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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

The seasonal development of the sagebrush defoliator, *Aroga websteri* Clarke, in Curlew Valley kept pace with that of 1973. The population density, however, was lower yet than the low level recorded in 1973, continuing a four-year downward trend. The unusually hot and dry weather conditions recorded in Curlew Valley in late June coincided with a crash in the population. In one week the sampled population decreased in density from 52.5 to 19.3 defoliators per kg of sagebrush. Parasitism was not an important mortality factor in the population. Findings from branch samples collected from the field indicate that hatching of larvae was not significant in the fall; only four larvae per kg of sagebrush were recorded. The main portion of the field population overwintered in the egg stage. The relative suitability of three sagebrush species (*Artemisia tridentata*, *A. tripartita* and *A. arbuscula*) for the growth of defoliator larvae was investigated at six sites in southern Idaho. *A. tridentata* and *A. tripartita* had greater numbers of feeding sites and defoliators than *A. arbuscula*. The pupal weight was also greater in the *A. tridentata* and *A tripartita*, indicating that these two species are most favorable to the establishment and growth of the sagebrush defoliator. Evaluation of defoliator impact on sagebrush productivity reveals that severe defoliation occurring in one year can have long-range effects on the survival and regrowth of plants. Of 148 severely defoliated plants tagged in 1973, 68 had died by the fall of 1974. Attempts to correlate levels of defoliator infestation with subsequent productivity indicate that the ability of a plant to produce flower stalks is inhibited by high levels of infestation.

INTRODUCTION

Research continued into a fourth year on *Aroga websteri* Clarke, a major insect pest of the big sagebrush, *Artemisia tridentata*. A major portion of the research in 1974, as in previous years, focused on the population dynamics of this species. There are now data accumulated and analyzed from four years on the seasonal history, population density and natural mortality of the defoliator at the study site. Population sampling techniques remained much the same as in 1973, although some innovations were employed.

In 1973, a new aspect of the study was introduced. The host range and feeding habits of the defoliators were investigated by determining the geographic distribution and natural hosts in Utah. This objective was continued into the 1974 study. Natural host plants, their geographic and altitudinal range, and their effect on defoliator density were assessed in the study areas in southern Idaho. These data, in conjunction with those of 1973, provide a basis for assessing defoliator infestation and potential expansion.

An attempt was made this year to correlate objectively the degree of defoliator infestation of individual *Artemisia tridentata* plants with their subsequent productivity. The infestations of several plants exhibiting varying defoliation were determined early in the season. Control plants were maintained defoliator-free by insecticide treatment. Following the regrowth period of the fall, all the plants were removed to the laboratory where several parameters were measured and analyzed. Heavily defoliated plants that had been tagged in 1973 were monitored periodically throughout the season. This provides a subjective look at the regrowth, survival and condition of individual plants for a year following the heavy defoliator damage.

The results obtained from these studies are included in this report.

OBJECTIVES

The following objectives have been pursued in 1974:

1. To determine seasonal history and natural mortality of the sagebrush defoliator at the study site.
2. To study the geographic range, natural host plants and their range, and the effect of host plants on population density of *A. websteri*.
3. To determine the effect of defoliator populations on the productivity of *Artemisia tridentata*.

METHODS

Population Sampling

Refinements of the sampling and sorting techniques used in previous years were employed in obtaining life table and mortality data. Samples of the immature stages of the defoliator were collected periodically from the study site in north Curlew Valley, Utah-Idaho. The 1-ha study plot that was established in 1972 was used. On each sampling date, 10 individual samples of single branches that extended from the ground level to the height of the plant were selected randomly from each of four quadrants within the plot. Also, 20 samples were randomly selected immediately outside the study plot, yielding a total of 60 samples for each date. The sample branch was cut off at ground level, measured, labeled and placed in a plastic bag.

In the laboratory these samples were initially examined for defoliator larvae by shaking. The number and instars of the defoliators were recorded. Then the samples were placed in Berlese funnels for a period of three to five days. The insects were collected in ethanol, sorted, counted by instar and added to the totals for each sample. This method has increased the numbers of early instar larvae collected. The population density was expressed in terms of the number of defoliators per kilogram of fresh sagebrush.

To measure the duration of adult activity in the field, a Malaise trap was erected near the study site at the beginning of the adult emergence. Periodic records were kept of the number of moths captured and the adult sex ratio.

In late summer and fall, field samples were collected frequently to determine if any hatching of the next generation would occur before winter. Twenty branches were cut randomly from sagebrush near the study site. In the laboratory they were measured, weighed and placed in the Berlese funnels for approximately 10 days. All larvae found in this manner were recorded.

Laboratory Rearing

Larvae collected from field samples were raised in the laboratory. Each age group of the defoliator was reared separately to determine the age-specific parasitism and mortality factors. The first and second instars were reared in groups of 10 to 20 individuals per plastic cage affixed to potted sagebrush plants. The cages were transferred to fresh plants every week. This technique was not entirely satisfactory, for several larvae were inexplicably lost between changes. Third-, fourth- and fifth-instar larvae were reared in plastic containers with excised sage sprigs. Food was changed every 2 to 3 days to maintain freshness. The fate of each insect was recorded. The larval and pupal parasites obtained were identified and recorded.

Host Range and Suitability Studies

In July, several sites in southern Idaho were visited. Samples of *Artemisia tridentata*, *A. tripartita* and *A. arbuscula* were taken where defoliator activity was conspicuous. These *Artemisia* species often occur in mixed stands. When sampling was conducted at such a site, comparison of species for host suitability was possible under similar growing conditions. The natural infestations of defoliators on these three species were determined by counting feeding sites on the foliage, hand-shaking and sorting. The numbers and stages of development were recorded. Laboratory studies of acceptability and suitability of various plants for growth of the defoliator were not undertaken in 1974. The generally lowered populations of defoliators and their early advanced development prevented a large collection of immature stages.

Defoliation Studies

In May, 20 healthy-looking plants (*A. tridentata*) at the north Curlew Valley site were treated with a systemic insecticide (Temik) to establish them as defoliator-free controls. Twenty more plants were selected and treated in June. These controls were maintained throughout the season with repeated insecticide treatment at regular intervals. In early July, a time coincident with approximately 50% pupation of the defoliators in the field, 75 mildly to heavily defoliated plants were measured and examined, and their live and dead branches were counted at the north Curlew site. All larvae, pupae and pupal cases were collected. The apparent extent of injury was recorded. Following the flowering and regrowth period of the sagebrush in the fall, all of the plants were measured and removed. In the laboratory, fresh and dry weights of the whole plant, the foliage and the woody branch parts were determined. The number of flower stalks and their length from the first to the terminal flower were recorded for each plant. The group of insecticide-treated plants provides information on the normal level of plant productivity under minimum insect damage. This control serves as a basis of comparison for the other, non-treated plants.

A further aspect of the defoliation study was the follow-up monitoring of the heavily defoliated plants tagged in 1973. The plants were examined to determine the size of the plant (height and diameter) and the status of growth (number of live branches, number and sizes of flower stalks, general appearance).

RESULTS AND DISCUSSION

Seasonal History and Population Trends

A summary of population density and progression of age structure for the sagebrush defoliator at the Curlew Valley site throughout the season is presented in Table 1. These data are represented in Figure 1 to illustrate, in relative percentages, the progression of development of these age groups. Sampling was conducted on 12 dates between March 30 and July 24. The first samples produced very few defoliators in comparison with samples of the same time in 1972. Late April samples in that year yielded over 100 defoliator larvae per kilogram of fresh sagebrush (Hsiao and Kirkland 1973). A sample taken during that same week in 1974 produced only about 75 defoliators/kg, and this was the highest level of defoliator density sampled throughout the 1974 season. Comparisons between the 1974 population density and that of 1973 indicate a reduction of the density by 23.78%. The mean density for 1974 was 36.73 defoliators/kg fresh sagebrush; the mean for 1973 was 48.19 defoliators/kg (Hsiao and Green 1974). The comparison of these two years is presented graphically in Figure 2.

Two aspects of Figure 2 are noteworthy. First, the deviation of the 1974 curve from the 1973 curve in the early dates indicates either that early spring populations of the defoliator were higher this year than last or that the refined sampling techniques produced a more accurate yield of the early instar larvae. More probably it is the latter. The Berlese funnel method of collecting larvae missed by hand-sorting probably accounts for the higher early population. This assumption will have to be tested next spring when the combined shaking-Berlese funnel method for sorting is again employed.

The second remarkable feature of the graph is the population crash depicted between June 15 and July 1. It may be that the record high temperatures and dry conditions recorded for southern Idaho and northern Utah in the last weeks of June account for this.

The last week of June and the first week of July marked the period of 50% pupation of the defoliator in the field. Pupae collected at this time possessed a lower mean weight than did pupae previously. Of 77 pupae collected, nine adults emerged normally with a mean weight of 6.55 g. Three more emerged incompletely with a mean weight of 5.8 g; 51 pupae did not yield adult moths. These dead pupae had a mean weight of 3.13 g. Parasites emerged from the other 14 cases.

Adult Activity

Adult emergence began in early to mid-June. This was determined by the appearance of the first pupal cases in the field samples of June 4. In 1972, the first pupal cases were found June 9; in 1973, the first were found in the July 3 samples. This perhaps indicates an acceleration of the development time in the field. The high temperatures discussed precipitated this early emergence.

The duration of adult moths was measured from field sampling (Table 1) and Malaise trap data (Table 2). The number of pupal cases found in field samples peaked on July 24, the date such sampling was terminated. The Malaise trap was not erected near the study site until July 8. This was perhaps a little late to monitor the entire adult activity period. The erection time was selected on the basis of past records for adult emergence. The early emergence witnessed this year was not anticipated. However, a peak of adults captured in the trap occurred during the week of July 17-24, corresponding to the period of adult emergence determined from field samples. By this time, 47.5% of the adult emergence was completed. Ninety percent of the adults had emerged by August 22. From August 22 to September 20, less than 10% of the total number of adults were collected, indicating a low level of adult activity during this period.

Males and females appear to have slightly different schedules of emergence. As in 1973, the male moth population peaked prior to the female population. Males peaked during the week of July 8-17; females during the week of July 17-24 (Table 2). Also concurring with the 1973 findings was the fact that females outnumbered males. Of 1684 adults collected in 1974, 52.9% were females, 47.1% were males.

Table 1. Age structure and population density of *A. websteri* at Curlew Valley site, 1974

Date of sampling	Larval instar 1st	2nd	3rd	4th	5th	Pupa	Pupal case	Total	Total defoliators/ kg fresh sagebrush
March 30	184							184	47.54
April 13	628	18	2					648	64.59
April 27	765	260	21					1046	81.32
May 11	152	381	141	6				680	73.16
May 25	32	204	244	88	5			573	58.41
June 4	4	55	257	243	121		3	683	56.04
June 13		1	49	130	352	2	3	537	52.52
June 22			3	10	140	23	21	197	19.33
July 1					15	54	51	120	9.41
July 8					5	23	60	88	10.30
July 17					6	10	62	78	9.48
July 24					5	1	75	81	11.20

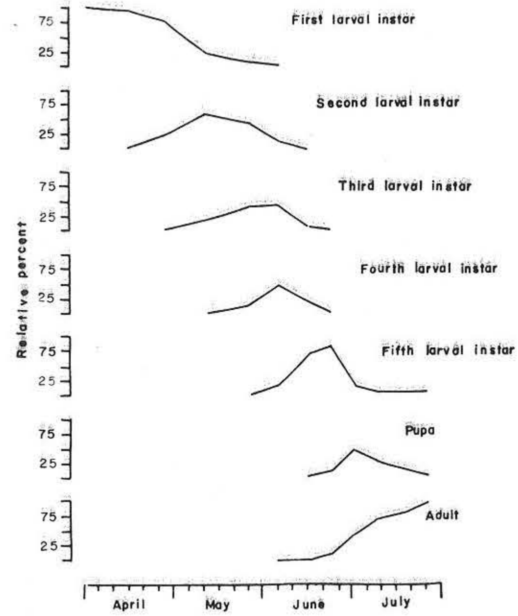

Figure 1. Age structure of *A. websteri* population at Curlew Valley site, 1974. Data obtained from successive sampling dates were calculated as relative percentages of each age-class.

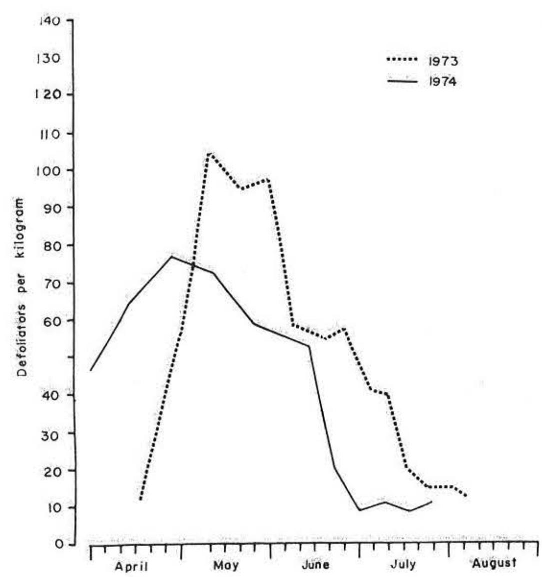

Figure 2. Comparison of defoliator population densities at Curlew Valley site during 1973 and 1974.

Table 2. Record of *A. websteri* moths captured in Malaise trap at Curlew Valley site, 1974

Dates	No. of adults	Females	Males	Unidentified
July 8-17	389	156	218	15
July 17-24	405	213	181	11
July 24-31	280	174	98	8
July 31-Aug. 7	194	97	80	17
Aug. 7-15	135	66	58	11
Aug. 15-22	131	57	70	4
Aug. 22-Sept. 2	110	62	43	5
Sept. 2-12	31	20	9	2
Sept. 12-20	9	7	2	-
Total	1684	852	759	73
%		52.89	47.11	

Table 3. Survey of fall samples for larval hatch

Date of sampling	No. of samples	Mean height (cm)	Mean weight (g)	Time in funnel (days)	Total larvae found	No. per kg sagebrush
Aug. 6	20	44.05	68.19	7-12	0	0
Aug. 22	20	49.3	85.97	10	7	4.07
Sept. 2	15	50.27	85.01	10	1	0.59
Sept. 12	20	52.8	82.78	8	15	9.06
Sept. 26	20	49.5	71.07	8	4	2.81
Oct. 17	20	56.4	90.71	8	13	7.16
$\bar{X}$ =						3.95

Overwintering Populations

Beginning on August 6, samples were taken to determine if hatching of eggs laid during the summer was occurring and to assess the population level of the overwintering population. It was thought that due to the early adult emergence, and thus early egg deposition, enough development might occur prior to winter to start the hatch of a second generation. In 1972, it was determined that the defoliator overwinters in the egg stage at the study site. The embryos are fully developed but apparently remain within the chorion until spring. The diapause mechanism is not understood.

The results from the Berlese funnels (Table 3) indicate that hatching of larvae is not very significant in the fall. An average of only four larvae was found per kilogram of fresh sagebrush. It is interesting to note, however, that the majority of larvae found must have been hatched prior to placement in the Berlese funnel. Thirty-six of the total 40 larvae were collected by the funnel during the first day. The heat produced by the light bulb in the funnel did not appear to have an effect on breaking the diapause of eggs that may have been present on the branches.

This study will be followed up in the early spring of 1975. Samples will be collected and handled in the same manner. Unless population levels have been definitiely affected by the

Table 4. Percent mortality of field-collected *A. websteri* during laboratory rearing

	Stage initiated 2nd	3rd	4th	5th	Pupae
Initial number and stage	266	200	243	342	67
Larval mortality (non-parasitized)					
2nd	38.7				
3rd	10.9	37.0			
4th	5.3	6.0	23.5		
5th	5.6	12.0	14.8	38.9	
Unidentified	5.3	3.5			
Total parasitized larvae	5.6	7.0	10.3	5.3	
Total dead larvae	71.4	65.5	48.6	44.2	
Total successfully reared to pupation	28.6	34.5	51.4	55.8	
Pupal mortality					
Injured					
Incomplete pupation			.4	1.2	1.5
Undeveloped	.8	1.0	.8	.3	1.5
Incomplete development	4.1	7.0	11.1	12.5	41.8
Failed to emerge	3.0	2.5	2.1	3.5	13.4
Parasites failed to emerge					
Parasitized pupae					7.5
Total dead pupae	7.9	10.5	14.4	17.5	65.7
Total successfully reared to adult	20.7	24.0	37.0	38.3	34.4
Total parasitism	5.6	7.0	10.3	5.0	7.5

crash that occured in late June this year, it is expected that the density of early instar larvae will be comparable to spring 1974.

Mortality Factors

Defoliators collected from field samples were reared in separate age groups to determine mortality factors affecting each group. Table 4 summarizes details of causes of mortality in each life stage. First instar larvae are omitted from these data because of high unexplained losses from rearing chambers.

Overall mortality for laboratory-reared defoliators remains high, averaging 57.4% for the four instars considered. Larval mortality was attributed either to parasitic cause or nonparasitic cause.

Pupal mortality was classified in categories of injury, incomplete pupation, underdevelopment, failure to emerge and parasitized. The percentage of pupae successfully reared to adult does not change appreciably with the age of the larvae when initiated to laboratory rearing. Of those pupae started as second-instar larvae, 73.37% emerged as normal adults; third instars, 69.5%; fourth instars, 72.0%; and fifth instars, 68.59%.

The age of the larvae upon initiation does, however, affect the percentage of larvae successfully raised to pupae. Only 28.6% of the larvae reared from the second instar pupated successfully. This percentage of success graded upward to

55.3% in larvae started as fifths. Field-collected pupae showed the highest percentage of mortality for any age-class initiated to laboratory rearing. Only 34.3% successfully emerged as adults.

Parasites reared from each age group were recorded carefully and a detailed accounting is given in Table 5. Three parasites (*Apanteles cacoeciae*, *Temelucha* sp. and *Copidosoma bakeri*) were found in significant numbers. *Orgilus ferus*, not present in 1973, was found again in small numbers this year. *C. bakeri* was the only parasite found to attack larvae in the first instar. *C. bakeri* and *A. cacoeciae* were the only two found to attack second and third instars. *Temelucha* sp. was found only in fourth and fifth larval instars.

Phaeogenes sp. and *Spilochalcis leptis*, pupal parasites, were not encountered in 1974 samples. A few were found, however, emerged from pupae collected outside of the regular sampling dates and sites. Their numbers were very insignificant.

In 1974, overall parasitism of *A. websteri* decreased slightly. The values for the two years are 5.1% in 1974 and 6.1% in 1973. If only the parasites attacking defoliators initiated to rearing as larvae are considered, the percentage of parasitism is actually higher in 1974 (5.1%) than in 1973 (3.8%). Very few parasites were recorded in defoliators initiated to rearing as pupae in 1974 (4.2%). In 1973, parasites of such defoliators reached 20.2%. If these data indicate a continued downward trend in parasitic numbers, it will be worthwhile to reassess the importance of parasitism as a factor in controlling defoliator populations.

Table 5. Records of *A. websteri* parasites reared from field samples

Date	No. hosts initiated	No. hosts successfully reared	No. hosts parasitized	*Apanteles cacoeciae*	*Temelucha* sp.	*Copidosoma bakeri*	*Phaeogenes* sp.	*Spilochalcis leptis*	*Orgilus ferus*	Other	Total % parasitism
1st instar											
May 11	100	4	1			1					1
Total	100	4	1			1					1
2nd instar											
May 11	234	28	5			5					2.1
25	90	25	10	1		1				8	11.1
June 4	28	8	3	1		2					10.7
Total	352	65	18	2		9				8	5.1
3rd instar											
May 11	67	9	0								0
25	93	28	6	2		4					6.4
June 4	140	11	5	2		2			1		3.6
13	16	0	0								0
22	1	0	0								0
Total	317	48	11	4		6			1		3.5
4th instar											
May 25	37	14	2			2					5.4
June 4	151	63	9	3	1	4			1		6
13	73	8	9	1	3				1		12.3
22	6	0	1			1					16.7
Total	267	85	21	4	4	7			2		7.9
5th instar											
May 25	2	2	0								0
June 4	57	33	1								1.7
13	214	72	6		1	5					2.8
22	114	25	14			13		1			12.3
July 1	5	0	1			1					20
Total	392	132	22		1	19		1			5.6
Pupae											
June 13	2	2	0								0
22	18	4	0								0
July 1	52	20	3					2		1	5.8
Total	72	26	3					2		1	4.2
Total	1500	360	76	10	5	42		'3	3	9	5.07

GEOGRAPHIC RANGE OF THE DEFOLIATOR AND PLANT SUITABILITY

Several areas in southern and eastern Idaho were surveyed in early July to assess the extent of defoliator damage. Defoliation was light in most areas, as in the Curlew Valley site. Samples were taken at six sites (Fig. 3) where there was evidence of defoliator activity. Three *Artemisia* species (*A. tridentata*, *A. tripartita* and *A. arbuscula*) were sampled

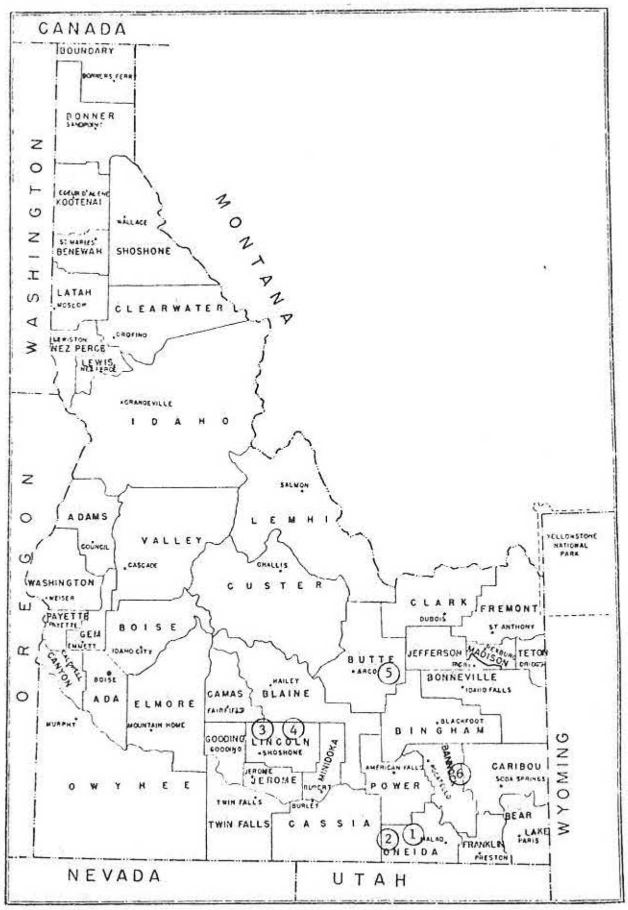

Figure 3. Localities surveyed for *A. websteri* populations on *Artemisia* species in southern Idaho during 1974:

1. Curlew Valley, 9.6 km north of Holbrook on Idaho 37 (El. 1440 m).
2. Holbrook, 24 km west of Holbrook on Holbrook Burn Road.
3. Shoshone, 16.6 km north of Shoshone on U.S. 93 (El. 1320 m).
4. Richfield, 8.0 km northeast of Richfield on U.S. 26.
5. Butte City, 8.0 km east of Butte City on Idaho 22 and 88.
6. South Pocatello, on I-15, 6.4 km south of turnoff to Indian Rock State Park and Lava Hot Springs.

Table 6. Survey of *A. websteri* populations on *Artemisia* species at different localities in Idaho during 1974

Date of sampling	Location	Plant species	No. plants sampled	Mean plant height (cm)	Mean plant weight (g)	Mean no. feeding sites	Mean no. feeding sites/kg sagebrush	Defoliators: Total	% larvae	% pupae	% pupal cases	Mean no. parasites	Mean pupal weight (mg)	No. defoliators /kg sagebrush
July 11	Curlew Valley	A.tripartita	10	54.8	146.56	2.9	19.8	10		100		-	-	6.82
July 11	Holbrook Burn Road	A.tripartita	2	-	796.05	Many	-	43	9.3	69.77	20.93	18.5	7.8	27.01
		A.tridentata	2	-	426.75	Many	-	128	14.06	61.72	24.22	54.5	7.2	149.97
July 11	Shoshone	A.arbuscula	10	44.1	121.76	13.7	112.5	20	-	50	50	.1	5.2	16.43
		A.tripartita	10	63.5	97.27	14.4	148.0	16	-	62.5	37.5	1.4	6.5	16.45
		A.tridentata	10	64.5	167.1	27.1	162.2	40	2.5	57.5	40	2.3	5.86	23.94
July 12	North of Richfield	A.tridentata	10	63.4	95.5	19.7	206.3	46	21.7	60.9	17.4	1.5	7.22	48.17
		A.tripartita	10	62.9	102.5	16.2	158.0	25	4	72	24	.6	7.0	24.39
July 12	Butte City	A.tridentata	10	52.4	190.86	74.5	390.3	55	3.64	76.36	20	.7	5.4	28.82
		A.tripartita	10	41.1	87.19	43.6	500.0	39	-	69.23	30.77	.1	6.25	44.73
		A.arbuscula	10	30.7	146.54	27.6	188.3	11	-	36.36	63.37	0	4.25	7.51
July 13	South Pocatello	A.tridentata	10	54.3	143.85	69.6	483.8	46	-	30.43	69.57	2.8	7.0	31.98
		A.tripartita	10	53.3	80.48	42.5	528.1	59	-	38.98	61.02	1.2	6.7	73.31

randomly. Ten plant branches extending from ground level were collected from each species, measured, weighed, examined for feeding sites and searched for defoliators. These records are presented in Table 6.

Some differences appear among the three sagebrush species (Table 7). The mean number of feeding sites per kilogram of fresh sagebrush in *A. tridentata* and *A. tripartita* is nearly twice that in *A. arbuscula.* Also, the mean number of defoliators is greater in *A. tridentata* (56.6) and *A. tripartita* (32.1) than in *A. arbuscula* (12.0). This is similar to findings made in 1973; at that time *A. arbuscula* was found to have a lower defoliator population density. The leaves of *A. arbuscula* appear to be less abundant and less succulent than those of *A. tridentata* or *A. tripartita*, and thus would provide less food for defoliators. In 1973, pupae found on *A. arbuscula* weighed less than those found on the other two species. This appears to be the case this year also. Too few pupae were collected to be significant.

Defoliation-Productivity Studies

One of the major objectives of the 1974 study was to devise more precise methods of assessing the effect of defoliator populations on the subsequent productivity of *A. tridentata.*

The 148 defoliated plants that were tagged in 1973 showed evidence of a long-range impact from defoliator damage. Assessment of the impact was made periodically during the season and on November 1, when sagebrush fall growth was nearly completed. Table 8 summarizes the findings obtained from the 127 surviving plants. During 1974, 36.4% of these plants had died, making an accumulated mortality of 45.3% among the 148 plants originally tagged. No significant correlation exists between plant height and survival. Of the surviving plants, more than 25% were judged to be barely alive. These plants had very sparse, dry foliage and had no flower stalks. It is anticipated that these plants will not survive into 1975. The total percentage of plants producing flower stalks was 49.9%, a slight decline from the 1973 level of 53.7%.

Table 7. Summary of defoliator population data on three species of *Artemisia* at different locations in Idaho in 1974

Plant species	Mean no. feeding sites per kg	Mean no. defoliators per kg sagebrush	Mean pupal weight (mg)
A. tridentata	310.8	56.6	6.5
A. tripartita	270.8	32.1	6.85
A. arbuscula	150.9	12.0	4.7

Table 9 summarizes the impact of defoliator infestation level on sagebrush productivity. The data were collected from 67 infested plants and 30 control plants that were examined for defoliators in the field, and then assessed for productivity following the period of fall regrowth. The levels of defoliation were not as high in 1974 as in previous years. Only a few plants of those examined had high defoliator populations. One apparent correlation exists between the level of infestation and the ability of plants to produce flower stalks. Those plants with 11-20 defoliators on them had an average of 7.11 flower stalks, whereas the control and the least-infested plants had nearly double that number. Other aspects of defoliator impacts on productivity will be analyzed more fully following a repeat of this study in 1975.

EXPECTATIONS

Through continued monitoring of the population dynamics of the sagebrush defoliator, *Aroga websteri* Clarke, on *Artemisia tridentata* during four field seasons, it has been possible to observe seasonal history, natural mortality factors and defoliator impact on sagebrush with defoliator populations at both high and low levels. Population dynamics will again occupy a major portion of the research in 1975.

Table 8. Impacts of defoliators on sagebrush plant defoliation. Severely defoliated plants evaluated in 1973 were evaluated again on November 1, 1974. Comparisons are presented here

Plant height group (mean cm)	No. plants examined	% plants alive	% plants dead since 1973	% live plants with flower stalks	% of live plants judged barely alive	Mean no. branches/ plant	Mean no. live branches/ plant	Mean no. branches/ plant dead since 1973
40- 49 (46.0)	2	0	100	0	-	4.5	0	-
50- 59 (56.4)	10	60.0	40.0	66.7	33.3	4.5	1.1	.8
60- 69 (65.5)	13	69.2	30.8	66.7	33.3	4	1.5	.54
70- 79 (75)	21	57.2	42.8	36.4	27.3	4.6	1.1	.70
80- 89 (84.1)	38	76.3	23.7	17.2	48.3	4.7	1.9	.71
90- 99 (93.6)	20	70	30	35.7	35.7	3.45	1.4	.60
100-109 (102.8)	17	64.7	35.3	60	20	4.7	1.4	.81
110-119 (115.25)	4	75	25	66.7	33.3	6	2.5	.25
120-150 (141)	2	100	0	00	0	6	3.5	0
All plants	127	63.6	36.4	49.9	25.7	4.7	1.6	.49

Table 9. Summary of impact of defoliator infestation level on sagebrush productivity

Level of infestation: no. defoliators per plant	No. plants examined	No. defoliators per kg fresh sagebrush	Ave. no. flower stalks per plant	Ave. flower stalk length (cm)	% green weight	Mean no. branches per plant	% dead branches	Mean plant height (cm)	Mean plant weight (kg)
11 - 20	9	84.56	7.11	46.72	13.49	3.89	13.7	46.11	.251
6 - 10	27	57.52	11.35	62.23	14.3	2.24	6.48	50.52	.189
1 - 5	29	22.53	15.34	61.51	15.59	3.0	20.23	51.53	.194
Control	30	---	15.63	64.0	14.67	1.97	0.76	62.5	.281

An attempt to assess the impact of the defoliator on sagebrush productivity was made in 1974. This effort included continued monitoring of defoliated plants tagged in 1973 for extent of plant regrowth and survival and correlating different levels of defoliator infestation on field-examined plants with their subsequent productivity. These two techniques of assessment will constitute a considerable portion of 1975 research.

Studies of host range and defoliator feeding habits in the past two years have provided information on the effect of host species on the distribution and outbreaks of the insects, as well as on host suitability and defoliator preference. These inquiries will not be pursued in the 1975 season.

Several environmental variables have been examined to assess their direct and indirect influences on defoliator populations. Altitudinal and geographical limits have already been roughly established. In 1975, the limits imposed by precipitation and moisture will be investigated through field trips to sample in areas of varying average annual precipitation throughout the Great Basin and by overlaying isohyetal maps of the region with the known sites of defoliator occurrence.

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