The Biology of *Scierus annectens* LeConte

(COLEOPTERA, SCOLYTIDAE)

By

KENNETH WILSON STEWART

Bachelor of Science

Oklahoma State University

Stillwater, Oklahoma

1958

Submitted to the faculty of the Graduate School
of the Oklahoma State University
in partial fulfillment of the
requirements for the
degree of
MASTER OF SCIENCE
May, 1959

THE BIOLOGY OF Scierus annectens LeConte

(COLEOPTERA, SCOLYTIDAE)

Thesis Approved:

D E Howell
Thesis Adviser

D. E. Bryan

William H. Drew

R R Walton

Robert MacVicar
Dean of the Graduate School

PREFACE

While employed by the Rocky Mountain Forest and Range Experiment Station, United States Department of Agriculture, the author became interested in a secondary bark beetle, *Scierus annectens* Lec. This small bark beetle is very closely associated with the Engelmann spruce beetle, *Dendroctonus engelmanni* Hopk.

A detailed outline of research on the biology of *S. annectens* was planned and soon initiated under the direction and supervision of Dr. B. H. Wilford, entomologist in charge at the Forest Insect Laboratory at Fort Collins, Colorado, and Dr. Fred B. Knight, station entomologist. Deep appreciation is extended to these two men and to Dr. Noel D. Wygant of the station. Appreciation is given also to Amel Landgraf, Roy Nagel, and Thomas Hinds of the Insect Laboratory. All of these men gave the author patient advice and helpful assistance in planning and collecting data for this study.

Grateful acknowledgement is given to John Chansler, Dan Jennings, and Gene Ammond, co-workers of the author, whose help in collecting data was invaluable.

Much indebtedness is extended to my graduate committee, Drs. D. E. Howell, thesis advisor and Professor of Entomology, Oklahoma State University, R. R. Walton, Professor of Entomology, D. E. Bryan, Associate Professor of Entomology, and W. A. Drew, Assistant Professor of Entomology. Each extended a helping hand when needed and constructively criticized this thesis.

The author's interest in forest entomology, which led to this study was stimulated by Dr. F. A. Fenton, Head Emeritus of the Department of Entomology at Oklahoma State University. To him much gratitude is felt.

This research report cannot be published in entirety or in part without prior permission of the author, the Oklahoma State University, and the Rocky Mountain Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture, which maintains central headquarters at Fort Collins, Colorado, in cooperation with Colorado State University.

Table of Contents

List of Tables

List of Figures

Chapter I

Introduction

Heretofore, many of the secondary bark beetles have not been considered of sufficient economic importance to warrant concentrated research on their biology and habits. However, with the need for more advanced knowledge of the destructive and economically important primary bark beetles, has come recognition that information on the habits and biology of their secondary associates is also necessary.

This thesis is concerned with the biology of one of these secondaries, Scierus annectens Lec., which is very closely associated with the Engelmann spruce beetle, Dendroctonus engelmanni Hopk., a destructive primary bark beetle which destroys high volumes of Engelmann spruce, Picea engelmannii Parry, throughout the Rocky Mountains.

Data for this study were collected from late June to October, 1958, on the Illinois River drainage near Rand, Colorado, at an elevation of approximately 10,000 feet. The Engelmann spruce beetle has been, until recently, at an epidemic level in this area. The surrounding forests are of typical Engelmann spruce-alpine fir and lodgepole pine types.

Due to deep snow in the winter months, data could not be collected in the beetle's natural environment. Therefore, this study is primarily concerned with the biology and habits of the beetle during its active period, from late June to early October.

Chapter II

Review of Literature

There is little information available pertaining to the biology of S. annectens. Most reports are limited to a description of the insect and its range.

The genus Scierus was described by LeConte (1876) as follows:

Scierus n.g. I have separated under this generic name a species which agrees in general form with Hylurgops but differs from it and Hylastes by the front coxae being widely separated by the prosternum. The form of the third joint of the tarsi is intermediate, it being not as deeply bilobed as in Hylurgops, but broader than in Hylastes. It agrees with both in the antennae, which have the funicle 7-jointed, and the club ovate-pointed, with the first joint smooth, shining, and nearly as long as the others united. The tibiae are dilated and broadly serrate as in Hylastes; the terminal mucro is short. The first and second ventral segments are equal, and the third and fourth are shorter; the fifth is as long as the second. The other characters are those of the tribe, and it is not necessary to repeat them.

Only the species annectens was recognized at this time. The original description is given below:

Scierus annectens n. sp. Oblong-cylindrical, dark brown, opaque, thinly clothed with very short depressed yellow hairs. Beak flat, punctured and hairy, about twice as wide as long, not impressed or carinate; head convex, punctures becoming finer and obsolete on the occiput. Prothorax one-third wider than long, rounded on the sides, narrowed in front, faintly impressed but not constricted on the sides, nearly truncate in front and at base; densely and strongly punctured with a narrow dorsal line, which is obsolete in some specimens. Scutellum rounded behind, not depressed. Elytra wider than the prothrax; basal margin rather acute, finely serrate; striae deeply impressed, punctured; interspaces wider than the striae, scabrous with transverse rugosities, becoming asperate on the sides towards the tip; the interspaces become more convex on the declivity, and the third and ninth unite near the tip, and then join the first so that the second is a little shortened. Beneath coarsely and sparsely punctured and pubescent, and less opaque; legs lighter brown. Length 3.6 mm; .14 inch.

Anticosti Island, Gulf of St. Lawrence, W. Couper; British Columbia and Vnacouver Island, G. R. Crotch. No sexual difference observed.

Swaine (1924) indicated that members of the genus *Scierus* were rare in Canadian collections, and gave the distribution as follows: "Generally throughout the spruce forests of the northern part of the continent."

At this time there were 85 adult specimens in the Canadian National Collection. Specimens were recorded from Gaspe, Quebec; Creighton Valley, British Columbia; Cariboo District, British Columbia; San Francisco Peak, Arizona; Big Bear Lake, California; Mammoth Mt., Utah; and Jasper Park, Alberta. Hosts of these 85 specimens were white spruce and Engelmann spruce. Four adults of this collection were of a distinctly different species. Swaine presented these as new species, *Scierus pubescens* Swaine.

Very little has been published on the external sex characters of *S. annectens*.

Swaine (1924) presented the only information available on external sex differentiation in *S. annectens* as follows:

"Antennal scrobes entirely lateral, with a fine, indistinct, median, longitudinal carina in the males (lacking this in the females)."

Hopkins (1894) described some external sex differentiation characters of the Scolytidae, but stated:

Comparatively little is known regarding the external sexual characters of species in the family Scolytidae. While the external sexual characters appear to be constant with the species in some genera, in others no particular character is possessed by all of the species. In fact, what may be a good male or female character in one species will be reversed in another species of the same genus.

Hopkins (1915) described internal sex structures in scolytids. Very good drawings of the male and female reproductive organs of various genera were presented, and were used as a guide in studying the internal sex structures of S. annectens. He recorded:

The presence of the chitinized spermatheca in the female or of the chitinized elements of the posterior section of the male organs is sufficient to settle the point of sex, even in old dried specimens.

Swaine (1929) described some of the habits of Canadian bark beetles, but did not mention S. annectens.

Chamberlin (1939) gave essentially the same description of S. annectens as presented by LeConte (1876). He presented a key to the genus.

Keen (1952) gave the following description:

A small reddish brown beetle about 1/8 inch long, breeds in White and Engelmann spruces, lodgepole pine, and probably in Sitka spruce in western Canada, the Northwest, and the Rocky Mountain States.

Chapter III

Materials and Methods

The natural habitat of S. annectens, the bark and cambial layer of weakened Engelmann spruce, was used for this experiment. Late in June, as the study area became accessible, ten merchantable Engelmann spruce were felled in random directions. Five of these were selected for this experiment. Trap trees not having sufficient space above the ground level to permit an unobstructed view of the lower one-half of the bole were jacked up to such a position and blocked permanently in place. The logs were then marked at a point 15 feet from the cut, and this length was used for all observations. Any limbs in this area on the log were eliminated.

Attack

On July 7, the trap trees were closely examined and all entrance holes on the lower one-half of the bole were circled with pencil. Their numbers were recorded by date. The upper portion of the bole was not used because both the Engelmann spruce beetle and S. annectens attack on the shady portion. Increased temperatures generated by the sun cause drying of the cambial layer on the upper portions of a log and render it an unsuitable habitat for these particular beetles.

Subsequent examinations were made weekly and new attacks were marked with an X across the entrance hole with pencil. Their numbers were recorded by date. This procedure was continued until no new *S. annectens* attacks were found.

Incidence of Attack in Engelmann Spruce Beetle Entrance Holes

As the initial attacks were being recorded, it was noticed that a high percentage of them were being made in the entrance holes of the Engelmann spruce beetle. Each new entrance hole of *S. annectens* which was independent from an Engelmann spruce beetle entrance hole was recorded as a fraction of the total attacks. These data were later converted to percentages.

The accuracy of identification of *S. annectens* entrance holes was verified as galleries were opened.

Gallery Development

In order to determine the progression in size and shape, one gallery from each of the five trap trees was measured at least once a week until after August 11, when two galleries were opened on each date for each trap log. This was accomplished by peeling off the bark around entrance holes to galleries of known age. A small plastic millimeter rule was used to measure from the center of the entrance hole inside to the tip of the egg gallery. Galleries were inspected for presence of any parasites or predators.

Variations found in gallery shape were recorded photographically.

Appearance, Size, and Numbers of the Life Stages

The numbers of adults found in the opened galleries were recorded and the beetles preserved for further study. Each beetle observed depositing eggs or found among eggs was recorded tentatively as a female. If another beetle was found in that same gallery, it was tentatively labeled as a male in an egg-laying gallery. As eggs appeared, they were recorded as to number per gallery and date. As the eggs began to hatch, the larvae were recorded also as to number per gallery and date. Weekly collections of larvae were made. They were preserved in FAA.

The total lengths of all adult beetles collected in the galleries were measured from the frons to the tip of the elytra in millimeters with a Bausch & Lomb 7x measuring magnifier. Larval head capsule lengths were measured from the frons to the occiputal suture with an ocular micrometer to determine the number of instars in the feeding period covered by this study. The general appearance and external morphological characters of all the stages were observed and recorded.

Emergence of Parent Adult Beetles

Life history cages were installed on five different trap trees in the first week of August. Each consisted of a wire mesh rectangle with a conical projection at the center. Jar lids were soldered into this projection. This allowed easy removal of collection jars. These cages covered an area on the lower portion of the trap logs of about 6.5 square feet, and were attached with tacks driven closely enough together to insure a beetle-tight seal.

Weekly examinations were begun to determine when the parent adults would emerge. When emergence commenced, all beetles were collected in individual vials per trap tree and recorded by date and number. Litter samples were collected adjacent to the trap trees in late September and placed in a Berlese funnel for a period of twenty-four hours to determine if this was the overwintering medium of the parent adults.

Sex Determination

All beetles which had been tentatively identified as to sex due to their position in the gallery or to being observed in the act of depositing eggs, were examined in detail under various magnifications for an external morphological character which could be used in differentiating between the sexes. The internal genitalia were exposed by dorsal dissection to check the validity of apparent external differences.

Weather Conditions

A hygrothermograph was placed in the area on July 17. Maximum and minimum temperatures and relative humidities were recorded for each gallery opening date. Two minimum thermometers were already in the area. Minimum readings were recorded from each of these for each date of gallery inspection. An overall seasonal minimum reading was also recorded.

Associated Bark Beetles

Bark beetles found in association in the same host with *S. annectens* were identified in the field or taken into the laboratory for further observation.

Internal Parasites

Fifty live adult beetles were selected at random on different dates and dissected to determine if nematodes were present. Nematodes found, were recorded as to stage and number per beetle.

Chapter IV

Results

Attack:

Initial attacks in Engelmann spruce trap logs by *S. annectens* occurred on June 25 (Table 1). By July 7, approximately one-half of the total attacks were completed. No feasible explanation is given for the low number of initial attacks on July 7 on trap log number one. The beetles continued to enter the cambium in lesser numbers until the first week in August. Almost without exception, entrance holes were cut in the bark on the lower one-half of the trap logs, which were in a horizontal position. Total numbers of attacks ranged from 44 to 105 per trap log from the point of cut to a distance of 15 feet (Table 1).

Trap log number five was abandoned for attack observations and gallery openings after July 10, due to excessive attacks made by *Dryocetes spp.* and *Polygraphus spp.* So many entrance holes resulted that the author could no longer distinguish between *S. annectens* entrance holes and galleries and those of others. It is believed this log was of sufficient height from the ground to cause more rapid drying of the cambium than in the other trap logs.

Incidence of Attack in Engelmann Spruce Beetle Entrance Holes:

The closeness of association between *S. annectens* and the Engelmann spruce beetle is exemplified by the large percentage of adult *S. annectens* which attack in spruce beetle frass-packed entrance holes

TABLE I

Numbers of *Scierus annectens* Lec. attacking Engelmann spruce trap trees, Rand, Colorado, 1958.

Date	Number of Attacks			
	Trap Tree #1	2	3	4
June 25	*Scierus annectens* attacks first discovered			
July 7	8	68	42	55
July 10	11	10	20	6
July 16	6	8	8	11
July 23	11	12	9	6
July 29	8	4	5	1
Aug. 5	0	3	1	1
Aug. 11	0	0	1	0
Aug. 18	0	0	0	0
Totals	44	105	86	80

(Figure 1). Of 322 S. annectens attacks recorded, 86.6% were cut in such entrance holes (Table II).

Gallery Development:

Brood gallery and it's parts - S. annectens began cutting the brood or egg gallery as soon as the cambium was reached. Later sexual determination of some of these beetles indicated they were females. The average length of the galleries at the end of the first week after attack, was 7.2 millimeters (Table III).

A short lateral gallery was cut in almost every instance close to the entrance hole and at approximately a 45 to 90 degree angle to the brood gallery (Figure 5). The lateral gallery was only slightly longer than an adult S. annectens. Many beetles were observed backing into this lateral gallery and turning around. Escape was then accomplished without backing out of the entrance hole.

The length of the brood gallery was gradually increased as eggs were deposited in niches on both sides (Figure 5). Brood gallery construction ceased as the last eggs were deposited. The beetles later resumed engraving at a reduced rate beyond the point of the last egg deposition (Figure 2). This portion of the gallery is hence considered to be the feeding extension. Maximum length of the main gallery was attained during the week of August 25 (Table III). The maximum length recorded of an individual S. annectens gallery was 42 millimeters.

Figure 2 illustrates the typical shape of S. annectens galleries. The scale shown in these pictures is divided into millimeters. Note the lateral gallery near the entrance hole and the feeding gallery extending beyond the point of last egg deposition. Figures 3 and 4

TABLE II

Incidence of *Scierus annectens* Lec. attack in Engelmann spruce beetle entrance holes, Rand, Colorado, 1958.

Date	No. Attacks Independent of ESB: Entrance Holes					No. Attacks in ESB: Entrance Holes					Total No. Attacks				
Trap Tree	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
July 7	-	3	5	6	3	-	65	37	49	2	-	68	42	55	5
July 10	0	1	4	0	3	11	9	16	6	7	11	10	20	6	10
July 16	1	2	2	2	-	5	6	6	9	-	6	8	8	11	-
July 23	4	3	0	1	-	7	9	9	5	-	11	12	9	6	-
July 29	1	0	1	0	-	7	4	4	1	-	8	4	5	1	-
Aug. 5	0	0	0	1	-	o	3	1	1	-	0	3	1	1	-
Aug. 11	0	0	0	0	-	0	0	1	0	-	0	0	1	0	-
Aug. 18	0	0	0	0	-	0	0	0	0	-	0	0	0	0	-
Totals					43					279					322
Percent					13.4					86.6					

TABLE III

Scierus annectens Lec. Gallery length measurements,
Rand, Colorado, 1958.

Date	Trap Tree No. 1	2	3	4	5	Average Gallery Length
	Gallery Lengths in Millimeters					
July 2	6	6	9	6	9	7.2
July 7	5	9	10	8	10	8.4
July 10	10	12	12	10	14	11.6
July 16	20	24	15	19	14	18.4
July 23	27	5	14	20	-	19.0
July 29	27	21	22	24	-	23.5
Aug. 5	4	18	35	37	-	23.5
Aug. 11	3	34	A	28	-	21.7
	32	A	3	A	-	17.5
Aug. 19	29	28	23	20	-	25.0
	A	33	13	34	-	26.7
Aug. 25	21	42*	36	33	-	33.0
	32	38	28	31	-	32.3
Sept. 4	A	34	32	23	-	29.7
	A	23	28	29	-	26.7
Sept. 11	35	15	33	23	-	26.5
	A	33	26	20	-	26.3

A Beetles had abandoned gallery.
* Longest gallery recorded.

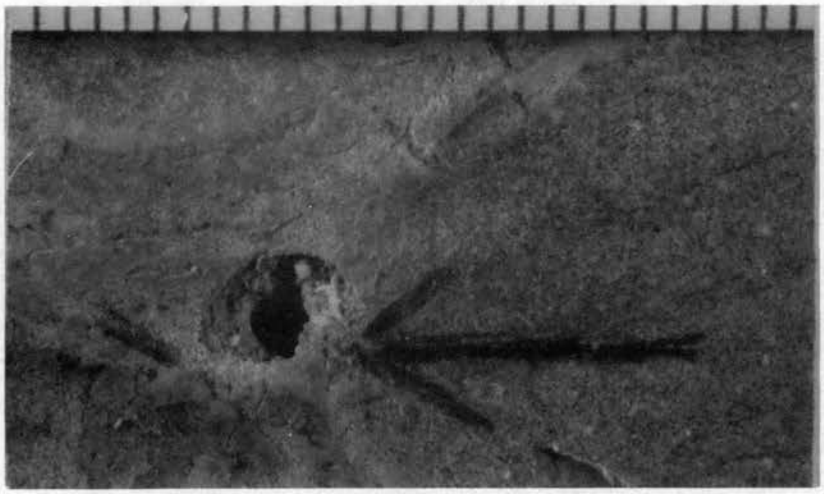

Figure 1. Scierus annectens Lec. entrance hole in spruce bark.

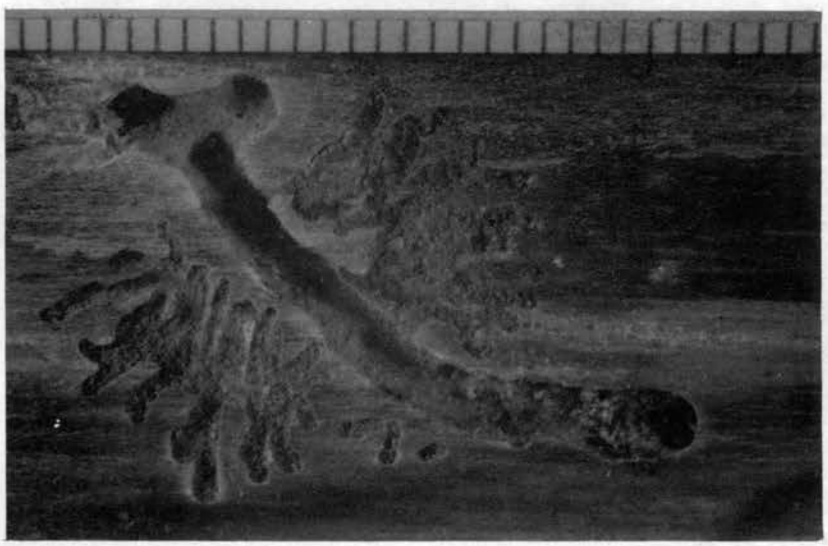

Figure 2. Typical Scierus annectens Lec. gallery.

Figure 3. Scierus annectens (Lec.) gallery.

Figure 4. Scierus annectens (Lec.) gallery.

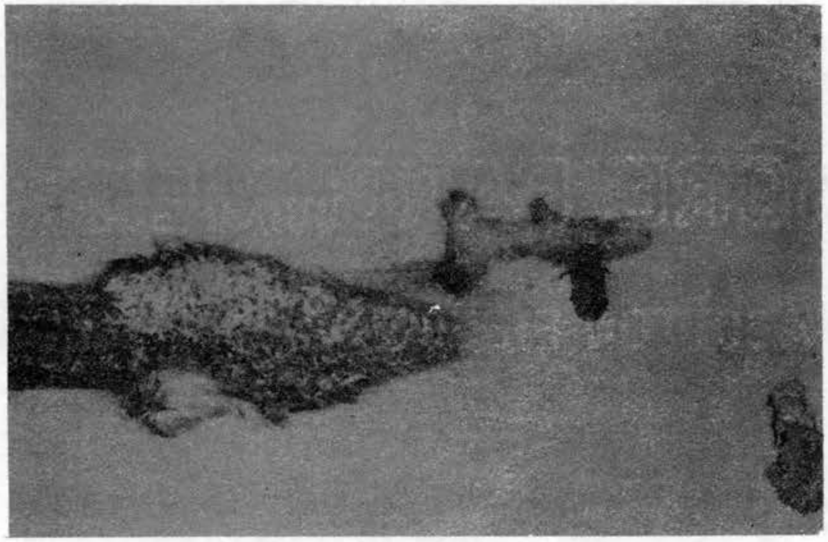

Figure 5. An adult Scierus annectens Lec.
and newly cut gallery.

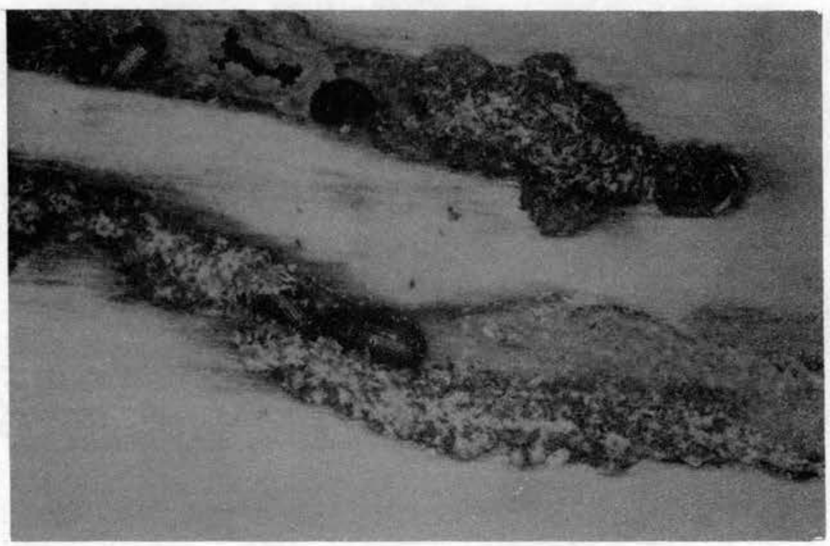

Figure 6. Adults, galleries, and eggs of
the Engelmann spruce beetle,
Dendroctonus engelmanni Hopk.

illustrate extreme variations in shape noted in S. annectens galleries. Note that in Figure 4 no lateral gallery was cut. Figure 5 shows an adult S. annectens at it's newly constructed gallery. Note that the first egg has been deposited and packed tightly in place with frass; also observe that this gallery has been cut in the opposite direction to that of the frass packed Engelmann spruce beetle gallery also shown in the picture. This pattern was followed by most S. annectens.

The brood gallery of S. annectens is typically cut parallel or at a 45 to 90 degree angle to the grain of the wood (Figures 2 and 5). However, some atypical galleries meander and have no particular pattern with respect to the grain of the wood. The brood gallery is kept clean of frass and excreta. The beetle engraves the inner bark and cuts into the cambium layer. Little engraving occurs on the wood or secondary xylem.

Larval galleries - Egg niches are cut exclusively in the inner bark. The cambium layer therefore is not damaged by them. This is shown clearly in Figure 2. Note the non-engraved space between the brood gallery and the larval mines. The larvae at first feed on inner bark but later begin to feed in the cambium. Larval galleries in contrast to brood galleries contain loose frass and larval excreta. The larvae burrow at approximate right angles to the brood gallery and often cross one another (Figures 2, 3, and 4).

The only other arthropods found in S. annectens galleries were mites and Collembola. Their numbers were very small. Another scolytid, also found in the gallery will be reported in the associated bark beetles section.

Appearance, Size, and Numbers of the Various Life Stages

Adults - Adult S. annectens were first found on June 25, as they commenced attack of spruce logs. Observations indicated that two beetles were often found in the gallery prior to, and during the egg laying period. These were assumed to be male and female. After egg laying was well initiated, only one beetle was observed in most galleries.

Of 50 adult beetles measured, the total length ranged from 2.8 to 4.0 millimeters. Average length of the 50 beetles was 3.6 millimeters (Table IV).

Eggs - The first eggs were found July 7. Most egg deposition took place from July 10 to 16 (Table V). The incubation period varies from three to four weeks (Tables V and VI). The shortest incubation would be indicated by the interval between the time of the first appearance of eggs (July 7, Table V), to the time when larvae first were noted (July 29, Table VI).

The eggs are small, from 1.0 to 1.5 millimeters in length, ovate, smooth, and white in color. The largest number of eggs recorded from one gallery was 32. Average numbers of eggs found in galleries after most oviposition had occurred ranged from 10 to 16.

Larvae - The first larvae were found July 29, with peak numbers being reached by August 25 (Table VI). Length of larvae collected October 9, latest date covered by this study, averaged 2.4 millimeters. They are soft, white and opaque, and they very much resemble the larvae of other scolytids. Average numbers of larvae after most eggs had hatched ranged from 8 to 19 per gallery (Table VI). Note that after August 11, two galleries were opened on each date for each trap log.

TABLE IV

Length of adult Scierus annectens Lec., Rand, Colorado, 1958.

Date	No. Beetles	Milimeters		
		Maximum	Minimum	Mean
July 7	5	3.9	3.1	3.5
July 10	7	3.8	3.1	3.5
July 16	5	3.6	3.0	3.5
July 23	6	3.8	3.0	3.5
July 29	6	4.0*	3.5	3.7
Aug. 5	8	4.0	3.6	3.8
Aug. 11	5	3.8	2.8**	3.4
Aug. 19	7	3.8	3.5	3.6
Total & Average	50			3.6

* Maximum length recorded of an adult S. annectens.
**Minimum length recorded of an adult S. annectens.

TABLE V

Numbers of eggs in galleries of
Scierus annectens Lec., Rand, Colorado, 1958.

Date	Numbers of Eggs Per Gallery					Average Number
	Trap Tree No. 1	2	3	4	5	Eggs Per Gallery
July 2	0	0	0	0	0	0.0
July 7	0	0	0	0	2	.4
July 10	0	0	3	0	2	1.0
July 16	8	22	15	12	15	14.4
July 23	17	A	9	4	-	10.0
July 29	7	10	17	16	-	12.5
Aug. 5	32	4	13	14	-	15.8
Aug. 11	A	8	A	2	-	5.0
	8	A	A	A	-	8.0
Aug. 19	7	0	0	0	-	1.8
	A	0	0	0	-	0.0
Aug. 25	0	0	0	0	-	0.0
	0	0	0	0	-	0.0
Sept. 4	0	0	0	0	-	0.0
	0	A	0	0	-	0.0
Sept. 11	0	0	0	0	-	0.0

A Gallery was abandoned.

TABLE VI

Numbers of <u>Scierus</u> <u>annectens</u> Lec. larvae in galleries in Engelmann spruce, Rand, Colorado, 1958.

Date	Numbers of Larvae per Gallery					Average Number
	Trap Tree No. 1	2	3	4	5	Per Gallery
July 2	0	0	0	0	0	0
July 7	0	0	0	0	0	0
July 10	0	0	0	0	0	0
July 16	0	0	0	0	0	0
July 23	0	0	0	0	0	0
July 29	0	3	0	0		.8
Aug. 5	0	0	0	0	0	0
Aug. 11	A	13	A	23		18.0
	0	A	A	A		0
Aug. 19	11	24	17	2		13.5
	A	14	16	17		15.7
Aug. 25	12	15	20	28		18.8
	15	20	25	17		19.3
Sept. 4	0	23	13	29*	Abandoned	16.3
	0	A	28	5		11.0
Sept. 11	20	14	13	4		12.8
	0	17	20	16		13.3
Oct. 9	10	15	20	10		13.8

A Beetles had abandoned gallery.
* Maximum number larvae found in a gallery.

After August 25, average numbers of larvae decreased due to undetermined mortality factors. (Table VI).

Larval head capsule length measurements indicate that there are four distinct instars from July through October 9 (Table VII). Lengths of the head capsules of first instar larvae range from .204 to .272 millimeters. Essentially, this instar covers a period from July 29 to August 19. A small number, however, are found as late as October 9. Second instar larvae measure .306 to .374 millimeters. They are found in the most part from August 19 through September 11. Some of these are also found as late as October 9. Third and fourth instar larvae range .408 to .476 and .510 to .578 respectively. There is considerable overlapping of the second, third, and fourth instars. The third instar larvae appear first about August 27. Many of these overwinter in this instar. Small numbers of fourth instar larvae appear late in September.

Pupae - The pupal stage did not occur during the period covered by this study. The trap logs were under snow by October 9, and the author assumes that no further development could occur beyond this date.

Emergence of Parent Adult Beetles

Parent adult *S. annectens* began emerging on August 29, and continued until October 3, (Table VIII). Maximum number emerging from an area of 6.5 square feet, in any one week interval, was 21. No parent adults were found in litter adjacent to trap logs during this period. The overwintering habitat or fate of these beetles is not known.

Sex Determination

External - Detailed observations of the external morphological characters of adult *S. annectens* collected at different intervals during

TABLE VII

Larval head capsule length measurements of four instars *Scierus annectens* Lec., Rand, Colorado, 1958.

Instar	Date First Found	Millimeters Minimum	Millimeters Maximum	Millimeters Mean
1	July 29	.204	.272	.237
2	August 19	.306	.374	.354
3	August 27	.408	.476	.441
4	Late Sept.	.510	.578	.527

TABLE VIII

Numbers of parent adult *Scierus annectens* Lec.
emerging from Engelmann spruce trap trees,
Rand, Colorado, 1958.

Date	Numbers of Parent Adults Emerging Trap Tree Cage No. 1	2	3	4	5
Aug. 15	0	0	0	0	0
Aug. 22	0	0	0	0	0
Aug. 29	0	0	1	1	1
Sept. 5	0	0	0	1	1
Sept. 12	0	1	4	6	0
Sept. 19	1	4	14	8	8
Sept. 25	1	4	0	5	0
Oct. 3	0	21	7	12	1
Oct. 9	0	0	0	0	0

the course of this study failed to provide a satisfactory external sex differentiation character. None of the external morphological characters which appeared to provide a means of separating the sexes were found to be significant when checked by dissection. Size, color, or shape of external parts was not indicative of sex.

Internal - The sex of a number of beetles was determined by dorsal abdominal dissection. The presence or absence of the posterior chitinized section of the male organs (Hopkins 1915) was used to determine the sex. In male S. annectens this heavily chitinized organ lies in the posterior tip of the abdomen, just to the right of the median line (observing the beetle dorsally). It's length is approximately one-fourth that of the abdomen. It is not readily visible to the naked eye, but can be found with a hand lens with ten power magnification. Females were identified by the process of elimination (absence of posterior chitinized male organ). This procedure was verified by the presence of nearly mature eggs found in females which had been observed ovipositing.

Weather Conditions

As shown on minimum temperature thermometer readings (Table X), only two frost free weeks, August 1 to 15, were recorded during the course of this study. Readings May 2, showed a low of -11 degrees F. for the early portion of 1958. By November 19, 1958, temperatures were back down to -9 degrees F. Due to insufficient data, a complete picture of maximum temperatures and relative humidities throughout the course of this study was not obtained. The author recorded maximum readings only for dates of gallery openings and collections. These data are presented in Table XI. Highs for these dates varied from 54 degrees F. to 70 degrees F. Relative humidities ranged from a low of

12% to a high of 100%. The weather station at nearby Walden, Colorado recorded average temperatures from the January low of 11.4 degrees F. to the high in August of 58.1 degrees F. A high of 87 degrees F. and a low of -26 degrees F. were recorded for 1958.

Associated Bark Beetles

Other genera of scolytids were found in the same host. Of these, the Engelmann spruce beetle was the closest and most common associate. The following additional beetles were found: *Polygraphus rufipennis* (Figure 7), *Dryocetes* spp. (Figure 8), and *Ips* spp. A beetle found in *S. annectens* galleries has been tentatively identified as *Xylechinus americanus* Blackman. If this identification is correct, it is believed to be a new record for Colorado.

Internal Parasites

Twenty percent of 50 live adult *S. annectens* dissected, were infested with immature nematodes. The species is not known. An average of two immature nematodes per infested beetle was found in the body cavity (Table IX).

TABLE IX

Presence of immature nematodes in live adult *Scierus annectens* Lec., Rand, Colorado, September 10, 1958

Beetle Number	Number Immatures Found
1-2*	
3	2
4	2
5	1
6-8*	
9	3
10	2
11-18*	
19	5
20	1
21	2
22-34*	
35	2
36	3
37-50*	
Totals 50	23
Total number of beetles infested	10

* Nematodes not found in these beetles.

TABLE X

Minimum temperature thermometer readings (degrees F.)
Rand, Colorado, May 2 - Nov. 19, 1958.

Date		Degrees F. Thermometer Number 1	Degrees F. Thermometer Number 2
May	2	-11	-
June	18	+14	+15
July	23	+26	+25.5
Aug.	1	+29	+27
Aug.	8	+32.5	+33
Aug.	15	+35	+36
Aug.	22	+31	+32
Aug.	29	+30	+28.5
Sept.	5	+28	+28.5
Sept.	12	+26.5	+28
Sept.	19	+17	+16
Sept.	25	+15	+12
Oct.	3	+17	+16
Oct.	9	+22	+21
Oct.	15	+17	+17
Oct.	23	+ 5	+ 9
Nov.	19	- 9	- 7

TABLE XI

Hygrothermograph readings for selected dates, Rand, Colorado, July 23 - Sept. 11, 1958

Date	Degrees F. Temperature High	Degrees F. Temperature Low	Percent Relative Humidity High	Percent Relative Humidity Low
July 23	66	48	58	34
July 29	70	45	64	12
Aug. 5	68	46	66	14
Aug. 11	68	46	64	18
Aug. 19	54	44	100	62
Aug. 25	58	36	98	40
Sept. 4	57	41	74	38
Sept. 11	68	46	78	32

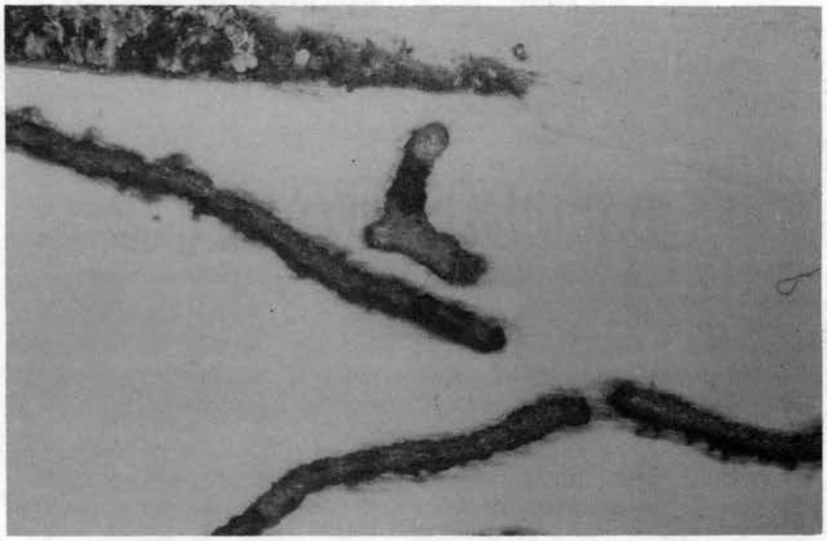

Figure 7. Scierus and Polygraphus galleries.

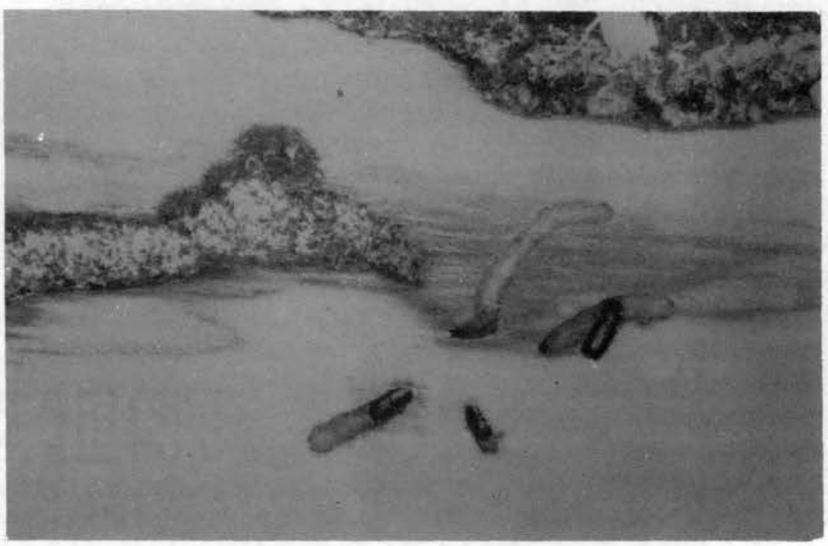

Figure 8. Dryocetes and their newly cut galleries.

Chapter V

Discussion

Attack of spruce logs by S. annectens is closely correlated with attack by the Engelmann spruce beetle of the same host. Engelmann spruce beetles were observed attacking the trap logs a few days in advance of S. annectens. The attack period, as established by this study, ranges from June 25 to August 1. This period would vary from year to year due to seasonal variations in temperature. The Engelmann spruce beetle attacked as early as June 26 in 1946 on the White River National Forest, Colorado due to an early spring. In 1944-45, however, first attacks did not occur until July 4 and July 10, respectively. Spring was late in both instances.

It is considered highly important by this author that 86.6% of S. annectens entrance holes recorded in this study were made in the same holes previously cut and tightly packed with frass by Engelmann spruce beetles. This would indicate that S. annectens populations might be in proportion to populations of Engelmann spruce beetles. Massey and Wygant (1954) stated:

> Scierus annectens Lec. seems to congregate around the entrance holes of D. engelmanni, it's galleries running laterally for a short distance from this point, then turning in a general upward direction. The galleries occur in the phloem. This species is not known to be aggressive in nature.

As in many of the bark beetles, S. annectens has such a distinctly shaped gallery (Figure 2), that the species could be identified by it alone. S. annectens does not pack boring dust and pitch in its entrance hole and lower egg gallery as does the Engelmann spruce beetle. Engelmann spruce beetle galleries have a characteristic crook at the base, whereas, S. annectens constructs a short lateral back-up gallery at the base. The Engelmann spruce beetle also constructs these short galleries at intervals on either side of the egg gallery. These are about the length of the beetle's body and are used by them as avenues for turning around. Maximum and mean lengths of Engelmann spruce beetle galleries are 216 and 120 millimeters (nine and five inches) respectively (Massey & Wygant 1954). Maximum and mean measurements of S. annectens galleries in comparison are 42 millimeters and 25-33 millimeters respectively.

Total numbers of eggs of S. annectens are low as compared with those of the Engelmann spruce beetle. A total of 144 in a 6.1 inch gallery has been recorded for the latter. The maximum number of eggs deposited by S. annectens in this study was 32. However, in comparing lengths of the galleries of the two species, S. annectens deposits about the same number of eggs per lineal inch of brood gallery as does the Engelmann spruce beetle.

S. annectens eggs resemble those of the Engelmann spruce beetle except for being smaller.

Average lengths of larval head capsules, plotted on log paper according to Dyer's law, showed four distinct instars occurred between late July and early October.

Rate of development of S. annectens larvae, like that of the Engelmann spruce beetle, is dependent upon exposure of the log to the sun and date of attack. The random directions of the trap logs used for this study seem to account for all four instars of S. annectens larvae being found as late as October 9. First and second instar larvae found on this date were probably offspring of beetles which attacked late (as late as August 1), and on the north side of the logs. Because southern exposures are warmer than northern exposures, larvae infesting the south sides of trap logs will develop more rapidly. Most of the larvae found on October 9, were in the third instar. These were probably broods of beetles which attacked the logs early and were on the lower side where exposure remained constant. The small numbers of fourth instar larvae found on October 9, were probably offspring of beetles which attacked early and on the southern exposure of the trap logs.

The fact that no S. annectens larvae or pupae were found in June and early July on Engelmann spruce felled in previous years, supports the author's belief that the beetle has a one year life cycle. These two stages are normally found in these months in beetles having a two year life cycle. However, the fact that some larvae go through the winter in the first and second instars supports those advocating a two year life cycle for S. annectens. The complete story will not be known until these beetles are reared in the laboratory so that development during the period when the host is normally still under deep snow can be studied. Those larvae going through the first winter in the third and fourth instar might pupate early the following spring, then emerge as new adults to begin the cycle over again after one year. Those larvae overwintering in the first and second instar might continue to develop the following growing season and pupate in the fall. If this were true, the beetle might conceivably have both one year and two year life cycles.

Many external morphological characters were studied in detail. The fine, indistinct, median, longitudinal carina on the antennal scrobes of males (Swaine 1924) was not seen by this author. No external characters of sufficient significance were found which would differentiate the sexes. Dorsal abdominal dissection of the beetles will yield sex differentiation. Male S. annectens have a rather large posterior chitinized organ (already described in results) which will distinctly differentiate it from the female. The genitalia of females was not studied intensively by this author.

Although no predators of S. annectens were observed, it is believed that the same woodpeckers which feed upon Engelmann spruce beetle larvae feed upon them also.

The significance of infestation of S. annectens with nematodes is not known. Massey (1956) established the fact that most species of nematodes infesting the body cavity of the Engelmann spruce beetle sharply reduced egg production in females, but do not kill their host. The assumption can then be made that the nematodes infesting the body cavity of S. annectens might conceivably cause the same reduction in females of that species. However, the fact that only 20% of live adult S. annectens checked were infested with nematodes, would indicate that egg production of whole populations of S. annectens would probably not be too much reduced.

Chapter VI

Summary

This study was undertaken in order to gain information on the biology of a small secondary bark beetle, S. annectens Lec. This species is probably the bark beetle most closely associated with the Engelmann spruce beetle in northern Colorado. This is emphasized by the large percentage of S. annectens which attack in the same entrance holes previously cut and packed tightly with frass by Engelmann spruce beetles.

S. annectens attacks weakened or dead Engelmann and other spruces throughout their natural range in North America. In Colorado, this attack occurs during late June and early July. The female cuts the initial gallery, later to be joined and mated by the male. Eggs appear early in July and require from two to four weeks incubation. Larvae begin to appear late in July. Four instars occur from this time to October when the host is covered with snow. Parent adults emerge from late August to early October. Their fate is not known. Although data could not be taken in deep snow, it is believed that S. annectens overwinters in the larval stage (mostly third instar), pupate early the following spring, pass through a short callow adult stage, then emerge to attack the host in late June and early July. This reasoning is supported by non-observance of any of the life stages, except adults,

in June and July on weakened or dead trees and logs of previous Engelmann spruce beetle infestation. Larvae or pupae of species with two year life cycles are normally found on those dates.

External sex differentiation of *S. annectens* was not accomplished. The sexes were determined by dorsal dissection of the abdomen.

A Selected Bibliography

Blatchley, W. S. and C. W. Leng. 1916. Rhynchophora or weevils of northeastern America. Nature Pub. Co: 665.

Bradley, J. C. 1930. A manual of the genera of beetles. Daw, Illston, and Co. Ithaca, N. Y.: 299.

Chamberlin, W. J., E. C. Van Dyke, and R. W. Doane. 1936. Forest insects. McGraw-Hill Book Co., Inc. New York & London: 112.

Chamberlin, W. J. 1939. The bark and timber beetles of North America north of Mexico. O. S. C. Cooperative Assoc. Corvallis, Oregon: 190.

Hopkins, A. D. 1894. Sexual characteristics of the Scolytidae. Can. Ent. 26: 274.

Hopkins, A. D. 1915. Classification and sex structures of Scolytidae. U. S. Dept. Agric. Ent. Techn. Ser. 17: 165-232.

Keen, F. P. 1952. Insect enemies of western forests. U. S. Dept. Agric. Pub. 273: 166.

LeConte, J. L. 1869. Synopsis of Scolytidae of North America north of Mexico. Trans. Amer. Ent. Soc. 2: 150-178.

LeConte, J. L. 1876. Scierus n.g. in The Rhynchophora of North America north of Mexico. Proc. Amer. Phil. Soc. 15: 390.

Massey, C. L. and N. D. Wygant. 1954. Biology and control of the Engelmann spruce beetle in Colorado. U. S. Dept. Agric. Cir. 944: 1-35.

Massey, C. L. 1956. Nematode parasites and associates of the Engelmann spruce beetle (Dendroctonus engelmanni Hopk.). Proc. Helminth. Soc. Wash. 23(1): 15-24.

Swaine, J. M. 1918. Canadian bark beetles. Dom. Can. Dept. Agric. Ent. Br. 14(2): 43-73.

Swaine, J. M. 1924. The species of Scierus. Can. Ent. 56: 287-288.

Swaine, J. M. 1929. The biology of Canadian bark beetles. Can. Ent. 61: 145-151.

Zimmerman, C. 1869. Synopsis of Scolytidae of North America north of Mexico. Trans. Amer. Ent. Soc. 2: 141-149.

VITA

Kenneth Wilson Stewart

Candidate for the Degree of

Master of Science

Thesis: The Biology of *Scierus annectens* Lec. (Coleoptera, Scolytidae).

Major Field: Entomology

Biographical:

Personal Data: Born in Walters, Oklahoma, March 5, 1935, the son of Nathan Anderson and Dorothy Vinita Stewart.

Education: Graduated in 1953 from Hugoton Rural High School, Hugoton, Kansas; received the Bachelor of Science degree from Oklahoma State University with a major in Forestry in May, 1958; completed the requirements for the Master of Science degree in May, 1959.

Experiences: U. S. Soil Conservation Service, Hugoton, Kansas summer 1955. U. S. Forest Service, Rocky Mountain Forest and Range Experiment Station (Research Aid) in Range Management Research, summer of 1956. Forestry Summer Camp, Perkinston, Mississippi summer of 1957. U. S. Forest Service, Rocky Mountain Forest and Range Experiment Station (Research Aid) in Forest Entomology Research, from June 16 to December 12, 1958.

Organizations: Phi Sigma, O. S. U. Forestry Club, Sanborn Entomology Club.