demographic study of the defoliator population at the north Curlew Valley study site was continued, and 2) defoliator impact on sagebrush productivity was assessed. The defoliator population at the study site continued to decline. The seasonal mean population density was 31.4 defoliators per kg of fresh sagebrush in 1975 as compared to 41.2 defoliators recorded in 1974. A population crash in June 1975, which resulted from a long period of high temperature and low precipitation, apparently was the major cause of the decline in numbers of defoliators. The same phenomenon was recorded in 1974 and undoubtedly contributed to the low defoliator population in the spring of 1975. Parasitism was low in 1975, accounting for only 4% of the mortality. Available evidence indicates that climatological factors exert decisive roles in regulating defoliator population. Of 123 severely defoliated sagebrush plants that were tagged in 1973, 33% had died by 1974, but the survivors remained alive through the survey in June 1976. The mean number of live branches per plant, however, continued to decrease; only 43% were alive in 1975 as compared to 60% in the fall of 1973. The number of plants flowering, however, increased to 71% in 1975 compared to 53% recorded in 1973. Investigation of the effects of different levels of defoliator infestation on sagebrush productivity showed significant reduction in the number of flower stalks and flower stalk length in the infested plants. The production of green foliage was also reduced as compared to insecticide-treated control plants, but the level of natural infestation at the study site was not high enough to produce a drastic reduction. The significance of these findings is discussed.

INTRODUCTION

The demographic study on the sagebrush defoliator, *Aroga websteri* Clarke, has been conducted since 1971. A major portion of the research was directed at determining the population dynamics of this species on the big sagebrush, *Artemisia tridentata*, at the north Curlew Valley site. A study on the impact of the defoliator on sagebrush productivity was conducted at the same site from 1973 to 1975. Several other types of studies were conducted off the site. In 1973, host plant-defoliator relationships were investigated in the field and in the laboratory to determine the actual and potential host range of the defoliator. In 1974 and 1975, a survey was made to determine its altitudinal distribution in Utah, Nevada and southern Idaho. In addition, laboratory studies were conducted on several aspects of biology, food utilization and mortality factors of this insect.

In 1975, major emphasis was directed at determining whether the level of defoliator infestation on individual *Artemisia tridentata* could be correlated with subsequent productivity of the plants. In another study, an attempt was made to correlate variations in rainfall and humidity as possible limiting factors in defoliator distribution.

This report includes findings made during 1975 and a summary of the major findings of the project.

OBJECTIVES

The following objectives were pursued in 1975:

1. To determine seasonal history and natural mortality of the sagebrush defoliator, *Aroga websteri* Clarke, at the north Curlew Valley site.
2. To determine the effects of defoliator populations on the productivity and survival of the big sagebrush, *Artemisia tridentata*.
3. To establish the distribution of the defoliator relative to the amount of annual moisture at various geographical locations.

METHODS

Population Sampling

Population sampling procedure was the same as that described in previous reports. On each sampling date, 10 randomly selected sagebrush branches were removed from each of four quadrats within the 1-ha study plot that had been established in 1972. Twenty additional samples were randomly collected immediately outside of the study plot, yielding a total of 60 samples for each sampling date. In the early part of the season, samples were taken at 10-day intervals; during June and July they were taken at weekly intervals.

Each sample, consisting of a branch cut off at ground level, was measured, labeled and placed in a plastic bag. In the laboratory they were hand-sorted for defoliator larvae. The number and instars of defoliators found were recorded. Then the samples were placed in Berlese funnels for three days. The additional insects were collected in ethanol, sorted by instar and their numbers added to the hand-sorted totals for each sample. Berlese funnels were not used in the latter part of the season, when 95% of the defoliators were found by hand-sorting. Population density was expressed as the number of defoliators per kg of fresh sagebrush.

Duration of adult activity and of adult sex ratio was measured with a Malaise trap installed in the field in early July, when moths began to emerge.

To determine the survival rate at various temperatures, newly emerged adults produced from laboratory-reared larvae were placed in cages at four different temperatures. The cages were Plexiglas cylinders, 20 cm high, capped with plastic screen and fitted at the bottom with a water container, containing a sagebrush sprig surrounded by a sponge stopper which acted as a wick for the water, which was replenished as needed. The sprigs provided oviposition sites. Four males and four females were placed in each cage. Three cages were maintained at each of the following temperatures: 15.5, 21.0, 26.5 and 32.0 C.

Laboratory Rearing

Defoliator larvae collected in the field were reared in the laboratory. Instars were raised separately to determine age-specific parasitism and mortality factors. First instar larvae were not initiated to laboratory rearing in 1975 because of the low success achieved in 1974 due to the inexplicable loss of many larvae between food changes. Second instar larvae were reared in groups of 10; third, fourth and fifth instar larvae were reared in groups of five, in plastic containers with excised sage sprigs. Food was changed every two to three days to maintain freshness. At these times any molts and changes in conditions were noted. The fate of each insect was recorded. All larval and pupal parasites were collected, identified and recorded.

Precipitation in Relation to Defoliator Infestation

In late June 1975, several sites in southern Idaho, eastern Nevada and western Utah were surveyed for defoliator infestation. The sites were selected on the basis of having variable average annual precipitation as listed in the U.S. Climatological Record. Stands of *Artemisia tridentata* were located and examined for defoliator infestation. Five branch samples from each site were measured, weighed and hand-sorted for defoliators. The number of defoliators and their stages of development were recorded.

Defoliation Studies

During May 1975, prior to extensive feeding by defoliators, 24 healthy plants were selected at the north Curlew Valley site. They were sprayed with Dieldrin to serve as defoliator-free controls. In early July, at a time coincident with approximately 50% pupation of defoliators in the field, plants with variable degrees of defoliation were examined near the north Curlew Valley site. Because of a sudden decline in defoliator numbers there, an additional site (4 km west of Holbrook, Idaho, on the Holbrook Burn Road) was utilized to select a total of 61 plants with evidence of defoliation. The height and width of the plants, number of live and dead branches, and number of feeding and webbing sites were recorded. All larvae, pupae and pupal cases on these plants were collected.

In October, following the flowering and regrowth periods of the sagebrush, the control plants and the infested plants were measured, cut and taken to the laboratory. The fresh and dry weights were determined for each entire plant, and separately for the foliage and flower stalks and for the woody stems. In addition, the numbers of flower stalks and their lengths from basal to terminal flower were recorded.

Additional information on the impact of defoliator infestation on sagebrush productivity was obtained by continued monitoring of plants that had been tagged at the north Curlew Valley site in 1973, when the defoliators had caused severe damage to plants. These plants were examined for changes in size, survival and status of growth (e.g., number of live branches, number and size of flower stalks, general appearance).

RESULTS AND DISCUSSION

Seasonal History and Population Trends

A summary of the progression of age structure and population density of the sagebrush defoliator throughout the 1975 season at the north Curlew Valley site is presented in Table 1. Samples were taken on 12 dates between April 2 and July 14. The overall defoliator population was lower than that of 1974 (Hsiao and Temte 1975) and the rate of development in the field was slower. The highest population density, 62.9 defoliators per kg of fresh sagebrush, was recorded April 21. In the field the first pupa was collected June 26, indicating a rather slow rate of development as compared to 1974, when pupae were first found two weeks earlier. By early July the defoliator population was drastically reduced to the lowest level recorded at the site. This follows a downward trend in defoliator density that had been observed during the five years of the study. Figure 1 compares seasonal population density of the defoliator for the past three years. Weather data from the Snowville station for the months from April through July, 1973 through 1975, are summarized in Figure 2. The first noteworthy aspect of Figure 1 is that the peak in population occurred each year during the same period in late April and early May. In 1973 the peak indicated a population density of over 100 defoliators per kg of fresh sagebrush. In 1974 the peak density was 73 defoliators, whereas only 63 defoliators per kg of fresh sagebrush were recorded for 1975. Comparison of seasonal mean density data for the three years indicates a 23.8% reduction in density between 1974 and 1975, from 41.2 defoliators per kg to 31.4 per kg. The reduction between 1973 and 1974 was 14.5%, from 48.2 to 41.2 defoliators per kg. The overall reduction in defoliator density from 1973 to 1975 was 34.9%.

The early season population curves for 1974 and 1975 were similar, but differed from the 1973 curve. A refined sampling technique using Berlese funnels in 1974 and 1975 appears to account for this difference. In 1975 the early season samples, from April 2 through May 6, were collected by the Berlese funnel technique, without initial hand-sorting. In subsequent samples, both techniques were employed. Table 2 compares for two years the initial defoliator recovery by hand-sorting with the additional recovery achieved with the Berlese funnel. In 1975, more than 50% of the defoliators were recovered with the Berlese funnel on May 17. As indicated in Table 1, the majority of the defoliators were in the first and second instars on that date, which evidently are the most difficult to sort out by hand. As the season progressed, the percentage of defoliators recovered by hand-sorting increased. Less than 3% were recovered with the Berlese funnel on June 26, when all of the defoliators were in the fourth and fifth instars (Table 1). The data for 1974 show the same trend with regard to the percent recovery by hand-sorting. An extremely high proportion of defoliators was recovered on April 27 with the Berlese funnel, of which 73% were first instar larvae.

Another significant feature shown in Figure 1 is a drastic population decline between June 20 and July 7. This crash appeared about the same time as the one recorded in 1974. Through May of 1975 there had been plentiful rainfall and temperatures lower than normal; but during the first week of July, temperatures were above 37.8 C daily (with a mean of 33.3 C for July) at the north Curlew Valley site, which may account for the disappearance of the defoliators (Fig. 2).

Adult Activity

In the field samples, the first pupal case was recorded on July 7. This is much later than the appearance in 1974 (June 3), but about the same time as in 1973 (July 3; Hsiao and Green 1974). The longer development in 1975 may be attributed to the cooler weather that predominated early in the season (Fig. 2).

Adult populations were monitored by Malaise trap between July 8 and September 18 (Table 3). The peak in the number of adults captured in the Malaise trap occurred during the week of July 30 to August 6, which was two weeks later than in 1974 (July 17 to 24). Also, at the peak period the total number collected in 1975 was only one-third that of the number collected in 1974. In 1973, the peak period occurred one week before that in 1975, but the population of adults was 11 times greater. The data on adult capture are consistent with the population trend shown in the field samples.

The different emergence schedules for males and females noticed in 1973 and 1974 were not particularly evident in 1975. Male and female numbers both peaked during the week of July 30 to August 6. In the previous seasons, male emergence preceded female by about a week. However, in all three years females outnumbered males. Of the 477 adults collected in 1975, 55.4% were females and 44.6% were males.

The effect of temperature on survival of the adult defoliators was determined in the laboratory (Table 4). The moths that had been subject to the coldest regime (15.5 C) survived the longest; only 20.8% had died after 50 days of the treatment. The group kept at 21.0 C had reached 100% mortality in 26 days, whereas at 26.5 and 32.0 C all of the moths had died by the 15th and 19th day, respectively. As shown in Table 3, a significant number of moths was collected in the Malaise trap even six weeks after the date of the peak adult period, indicating that many adults live for a long duration under field conditions. The present data suggest that the longevity of defoliator adults would be lengthened if the field temperatures were low during July and August.

Table 1. Age structure and population density of *Aroga websteri* at Curlew Valley site, 1975

Date of sampling	Larval instar					Pupa	Pupal case	Total	Total defoliators /kg fresh sagebrush
	1st	2nd	3rd	4th	5th				
April 2	71	2						73	33.3
April 12	179	13	4					196	29.7
April 21	454	31	3					488	62.9
May 6	428	64	11					503	56.4
May 17	41	167	20	1				229	36.0
May 27	10	327	92	9				438	44.2
June 7		10	208	102	5			325	38.2
June 14		2	54	171	32			259	37.8
June 20		1	10	96	55			162	23.4
June 26				21	49	1		70	12.3
July 7					8	1	3	12	3.1
July 14					5	2	1	8	1.9

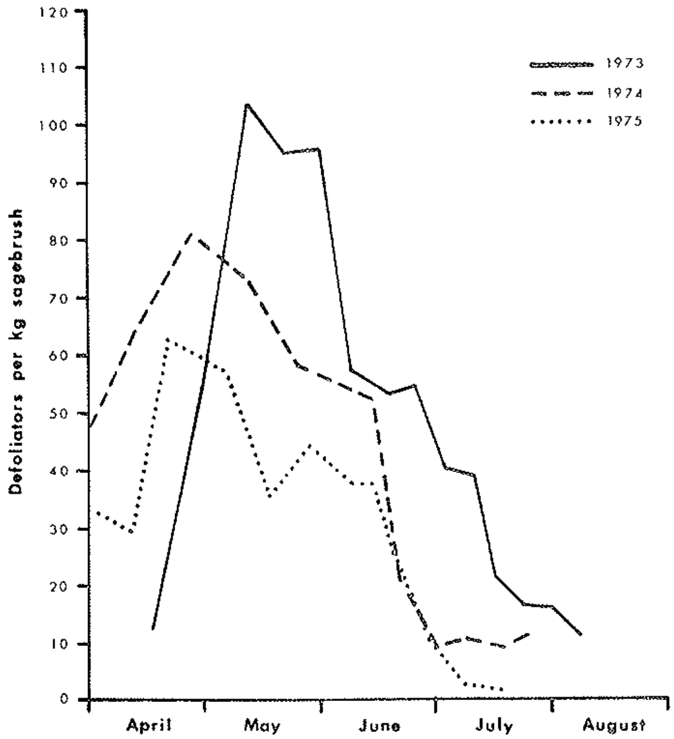

Figure 1. Comparison of defoliator population densities at the north Curlew Valley site during 1973, 1974 and 1975.

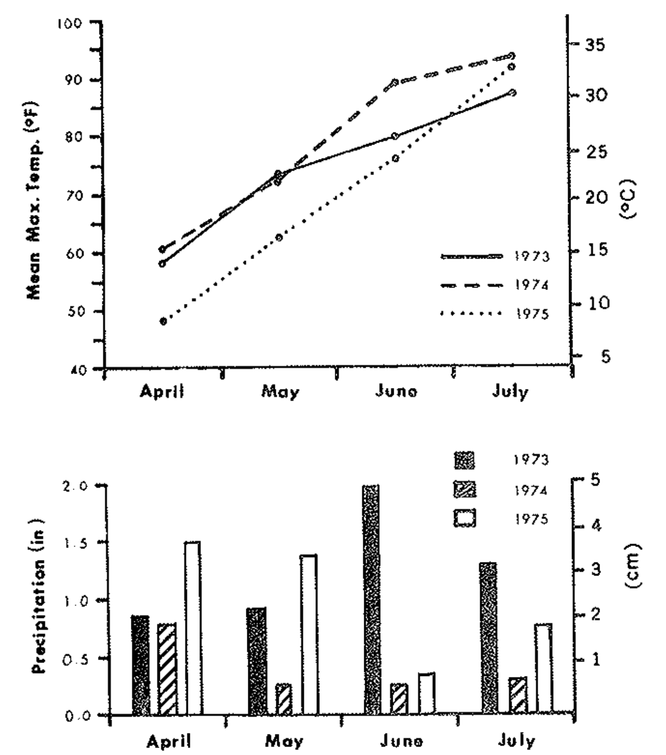

Figure 2. Mean monthly maximum temperature and precipitation recorded at Snowville station for 1973, 1974 and 1975.

Table 2. Comparison of defoliator recovery from field samples, 1974 and 1975. Initial recovery by hand-sorting; additional recovery with Berlese funnel

Sampling date	Total number of insects	% recovery by hand-sorting	% recovery with Berlese funnel
1974			
April 27	1046	12.2	87.8
May 11	640	42.5	57.5
May 25	573	55.3	44.7
June 4	683	65.7	34.3
June 13	537	79.5	20.5
1975			
May 17	229	44.1	55.9
May 27	438	67.6	32.4
June 7	325	79.1	20.9
June 14	259	88.4	11.6
June 20	162	85.2	14.8
June 26	71	97.2	2.8

Table 3. Record of *Aroga websteri* moths captured in Malaise trap at Curlew Valley site, 1975

Dates	Total adults	Females	Males	Unidentified
Jul 8-14	16	8	5	3
Jul 14-22	29	18	10	1
Jul 22-30	107	45	53	9
Jul 30-Aug 6	133	70	58	5
Aug 6-13	54	35	19	0
Aug 13-20*	64	29	28	7
Aug 27-Sep 3	17	5	12	0
Sep 3-11	39	26	10	3
Sep 11-18	18	12	5	1
Total	477	248	200	29
%		55.4	44.6	

*The trap was knocked down by animals during the week. No data were collected between Aug. 21 and 26.

Table 4. Percent mortality with time for adult defoliators maintained at various constant temperatures; experiment initiated July 23, 1975

Examination interval (days)	% mortality			
	at 15.5°C	at 21.0°C	at 26.5°C	at 32.0°C
3	0	12.5	20.8	26.3
8	0	37.5	54.1	57.9
12	0	50.0	91.7	73.7
15	0	70.8	100.0	84.2
19	0	83.3		100.0
26	0	100.0		
33	4.1			
50	20.8			
Number of moths	24	24	24	19

Mortality Factors

Defoliator larvae collected from field samples were reared in separated age groups in the laboratory to determine age-specific mortality factors. First instar larvae were omitted from laboratory rearing because of the low survival rate obtained in previous years. Table 5 summarizes the causes of mortality in the second to fifth larval stages. Larval mortality during rearing was high, averaging 48.7% for the four instars. This figure, however, is lower than the 57.4% recorded for 1974. Percentage of larvae successfully raised to pupation reflects the age at which larvae were initiated to laboratory rearing (Table 5). Only 27.4% of those larvae reared from the second instar pupated. There was 53.3% success with third instars, 58.7% with fourth instars and 65.9% with fifth instars. The fifth instar pupation rate was higher than the 55.3% recorded in 1974.

The larval parasites recorded in 1975 were *Apanteles cacoeciae*, *Temelucha* sp., *Copidosoma bakeri* and *Orgilus ferus*. The percent parasitism, averaged for the four instars, was quite low, accounting for only 4% of the mortality, compared with 7% in 1974 and 3.3% in 1973. As can be seen from these three-year data, parasitism cannot be considered an important factor in defoliator mortality.

Causes of pupal mortality were classified as injury, incomplete pupation, underdevelopment or failure to emerge. The factor contributing most to pupal mortality was underdevelopment. The variability among the various age classes in the percentage of pupae successfully reared to adults followed no pattern. Of those pupae started as second instar larvae, 74.0% emerged as normal adults; third instars, 87.6%; fourth instars, 78.2%; and fifth instars, 73.3%.

The number of field-collected pupae was low (Table 1); neither parasites nor host emerged. These pupae had an average weight of 6.3 mg, which is below the normal weight range.

Defoliator Population in Relation to Range in Precipitation

The main objective of this study was to determine if there is a correlation between high precipitation and heavy defoliator infestation. In 1975, 13 sites with different precipitation were surveyed during the last week of June to assess the degree of defoliator infestation. Table 6 summarizes the findings at 10 defoliator-infested sites arranged in decreasing order of average annual precipitation. For comparison, U.S. Weather Bureau data on total precipitation for the four months of April, May, June and July are included. On the whole, defoliator infestation was low at all sites, ranging from 4.5 to 52.4 defoliators per kg of fresh sagebrush. There is no correlation between the level of defoliator infestation and the range of annual precipitation or the total precipitation for the four months, April through July, which is the crucial period for defoliator development. The rate of development of the defoliator does not correlate with the precipitation or with the elevations of the sites. The data reveal, however, that a level of precipitation as low as 6.35 cm during the four crucial months can sustain defoliator development. Additional study is needed on temperature and other climatological factors to determine their influence, singly or jointly with precipitation, on defoliator abundance.

Defoliation-Productivity Studies

Two aspects of defoliator impact on sagebrush productivity were pursued. The first involved tagging heavily defoliated sagebrush plants and recording subsequent growth status to determine the long-term impact of defoliation. The second aspect was carried out by annually selecting sagebrush plants with different levels of defoliator infestation and assessing the growth status and productivity following the period of fall regrowth. Table 7 summarizes the evaluation of the defoliator impact on the tagged plants. Of the original 148 sagebrush plants that had been tagged in July 1973, complete records over the four seasons were available for 123 plants. These were separated into eight groups according to initial plant heights, in 10-cm intervals ranging from 41 to 140 cm, with a mean of 82.9 cm.

Table 5. Percent mortality of field-collected *Aroga websteri* during laboratory rearing

	Stage initiated			
	2nd	3rd	4th	5th
Initial number of larvae	168	182	281	91
Larval mortality				
Nonparasitized larvae				
2nd	50.0			
3rd	10.7	25.3		
4th	6.0	8.2	19.9	
5th	4.7	5.5	17.8	30.8
Parasitized larvae	1.2	7.7	3.6	3.3
Total dead larvae	72.6	46.7	41.3	34.1
Total successfully reared to pupation	27.4	53.3	58.7	65.9
Pupal mortality				
Injured	.6	.6	.4	1.1
Incomplete pupation	0	.6	1.4	0
Undeveloped	6.0	2.7	6.7	12.1
Failed to emerge	.6	2.7	4.3	4.4
Total dead pupae	7.2	6.6	12.8	17.6
Total successfully reared to adult	20.2	46.7	45.9	48.3

Table 6. Survey of *Aroga websteri* populations on *Artemisia tridentata* at locations with various annual average precipitation in Idaho, Nevada and Utah, June 1975

Site	Average annual precipitation (in)	Total precipitation Apr-Jul, 1975 (in)	Elevation (ft)	Total sagebrush samples (g)	Defoliators: Total	Larval stage IV	Larval stage V	Pupae	Pupal cases	No. defoliators/kg sagebrush
Santaquin, UT (39°58'N, 111°47'W)	19.66	6.61	5120	402.0	6	0	2	0	4	14.9
Hill City, ID (43°18'N, 115°03'W)	15.49	2.50	5090	439.7	2	0	2	0	0	4.5
Owyhee, NV (41°57'N, 116°06'W)	14.71	4.17	5396	236.4	11	1	10	0	0	46.5
Nephi, UT (39°43'N, 111°50'W)	13.89	3.74	5133	339.8	9	0	1	0	8	26.5
Strevell, ID (42°10'N, 113°17'W)	11.15	7.40	5290	553.7	6	0	2	0	4	10.8
Shoshone, ID (42°58'N, 114°26'W)	10.41	3.10	3950	304.3	2	0	0	0	2	6.6
Elko, NV (40°50'N, 115°47'W)	9.78	3.23	5075	324.2	17	0	17	0	0	52.4
Mountain Home, ID (43°09'N, 115°43'W)	9.60	2.85	3185	206.3	5	0	0	0	5	24.2
Ely, NV (39°17'N, 114°51'W)	8.70	4.03	6253	319.9	4	0	1	0	3	12.5
Eureka, NV (39°31'N, 115°58'W)	7.78	7.53	6540	202.0	2	1	1	0	0	9.9

Table 7. Evaluation of defoliator impact on sagebrush plants. Severely defoliated plants were tagged in July 1973, and growth status recorded annually for four years

		Plant height group (cm)								
		41 to 50	51 to 60	61 to 70	71 to 80	81 to 90	91 to 100	101 to 110	111 to 140	Total or Mean
	No. plants examined	2	11	12	30	36	17	10	5	123
	Initial mean plant height (cm)	49.0	56.7	66.3	76.5	86.0	96.0	105.5	119.6	82.9
	Mean total branches/plant	5.0	4.2	4.6	3.8	4.3	4.1	4.0	5.4	4.2
Oct 1973	No. live plants	0	7	10	26	31	14	8	4	100
	No. plants with flowers	0	1	8	13	15	5	7	4	53
	Mean plant height (cm)	0	56.6	66.5	77.0	86.1	95.9	106.0	121.3	84.1
	Mean live branches/plant	0	2.3	2.3	2.2	2.7	2.1	2.6	3.8	2.5
Aug 1974	No. live plants	0	6	8	21	27	10	7	4	83
	No. plants with flowers	0	2	4	8	8	3	6	3	34
	Mean plant height (cm)	0	61.2	65.6	78.1	85.7	96.7	104.4	123.3	84.8
	Mean live branches/plant	0	1.7	2.0	1.9	2.4	2.1	1.9	3.5	2.1
Nov 1975	No. live plants	0	6	8	21	27	10	7	4	83
	No. plants with flowers	0	2	7	16	17	8	5	4	59
	Mean plant height (cm)	0	51.3	69.1	74.1	81.1	89.3	93.1	98.0	78.8
	Mean live branches/plant	0	1.3	1.8	1.6	1.9	1.9	1.7	3.0	1.8
Jun 1976	No. live plants	0	6	8	21	26	10	7	4	82
	Mean plant height (cm)	0	54.5	72.0	71.1	70.5	89.0	85.7	97.5	74.5
	Mean live branches/plant	0	1.3	1.8	1.6	2.0	1.9	1.7	3.0	1.8

Table 8. Impact of defoliator infestation level on sagebrush productivity; data arranged according to numbers of defoliators/kg fresh sagebrush

Level of infestation: no. defoliators /kg sagebrush	No. plants examined	Mean no. defoliators /kg fresh sagebrush	Mean no. flower stalks /plant	Mean flower stalk length (cm)	% green weight	Mean no. branches /plant	Mean plant height (cm)	Mean plant weight (kg)
1975								
Control	24	-----	63.7	12.6	25.6	1.6	67.3	.479
1 - 30	22	11.1	19.4	6.6	18.3	1.9	52.7	.213
31 - 60	22	43.1	17.3	5.3	21.0	1.7	54.7	.205
61 - 90	7	72.9	10.3	8.2	22.4	1.3	48.0	.130
91 and up	10	128.2	7.5	4.9	21.3	1.5	47.2	.097
1974								
Control	33	-----	24.8	6.6	14.6	2.1	64.1	.321
1 - 30	25	16.3	19.3	6.3	13.4	3.2	54.0	.283
31 - 60	24	45.4	9.4	5.7	14.6	2.3	49.7	.165
61 - 90	6	76.2	14.0	9.4	21.6	3.8	49.2	.141
91 and up	10	161.0	8.3	5.4	19.2	3.0	46.0	.091

The data show several interesting long-term effects of the defoliator on the sagebrush. When the number of plants surviving each year is considered, 20% mortality was recorded in 1973, the same year that the plants had been tagged. Another 13% died in 1974, making a total of 33% mortality. There was no significant increase in percent mortality during 1975 and 1976. When the mean number of live branches per plant is considered, a 40% decrease was noted in the fall of 1973. The decrease reached 50% in 1974, and stabilized at 57% in 1975. Therefore, only 43% of the total branches were alive at the end of the study period. This result indicates that the surviving plants averaged fewer live branches. However, the surviving branches were healthy, as indicated by the number of live plants that flowered each year. The data show that 53% of the live plants were flowering in 1973, decreasing to 41% in 1974, but increasing to 71% in 1975. Plant height does not appear to be a significant factor influencing the growth status in the parameters that were measured, an exception being the two plants in the 41-50 cm height group, which did not survive the defoliator infestation during the first season. It should also be pointed out that after the initial heavy defoliation in 1973, defoliator infestation at the study site was lower in both 1974 and 1975 (Fig. 1). This condition undoubtedly lessened their impact on the surviving plants. On the basis of this evidence, it would seem that one season of severe defoliation of sagebrush by the defoliator does not necessarily cause the plant to die. Heavy defoliation for a consecutive number of years would be required for a large-scale devastation of sagebrush.

The 1975 study on the impact of different levels of defoliator infestation on sagebrush productivity included several procedùral changes from that of the 1974 study. The systemic insecticide, Temik, was not used on the control plants because, in order for it to be effective, a large amount of water had to be applied to the soil. Dieldrin was substituted. The low defoliator population at the north Curlew Valley study site made it infeasible to continue the study there; therefore, the Holbrook site was selected. However, the control plants were maintained at the Curlew site because it was too late in the season to treat a new group of control plants at the Holbrook site. Data were recorded for a total of 24 control plants and 61 infested plants at both sites (Table 8). The 1974 data have been recalculated in the same manner and included in Table 8 for direct comparison. In the 1975 data, the 61 infested plants were grouped into four levels according to severity of infestation: 1-30, 31-60, 61-90 and 91-and-more defoliators per kg of sagebrush. As shown in Table 8, over 70% of the plants were in the groups having from 1 to 60 defoliators per plant. This low level of infestation makes it somewhat difficult to assess the impact of the defoliator on plant productivity. There is a significant difference in the mean number of flower stalks and mean flower stalk length between the control and infested plants. However, no clear trend is apparent among the infested plants. The percent green weight was higher in the control than in the infested plants; but the controls are larger plants, as indicated by the mean plant weight. The 1974 data show the same trend, with the flower stalks having the most obvious differences between the control and the infested plants. It must be concluded for the past two years of study that the general infestation at the study sites was not sufficiently high to give a clear picture of defoliator impact on the sagebrush plants. It can be gathered from these data that a population density of more than 100 defoliators per kg of sagebrush would be needed to yield significant damage levels to the sagebrush. Unfortunately, the decline in defoliator population at the study site in the past two years resulted in very few heavily defoliated plants that could be used for this study.

CONCLUSION

Population dynamics of the sagebrush defoliator were monitored for the past five years at the Curlew Valley study site. Considerable improvement was made toward standardization of the sampling procedures. By using both hand-sorting and Berlese funnel techniques, good recovery from field samples of defoliators of different stages was achieved. At the study site, the defoliator population continued to show a downward trend during the five years of sampling. During the same period, defoliator mortality due to parasitism was quite high, 44.8% initially in 1971, decreased to 16.3% in 1972 and remained below 10% between 1973 and 1975, indicating that parasitism is not an important factor in regulating defoliator population. In 1974 and 1975, the defoliator population decreased drastically toward the latter part of June. This phenomenon coincided with a long period of high temperature and low precipitation (Fig. 2). It would seem that climatological factors exert greater impact than biotic factors, such as parasitism and predation, on the defoliator population. Field observations suggest that the water content of the sagebrush foliage may influence the acceptability of the plants to the defoliators. The change in water potential during the growth season of sagebrush is well documented (DePuit and Caldwell 1973). In northern Utah, water stress usually rises in June and July and reaches a peak in August. June and early July is the most crucial feeding period for the defoliator. It is quite possible that if severe water stress had occurred during that period, the defoliator may have been deprived of suitable food plants. The defoliator population crashes in 1974 and 1975 may have resulted from such water stress. Additional study will be needed to verify this assumption.

Defoliator impact on sagebrush survival and productivity was studied for the past three years. Two aspects of the problem were investigated. The long-term evaluation of defoliator impact on sagebrush yielded significant results. Plants that were tagged in 1973 after a severe defoliator infestation were examined periodically. The data revealed that after the heavy defoliation, one-third of the plants died that year but no subsequent mortality was recorded. Since defoliator infestation on the tagged plants was low since 1974, it may be assumed that continued severe infestation for a consecutive number of years would be needed to cause the death of a sagebrush plant. However, weakening of the sagebrush through defoliator infestation is revealed by the reduction in the number of live branches per plant and the number of plants that produce flower stalks. From these results it would seem that perennial shrubs such as sagebrush respond to insect defoliation in very much the same way as that described for coniferous and hardwood trees (Franklin 1970). Evaluation of defoliator impact on annual sagebrush productivity was less successful because of the low level of natural defoliator infestation occurring at the study sites. The most noticeable effect was the reduction in the number of flower stalks produced by the infested plants. The amount of green foliage produced in the fall was also less, but not significantly different among the various levels of defoliator infestation. It is apparent that a higher level of defoliator infestation would be needed to define the different types of defoliator impact on sagebrush productivity.

Several aspects of defoliator biology were also investigated. Quantitative data were obtained on host preference and suitability, food utilization, adult activity pattern and temperature effects on rate of development and adult longevity. These results provide valuable information for assessing food consumption and defoliator-host plant relationships. This study has provided some basic information on the biology and demography of the sagebrush defoliator. Like most ecological studies, it has raised many other questions that require further elucidation.

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