RED PINE BORER BIOLOGY AS INFERRED FROM TRAP LOG DATA

By

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ABSTRACT

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A red pine (*Pinus resinosa* Ait.), trap log study was carried on in 1960-61 in Kellogg Forest, Kalamazoo County, Michigan. The purpose of this study was to obtain information on the insect species complex, population levels, and extent of injury. The logs were cut at monthly intervals, exposed to attack by insects for 30 day-periods, and then covered with wire screens. In this way, it was possible to obtain information concerning the time these insects are most likely to attack.

Among the attacking Cerambycids, three species were identified. These were *Monochamus titillator* (Fab.), *M. scutellatus* (Say), and *A. sexguttata* (Say).

Monochamus titillator was the most abundant species. The highest infestation was in logs freshly cut in July. No infestation was found in logs freshly cut in May and September. In general the degree of infestation diminished as the length of seasoning time increased.

There appeared to be strong evidence that newly hatched larvae of *Monochamus* species made sapwood surface excavations in August which were twice the size (in volume) of those excavated in June and July. Whether this was due to the relatively low precipitation in August, or to seasonal differences in suitability and palatability of the food cannot be ascertained from this study. Such differences may have

significance in terms of economic loss or the need of control, or a selection of control method.

The second group of insects found in considerable quantity was two species of *Pissodes*, namely *P. approximatus* (Hopkins) and *P. affinis* (Randal).

Pissodes spp. attacked logs almost uniformly in every month from May to August. *P. approximatus* under some conditions attacked standing apparently healthy trees. Either they preferred logs freshly cut, and logs seasoned for one month or there was a mass flight in June in a search for suitable breeding material.

ACKNOWLEDGMENTS

The author expresses his deep appreciation to Dr. James W. Butcher for his guidance in the preparation of this thesis as well as for making financial arrangements in support of this study. His continuous interest influenced and encouraged the writer to complete this investigation.

Grateful acknowledgment is extended to Professor Ray Hutson, Chairman of the Department of Entomology for making this study possible and to Dr. Philip Clark for his suggestions on statistical treatment of the data. The writer is also indebted to Dr. W. H. Anderson and Miss R. E. Warner of the Agricultural Research Division, Beltsville, Maryland, for making positive identification of insect specimens collected in this study. Grateful acknowledgment is also extended to Mr. Walter A. Lemmien, Forester in charge of Kellogg Forest for assistance and for furnishing meteorological data used in this study. Dr. Gordon Guyer and Mr. Arthur Wells also gave helpful advice in presenting the results of this study.

Thanks are also extended to Dr. Walter F. Morofsky, Director of Kellogg Biological Station, Dr. Victor Rudolph, Department of Forestry and Dr. Louis F. Twardzik, Department of Resource Development, for serving on the writer's guidance committee and offering helpful criticisms of the thesis.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Craighead (1923), Gardiner (1950), Parmelee (1941), and Swaine and Craighead (1924) have reported on the biology and taxonomy of economically important species of Cerambycidae. Belyea _et_ _al_. (1952), Richmond (1925), and Thothill (1923) have published on damage caused by these pests. Finnegan (1958) has studied the biology of the pine weevil in Ontario. Blair (1953), Becker _et_ _al_. (1956), Simpson (1951), Morley (1939), and Morofsky (1952) have reported on control measures against red pine borers attacking coniferous trees.

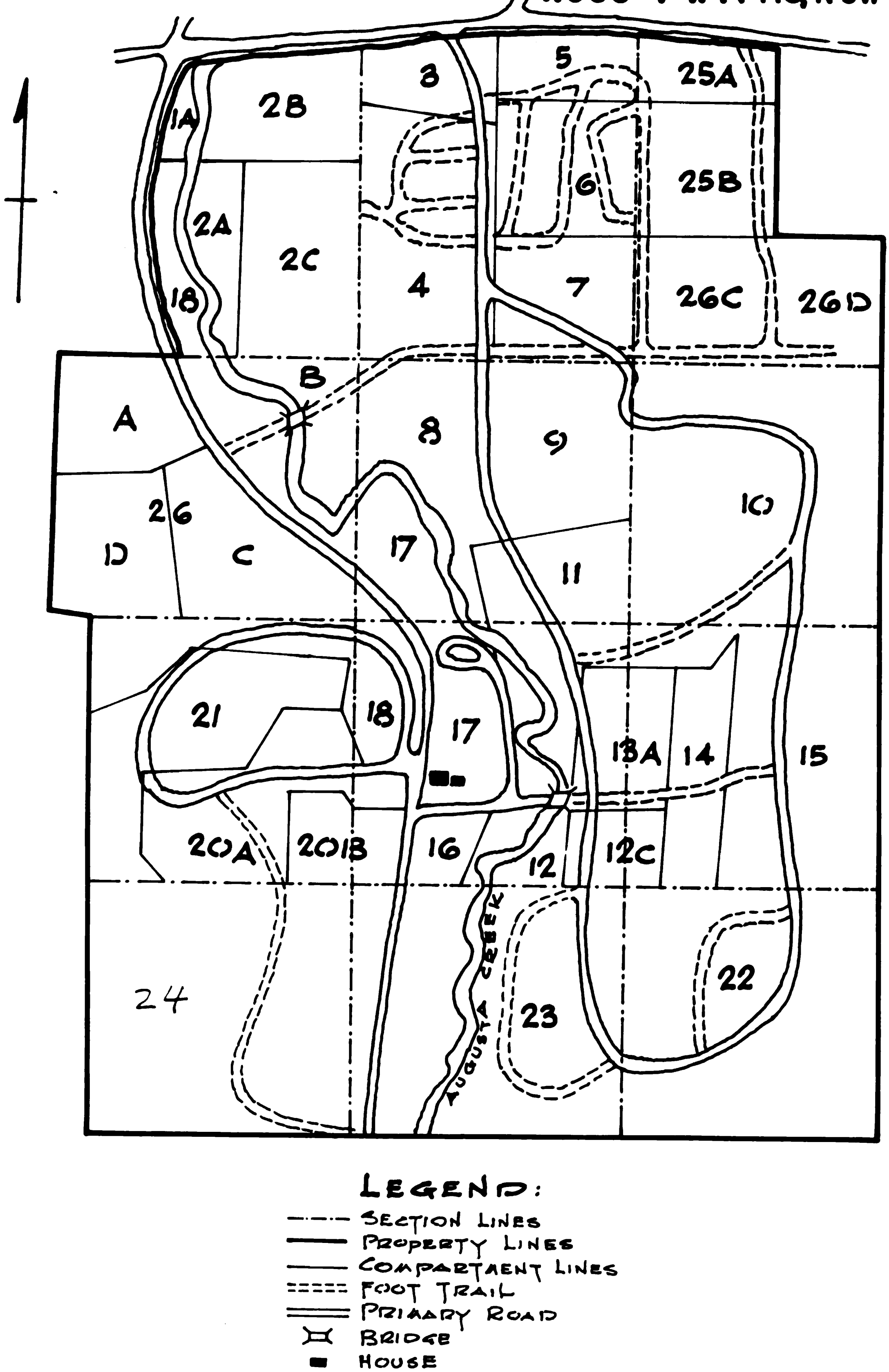
In 1959, the Forestry Department of Michigan State University became concerned about red pine (_Pinus_ _resinosa_ Ait.) mortality in the Kellogg Forest, Kalamazoo County, which is managed by the University as a field laboratory. Because wood boring insects were associated with the dying trees, there was considerable interest in studies that might show what the principal insects were, and if possible, something about their life history and biology. In the spring of 1960, studies were undertaken designed to supply some of the needed information.

The stand selected for the investigations consisted of 6 acres, planted in the fall of 1932. The seedlings were planted in a 6 x 6-foot spacing, for a total of 1,210 trees per acre. The topography of the planting site ranged from gently rolling to hilly, with slopes of 5 to 25 percent. The soil consisted of white Oshtemo loamy sand, except for hills where Coloma loamy sand occurred. The top soil and a considerable amount of subsoil had eroded over most of the area under study (Figure 1, Compartment 6B).

Figure 1.

MAP OF KELLOGG FOREST

SCALE–1"= 800' ROSS TWP. T1S, R9W



The stand had shaded out the ground cover by 1942, and branches in the lower 3 feet of the crown were dying. As a result, by the fall of 1946 all branches on the lower half of the trees were dead. This stand had reached a basal area of 110 to 116 square feet, and was beginning to show the effects of competition. In the winter of 1946 - 47, the stand was thinned and pruned. Approximately 2 cords of pulpwood per acre were removed. In the thinning and pruning process, the slash was lopped and scattered. In 1948, abnormal reactions were noted in certain trees, some of which were dead or dying, and heavily infested with bark beetles and wood borers. One- and two-year old slash in the area was infested with bark beetles and wood borers. In the fall of 1954, the stand was thinned again by removing 4.8 cords of pulpwood per acre. The slash was scattered throughout the area or left where felled. Concern over developing wood borer attacks suggested the trap-log investigation reported here.

PROCEDURE

In view of the time and man power available for these studies, a trap-log approach was selected. By cutting at monthly intervals during the growing season, a replicated supply of fresh, unseasoned logs was available for attack from May through September. By caging freshly cut logs before attack took place, and then exposing replicated logs 1, 2, and 3 months later, the possible effects of seasoning upon insect attack, could conceivably be evaluated. A description of the cutting and caging procedure follows:

A cut of experimental logs was made each month from apparently uninjured trees in the study area. The first cut was made on May 20, 1960. At that time, five 12-foot long logs were cut to a 4-inch top. They were then sawed into 3-foot sections, which were grouped at random into five 4-log replicates. Logs of each replicate were marked as follows:

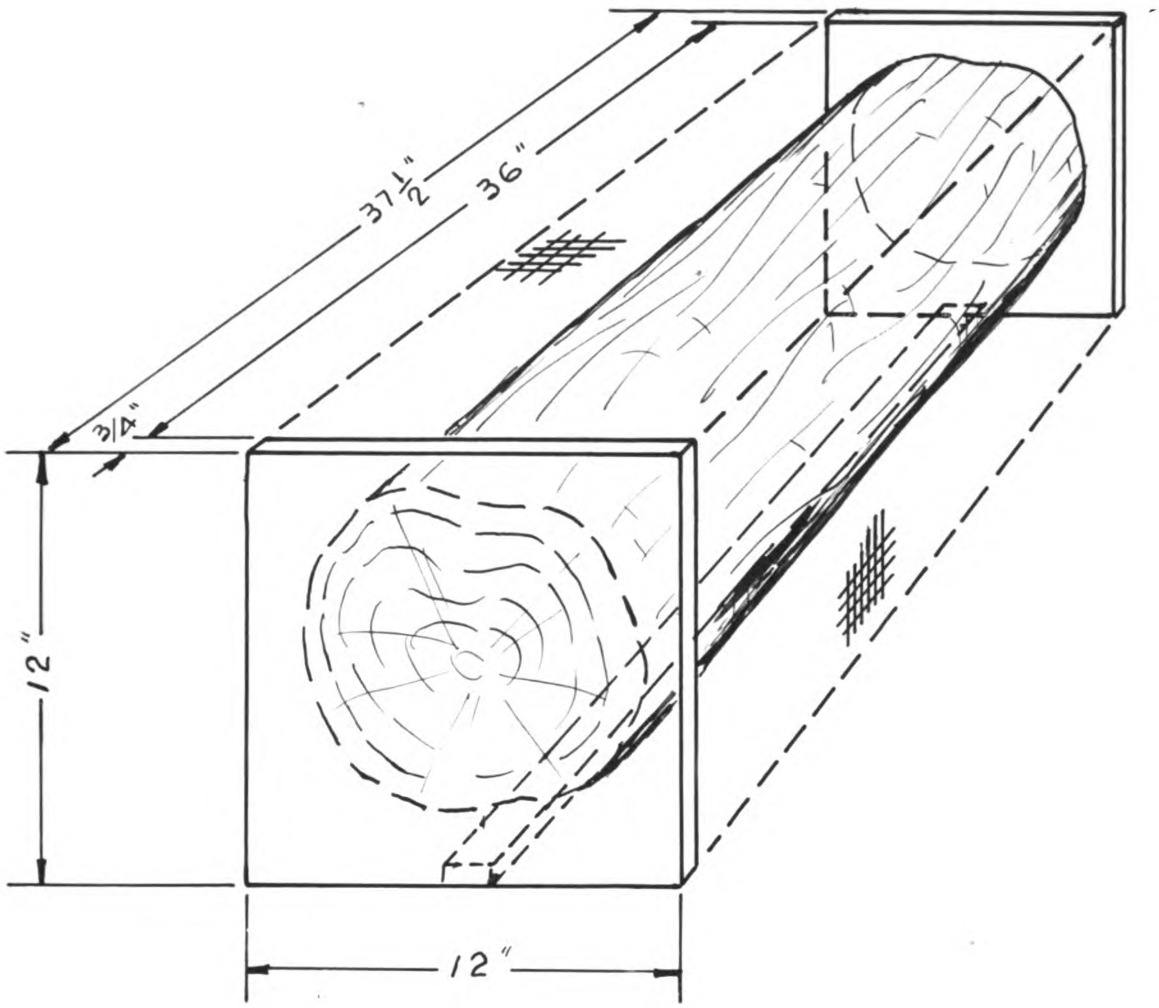
"A" (4 logs); "B" (4 logs); "C" (4 logs); "D" (4 logs)
and Check no. 1 (4 logs).

Logs in replicates "A" and Check no. 1 were left open, while all others were put in separate 32-mesh wire screen cages.

Construction of Log Enclosures

A 1 x 12 x 12-inch board was fastened to each end of a 3-foot log with two-inch common nails, in such fashion that the log appeared in the center of each board. The board was connected with a 1/2 x 2-inch strap-board the same length as the log (see Figure 2).

Figure 2. Plan showing construction of log enclosures.



A copper window screen (32 mesh) 3 feet wide was attached to the strap, wrapped around and fastened at the end by stapling it to the edges of the 1 x 12 x 12-inch end boards. The screen was overlapped and stapled to the 3-foot long strap board. Each enclosure required a 50-inch long, 36 inch wide screen, or a total of 1,800 square inches. Inasmuch as the logs had an 8-inch maximum diameter, this gave a clearance of several inches between the log and screen. All logs, open or caged, were laid flat, 4 feet apart, among the standing trees. The logs rested on the cage ends and thus did not contact the ground directly (see Figure 3). All logs, with the exception of checks, were about 3 inches above the ground.

On June 22, 1960, four additional replicates of 4 logs each were prepared from four 12-foot freshly cut logs. The replicates were marked as follows:

"E" (4 logs); "F" (4 logs); "G" (4 logs) and Check no. 2.

Replicates "E" and Check no. 2 were left open, while the logs in replicates "F" and "G" were enclosed in cages. At this time, the logs in replicate "A" were enclosed and logs in replicate "B" from the first cut were uncaged.

The third cut was prepared on July 22, 1960. Four 3-foot logs were cut from 3 freshly felled 12-foot logs, and designated as replicates "H" (4 logs); "I" (4 logs) and Check no. 3 (4 logs). Only logs in replicate "I" of this cut were caged. Uncaged logs in replicates "B" (second cut) and "E" (third cut) were caged, and logs in "G" (second cut) and "F" (third cut) were uncaged simultaneously.

Only two 12-foot logs were cut on August 22, 1960 from which two more replicates were made: "J" (4 logs) and Check no. 4 (4 logs).

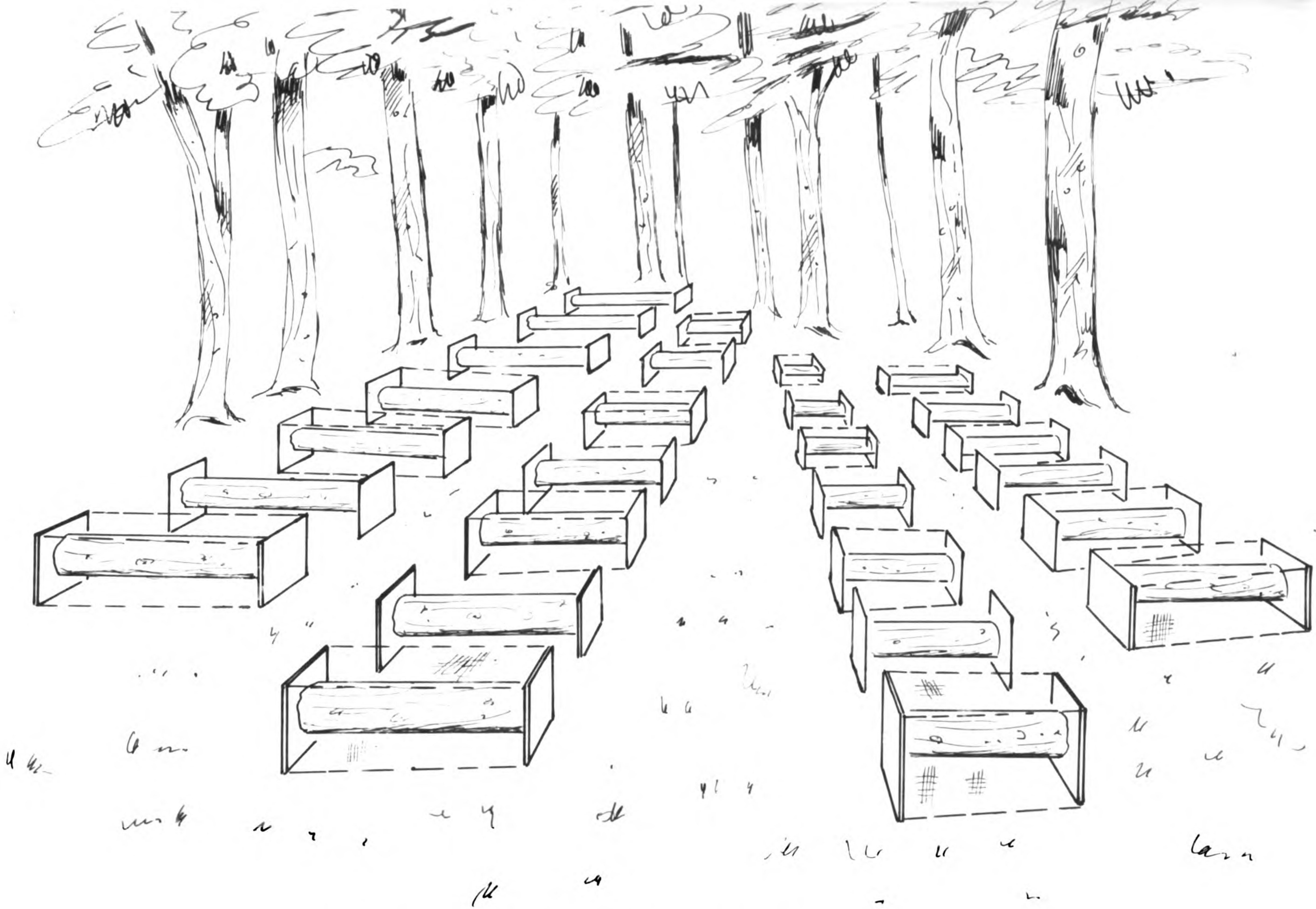


Figure 3. Sketch of log location in experiment area.

All of these logs were left open at the time. According to the established procedure on that date, the replicates "D", "G" and "I" from the previous cut were uncaged. The replicates "C", "F" and "H" were caged the same as before.

The last cut was taken on September 22, 1960 and consisted of only the Check no. 5 (4 logs), which were left open. Following the same procedure, replicates "D", "G", "I" and "J" were closed. All logs except those in check replicates were screened. All logs were left in the forest as described above until December 10, 1960, when they were removed and placed on end adjacent to the side of the greenhouse at the Kellogg Biological Station. Table 1 summarizes the cutting dates and exposure time of all red pine logs used in this study.

On March 20, 1961, all logs were taken to Michigan State University, East Lansing, Michigan. All logs which were left open all the time (checks) and those last cut and still uncaged, were caged and placed on shelves in a rearing room for observation and recording of insect emergence data.

Room temperature was controlled at 80^{o} F., and the relative humidity was maintained at 50 percent for the duration of insect emergence.

Meteorological Observations

Temperature and light intensity studies were started on June 24, 1960 on 8 logs scattered at random over the study area. Light intensity was measured by a Weston Illumination Meter (Model 756), which indicated illumination on the log surface in foot-candles. Out of the 8 logs used for light measurement, 4 were covered with screen and the other

Table 1. Cutting dates and exposure time of red pine logs.

Date of Cut	Fresh cut; exposed for one month	Exposed after one month seasoning	Exposed after two months seasoning	Exposed after three months seasoning	Exposed all the time
May 22 1960	Replicate "A" May 22 to June 22	Replicate "B" June 22 to July 22	Replicate "C" July 22 to August 22	Replicate "D" August 22 to Sept. 22	Check no. 1
June 22 1960	Replicate "E" June 22 to July 22	Replicate "F" July 22 to August 22	Replicate "G" August 22 to Sept. 22		Check no. 2
July 22 1960	Replicate "H" July 22 to August 22	Replicate "I" August 22 to Sept. 22			Check no. 3
August 22 1960	Replicate "J" August 22 to Sept. 22				Check no. 4
September 22 1960					Check no. 5

4 were uncovered. The light measurements were recorded every 3 or 4 days at 2-hour intervals from 8 A.M. to 8 P.M., at the top and bottom of the logs. These recordings are represented in Figures 4 and 5, giving the maximum and minimum range of light intensity on the top and bottom of the logs.

At the same time light recordings were being taken, the temperatures on the top and bottom of the logs were recorded. Temperature was measured with a Rubicon Portable Potentiometer by means of thermocouples inserted between the bark and sapwood at the top and bottom of each of the 8 logs. The measurements were taken twice each week beginning on June 24 and continuing through September 22, 1960. The temperature readings for the duration of the experiments are also shown on Figures 4 and 5.

Light intensity in June was low, as shown in these figures. Average maximum light intensity for June on the top of the logs was 1,280 foot-candles, and on the bottom, 141 foot-candles. In the next two months more bright sunlit days were recorded. Average maximum light intensity on the top of the logs for July was 2,824 foot-candles and for August, 2,485 foot-candles, and maximum on the bottom of the logs was 125 and 67 foot-candles, respectively.

September, as was expected, showed a decrease in average maximum light intensity on the top to 1,062 foot-candles, and on the bottom to 40 foot-candles. Due to shorter days in September, readings of light intensity at 8 P.M. were not taken.

The average bark temperature in degrees centigrade on the top of the logs was 30.46 in June, 32.24 in July, 26.74 in August, and 22.86 in September. Average temperature in the bottom of the logs for these

Figure 4. Graph showing maximum and minimum light on top of logs and maximum and minimum temperature of logs in degrees centigrade.

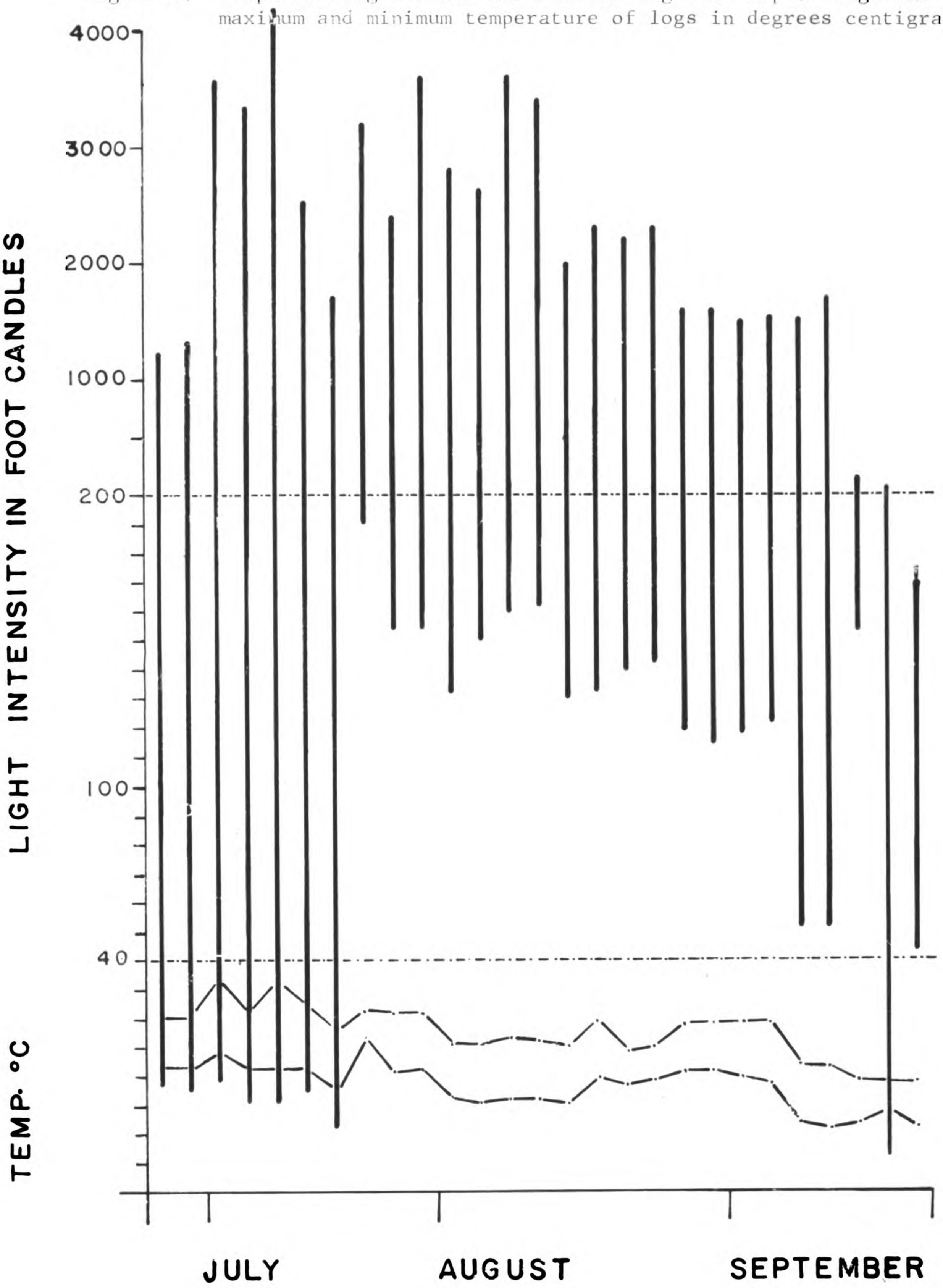
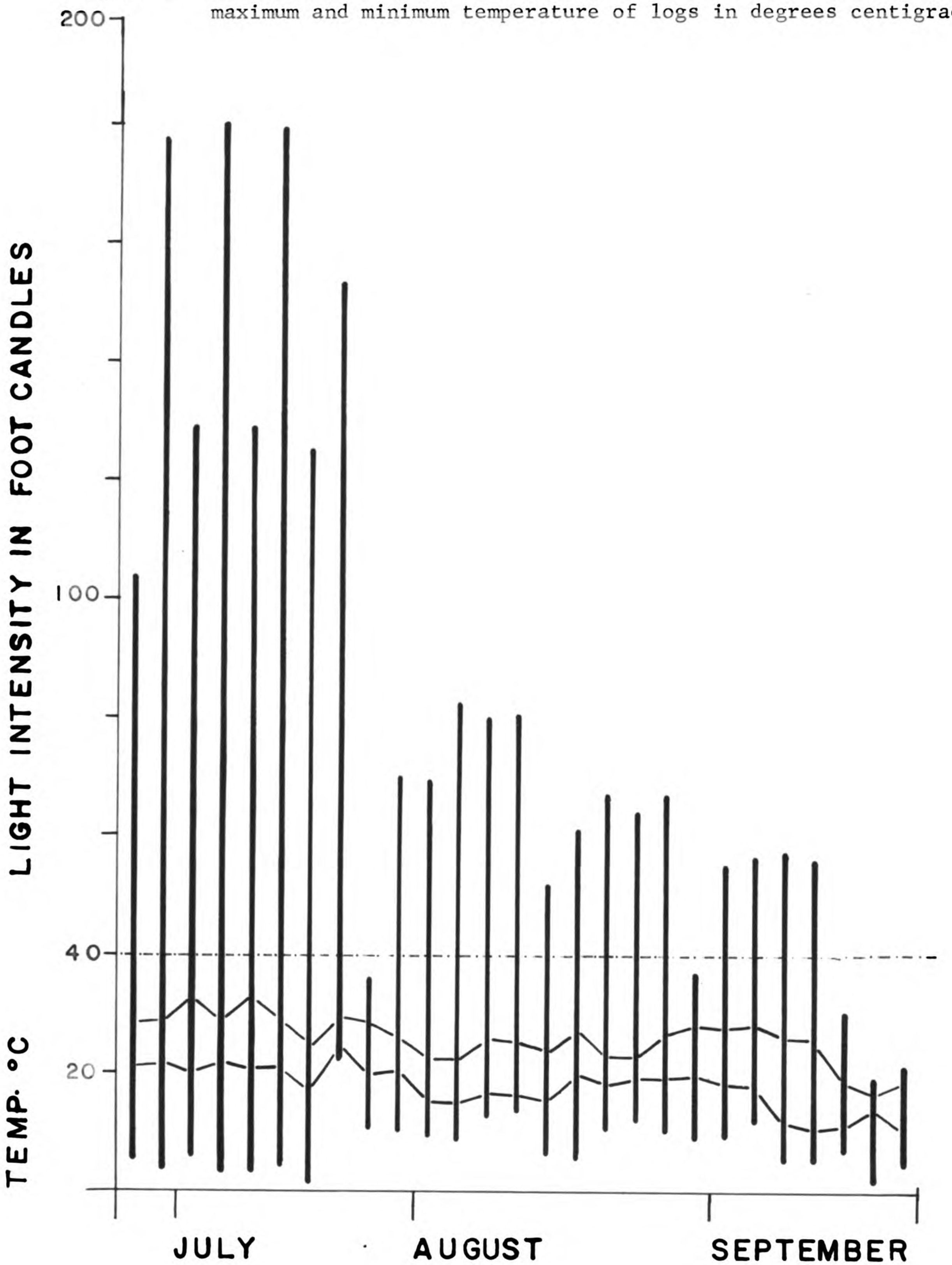


Figure 5. Graph showing maximum and minimum light on bottom of logs and maximum and minimum temperature of logs in degrees centigrade.



3 months was 28.53, 28.86, 24.60 and 21.66, respectively.

Climatological data such as maximum and minimum daily air temperatures and rainfall were available at the meteorological station in Kellogg Experimental Forest, where standard recording instruments were already in place. Data concerning temperatures and precipitation for the season as recorded by the meteorological station at Kellogg Forest are presented in Figure 6.

Distribution of precipitation was rather uneven. Total precipitation for the months of June, July, August and September was 12.09 inches. More than 50 percent of this was recorded by July 3. The following two and one-half months were fairly dry, and only 3.23 inches of precipitation was recorded. This was followed by two days (September 19 and 20) of rain which totaled 2.12 inches.

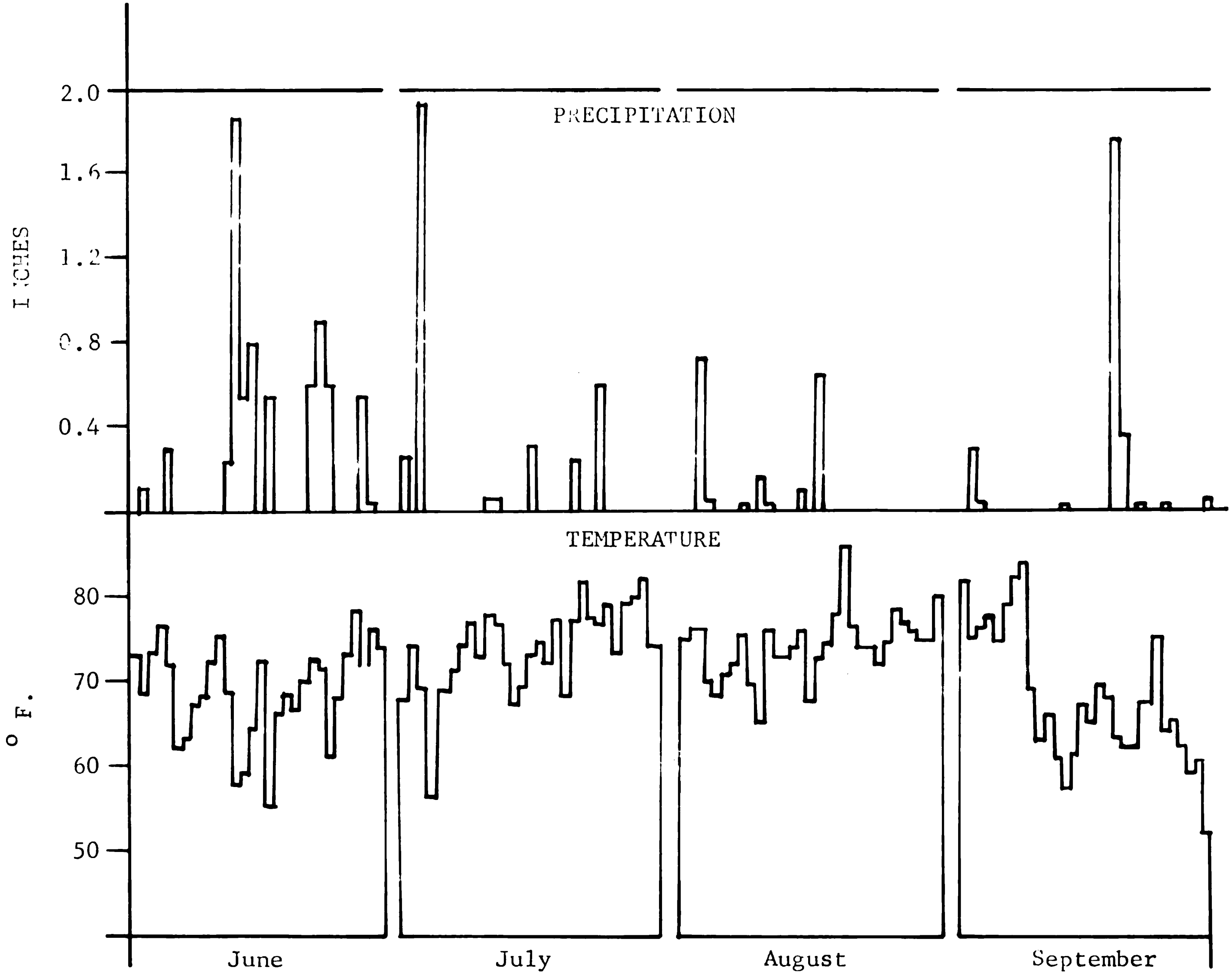
In summary, it may be stated that until the first half of July, there was an abundance of moisture. On the other hand, the second half of July and August and the first half of September were dry.

Average day temperatures measured at 8 A.M., 1 P.M. and 5 P.M. show that at the time of the rainy period in June, mean average temperature was low (68.51° F.). July, August and up to September 8, temperatures averaged 75° F. At the same time a precipitation deficiency was recorded.

Method of Collecting and Counting Insects

On March 24, 1961, activity of wood boring larvae was indicated by the presence of fresh boring dust. On March 28, the first Cerambycid adult emerged. When emergence was completed, the adults were collected

Figure . Graph showing daily air temperature and precipitation at Kellogg Forest.



and labelled as to logs from which they had emerged. About May 2, the first Curculionid adults were observed to emerge. These were collected and grouped as above. Bark beetles were permitted to escape through the screen cage. As parasites emerged, they were taken from cages in the manner previously described. There is no way of knowing what host they may have parasitized.

Method of Estimating Infestation

On June 25, 1961, all logs were taken from the rearing room and the bark was carefully removed. Since emergence holes appear at the outer bark surface only for those adults which have completed development, it was necessary to remove the bark to determine the total number of Cerambycids which had hatched and initiated feeding in sapwood. When the bark was removed, it was noted that many logs, with seemingly only slight external evidence of damage showed extensive infestation and large numbers of Curculionidae pupae.

Because it appeared that sapwood surface feeding initiated by Cerambycids in June resulted in smaller wounds than did feeding initiated in August, all holes, including emergence and surface sapwood feeding, were counted and related to time when the infestation took place. Feeding by Cerambycid larvae on the log surface was noted and replicated measurements were taken from the logs which were infested in June, July or August, 1960.

Two methods, a) calculation of volume by a modification of Simpson's Rule; and b) filling the cavities with a modeling clay called "Student Plastilina"[1] were used to estimate the relative size of cavities caused

[1]Manufactured by Crumbacher, Inc., New York.

by Cerambycid feeding at different times of the year.

a) Simpson's Rule (modified):

The actual volume of wood loss area was calculated according to the following formula for irregular area;

$$As = 1/3h\ (y_o + y_n) + 4(y_1 + y_3 + \dots + y_{n-1}) + 2y_2 + y_4 + \dots y_{n-2})$$

As = Area by approximation.

y_o, y_1, y_2, ... y_n represent lengths of a series of equally spaced parallel chords, and;

h = their distance apart

Volume = (As)(average depth)

b) Procedure for applying Student Plastilina to measure holes made by Cerambycids:

In order to figure out the volumes of wood excavated by Cerambycid larvae, the tunnels were filled with Plastilina. The Plastilina was then removed and weighed. Since each cubic centimeter weighs 1.70 grams, it was possible to convert to volume readily.

RESULTS

Species of Insects Found

The following species of insects emerged from the caged logs, were retained within the cages and subsequently identified:

Order Coleoptera

Family Cerambycidae

Monochamus titillator (Fab.)

Monochamus scutellatus (Say)

Astylopsis sexguttata (Say)

Family Curculionidae

Pissodes approximatus (Hopkins)

Pissodes affinis (Randal)

Family Cleridae

Enoclerus nigripes (Say)

Family Histeridae (no genus or species identification)

Family Scolytidae

Orthotomicus coelatus (Eich)

Ips sp.

(prob. *grandicollis Eich*)

(possibly *chagnoni* (Swaine))

Ips pini (Say)

Dryocoetes americanus (Hopk.)

Dendroctonus valens (Lec.)

Hylurgops pinifex (Fitch)

Order Hymenoptera

Family Braconidae

Eubadizon sp. (no species identification)

Superfamily Cynipoidea

Ibalia ensiger Norton

The approach used in this study made no provision for extensive collection or rearing of parasites and predators associated with the wood borers themselves; nor was any effort made to differentiate injury by the three species of Cerambycidae.

The total number of adult insects collected from the cages gives an estimate of the relative abundance of each species. Feeding injury is attributed only to the family in the case of the Cerambycidae and Curculionidae (Figure 7).

Cerambycidae

A good description of *Monochamus titillator* (Fab.) and *Monochamus scutellatus* (Say) may be obtained from Dillon and Dillon (1941).

In Figures 7 and 8 are data representing infestation by Cerambycids in freshly cut logs exposed after being caged for 30 days immediately after cutting.

The highest infestation took place in July on freshly cut logs. The June infestation was only 5.6 percent and the August only 4.4 percent of the July level. In general, seasoned wood showed a much lower infestation than did freshly cut wood exposed in the same month.

The highest infestation took place in the June cut (replicate "E"), with 71 attacks. The May cut (replicate "B") had 21.8 percent, and the July cut (replicate "I") had 12.7 percent of the June level.

Figure 7. Attacks by Cerambycids on freshly cut logs (30-day and continuous exposure).

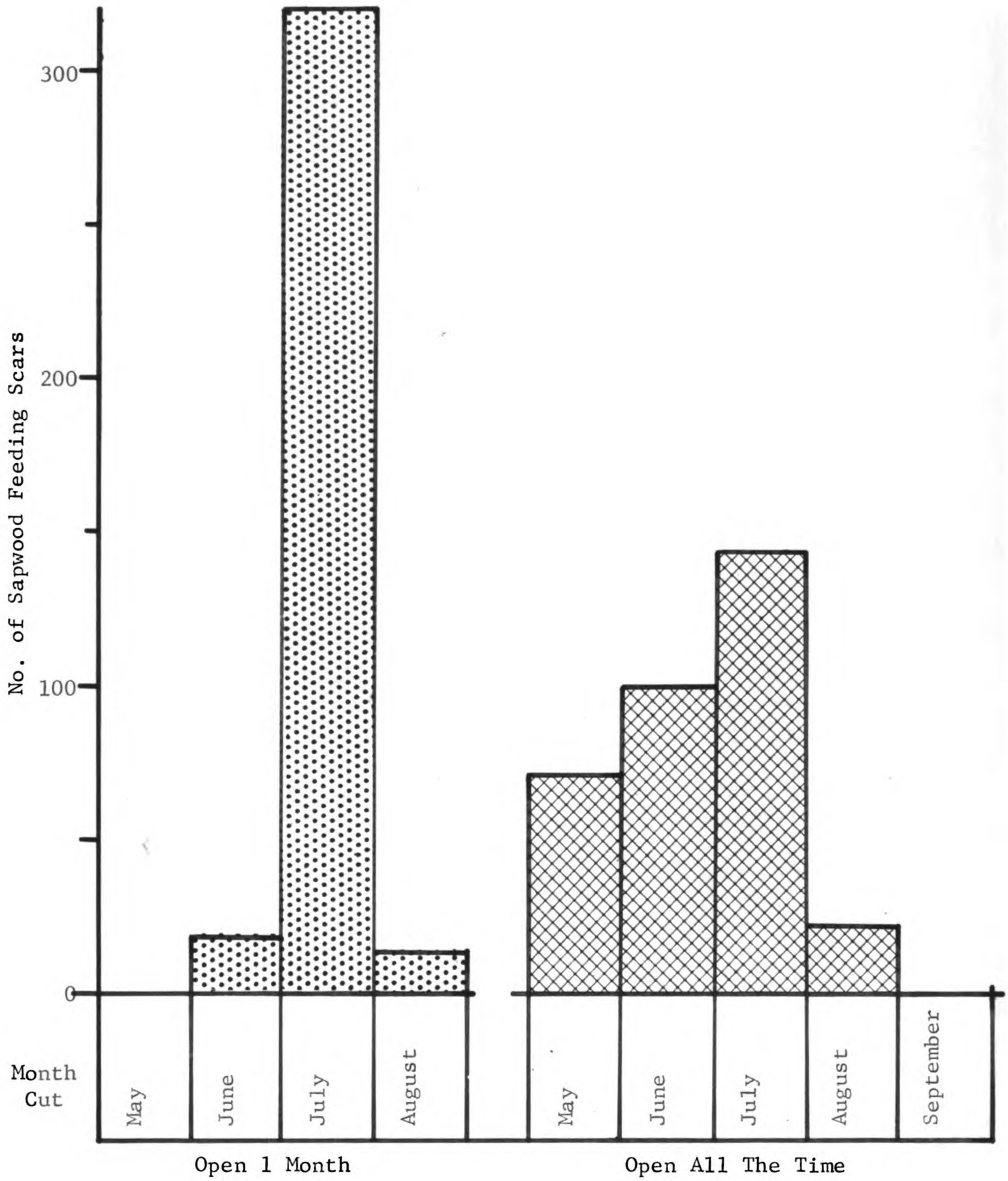
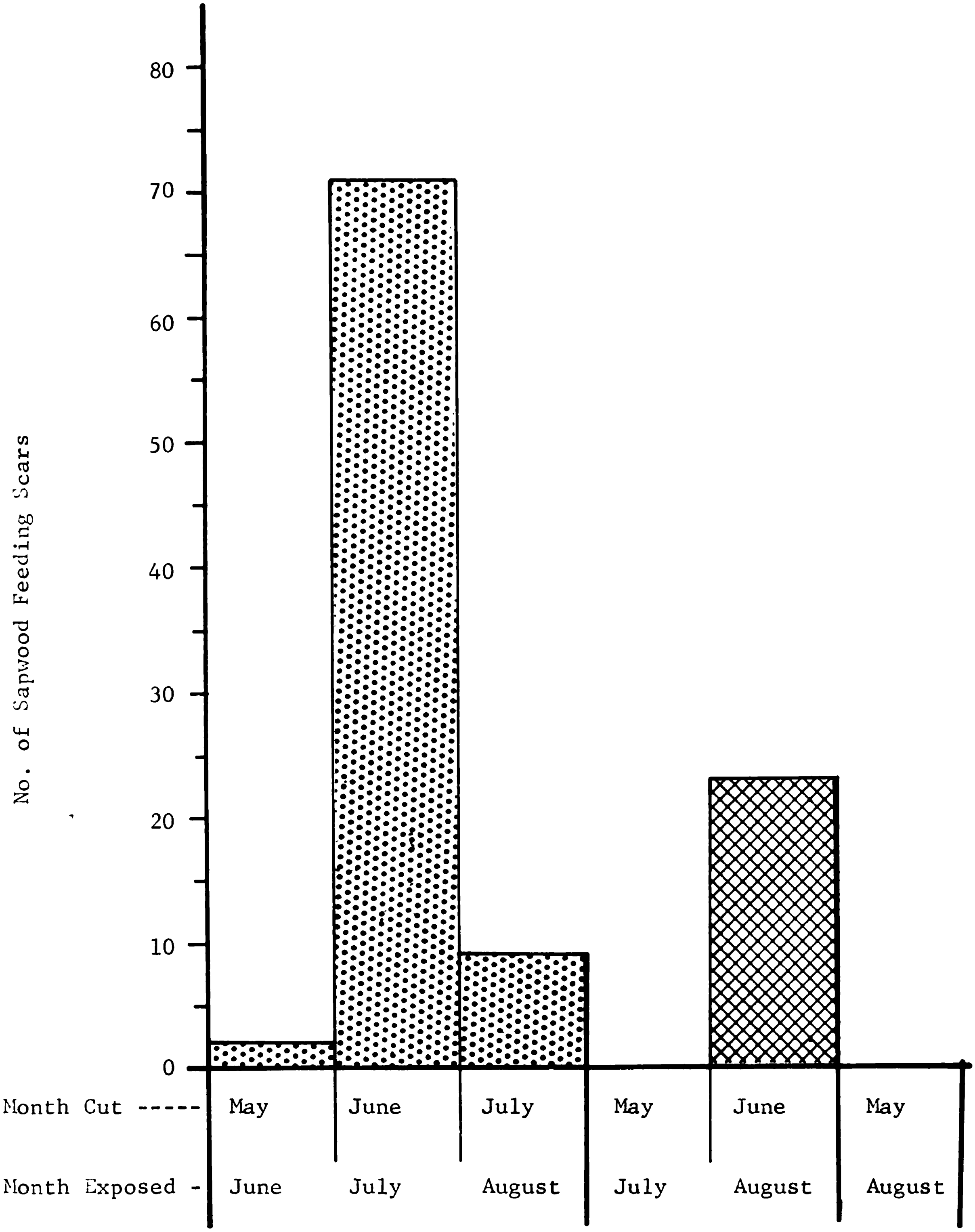


Figure 8. Effect of seasoning on Cerambycid attack.



Logs seasoned for two months, cut in May and exposed in July (replicate "C"), showed no infestation, but logs cut in June and exposed in August (replicate "G") had 23 attacks.

Wood seasoned for three months, cut in May and exposed in August (replicate "D"), was not infested. In general, seasoned wood had a lower infestation when compared to freshly cut logs. The logs seasoned for one month showed 23.5 percent and logs seasoned for two months showed 6.5 percent of the attacks on freshly cut logs.

Check logs (those left open until the end of the season) showed the following infestations: May (71), June (99), July (144), and August (23) attacks. All checks gave higher infestations than fresh cut logs, but those cut in July showed only 45 percent of the recognizable attacks visible in those cut in July and exposed only 30 days before caging. These conceivably reflect the presence of intra- and interspecific competition in logs where attacks could take place all summer.

Curculionidae

The data on weevil infestation of logs exposed for 30 days after cutting are presented in Figures 9 and 10. The highest infestation took place in May (341), July (158) and August (245). There was no infestation in logs cut in June.

Figure 7 presents data on infestation of seasoned logs. Those having one month of seasoning showed the highest infestation (cut in May and exposed in June; replicate "B" 679 attacks). The June cut exposed in July (replicate "F") showed 143 attacks, and the July cut exposed in August (replicate "I") showed only 53 infestations.

Figure 9. Attacks by Curculionids on freshly cut logs (30 day and continuous exposure).

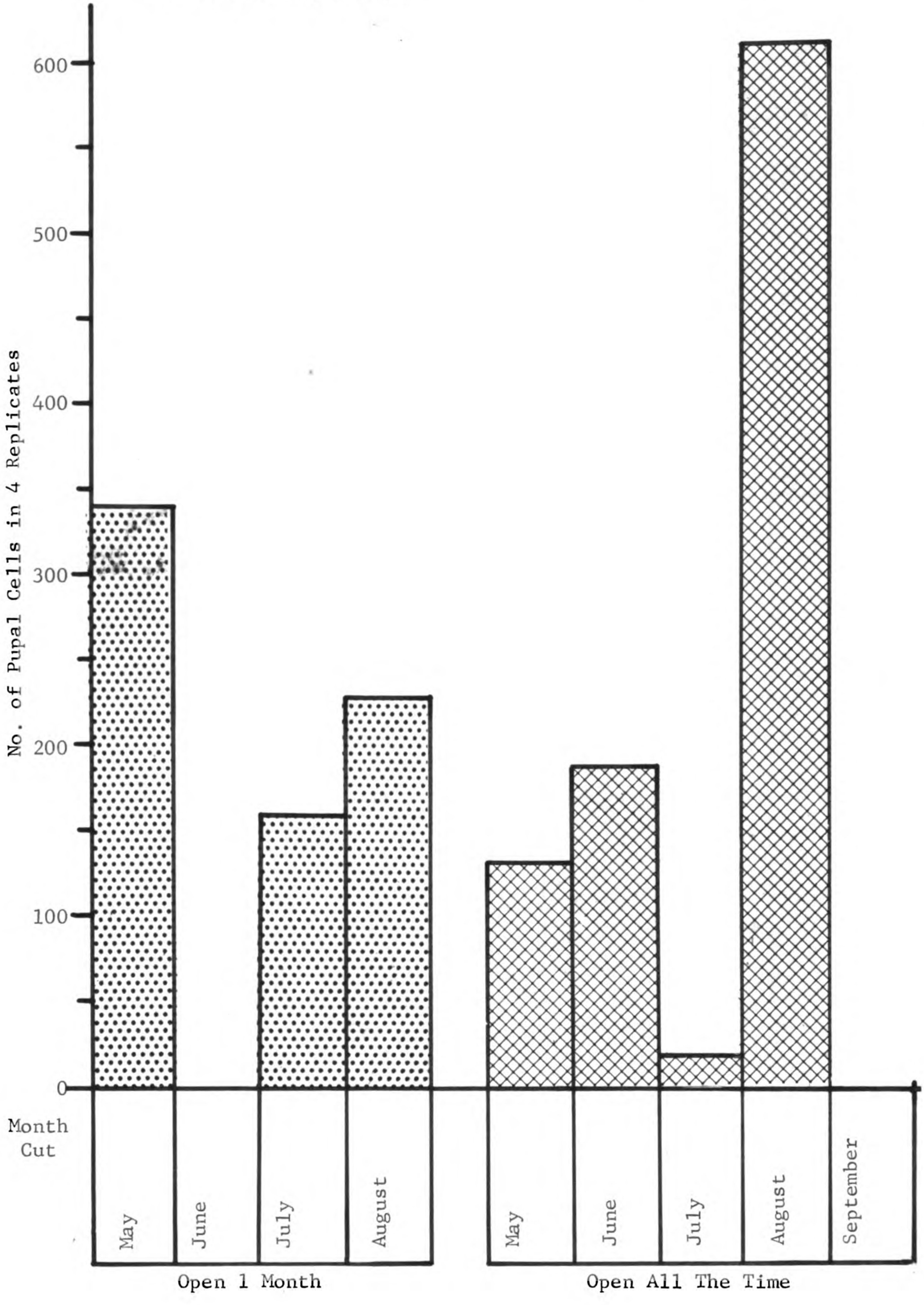
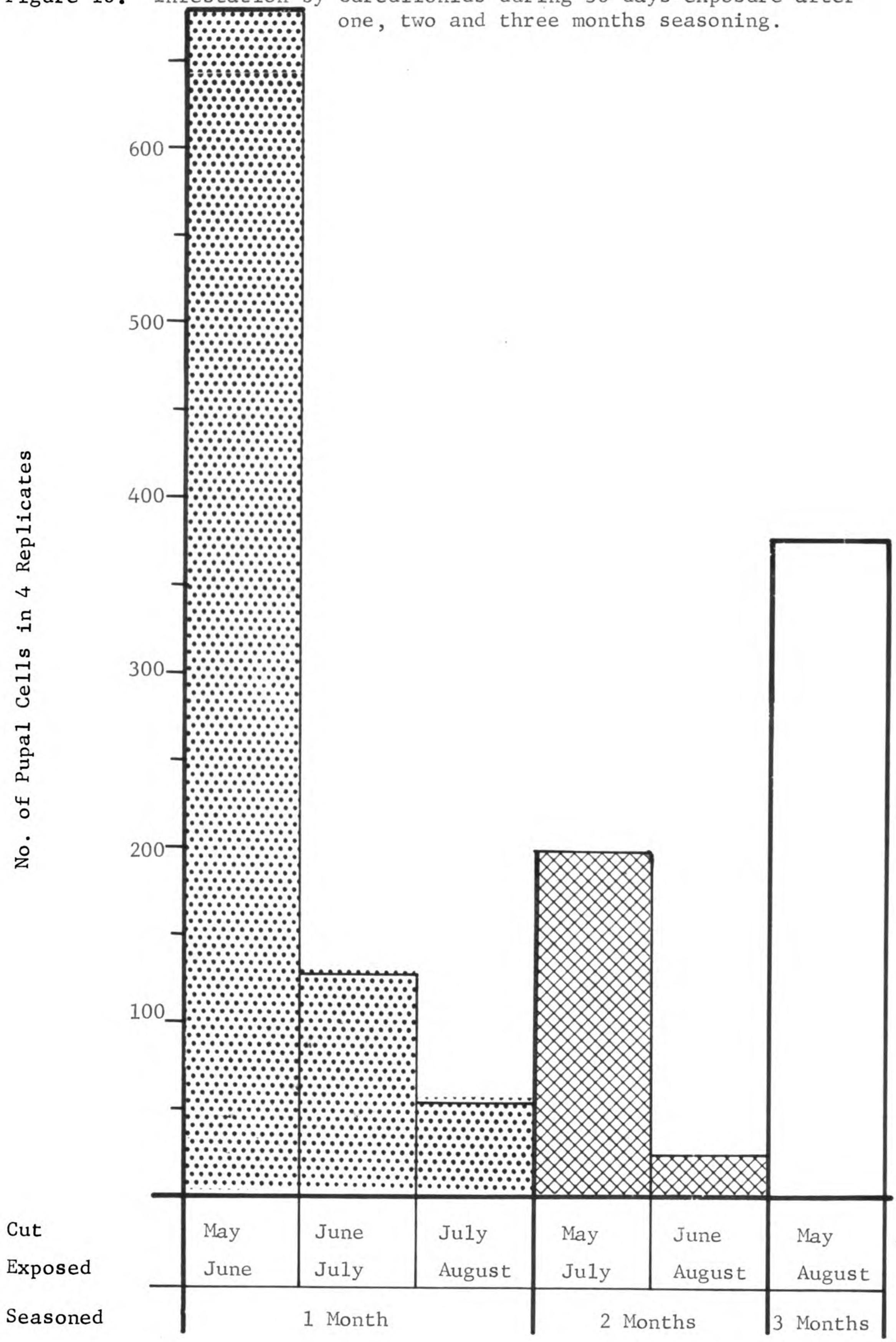


Figure 10. Infestation by Curculionids during 30 days exposure after one, two and three months seasoning.



Two months of seasoning gave still lower infestations; only 25.14 percent of logs seasoned one month as illustrated. Those cut in May and exposed in July (replicate "C") showed 196 infestations. The June cut, exposed in August (replicate "G"), gave only 24 infestations or 12.24 percent of replicate "C".

Logs seasoned for three months, those cut in May and exposed in August (replicate "D") showed a high infestation of 375 attacks. This was probably due to an infestation which had taken place on the standing tree in 1959. Before it was exposed, 178 adult Curculionidae were collected from this replicate. After exposure for one month, adults were collected again from this replicate.

Checks, as compared with freshly cut logs, showed the highest infestation in August (Check no. 4), while the lowest was in the July cut (Check no. 3), with only 15 infestations. May (Check no. 1) showed 124 and the June check (no. 2) 187 infestations.

Specimens of the weevils were sent to the Agricultural Research Service, Entomology Research Division, Beltsville, Maryland for identification. They were identified by Miss R. E. Warner as _Pissodes approximatus_ Hopkins, and _Pissodes affinis_ Randall. The communication states,[1]

> ... that _Pissodes approximatus_ is commonly confused with _P. strobi_. _P. approximatus_ is usually distinguished from _strobi_ by the average larger size and the (usually) separation of the smaller posterior spots - the posterior ones in _strobi_ are connected. These species are very similar and usually are separated by the difference in habits - _P. strobi_ attacks leaders or terminals - usually not killing the trees. _P. approximatus_ occurring in bark on trunks of trees and base of

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[1]Personal communication dated 21 February 1962 from W. H. Anderson, Chief, Insect Identification and Parasite Introduction Branch, Agricultural Research Service, Entomology Research Division, United States Department of Agriculture, Beltsville, Maryland.

> saplings, sometimes injurious to the saplings but apparently not killing older trees. There is some question as to whether P. approximatus may not be identical with P. strobi - further observations are necessary for a definite answer.

Obviously there is lack of agreement as to the differences between P. approximatus and P. strobi. In connection with this, R. J. Finnegan has stated[1] that,

> Morphologically - these species are indistinguishable from one another (if they are indeed separate species) and have been separated in the past on other biological evidence. The group is apparently in a state of active evolution with several subspecies present.

Seasonal Difference in Feeding on Sapwood

After the bark was removed it was possible to observe surface sapwood excavations, in addition to the elliptical entrance holes which lead into the tunnels.

Logs from replications "E", "H", and "J" (those cut in June, July and August, respectively) were examined for feeding damage. These had been left exposed for 30 days immediately after cutting and had been infested by Monochamus species.

The early instars of Cerambycid larvae feed upon the inner bark, cambial layer, phloem, and outer sapwood, forming hollow excavations called surface galleries. As the larvae grow older, they bore a deep tunnel from the surface gallery to the heartwood. The elliptical or oval-shaped holes to the tunnels are conspicuous and easily recognized (see Figures 11 and 12). It appeared that the surface excavations

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[1]Personal communication dated 12 February 1962 from R. J. Finnegan, Forest Entomologist, Canada Department of Forestry, Sillery (Quebec), P. Q., Canada.

Figure 11. Plate showing emergence holes of weevils and cocoons formed under the bark.

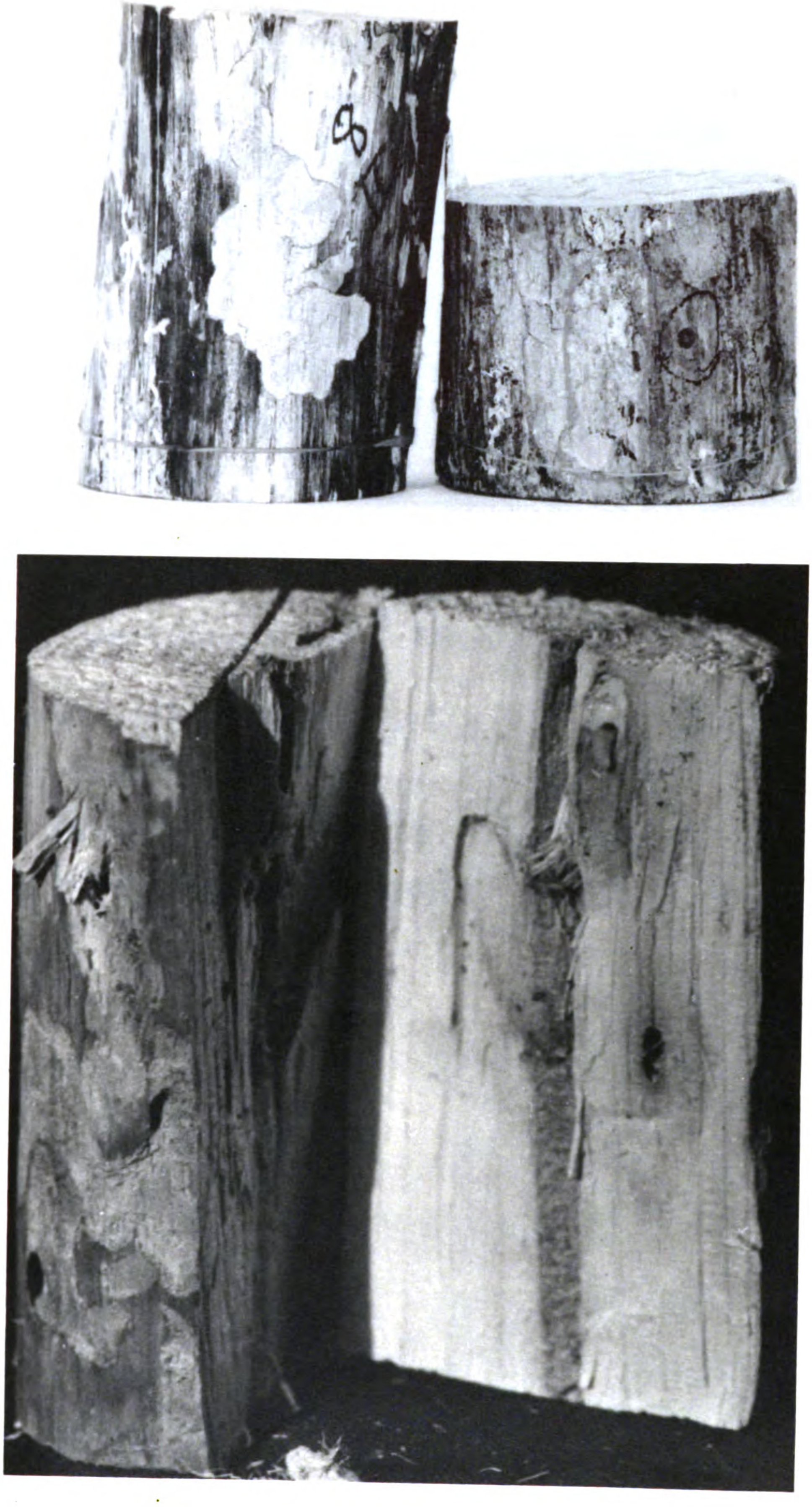

Figure 12. Plate showing surface galleries and entrance hole to tunnel, pupal chamber and emergence hole.

produced by Cerambycid larvae attacking logs cut in June were consistently smaller than those that attacked logs cut in August.

It was decided to devise a method to measure this feeding, and record the interpretation of volume loss in the outer sapwood in June, July and August to see if the differences could be substantiated statistically (see Procedure). A number of holes were selected at random from June, July and August cut logs.

Feeding galleries were measured by each of the methods previously described. Each measurement included: a) surface galleries; b) entrance tunnels into the wood; and c) pupal chambers and emergence holes.

Comparison of Volume by Two Methods

The correlation of volume loss by Cerambycid feeding entailed the use of "Simpson's Rule" (Burington 1956) and Student Plastilina. For this test, 37 sample holes were measured (15 infested in June, 11 in July and 11 in August). These sample volumes (in cc.) are presented in Table 2.

Table 2. Volume loss by Cerambycid feeding.

June Attack		July Attack		August Attack	
Plastilina	Simpson's Rule	Plastilina	Simpson's Rule	Plastilina	Simpson's Rule
c.c.	c.c.	c.c.	c.c.	c.c.	c.c.
3.78	3.80	3.64	3.46	11.60	10.73
2.43	2.33	3.97	3.33	12.78	11.56
6.56	6.16	4.17	3.57	10.47	9.96
8.44	7.87	3.62	3.54	7.60	6.94
2.81	2.68	3.34	2.97	3.89	3.47
3.21	3.17	4.20	3.80	4.13	3.68
2.80	6.61	3.55	3.44	3.69	3.67
3.66	3.53	5.10	5.12	10.02	8.85
5.47	5.14	4.69	4.37	4.22	4.07
4.30	4.10	5.12	4.88	3.80	8.50
2.74	2.44	4.16	3.88	12.42	11.91
5.54	4.91				
2.75	2.30				
2.32	2.25				
3.02	2.84				

The coefficient of correlation between the estimates obtained by these two methods was .9938, as indicated by the data below.

June	SSpp =	37.9266
July	SSpp =	3.7268
August	SSpp =	130.8210
		172.4744
June	SSss =	43.9298
July	SSss =	4.4871
August	SSss =	112.7552
		161.1721
June	SSsp =	40.6633
July	SSsp =	3.9806
August	SSsp =	121.0499
		165.6938

$$r \text{ ave.} = \frac{SSsp}{\sqrt{SSss \times SSpp}} = 0.99380$$

The volumes estimated by these two methods demonstrated that the Plastilina method, which is simple to use, is nearly as accurate as the more difficult method involving Simpson's Rule.

Using the Plastilina method the volume of wood removed from the surface sapwood is expressed as percent of the total wood removed by Cerambycid larvae for each gallery for each of the three months listed in Table 3.

An analysis of variance was performed on the data in Table 3, giving an F value of 256 which is significant at the one percent level. This indicated that the observed differences between months are not readily attributable to chance.

Table 3. Volume of surface sapwood removed by Cerambycid larvae expressed as % of total volume of each gallery measured.

June	July	August
% c.c.	% c.c.	% c.c.
.1085	.4093	.5689
.1934	.3904	.4710
.2058	.4412	.4813
.2535	.2679	.3789
.1708	.4550	.3059
.1433	.3142	.3099
.1785	.4507	.3767
.1503	.5754	.2175
.3300	.4669	.2535
.2023	.4023	.4636
.1752	.4110	.4090
.1931		
.1236		
.1379		
.3874		

The measurements (with Plastilina) are given in cubic centimeters. They show a central tendency

$$\bar{x} = \frac{\sum x}{N}$$

Where $\bar{x}$ = mean
$\sum$ = all the data represented to be added together
x = any given volume of variate
N = the number of observations made (or total frequency)

N	Month	Surface galleries	Entrance tunnels inside	Total volume loss by excavation
15	June	0.82 cc.	3.16 cc.	3.99 cc.
11	July	1.72 cc.	2.42 cc.	4.14 cc.
11	August	3.35 cc.	4.80 cc.	8.15 cc.

Means of the feeding holes for June, July and August were 3.99 cc., 4.14 cc., and 8.15 cc., respectively.

SUMMARY AND CONCLUSIONS

A red pine trap log study was carried on in 1960 - 1961 in Kellogg Forest near Augusta, Michigan. The primary purposes of this study were to obtain information on the presence of wood boring insects in this area, and to determine the population level of wood boring insects in cut red pine logs. The time of infestation, damage, moisture, and extent of observation on biology of the insects, were also included in the study.

The study did not include coverage of bark beetles, since they were permitted to escape through the screen cages. Although some adult parasites were recovered, there was no way of knowing which host they attacked.

Results of this study indicate that infestation by Cerambycids takes place in red pine logs cut during June, July and August. Infestation occurred in freshly cut logs, and logs seasoned for as long as 3 months. Three species of Cerambycidae were found infesting freshly cut red pine trap logs in the Kellogg Forest. These were:

Monochamus titillator (Fab.)

Monochamus scutellatus (Say)

Astylopsis sexguttata (Say)

M. tittillator was the most abundant. The highest infestation took place in logs freshly cut in July. No infestations occurred in logs freshly cut in May and September. In general, logs seasoned in cages for one, two and three months before exposure showed progressively lower infestations. Logs seasoned for one month showed infestations totaling only 23 percent of those in freshly cut logs. In logs seasoned for two months, the infestation was only 6.5 percent of that in the freshly-cut logs. In logs seasoned for three months no infestation was found.

Damage by M. titillator is caused by larval feeding in the sapwood. The wood volume loss from feeding in the outer sapwood in June and July was only 24.47 percent and 51.34 percent, respectively, of that which took place in August. In June and July, early instar larvae fed primarily in the phloem and cambium tissues, and then bored tunnels in the wood. In August, early instars fed less in phloem and cambium and more in the outer sapwood, producing large irregular surface excavations.

It appears that volume loss by Cerambycid feeding is correlated with precipitation. Precipitation in June, July, and August was 4.54, 3.46, and 1.73 inches of rain, respectively. The means of volume loss were 3.99 cc., 4.14 cc., and 8.15 cc. during June, July and August, respectively. Such a correlation might suggest, that with more available moisture, the larvae fed in phloem and cambium; and with less moisture, the larvae fed more on the outer sapwood by excavating larger surface galleries. Whether these demonstrable feeding patterns are due to seasonal tree growth differences or to some climatic factor cannot be stated with assurance on the basis of these limited data. The extensive outer sapwood excavations could be significant to pulp or sawlog industries, however, and this might justify further study.

Bark temperatures averaged 30.46, 32.76, and 26.74° C., for June, July, and August, respectively. It appears that the amount of damage by the feeding larvae increases as bark temperatures decrease. The larvae beneath the bark are insulated to a degree from sudden temperature changes and from extremes in temperatures; but Craighead (1920) has pointed out that solar radiation may raise the subcortical temperature to a point which will prove fatal to the insects.

The second group of insects found in considerable numbers was in the family Curculionidae. These were:

Pissodes approximatus (Hopkins)

Pissodes affinis (Randal)

P. approximatus is particularly important. This species attacks freshly cut and seasoned logs and under some conditions attacks standing healthy trees.

The eggs were laid throughout the trunk, however they appeared to prefer the upper portion. Upon hatching, the larvae begin feeding in the cambium layer and normally tunnel in either direction along the grain of the wood. When the larvae reach maturity, they construct a chip cocoon, and pupate in the outer surface of the sapwood. The newly emerged adults chew and make their way to the outside. According to the data obtained in this study, *P. approximatus* will infest cut logs earlier in the season than will the Cerambycids.

In logs exposed for 30 days after cutting, the highest infestation took place in logs cut in May (replicate "A"), an average of 19 adults per square foot of bark. Logs cut in July (replicate "H") had 50 percent less infestation than logs cut in May. Logs cut in August (replicate "J") showed 14 adults per square foot of bark. There was no infestation in logs cut in June.

Logs seasoned for one month after cutting and then exposed for 30 days showed approximately 15 percent higher infestation than freshly cut logs.

Logs seasoned for two months after cutting and then exposed, showed the lowest infestation, only 25 percent of that in freshly cut logs. But in logs seasoned for 3 months (cut in May and exposed in August) infestation was 50 percent of that in freshly cut logs, or approximately double that in logs seasoned for two months.

In general, infestation by weevils takes place in every month from May to August. Either they preferred logs freshly cut and logs seasoned for one month (cut in May and exposed in June) in which there was the highest infestation, or there was a mass flight period when the weevils were searching for suitable breeding material. Only two specimens of P. affinis were collected from the caged logs.

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