T H E S I S

THE EFFECTS OF WOODPECKERS ON THE ENGELMANN SPRUCE BEETLE *DENDROCTONUS ENGELMANNI* HOPKINS

Submitted by

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In partial fulfillment of the requirements

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WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY FRANK T. HUTCHISON

ENTITLED THE EFFECTS OF WOODPECKERS ON THE ENGELMANN SPRUCE BEETLE, DENDROCTONUS ENGELMANNI HOPKINS.

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE.

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It is the writer's desire to dedicate this work to his wife, in appreciation for her helpfulness and encouragement during the study.

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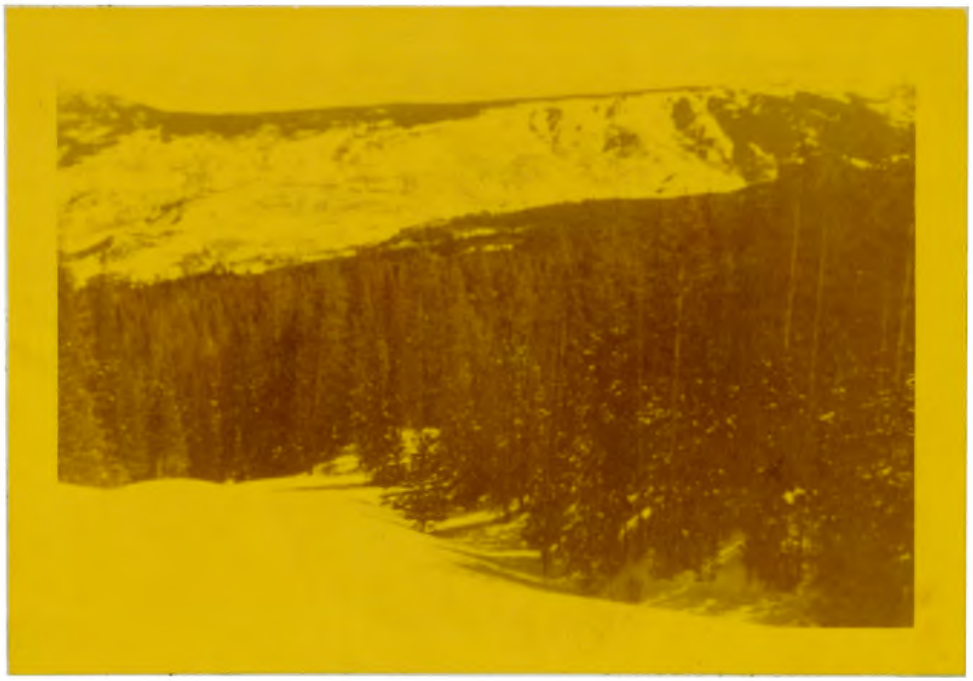

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Chapter I

INTRODUCTION

It is very probable that as long as extensive Engelmann spruce forests have existed, there also has existed one of their main enemies, the Engelmann spruce beetle, Dendroctonus engelmanni Hopkins. The destructiveness of this insect is not spectacular, but so quiet that it may cause serious damage before its presence is discovered. It is not easy to comprehend that large areas of a spruce forest may be killed or so neglected that near-by forests can be protected only by intensive physical and costly efforts. This has taken place in Colorado during the last ten years.

In 1939 a severe windstorm swept over the spruce forests of western Colorado. This caused many trees to be blown over and weakened, providing an ideal breeding place for the beetles. Under these conditions their numbers have increased so tremendously that they have been able to attack and kill healthy trees.

There are many enemies of the Engelmann spruce beetle with the woodpeckers ranking foremost among these. The bark beetles make up a large percentage of the woodpecker's diet. At the present there is an enormous supply of Engelmann spruce beetles upon which they can feed.

Waste and loss resulting from destruction of forests by the Engelmann spruce beetle is increasing daily. Until 1950 there had been no chemical methods used in control of these beetles. These devastators possibly could be controlled by woodpeckers provided the woodpeckers were present in sufficient numbers.

A study of the effects of woodpeckers on the Engelmann spruce beetle is now completed and the results are reported herein. The main object was to try to determine the possibilities of control of Dendroctonus engelmanni Hopkins afforded by an increase in the woodpecker population. This study was begun in November 1949 and terminated June, 1950.

Chapter II

REVIEW OF LITERATURE

Colorado Engelmann spruce forests are being depleted by the Engelmann spruce beetle. Woodpeckers are one of the many predators of those beetles. Before making this study on effects of woodpeckers on Engelmann spruce beetle population information was obtained as to the species of woodpeckers. Previous studies made by Massey (12) showed that the Downy, Rocky Mountain Hairy, and Alpine Three-toed woodpeckers were the most important species.

Alpine Three-toed woodpecker, Picoides tridactylus dorsalis Baird

In 1911 Beal (2) reported "all the three-toed woodpeckers rank high as conservators of the forest, with individuals eliminating annually as many as 13,675 of the grubs most destructive to forests."

Forbush (7) stated in 1927 that Picoides tridactylus dorsalis Baird, commonly known as the Alpine Three-toed woodpecker ranges from northern Montana to northern Arizona and New Mexico and is common in the boreal forest of the Rocky Mountains.

According to Bailey (1), 1926, the food of this woodpecker consists over 75 percent of destructive wood-boring larvae and beetles. The scarcity of these useful

woodpeckers makes their protection and encouragement especially important.

Downy woodpecker,
Dryobates pubescens Swainson

The Downy woodpecker, Dryobates pubescens Swainson, is an important predator of bark beetles. As reported in 1911, Beal's (2) analysis of stomach contents of the Downy woodpecker showed 76.05 percent of its food to consist of animal matter. Beetles formed 21.55 percent of the stomach contents and of these 14 percent were harmful wood-boring larvae. Beal further stated that this is only about half of the amount of beetles found in the stomach of Dryobates villosus monticola Anthony. The Downy woodpecker feeds on larvae at all times of the year but most heavily during the cooler months. Forbush (7) stated in 1927 that the Downy woodpecker is particularly important in destruction of the white pine weevil which kills topmost shoots of young white pines causing them to be unfit for lumber production.

In 1939 Bent (3) wrote that with its various forms, Dryobates pubescens Swainson occupies practically the entire United States and extends north into British Columbia and sometimes as far as Alaska. Bent also wrote that the Downy woodpecker is the smallest member of the woodpecker family. It is very similar in plumage to the Hairy woodpecker, but only about one-half the size.

Hairy woodpecker, Dryobates villosus monticola Anthony

Beal (2) in 1911 said that Dryobates villosus monticola Anthony is not migratory unless within very narrow limits. He continued by saying that cerambycid and buprestid beetles with a few other wood-borers make up a large portion of the annual diet of the Hairy woodpecker. These insects constitute over 31 percent of the food and are eaten in every month of the year. The greatest numbers are taken in December when they constitute 41 percent of the total food supply. Other beetles form about 9 percent of the food. The latter are distributed among a number of families, all of which are more or less harmful.

Jensen (10), 1923, reported that in the Sangre de Cristo Mountains the Hairy woodpeckers range from 8,000 to 11,000 feet. In 1939 Bent (3) wrote that the Hairy woodpecker inhabits the Rocky Mountain region, the Canadian and Transition Zones, from central British Columbia and Montana, southward to eastern Utah and northern New Mexico, and eastward to South Dakota and western Nebraska. According to Bent this woodpecker seeks its food in the trunks of lodgepole and limber pines, cedars, firs, aspens and willows. It prefers dead or weakened trees to work on, probably because of the presence of more borers and grubs.

Engelmann spruce beetle,
Dendroctonus engelmanni Hopkins

In 1909 Hopkins (9) described Dendroctonus engelmanni Hopkins as varying in length from 5 to 7 mm., with the average about 6.5 mm. The color ranges from uniform light to dark red and black, to black head, thorax and abdomen, and red elytra. The sculpture and vestiture of the epistoma vary in size and color.

Hopkins also wrote that the Engelmann spruce beetles in Colorado were found near Clyde, Boulder, Craig, Fort Collins, Glenwood Springs, Gunnison, Hahn's Peak, Holy Cross National Forest, Meeker, Ouray National Forest, San Isabel National Forest, Steamboat Springs and White River National Forest.

Describing the Engelmann spruce beetle in 1926, Essig (6) wrote that they were pale brown to dark red or black. The egg galleries they produce were short and longitudinal; the larval galleries contiguous for some distance, grooved in wood and deep in the inner bark. However, during this study observations show that neither the larvae nor the adults form grooves in the wood of an infested tree. Essig, continuing, said that the Engelmann spruce beetle often kills or does much damage to Engelmann and Canada spruces.

Doane (5) in 1936 further reported that the body of Dendroctonus engelmanni Hopkins is sparsely clothed

with long hairs. The galleries they produce are excavated much wider than the beetle and are packed with boring dust, through which the adults keep open a passageway. Eggs are laid side by side in elongate cavities alternating from side to side of the egg gallery. The larvae at first bore out en masse transversely from the egg gallery but later make separate mines. The pupal cells are usually constructed in the inner bark so as to be exposed when the bark is removed but may be made deeper in the inner bark and quite concealed.

Doane also noted that the attacks are made during June and July, and there is one complete generation annually with considerable overlapping of broods. This species has caused widespread destruction of mature Engelmann spruce through the Rocky Mountain region from Mexico to Canada and westward into Oregon.

Metcalf and Flint (14) in 1939 wrote of the bark beetles in general. They reported that some of the beetles attack perfectly healthy trees, others restrict themselves to trees already weakened from various causes. Their feeding destroys the cambium, loosens the bark, and rapidly kills the trees usually from the top downward. Metcalf and Flint also said that many foresters believe that these insects are largely responsible for forest fires by producing areas of dead and highly flammable material.

Also writing in 1939, Chamberlin (4) described the Engelmann spruce beetle and said that it is similar to Dendroctonus piceaperda Hopkins but averages larger and is more coarsely punctured. The distribution and hosts are also distinct. It differs from Dendroctonus obesus Mannerheim by the darker pronotum and more distinctly impressed lateral striae of the elytra, with coarser punctures.

Chamberlin also wrote that the host of this beetle is primarily Engelmann spruce, Picea engelmanni Parry, but the beetle does attack other species of Picea within its range. He said too that the height of emergence and flight occurs from late June to early August. This differs slightly from the statement Doane (5) made in 1936. Chamberlin wrote also that the Engelmann spruce beetle seldom attacks near the base of the tree, especially larger trees, but will be found entering the trunk at six feet from the ground or higher.

Keen (11) writing generally of the Dendroctonus beetles in 1939 noted that they made up by far the most destructive group of bark beetles attacking pine trees in North America. Attacked trees can first be distinguished by reddish boring dust caught in bark flakes or crevices and around the base of the tree, or by pitch tubes that form on the bark at the mouth of the enterance tunnels. In

the case of heavily attacked or decadent trees, pitch tubes are often either missing or are so small that they can be seen only from a short distance. Later, discoloration of the foliage furnishes a more noticeable evidence of attack. It is difficult, Keen recorded, to correlate accurately the degree of discoloration with the status of brood development, as this varies with different tree species, regions and seasons.

Findings by Massey, 1944, (12) show the average number of beetles per square foot in infested trees to be 308.38 ± 30.76. Massey's study was made on the White River National Forest in an Engelmann spruce beetle infestation similar to the infestation on Rabbit Ears Pass from which the data for this work were taken. This number was obtained by felling about 35 infested trees. Beginning at the base of the tree, population counts were made from one-half square foot samples every five feet to the maximum height of the infestation. From the overall counts made, an average was taken.

Swain (16) reported in 1948 that bark beetles are highly destructive to our best timber trees. Also he noted that most woodpeckers feed upon the bark beetles to some estent but he does not consider them important in their control.

In 1949 Wygant and Nelson (17) wrote that in its

adult stage, the Engelmann spruce beetle is a small, cylindrical, hard-shelled beetle; it is about one-fourth inch in length and about the size of an ordinary housefly. In June and July, when the adults leave the dead trees and start to fly, they are reddish brown to black in color. They soon settle on recently felled or standing green trees and bore through the outer bark into the living inner bark. This attack extends over most of the lower main stem of the tree.

According to Massey (13) the beetles work in pairs of male and female, each pair raising separate broods. The female makes the entrance, followed by the male, and bores a tunnel between the bark and wood, which usually extends in a vertical direction and parallels the grain of the wood. This tunnel is known as the egg gallery. The eggs are laid in alternate groups along the sides of the gallery, and the galleries are packed with boring dust mixed with pitch. There are usually 3 to 4 groups of eggs and a total of about 125 eggs in each gallery. On the average there are from 6 to 8 such egg galleries for each square foot of bark.

When the eggs hatch in 3 or 4 weeks, the larvae feed on the succulent inner bark and cut mines that run at right angles to the egg gallery. This larval feeding continues through the late summer and fall. When winter

arrives they are still in the inner bark, where they become dormant.

The following spring the larvae resume feeding. As summer advances they become mature, transform to pupae, and then into adult beetles. This new adult stage is reached by mid-summer, and the beetles first start feeding on the inner bark of the tree in which they were reared. By August or September they appear to be mature. Then some of the beetles emerge and congregate under the bark around the base of the tree. Others remain under the bark where they developed. In both cases they rest quietly during the second winter, and when warm weather returns the following spring they are ready to take flight and attack other living trees.

Previous Dendroctonus engelmanni Hopkins attacks.--All previous outbreaks of the Engelmann spruce beetle occurred in the Rocky Mountain region, but most of them were so long ago that their exact extent is not known. In 1909, Hopkins (9), of the Department of Agriculture, found evidence on the White River National Forest of an outbreak that had occurred 20 to 25 years earlier. He also found evidence that severe attacks occurred on the areas now known as the Pike National Forest about 1855 and on the Lincoln National Forest in New Mexico about 1890.

According to Wygant and Nelson (17), 1949, an

outbreak that killed nearly 100 percent of the volume of spruce took place on the Aquarius Plateau in Utah between 1918 and 1928. A localized outbreak was reported in the northwestern part of Yellowstone National Park in 1937. None of these earlier infestations even approached the intensity and total destruction of the one that started in Colorado in 1942. These authors indicated that several factors made conditions for this devastation favorable. In June 1939 a severe windstorm swept from the southwest corner of Colorado, in a northeasterly direction, across the mesa-type plateaus of the state. Thousands of acres of shallow rooted Engelmann spruce blew over. Many of the roots on the down side remained in the soil sufficiently to keep the trees alive for several years and favorable for attacks by the beetles. The Engelmann spruce beetle was present in small numbers in decadent trees.

By 1942, this favorable breeding material had built up great populations. With a previously unknown reproductive force, coupled with the limited natural control factors, the beetles invaded the standing spruce. By 1943, when the infestation was first discovered, the number of infested trees was so great that control by destroying the insects with fire or insecticides seemed economically impractical due to the condition of international affairs. The problem then became one of

determining the extent and severity of the outbreak so as to prevent its spread into other spruce forests, salvaging the dead timber, and studying the life history and habits of the beetle as a basis for development of control measures.

The latest report on Engelmann spruce losses by the beetles was by Nelson (15) in 1950. Mr. Nelson wrote that Engelmann spruce occupies the high mountain country. It is found from 9,500 feet above sea level to timberline, an elevation of 11,500 to 12,000 feet above sea level. Over one-third of the stands is considered inoperable, while less than 25 percent could be classed as easily accessible. It is primarily back country where the beetle has destroyed entire forests.

By 1942, its increase was tremendous; two years later it was estimated that 90 percent of the trees eight inches and above in diameter were dead on the White River National Forest. At the present time, all the Engelmann spruce north of the Colorado River on this forest--about three and one-half billion board feet--are dead. In addition, a 1948 survey shows a loss of 35 to 50 million board feet on the Grand Mesa National Forest, where the epidemic was first discovered; 74 million on the Routt; 5 million on the Uncompahgre; 29½ million on the Arapahoe; and lesser amounts on the Gunnison and San Juan National

Forests.

Mr. Nelson also wrote that entomologists studied the epidemic in 1942. Methods of control which they recommended required men by the thousands; but, with the war on, manpower was at a premium. Foresters were helpless. The possibility of a government salvage program in 1944 and again in 1945 was analyzed but proved impractical, as the short logging season permitted too little use during the war of scarce and vital logging equipment.

Summary and implication

A wealth of information on the habits and habitat of woodpeckers and the Engelmann spruce beetle is still to be determined by further study. Most of the material concerning the Engelmann spruce beetle taken from references by Chamberlin (4), Doane (5), Essig (6), Keen (11), Metcalf and Flint (14), and Swain (16) was based on original work by A. D. Hopkins. There are unpublished findings on effects of woodpeckers on Engelmann spruce beetle population made in a summer food habits study by Massey (13).

Chapter III

METHODS AND MATERIALS

The Engelmann spruce forests of Colorado are being rapidly devastated by the Engelmann spruce beetle, Dendroctonus engelmanni Hopkins. Since bark beetles are known to be taken by woodpeckers, a study of effects of woodpeckers on Engelmann spruce beetle population was made.

By the use of information from surveys made by the Forest Insect Laboratory, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, Fort Collins, Colorado a location on the west side of Rabbit Ears Pass having the beetle in epidemic numbers was selected for the problem. Much necessary information, equipment, and assistance was furnished by the Forest Insect Laboratory.

The author spent one week each month from November, 1949 to June, 1950 in the area of study. A United States Forest Service cabin was authorized for use during this time. The cabin is located six miles west of Rabbit Ears Pass on U. S. Highway 40 near Steamboat Springs, Colorado.

One of the first steps in the research was to mark off three ten acre plots of infested trees. These

plots were numbered one, two, and three. Number one plot had a majority of the infested trees from the 1949 attack and a small proportion of the trees attacked in 1948. Number two plot had approximately a one to one ratio of 1948 and 1949 attacked trees. Number three plot had a majority of 1948 attacked trees and a small part of 1949 attacked trees. These three types of plots were chosen to determine whether the woodpeckers would feed more on adult beetles or the larvae. The 1948 attacked trees had a large population of adults and a few larvae.

Several hours were spent each day in observation to determine the species and number of pairs of woodpeckers feeding on the plots. This was done with the use of field glasses and by slowly moving around in the plot until the area had been completely covered. Their feeding habits were studied and data obtained on the time of day and the temperatures at which maximum feeding was taking place. The effects of such weather factors as to overcast sky, snowfall, or clear sky on the feeding habits were observed.

Ten woodpeckers were killed each month from an infested area similar to the infestation on the study plots. This was done to avoid killing the woodpeckers that might be feeding on the plots from which the data were taken. Authorization for killing the birds was given by the Colorado State Fish and Game Commission and the Fish and

Wildlife Service of the United States Department of the Interior. The stomach contents of these birds were analyzed to determine what percentage of their food was made up of the Engelmann spruce beetle. Director E. R. Kalmbach, Wildlife Research Laboratory, Fish and Wildlife Service, Denver, Colorado, stated that in the case of hard-shelled beetles (such as the Engelmann spruce beetle) the undigested portions may remain in the stomach for the better part of the day and that in the case of woodpeckers there probably would be some fragments of the beetles in the stomach at all times with the possible exception of late at night or at dawn.1/

After the study was completed, the plots were sampled and estimates made to determine the approximate amount of beetles the woodpeckers had taken from the 1949 attacked trees.

The method of sampling is described in the following paragraphs. Twenty infested trees were felled. The heights of infestation were measured. Diameters of the trees were taken at varying heights so that the taper of boles would be considered when calculating the surface area of infestation. The areas where the bark had been removed from the trees by woodpeckers were measured. These measurements were so the sampling estimates on the plots

1/ See Appendix G

would be more accurate.

The plots were measured in five yard strips. On each strip a coin was flipped to determine whether the even or odd trees were used in the sample. One hundred trees each were used from plots one and two. Fifty trees were used from plot three because there were less than 100 infested 1949 attacks on the plot. Random numbers were used on the original samples and populations of 35 trees were set up for each of the three plots.

Chapter IV

OBSERVATIONS

The notes made herein on habits and activities of woodpeckers are from observations made during a few days from each of the following months; November 1949, December 1949, January 1950, February 1950, March 1950, April 1950, May 1950, and June 1950. It is probable that certain climatic conditions between periods of observations may have affected habits and activities of the woodpeckers in manners that were not observed.

It is common for a pair of birds to limit their feeding to a group of seven or eight infested trees until there are no longer enough accessible beetle larvae there to provide sufficient food for them. They will then move on to another small group of trees where the larval population has not been fed upon. When the infested trees are in a relatively dense stand the birds feed first from those trees most exposed to the sun. This may be due to the more advanced development of the broods in those trees.

The Alpine Three-toed and the Rocky Mountain Hairy woodpeckers nearly always feed in pairs. The male and female can often be seen working within a foot of each

other on the tree. Until early spring the Downys were seldom seen feeding in pairs.

The woodpeckers seem always to know exactly where to find the broods of the beetle under the bark of a tree. One hundred bark samples showing outside evidence of woodpecker work on them were taken from infested trees. Holes made completely through the bark by the woodpeckers were checked from the under side, and in every case they led directly to a gallery of the beetles.

During clear weather feeding will start at the first light of day. It will continue heavily until about 10:00 A.M. or 10:30 A.M. and then slow down considerably. On many days it was difficult to find birds feeding from 11:00 A.M. to about 2:00 P.M.. They will start feeding heavily again around 2:00 P.M. and continue until nearly dark. During these feeding periods on clear days the pecking of the birds can be heard clearly for over two hundred yards. On days when it is snowing or heavily overcast the feeding habits are changed to almost the opposite of clear days. The feeding is light and mostly during mid-day hours. It is difficult to observe the birds feeding during periods of inclement weather. The easiest way then to locate a feeding bird is to watch for falling bark or fresh fallen bark on the snow. The noise made by their pecking during snowy weather can barely be heard

from a few feet away.

The woodpeckers were most active in feeding during December, January, and February. There was considerable feeding in early March with a slackening off later in the month. After nesting season began about the middle of May and the young were hatched, both the male and female worked continuously on infested trees throughout daylight hours.

During the winter months the bases of the trees are covered with several feet of snow. The beetles beneath the snowline in the trees are protected from the woodpeckers until the snow melts. As the snow begins to melt the birds tend to concentrate their feeding on the freshly exposed surfaces of the infested trees. Most of the hibornating adults are in the bases of trees and they usually started flying about the second week in June. The birds had not had time to consume many of them before the beetles had completed emergence.

Chapter V

ANALYSIS OF DATA

This study considers the following phases:

1. Determining the amount of Engelmann spruce beetle infestation in the study plots.

2. Determining the average number of pairs of woodpeckers on each plot during the period of study.

3. Investigating the winter food habits of woodpeckers involving Engelmann spruce beetles and other animal forms.

4. Determining the approximate percentage of control exercised by the present woodpecker population in ratio to the present Engelmann spruce beetle population.

Spruce beetle infestation in the study plots

Plot 1 had an approximate ratio of 1:3 1948 to 1949 infested trees. On the plot there were 86 unattacked trees, 161 attacked in 1949, and 67 attacked in 1948. The total surface of 1949 infestation for plot 1 is 12,382.5 square feet. Thirty-five 1949 infested trees were sampled from the plot. From each of these trees the diameter and height of infestation was estimated. The surface area of infestation was then determined for each tree. Using the number 308.38 $\pm$ 30.76, Massey (12), as an average number of

beetles per square foot in an infested tree, the beetle population per each tree was determined.

The average number of beetles per tree --

23,732.9 ± 2,367.2

The average surface area of infestation per tree--

76.96 square feet

Data shown in Appendix A, Table 9.

Plot 2 had an approximate ratio of 1:1 1948 to 1949 infested trees. On the plot there were 62 unattacked trees, 190 attacked in 1949, and 187 attacked in 1948. The total surface area of 1949 infestation is 14,753.5 square feet. The trees were sampled the same as in plot 1 and the same method used to determine the results.

The average number of beetles per tree --

23,945.7 ± 2,388.5

The average surface area of infestation per tree--

77.65 square feet

Data shown in Appendix B, Table 10.

Plot 3 had an approximate ratio of 3:1 1948 to 1949 infested trees. On the plot there were 23 unattacked trees, 53 attacked in 1949, and 168 attacked in 1948. The total surface area of 1949 infestation is 5,554.4 square feet. The trees were sampled the same as in plot 1 and the same method used to determine the results.

The average number of beetles per tree --

32,318.2 ± 3,234.6

The average surface area of infestation per tree--104.8 square feet

Data shown in Appendix C, Table 11.

Population of woodpeckers in the study plots

The number of pairs of woodpeckers varied in the plots from one period of observation to the next. From counts made each month for eight months, the number of pairs on plot 1 is seven, on plot 2 seven, and on plot 3 five.

Table 1.--THE NUMBERS OF PAIRS OF WOODPECKERS COUNTED ON THE PLOTS OF INFESTED ENGELMANN SPRUCE

	Plot 1	Plot 2	Plot 3
1949			
November	3	6	5
December	5	6	6
1950			
January	9	8	7
February	9	7	4
March	8	7	5
April	7	6	2
May	8	9	6
June	7	7	5
	$\bar{X}_1 = 7$	$\bar{X}_2 = 7$	$\bar{X}_3 = 5$

Food habits of woodpeckers

Some of the food habits are discussed in chapter 5. The following data are from analysis of woodpecker stomachs and are presented by tables showing relation to the conditions under which the woodpeckers were killed.

1st. Months in which the birds were killed.

2nd. Months and weather conditions during which birds were killed.

3rd. Time of day the birds were killed.

4th. Minimum temperatures on days the birds were killed.

5th. Comparison of the males with the females.

Table 2.--ENGELMANN SPRUCE BEETLE CONTENTS FROM WOODPECKER STOMACHS ARRANGED BY MONTHS.

November 1949		December 1949		January 1950		February 1950	
larvae	adults	larvae	adults	larvae	adults	larvae	adults
112	3	64	4	17	5	40	7
91	1	75	7	21	2	7	3
41	0	33	5	36	0	18	0
38	6	76	0	72	1	7	3
39	2	33	5	70	1	40	1
31	1	127	1	19	3	32	6
43	0	127	3	40	1	152	0
117	3	116	4	42	4	59	3
87	6	72	3	45	1	82	1
---	--	---	--	71	2	152	2
$\bar{X}_1$= 66.6	$\bar{X}_2$= 2.4	$\bar{X}_3$= 80.3	$\bar{X}_4$= 3.5	$\bar{X}_5$= 43.3	$\bar{X}_6$= 2.0	$\bar{X}_7$= 58.9	$\bar{X}_8$= 2.6
March 1950		April 1950		May 1950		June 1950	
larvae	adults	larvae	adults	larvae	adults	larvae	adults
26	0	37	4	51	0	7	0
62	0	40	1	50	4	24	0
102	1	24	0	31	0	95	8
55	1	51	3	38	1	37	2
178	8	61	9	27	0	31	0

Table 2.--ENGELMANN SPRUCE BEETLE CONTENTS FROM WOODPECKER STOMACHS ARRANGED BY MONTHS. (Continued)

March 1950		April 1950		May 1950		June 1950	
larvae	adults	larvae	adults	larvae	adults	larvae	adults
64	0	11	0	24	0	47	3
17	2	41	6	30	2	29	1
37	6	9	0	47	7	31	0
22	3	27	0	17	0	24	0
40	0	31	8	--	--	51	0
$\bar{X}_1$= 60.3	$\bar{X}_2$= 2.1	$\bar{X}_3$= 33.2	$\bar{X}_4$= 3.1	$\bar{X}_5$= 35.0	$\bar{X}_6$= 1.6	$\bar{X}_7$= 37.6	$\bar{X}_8$= 1.4

Table 3.--ENGELMANN SPRUCE BEETLE CONTENTS FROM WOODPECKER STOMACHS ARRANGED ACCORDING TO WEATHER CONDITIONS AND MONTHS.

November 1949				December 1949			
clear		not clear		clear		not clear	
larvae	adults	larvae	adults	larvae	adults	larvae	adults
112	3	--	--	64	4	33	5
91	1	--	--	75	7	--	--
41	0	--	--	76	0	--	--
38	6	--	--	33	5	--	--
39	2	--	--	127	1	--	--
31	0	--	--	127	3	--	--
43	0	--	--	116	4	--	--
117	0	--	--	72	3	--	--
87	6	--	--	---	--	--	--
$\bar{X}_1$= 66.6	$\bar{X}_2$= 2.0			$\bar{X}_5$= 86.1	$\bar{X}_6$= 3.4	$\bar{X}_7$= 33.0	$\bar{X}_8$= 5.0
January 1950				February 1950			
clear		not clear		clear		not clear	
larvae	adults	larvae	adults	larvae	adults	larvae	adults
72	1	17	5	152	0	40	7
19	3	21	2	59	3	7	3
40	1	36	0	82	1	18	0
42	4	70	1	152	2	7	3

Table 3.--ENGELMANN SPRUCE BEETLE CONTENTS FROM WOODPECKER STOMACHS ARRANGED ACCORDING TO WEATHER CONDITIONS AND MONTHS. (Continued)

January 1950				February 1950			
clear		not clear		clear		not clear	
larvae	adults	larvae	adults	larvae	adults	larvae	adults
45	1	--	--	---	--	40	1
71	2	--	--	---	--	32	6
$\bar{X}_1$= 48.2	$\bar{X}_2$= 2.0	$\bar{X}_3$= 36.0	$\bar{X}_4$= 2.0	$\bar{X}_5$= 111.2	$\bar{X}_6$= 1.5	$\bar{X}_7$= 24.0	$\bar{X}_8$= 3.3

March 1950				April 1950			
clear		not clear		clear		not clear	
larvae	adults	larvae	adults	larvae	adults	larvae	adults
62	0	26	0	37	4	9	0
102	1	17	2	40	1	27	0
55	1	37	6	24	0	31	8
178	8	22	3	51	3	--	--
64	0	40	0	61	9	--	--
---	--	---	--	11	0	--	--
---	--	---	--	41	6	--	--
$\bar{X}_1$= 92.2	$\bar{X}_2$= 2.0	$\bar{X}_3$= 28.4	$\bar{X}_4$= 2.2	$\bar{X}_5$= 37.9	$\bar{X}_6$= 3.3	$\bar{X}_7$= 22.3	$\bar{X}_8$= 2.7

Table 3.--ENGELMANN SPRUCE BEETLE CONTENTS FROM WOODPECKER STOMACHS ARRANGED ACCORDING TO WEATHER CONDITIONS AND MONTHS. (Continued)

May 1950				June 1950			
clear		not clear		clear		not clear	
larvae	adults	larvae	adults	larvae	adults	larvae	adults
51	0	31	0	7	0	--	--
50	4	38	1	24	0	--	--
30	2	27	0	95	8	--	--
47	7	24	0	37	2	--	--
17	0	--	--	31	0	--	--
---	--	--	--	47	3	--	--
---	--	--	--	29	1	--	--
---	--	--	--	31	0	--	--
---	--	--	--	24	0	--	--
---	--	--	--	51	0	--	--
$\bar{X}_1$= 39.0	$\bar{X}_2$= 2.6	$\bar{X}_3$= 30.0	$\bar{X}_4$= .25	$\bar{X}_5$= 37.6	$\bar{X}_6$= 1.4		

Table 4.--ENGELMANN SPRUCE BEETLE CONTENTS FROM WOODPECKER STOMACHS ARRANGED ACCORDING TO TIME OF DAY.

A.M.		P.M.	
larvae	adults	larvae	adults
112	3	38	6
91	1	39	2
41	0	31	0
63	4	43	0
33	5	117	3
76	0	87	6
33	5	75	7
17	5	127	1
21	2	127	3
36	0	116	4
72	1	72	3
19	3	70	1
40	1	45	1
42	4	71	2
40	7	32	6
7	3	152	0
18	0	62	0
7	3	102	1
40	1	17	2
59	3	40	0
82	1	40	1

Table 4.--ENGELMANN SPRUCE BEETLE CONTENTS FROM WOODPECKER STOMACHS ARRANGED ACCORDING TO TIME OF DAY. (Continued)

A.M.		P.M.	
larvae	adults	larvae	adults
152	2	24	0
26	0	11	0
55	1	41	6
178	8	31	8
64	0	51	0
37	6	50	4
22	3	30	2
37	4	47	7
51	3	17	0
61	9	7	0
9	0	24	0
27	0	95	8
31	0	37	2
38	1	29	1
27	0	31	0
24	0	24	0
31	0	51	0
47	3	--	--
$\bar{X}_1$=47.8	$\bar{X}_2$=2.4	$\bar{X}_3$=55.3	$\bar{X}_4$=2.3

Table 5.--ENGELMANN SPRUCE BEETLE CONTENTS FROM WOODPECKER STOMACHS GROUPED ACCORDING TO TEMPERATURE RANGES.

Below 5° F.		5°F. to 20°F.		Above 20°F.	
larvae	adults	larvae	adults	larvae	adults
76	0	112	3	9	0
33	5	91	1	27	0
127	1	39	2	31	8
127	3	31	0	51	0
19	3	33	5	50	4
40	1	59	3	31	0
42	4	82	1	38	1
45	1	152	2	27	0
71	2	17	5	24	0
63	4	21	2	30	2
75	7	36	0	47	7
116	4	72	1	17	0
72	3	70	1	7	0
43	0	40	7	24	0
117	3	7	3	95	8
87	6	18	0	37	2
41	0	7	3	31	0
38	6	40	1	47	3
--	--	32	6	29	1
--	--	152	0	31	0

Table 5.--ENGELMANN SPRUCE BEETLE CONTENTS FROM WOODPECKER STOMACHS GROUPED ACCORDING TO TEMPERATURE RANGES. (Continued)

Below 5°F.		5°F. to 20°F.		Above 20°F.	
larvae	adults	larvae	adults	larvae	adults
--	--	26	0	24	0
--	--	62	0	51	0
--	--	102	1	--	--
--	--	55	1	--	--
--	--	178	8	--	--
--	--	64	0	--	--
--	--	17	2	--	--
--	--	37	6	--	--
--	--	22	3	--	--
--	--	40	0	--	--
--	--	37	4	--	--
--	--	40	1	--	--
--	--	24	0	--	--
--	--	51	3	--	--
--	--	61	9	--	--
--	--	11	0	--	--
--	--	41	6	--	--
$\bar{X}_1$=68.4	$\bar{X}_2$=2.9	$\bar{X}_3$=53.5	$\bar{X}_4$=2.4	$\bar{X}_5$=34.5	$\bar{X}_6$=1.6

Table 6.--ENGELMANN SPRUCE BEETLE CONTENTS FROM WOODPECKER STOMACHS ARRANGED ACCORDING TO SEX.

Male		Female	
larvae	adults	larvae	adults
112	3	41	0
91	1	39	2
38	6	43	0
31	0	63	4
117	3	33	5
87	6	116	4
75	7	17	5
33	5	21	2
76	0	40	1
127	1	42	4
127	3	45	1
72	3	7	3
36	0	18	0
72	1	7	3
70	1	40	1
19	3	32	6
71	2	26	0
40	7	64	0
112	0	17	2
59	3	40	0

Table 6.--ENGELMANN SPRUCE BEETLE CONTENTS FROM WOODPECKER STOMACHS ARRANGED ACCORDING TO SEX. (Continued)

Male		Female	
larvae	adults	larvae	adults
82	1	24	0
152	2	51	3
55	1	11	0
178	8	27	0
37	6	51	0
22	3	50	4
37	4	30	2
40	1	17	0
61	9	24	0
41	6	37	2
9	0	31	0
31	8	29	1
31	0	31	0
38	1	24	0
27	0	--	--
24	0	--	--
47	7	--	--
7	0	--	--
95	8	--	--
47	3	--	--

Table 6.--ENGELMANN SPRUCE BEETLE CONTENTS FROM WOODPECKER STOMACHS ARRANGED ACCORDING TO SEX. (Continued)

Male		Female	
larvae	adults	larvae	adults
51	0	--	--
62	0	--	--
102	1	--	--
$\bar{X}_1$=64.7	$\bar{X}_2$=2.9	$\bar{X}_3$=34.9	$\bar{X}_4$=1.6

Woodpeckers will not feed entirely upon Engelmann spruce beetles even in heavily infested areas. The following is a list of insects other than the Engelmann spruce beetles, that were found in the stomachs of woodpeckers:

	Order	Family	Genus
1.	Araneida	--	--
2.	Homoptera	--	--
3.	Coleoptera	-- Staphylinidae	--
4.	"	-- Dermestidae	--
5.	"	-- Cleridae	--
6.	"	-- Scolytidae	-- Ips
7.	"	-- "	-- Pityopthorous
8.	"	-- "	--
9.	"	-- "	-- Polygraphus
10.	"	-- "	-- Dryocetes

	Order	Family	Genus
11.	Coleoptera	-- Scolytidae	-- Carphoborus
12.	"	-- "	-- Scolytus
13.	"	-- Cerambycidae	--
14.	Lepidoptera	--	--
15.	Hymenoptera	--	--
16.	"	-- Braconidae	--
17.	"	-- Apidae	--
18.	Diptera	-- Dolichopodidae	-- Medetera

Approximate percentage of beetle population consumed by the present woodpecker population in ratio to the present Engelmann spruce beetle population

In plot 1 there were seven pairs of woodpeckers. The spruce beetle population per tree was 23,732.9 ± 2,367.2. The number of beetles consumed per tree by woodpeckers was 12,746.9 ± 1,271.4. These numbers show that the approximate amount of beetle population taken from plot 1 was 53.7 percent. Refer to Appendix D - Table 12.

In plot 2 there were seven pairs of woodpeckers. The spruce beetle population per tree was 23,945.7 ± 2,388.5. The number of beetles consumed per tree by woodpeckers was 13,716.0 ± 1,368.1. These numbers show that the approximate amount of beetle population taken from plot 2 was 57.2 percent. Refer to Table 13 - Appendix E.

In plot 3 there were only five pairs of woodpeckers. The spruce beetle population per tree was 32,318.2 ± 3,234.6. The number of beetles consumed per tree by woodpeckers was 17,080.1 ± 1,709.4. These numbers show that the approximate amount of beetle population taken from plot 3 was 52.8 percent. Refer to Table 14 - Appendix F.

The percent of beetle population taken from the three individual plots appear very nearly the same. However, an analysis of variance, used to show whether these percentages of the beetle population consumed on the three plots differed appreciably because the numbers of pairs of woodpeckers varied for the plots, indicated that the analysis should be made on a unit basis. Upon this basis and as is shown in Table 7 there is a significant difference between the percentages of beetles consumed.

Table 7.--ANALYSIS OF VARIANCE OF PERCENTAGES OF THE SPRUCE BEETLE POPULATION CONSUMED ON THE THREE PLOTS OF INFESTED ENGELMANN SPRUCE.

Variability due to	D/F	Sums of squares	Mean squares	F value	Required F. .05	.01
Totals	104	1,484.6				
Between plots	2	167.8	83.9	6.50	3.09	4.08
Within plots	102	1,316.7	12.9			

Table 7.--ANALYSIS OF VARIANCE OF PERCENTAGES OF THE SPRUCE BEETLE POPULATION CONSUMED ON THE THREE PLOTS OF INFESTED ENGELMANN SPRUCE. (Continued)

MSD .05 = 1.704 MSD .01 = 2.255

Standard Error = .607

MSD = Minimum difference required for significance

The numbers of 1949 infested trees on the three plots varied from 190 on plot 2 to 53 on plot 3. An analysis of variance is made to determine whether the total amount of beetles consumed from each of the three individual plots differ significantly. This analysis in Table 8, shows that the amounts of beetles consumed from each plot do differ highly significantly.

Table 8.--ANALYSIS OF VARIANCE ON THE TOTAL AMOUNT OF BEETLES CONSUMED ON THE THREE INDIVIDUAL PLOTS OF INFESTED ENGELMANN SPRUCE.

Variability due to	D/F	Sums of squares	Mean squares	F value	Required F. .05 / .01
Totals	104	21,375,176,630			
Between plots	2	3,488,306,848	1,744,153,424	9.94	3.09 4.82
Within plots	102	17,886,869,782	175,361,468		

MSD .05 = 6280 MSD .01 = 8313

Standard Error = 2238

MSD = Minimum difference required for significance

Chapter VI

DISCUSSION

The main problem of this study is concerned with the extent to which Engelmann spruce beetles are involved in the winter food habits of woodpeckers.

The three species of woodpeckers used in this study, Alpine Three-toed, Downy, and Rocky Mountain Hairy, were to be considered separately in their effects on the Engelmann spruce beetle. Seventy-seven birds were killed and it was found that the number of Downy and Hairy woodpeckers killed was not large enough to compare with the number of Alpine Three-toed woodpeckers killed. In working the data, the effects of all three species were combined and used as a unit.

Infestation in the study plots

The ratio of 1949 to 1948 infested trees was 3:1 in plot 1. Plot 2 had a ratio of 1:1 of 1949 to 1948 attacked trees and plot 3 had a ratio of 1:3 of 1949 to 1948 attacked trees.

There was no significant difference in the beetle population per tree in the first two plots. Plot 3, however, differed significantly from plots 1 and 2 in that

it had a larger population of beetles per tree.

Population of woodpeckers in study plots

During each period of study several hours were spent each day to make counts on the pairs of woodpeckers on the plots. On plot 1 the counts varied from three pairs in November 1949 to nine pairs in January and February of 1950. Plot 2 had the most consistent number of pairs during the study. They varied from six pairs in November 1949 to nine pairs in May 1950. Plot 3 varied from seven pairs in January 1950 to as low as two pairs in April 1950. At nearly all times when the number of birds on the plots would be low, there would be several feeding just outside the plot perimeter.

Food habits of the woodpeckers

The largest count of beetles per bird stomach for an average in any one month was in December 1949. It was during this month that the greatest amount of activity seemed to take place. The smallest count of beetles per bird stomach for an average in any one month was April 1950. During April and the first part of May 1950 the least amount of activity was noticeable.

During clear weather the birds would be extremely active in feeding. When it became overcast or started snowing, the feeding would slow down considerably and at times would stop altogether. If the weather continued bad for several days, the birds would feed mostly during the mid-day hours, and then only for a short period.

There was very little difference in the amount of feeding between mornings and the afternoons. If the weather conditions do not interfere, the hours of feeding in the mornings and afternoons are about the same.

There was definitely much more feeding activity at temperatures below 10° F. than temperatures above 20° F. Even during periods of snow the feeding, which always slowed down in such weather, was more pronounced at the lower temperatures.

According to counts of stomach contents, the average number of beetles found in the stomachs of the males was almost twice the number found in the females. Only in one case were there over a hundred beetles counted from the stomach of a female bird. In seven of the males there were over a hundred.

The Engelmann spruce beetles made up nearly 99 percent of the insects in the diet of the woodpeckers. Other orders represented in the diet of the birds were

Homoptera, Lepidoptera, Hymenoptera, Diptera, and Araneida.

Approximate percentage of beetle population taken by the woodpeckers

The percents of the beetle population taken from the three individual plots appeared relatively close. There is a significant difference as shown in Table 7 in the percent of beetles consumed on the three plots because plot 3 had only five pairs of birds as compared to seven pairs each on the other two plots. In considering that plots 1 and two had more than three times as many 1949 infested trees as plot 3, and less than one and one-half times as many woodpeckers, then the actual amount of feeding by the woodpeckers on plots 1 and 2 was much greater than on plot 3. The percent of the beetles taken over all three plots was approximately 55 percent of the population.

The native sites on which Engelmann spruce stands occur have natural barriers against the food habits of woodpeckers on Engelmann spruce beetles. In the basal five to six feet of the infested trees there are heavy broods of the beetles consisting of both larvae and the hibernating adults. Under normal conditions of winter, this section of the trees is covered with snow. It will remain covered until late May or early June. After the snow melts down to the base of the trees, the woodpeckers do not have time to

consume these beetles before they emerge. This will probably prevent any efforts of the woodpecker from taking more than 75 to 80 percent of the beetle population under normal conditions.

Chapter VII

SUMMARY

In the last ten years a large volume of the Engelmann spruce forests in Colorado has been destroyed by the Engelmann spruce beetle. The infestation spread very rapidly and up to the present time it has covered most of the spruce timber on the White River, Routt, and Arapahoe National Forests.

This study was made to investigate the winter food habits of woodpeckers and to determine their value in control of the Engelmann spruce beetle.

The area of study was an Engelmann spruce beetle infested area on Rabbit Ears Pass near Steamboat Springs, Colorado. The periods for gathering data were one week of each month from November 1949 to June 1950. The study was made on thirty acres of infested spruce timber.

The three species of woodpeckers involved in the study were the Alpine Three-toed, Picoides tridactylus dorsalis Baird, the Downy, Dryobates pubescens Swainson, and the Rocky Mountain Hairy, Dryobates villosus monticolae Anthony.

Results obtained:

1. There were 19 pairs of woodpeckers that fed on the area under study.

2. The greatest average number of beetles found in woodpecker stomachs in any one month was December 1949.

3. The woodpeckers are much more active in feeding on clear days than on cloudy days.

4. There is no significant difference in the feeding in the morning and that of the afternoons.

5. The woodpeckers feed more when the temperatures are below 5°F. than when temperatures are around 20°F. and above.

6. Stomach contents from the male woodpecker indicated that they took almost twice as many beetles as the females.

7. Engelmann spruce beetles made up about 99 percent of the insects consumed by the woodpeckers.

8. There was approximately 55 percent of the beetle population consumed by the woodpeckers in the area of study.

From data presented, it could be concluded that an increase in the woodpecker population would aid materially in cutting the cost of artificial control on Engelmann spruce beetle infestations. It would also tend to prohibit future epidemics once the beetles are under control.

A P P E N D I X

APPENDIX A

Table 9.--PLOT 1 - SPRUCE BEETLE POPULATION PER INFESTED TREE.

Infested bark area per tree in square feet		
28.3	70.7	102.6
172.8	109.9	47.1
130.9	29.3	78.5
52.4	58.9	75.4
150.8	31.4	87.9
150.8	81.7	213.1
80.6	49.7	40.3
37.7	106.3	62.8
29.3	150.8	56.5
28.3	47.1	97.7
44.5	31.4	62.8
		78.5
		26.7

Average infested bark area per tree in square feet	Average number of beetles per square foot	Average beetle population per tree
$\bar{X}_1$=76.96	$\bar{X}$=308.38 ± 30.76	$\bar{X}_2$=23,732.9 ± 2,367.2

APPENDIX B

Table 10.--PLOT 2 - SPRUCE BEETLE POPULATION PER INFESTED TREE.

Infested bark area per tree in square feet		
69.1	22.0	75.4
102.6	62.8	55.0
142.4	88.0	65.5
33.0	36.7	65.6
95.3	56.5	37.7
37.7	81.7	87.9
108.9	102.6	47.6
88.5	53.4	87.9
43.2	78.5	62.8
61.3	40.3	209.4
134.0	164.9	73.3
		81.7
		62.8

Average infested bark area per tree in square feet	Average number of beetles per square foot	Average beetle population per tree
$\bar{X}_1$=77.65	$\bar{X}$=308.38 ± 30.76	$\bar{X}_2$=23,945.7 ± 2,388.5

APPENDIX C

Table 11.--PLOT 3 - SPRUCE BEETLE POPULATION PER INFESTED TREE.

Infested bark area per tree in square feet		
36.7	87.9	62.8
137.4	75.4	78.5
94.2	146.6	36.7
141.4	68.0	50.3
80.6	179.0	53.4
128.3	308.4	56.5
104.7	136.1	144.0
208.9	155.5	25.1
127.2	135.6	125.7
50.3	91.6	75.4
37.7	183.3	94.2
		57.6
		94.2

Average infested bark area per tree in square feet	Average number of beetles per square foot	Average beetle population per tree
$\bar{X}_1$=104.8	$\bar{X}$=308.38 ± 30.76	$\bar{X}_2$=32,318.2 ± 3,234.6

APPENDIX D

Table 12.--PLOT 1 - PERCENT AND NUMBER OF BEETLES CONSUMED BY WOODPECKERS.

Percent of bark removed from tree by woodpeckers		
85	50	50
50	40	50
50	5	40
70	95	60
85	75	5
80	20	40
70	20	70
70	75	40
65	60	25
20	65	90
40	30	90
		20
		80

Average beetle population per tree	Average percent of bark removed from tree by woodpecker	Average number of beetles consumed by woodpeckers
$\bar{X}_1 = 23,732.9 \pm 2,367.2$	$\bar{X} = 53.71$	$\bar{X}_2 = 12,746.9 \pm 1,271.4$

APPENDIX E

Table 13.--PLOT 2 - PERCENT AND NUMBERS OF BEETLES CONSUMED BY WOODPECKERS.

Percent of bark removed from tree by woodpeckers		
50	80	50
50	50	60
75	60	70
80	30	20
70	40	60
70	60	65
80	15	20
70	50	60
35	75	90
35	50	45
75	90	90
		15
		70

Average beetle population per tree	Average percent of bark removed from tree by woodpecker	Average number of beetles consumed by woodpeckers
$\bar{X}_1$=23,945.7 ± 2,388.5	$\bar{X}$=57.28	$\bar{X}_2$=13,716.0 ± 1,368.1

APPENDIX F

Table 14.--PLOT 3 - PERCENT AND NUMBERS OF BEETLES CONSUMED BY WOODPECKERS.

Percent of bark removed from tree by woodpeckers		
30	70	60
35	90	65
60	75	40
60	40	50
70	50	25
40	60	90
50	60	50
60	50	20
70	90	50
90	30	30
40	25	20
		40
		65

Average beetle population per tree	Average percent of bark removed from tree by woodpecker	Average number of beetles consumed by woodpeckers
$\bar{X}_1$=32,318.2 ± 3,234.6	$\bar{X}$=52.85	$\bar{X}_2$=17,080.1 ± 1,709.4

APPENDIX G

United States
Department of the Interior
Fish and Wildlife Service

Wildlife Research Laboratory
Denver Federal Center, Denver 2, Colorado

August 17, 1951

Mr. T. O. Thatcher, Ass't. Entomologist
Colo. Agricultural and Mechanical College
Department of Entomology
Fort Collins, Colorado

Dear Mr. Thatcher:

In your letter of August 9 you inquire about the period of time during which insects can be identified in the stomachs of birds. A number of factors determine this. Among these are the character of the insects themselves (whether soft and easily digested larvae or a hard-shelled beetle), the actual size of the insect, the volume of food in the stomach at the time, and possibly the hunger status of the bird itself, which might affect the rapidity of digestion.

I might cite an extreme case in which I fed English sparrows quantities of one of the smaller nematodes, primarily to learn whether they passed the digestive tract uninjured. I discovered to my surprise that some of these nematodes were voided by the birds within an hour from the time they were eaten. That, of course, is an extreme case.

In the case of hard-shelled beetles and certain seeds, the undigested portions may remain in the stomach for the better part of the day. Generally, diurnal birds have 2 feeding periods, in the morning and towards evening. Normally the morning feeding would have largely passed the

APPENDIX G.--Continued

stomach before the evening feeding began. Likewise, on the morning following evening feeding, the stomach again would be empty.

Many of our birds, commonly, and a few of them regularly, regurgitate undigested food items. The outstanding examples of these, of course, are the birds of prey, hawks and owls, and void pellets of undigested food. After this has been done, the stomach is apt to be completely empty.

Between the extremes I have mentioned there are all degrees of variation and in the case of woodpeckers there probably will be some fragments of insect food in the stomach at all times except possibly late at night or at dawn.

Sincerely yours,

E. R. Kalmbach
Director

B I B L I O G R A P H Y

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The effects of woodpeckers on the Englemann spruce beetle.

ABSTRACT

INTRODUCTION.

In the last few years the Engelmann spruce beetle has destroyed several billion board feet of Engelmann spruce timber in Colorado. Chemical control of this beetle can be made only by intensive physical and costly efforts.

A severe wind storm in 1939 caused many trees to be blown over and weakened. This provided an ideal breeding place for the beetles. Under these conditions their numbers have increased so tremendously that they have been able to attack and kill healthy trees.

Among the many enemies of the Engelmann spruce beetle, the woodpeckers probably rank foremost. A large percentage of bark beetles are included in the diet of woodpeckers. Previous studies made by Dr. Calvin L. Massey of the Forest Insect Laboratory, Fort Collins, Colorado showed that the Downey, Rocky Mountain Hairy, and the Alpine Three-toed woodpeckers were the most important species localized in spruce beetle infested areas.

The spruce beetle possibly could be controlled by woodpeckers provided the woodpeckers were present in sufficient numbers.

The main objective of this study was to determine the effects of woodpeckers on the Engelmann spruce beetle and determine the approximate percentage of control exercised by the woodpeckers on the beetle. The study was divided into the

following steps.

The problem:

What are the effects of woodpeckers on the Engelmann spruce beetle and what percent control will the present woodpecker population exercise on the present Engelmann spruce beetle population.

Problem analysis.

1. What areas of Engelmann spruce are now infested with the Engelmann spruce beetles?

2. What species of woodpeckers are now localized in these infested areas?

3. What are the food habits of these woodpeckers involving the Engelmann spruce beetle?

4. What percentage of the present Engelmann spruce beetle population will be consumed by the present woodpecker population?

Delimitations.

This study will be limited to three species of woodpeckers and to the Engelmann spruce beetle infested area on Rabbit Ears Pass and vicinity.

METHODS AND MATERIALS.

From information made on surveys by the Forest Insect Laboratory, Fort Collins, Colorado, a location on the west side of Rabbit Ears Pass having the spruce beetle in epidemic numbers was selected for the problem. Much necessary information, equipment and assistance was furnished by the Forest Insect Laboratory.

One week was spent each month from November, 1949 to June, 1950 in the area of study. A U. S. Forest Service cabin was used during this time.

Three ten acre plots were marked off in the infested area. They were numbered one, two, and three. Number one plot had a small proportion of 1948 attacked trees and a large proportion of 1949 attacked trees. Number two plot had a ratio of about 1:1 of 1949 to 1948 attacked trees. Number three plot had a small proportion of 1949 attacked trees and a large proportion of 1948 attacked trees. These three types of plots were chosen to determine whether the woodpeckers would feed most on larvae or adult beetles. The 1948 attacked trees had a hibernating adult population in them, with very few larvae, and the 1949 attacked trees had a large population of larvae and a very few adults.

Observations were made each day on the plots to determine the number of pairs of woodpeckers feeding there. Their feeding habits were studied and data obtained on the time of day and the temperatures at which maximum feeding took place. The effects of such weather factors as to clear and cloudy weather were observed.

Ten woodpeckers were taken each month and the stomach contents analyzed to determine what percentage of their food was made up of the Engelmann spruce beetle. Authorization for killing of the birds was given by the Colorado State Fish and Game Commission and the U. S. Fish and Wildlife Service.

After the study was completed, the plots were sampled and estimates made to determine the approximate amount of beetles the woodpeckers had consumed from the 1949 trees.

Twenty infested trees were felled. The height of the infestation on each tree was measured. Diameters on the trees. were made at varying heights so that the taper of the boles would be considered when calculating the surface area of infestation on each tree. The areas where bark had been removed from the trees by woodpeckers were measured. These measurements were made so that sampling estimates on the plots would be more accurate.

The plots were measured in five yard strips. On each strip a coin was tossed to determine whether the even or odd trees were used in the sample. One hundred trees each were used from plots one and two. Fifty trees were used from plot three because there were less than one hundred 1949 attacked trees on the plot. Random numbers were used on the original samples and populations of 35 trees were set up for each of the three plots.

A study by Dr. C. L. Massey of the Forest Insect Laboratory shows the average number of beetles per square foot in infested trees to be 308.38 ± 30.76.

OBSERVATIONS.

1. It is common for a pair of birds to limit their feeding to a group of seven or eight infested trees until there are no longer enough accessible larvae to provide a sufficient

food supply for them.

2. The Alpine Three-toed and the Rocky Mountain Hairy woodpeckers nearly always feed in pairs.

3. Woodpeckers seem always to know exactly where to find broods of the beetle under the bark of the tree.

4. In clear weather the feeding is done mostly in the early morning and late afternoon. In cloudy weather the birds feed mostly during the noonday hours.

5. The woodpeckers were most active in feeding during the months of December, January, and February.

6. The number of pairs of woodpeckers observed on the plots during the period of study averaged seven on plot one, seven on plot two, and five on plot three.

ANALYSIS OF DATA.

Much of the data gathered during the study was from analysis of woodpecker stomachs. The following findings was made from this data:

1. Larvae made up most of the food contents.

2. More beetle larvae were found in the stomachs of the male birds than in the female birds.

3. More beetle larvae were found in the stomachs during clear weather than during cloudy weather.

4. More beetle larvae were found in the stomachs during the month of December than any other month. The least number were found in April.

5. There was no significant difference as to the number of beetle larvae found in the stomachs during the morning or the afternoon.

6. There were more beetle larvae found in the stomachs of birds taken at temperatures below 5° F. than at higher temperatures.

7. The spruce beetles made up nearly 99 percent of the insects found in the woodpeckers stomachs.

An analysis of variance showed a significant difference in the percentage of the beetle population consumed from the three plots. The percent of the beetle population consumed on all three plots was approximately 55 percent.

The native sites on which Engelmann spruce stands occur have natural barriers against the food habits of woodpeckers on Engelmann spruce beetles. In the basal five to six feet of the infested trees there are heavy broods of the beetles consisting of both larvae and the hibernating adults. Under normal conditions of winter this section of the trees is covered with snow. It will remain covered until late May or early June. After the snow melts down to the base of the trees, the woodpeckers do not have time to consume these beetles before they emerge. This will probably prevent any efforts of the woodpeckers from taking more than 75 to 80 percent of the beetle population under normal conditions.

From data presented it could be concluded that an

increase in the woodpecker population would aid materially in cutting the cost of artificial control on Engelmann Spruce beetle infestations. It would also tend to prohibit future epidemics once the beetles are under control.