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Biology of Rain Beetles, *Pleocoma* Spp.,

Associated with Fruit Trees in Wasco and
Hood River Counties

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Biology of Rain Beetles, *Pleocoma* Spp., Associated with Fruit Trees in Wasco and Hood River Counties

INTRODUCTION

A decline of apples trees in the Hood River Valley was partly explained in September, 1953, by the discovery that grubs of the genus *Pleocoma* (Coleoptera: Scarabaeidae) were responsible. This was the first record of *Pleocoma* causing injury to orchard trees in Oregon.

Two published records from California noted grubs of this genus attacking roots of pear and apple (Essig, 1926 and Linsley, 1945). The genus has been a scientific curiosity because of the strange habits of the adults and their primitive characters. Consequently, publications on the group have dealt primarily with taxonomy and morphology. Several articles have been published concerning the morphology of *Pleocoma* larvae occurring in California. (Osten Sacken, 1874, Ritcher, 1947 a and b, and Hayes and Chang, 1947). Virtually nothing was known concerning the biology of this genus.

Research was undertaken to establish basic facts about these insects so that intelligent control measures could be devised, because an economic problem of considerable magnitude presented itself. There are 12,000 acres of pome fruit trees in the Hood River Valley, which potentially could be hosts of these grubs. In March, 1954, the grubs of *Pleocoma* were found attacking roots of sweet cherries at The Dalles, where approximately 6,000 acres of tree fruits are grown.

Prior to 1953, *P. minor* Linsley was the only species known to occur in the Hood River Valley (Linsley, 1938 a). In November, 1953, another species, *P. crinita* Linsley¹ was collected in the Odell district. A third species was collected in cherry orchards near The Dalles in 1953 and 1954, and identified as *P. oregonensis* Leach¹.

The three species were originally described from either one or two male specimens. Females of the species were unknown. Due to the lack of a long series for comparison, errors have appeared in print

¹ Identification by Dr. E. G. Linsley, Department of Entomology and Parasitology, University of California, Berkeley, California.

on several occasions. Males of *P. crinita* collected and submitted to Linsley in 1953 were misidentified as *P. minor*. This resulted in a reference to *P. minor* instead of *P. crinita* (Ritcher, 1955). An additional error was made in a report that four males of *P. minor* were collected October 23, 1930, at Mosier, Oregon, and that two of these specimens were used when the species *P. minor* was described (Ritcher and Olney, 1953). In reality two of these specimens were *P. minor* collected near Hood River (Linsley, 1953 a). The other two specimens were *P. crinita* from Mosier, Wasco County, Oregon (Linsley, 1956 b).

HABITAT

Pleocoma crinita occurs at Mosier, Wasco County, Oregon; in many Hood River Valley orchards and woodlands, Hood River County, Oregon; and near Glenwood and Husum, Klickitat County, Washington (Linsley, 1956 b and 1938 a).

Bailey (1936) shows Mosier to border on the semihumid division of the Transition Zone. Forest trees in the area are Ponderosa pine, (*Pinus ponderosa*), Douglas-fir, and Oregon white oak (*Quercus garryana*).

Hood River Valley with an average of 30.1 inches of moisture annually is in the humid division of the Transition Zone (Bailey, 1936). Some of the native trees include Douglas-fir, white fir (*Abies concolor*), black cottonwood (*Populus trichocarpa*), Oregon maple, vine maple, and "islands" of Ponderosa pine and Oregon white oak in scattered localities. *Pleocoma crinita* is widely distributed in this habitat (Figure 1) and in adjoining pome fruit orchards, beginning west of Hood River at an elevation of 260 feet, and extending southward to Odell and southwest to Oak Grove at elevations ranging to 1,150 feet (Figure 2). Ecologically, both localities in Washington where *P. crinita* occurs are similar to the Hood River Valley of Oregon.

Pleocoma minor has a more limited distribution than *P. crinita*, being known only from Hood River County (Linsley, 1956 a and 1938 a). The species occupies the same kind of habitat and is often found within one-fourth mile of areas occupied by *P. crinita* (Figure 1). The territory occupied by *P. minor* begins southeast of Hood River at an elevation of 540 feet, extends southward in the vicinity of Dee, thence southwest of Hood River to an elevation of 2,000 feet. (Figure 2).

The third species, *P. oregonensis*, has been recorded from The Dalles, Wasco County; from 15 miles east of Wasco, Sherman

County; and from Wasco, Sherman County (Ellertson, 1956, and Leach, 1933). It has the widest range in habitat, distribution, and elevation, being found in the humid and semihumid division of the Transition Zone in Wasco County and the Upper Sonoran Zone in Sherman County (Bailey, 1936). The ground cover in these zones ranges from mixed stands of Douglas-fir and Ponderosa pine to pure stands of Ponderosa pine, or Ponderosa pine and Oregon white oak, or sagebrush and short grass (Figure 1).

Specimens collected near The Dalles are from cherry orchards, pure stands of Ponderosa pine, or associations of Ponderosa pine and Oregon white oak at elevations ranging from 350 to 600 feet. The known range extends south from The Dalles to Friend (2,430 feet) and Wamic (1,664 feet), thence northwest to Camp Baldwin (Boy Scout camp) at 3,700 feet. *Pleocoma oregonensis* is also recorded from Wasco, in the Upper Sonoran Zone, and 15 miles east of Wasco on the west bank of the John Day River at an elevation of 550 feet, in Sherman County.

The annual precipitation in this area ranges from 13.6 inches at The Dalles, to over 30 inches at Camp Baldwin. Wasco in Sherman County has 11.8 inches of moisture annually.

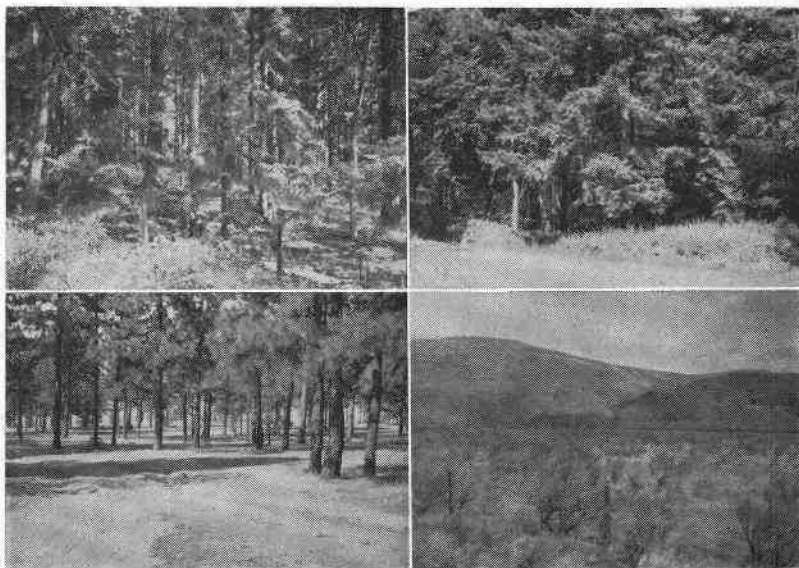


FIGURE 1. Upper left, native habitat of *P. crinita*, Hood River County. Upper right, native habitat of *P. minor*, Hood River County. Lower left, western yellow-pine habitat of *P. oregonensis*, The Dalles. Lower right, sagebrush habitat of *P. oregonensis*, east of Wasco, Sherman County.

ECONOMIC IMPORTANCE AND HOST PLANTS

Early reports which associate *Pleocoma* grubs with roots of orchard trees are uncommon in the literature. Two unpublished reports concern larvae now in the U. S. National Museum collection. In one instance, larvae were reported by G. P. Weldon as injuring young fruit trees near Sacramento, California. On March 5, 1936, Steward Lockwood collected larvae from soil in a young pear orchard at Camino, El Dorado County, California. These larvae were suspected of causing serious injury to newly-planted fruit trees.

A *P. fimbriata* grub and the injury it caused on roots of a young pear tree is illustrated by Essig (1926). In 1945, H. H. Keifer reported grubs injuring roots of apple trees at Leona Valley, Palmdale, Los Angeles County, California (Linsley, 1945). Hayes and Chang (1947) referred to a larva of *Pleocoma* in their collection as being discovered at the roots of a pear tree near Camino, El Dorado County, California.

In the period from 1953 through 1957, reports of *Pleocoma* larvae injuring roots of orchard trees and other plants increased after the first discovery of injury in Hood River pome fruit orchards. *Pleocoma* grubs were noted as injuring roots of orchard trees in Butte and perhaps northeastern Shasta County, California, by F. P. Platt (personal communication). Later, F. P. Platt reported *P. edwardsi* Le Conte grubs attacking roots of apple trees in an abandoned orchard at De Sabla, Butte County, California (Linsley, 1957).

Two records associate *Pleocoma* grubs with roots of plants other than orchard trees. Larvae of *P. hirticollis vandykei* Linsley were noted as feeding on grass roots near Patterson Pass, California (Ritcher, 1947a). In the second instance a *Pleocoma* grub was found injuring a strawberry plant at Newberg, Oregon.

The first recorded instance of *Pleocoma* injury to orchard trees in Oregon occurred at Hood River in 1953 (Ritcher and Olney, 1953). The report stated that *P. minor* grubs (adults later identified as *P. crinita*) were causing serious damage to roots of apple and, to a lesser extent, to the roots of pear trees. After the report of severe injury in the McKeown orchard near Odell, Hood River County, other growers mentioned having had difficulty in establishing new plantings of fruit trees and observing injury of a similar nature on trees removed in the past. By December of 1953, damage was known to be widespread in approximately twenty Hood River orchards. The writers have also observed *P. crinita* larvae feeding on roots of apple trees near Husum, Klickitat County, Washington (Linsley, 1956 b).

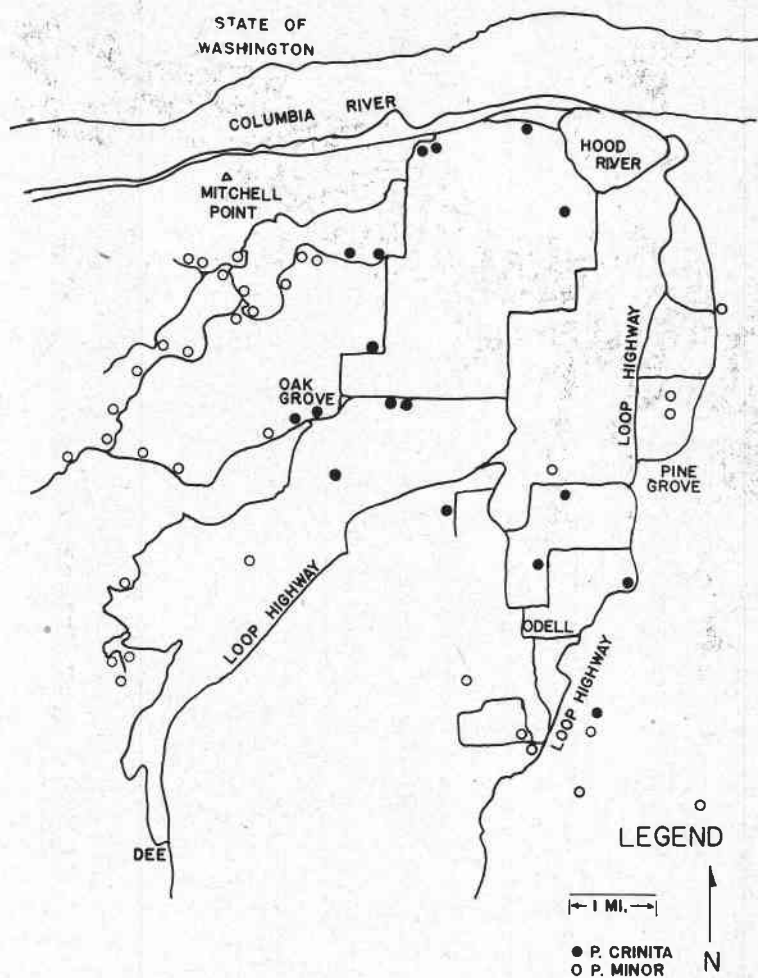


FIGURE 2. Distribution of *P. crinita* and *P. minor* in the Hood River Valley.

The record of one species injuring apple trees in the Hood River Valley suggested the possibility that groups of other *Pleocoma* species might be attacking fruit trees in this area or at The Dalles (Ellertson, 1955). Grubs of *P. oregonensis* were discovered injuring roots of sweet cherries at The Dalles in 1954 (Ellertson, 1956).

One other species, *P. minor*, was known to occur in Hood River County (Linsley, 1938 a). Additional specimens were collected in

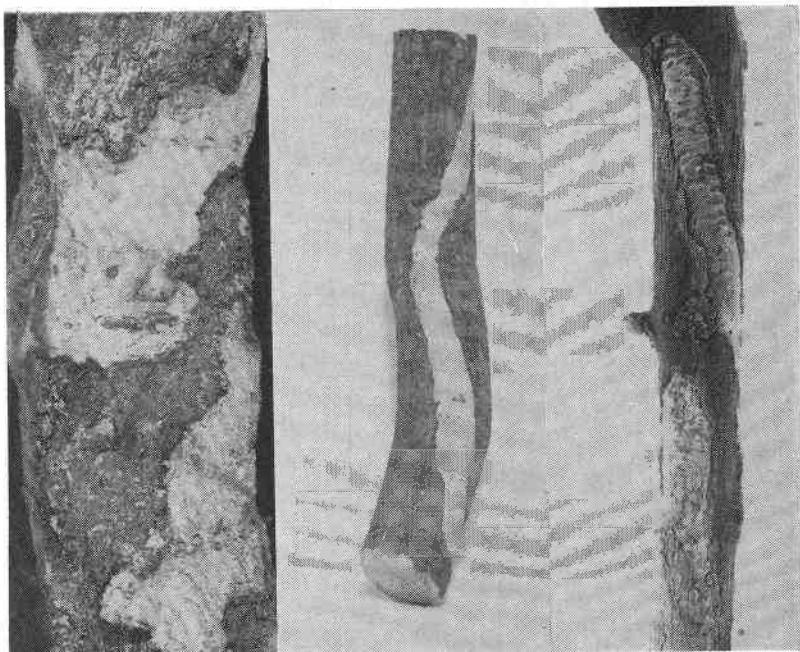


FIGURE 3. Left, injury to apple root by larvae of *P. crinita*. Center, injury to root of sweet cherry by larvae of *P. oregonensis*. Right, injury to root of young apple tree by larvae of *P. minor*.

1954 and 1955, in a forested area northwest of Dee, Hood River County (Linsley, 1956 a). In October, 1955, adults were collected in a Hood River orchard. During 1956 and 1957, *P. minor* was found to be as common and widespread in distribution as *P. crinita* and causing much the same type of injury to orchard trees.

Fibrous roots, main roots, and underground portions of the trunk of bearing and nonbearing trees are destroyed or scored by the grubs. The feeding injury may be shallow or relatively deep, occurring as patches or winding bands and often girdling the roots (Figure 3). This injury may occur throughout the entire root zone.

Affected bearing apple trees in the Hood River Valley are low in vigor, with foliage sparse, small, and yellow (Figure 4). Pear trees infested with grubs lack terminal and sucker growth. The leaves are yellow and sparse and there is little or no fruiting. Large populations of grubs are causing injury in only small areas of 5 or 6 trees, or the injury may extend over 10 or more acres.

At present, the declining apple trees in Hood River are in the older age group (40-50 years). However, trees in the 25- to 35-year

age group, though not showing visible symptoms, have large populations of grubs feeding on the roots. This would lead one to conclude that these grubs are not serious pests unless present in large numbers, whereupon destruction of the fibrous root system results in a slow decline of the tree.

In 1954, at The Dalles, twenty-six 20-year-old dead or dying Bing cherry trees were removed because of *P. oregonensis* grub injury. Since then, no further reports of tree removal due to grub damage have been received. Sample diggings in three widely separated cherry orchards revealed grubs in varying numbers. It is difficult to determine whether grub injury to roots of cherry trees at The Dalles is wholly responsible for all the decline in that area. Gopher injury to roots, drought, winter injury, and viruses are also contributing to the unthrifty condition of many cherry trees.

Approximately 6,000 acres of fruit trees in the Hood River Valley are located within the present known range of *P. crinita* and *P. minor*. At The Dalles, 6,000 acres of tree fruits lie within the known range of *P. oregonensis*.

Larvae of *P. crinita*, *P. minor*, and *P. oregonensis* are oligophagous in their feeding habits. The two species in the Hood River Valley are feeding on *Malus* (apple), *Pyrus* (pear), and *Prunus avium* (Mazzard) rootstock. Grubs of *P. crinita* and *P. minor* will shift their feeding from *Prunus* to *Malus* and from *Malus* to *Pyrus* roots. Grubs of *P. oregonensis* at The Dalles feed on sweet cherry rootstock (Mazzard or Mahaleb) and on apple clonal rootstock, Malling II and VII.



FIGURE 4. Apple trees showing effects of grub injury to roots.

A grower at Hood River planted three acres of apple trees on seedling rootstock in an acreage previously planted to sweet cherry. When leaves of the 2-year-old apple trees began wilting in May, 1957, examination revealed one to four grubs of *P. minor* feeding on the root systems. One-third of the young trees were severely damaged or died as a result of this feeding (Figure 3).

Another Hood River grower had a 6-acre planting of 40-year-old Newton apples which was interplanted with Bartlett pears in 1946. The apple trees were systematically removed to provide space for growth of the pears. After removal of the apples, grubs of *P. crinita* shifted their feeding to roots of the pears.

In 1956, a grower at The Dalles planted 7 acres of apples on Malling II and VII. This acreage had previously been planted to sweet cherry. *Pleocoma oregonensis* grubs immediately began feeding on the Malling rootstocks.

Egg Stage

Nearly a century elapsed between the description of the genus and type species of *Pleocoma* by Le Conte in 1856 and the first published accounts on the egg stage of the group. Several papers published recently on *P. crinita*, *P. oregonensis*, and *P. dubitalis dubitalis* Davis have furthered our knowledge of the egg stage (Ritcher and Olney, 1953; Ellertson, 1955 and 1956; and Ritcher and Beer, 1956).

Description

Eggs of *P. crinita*, *P. minor*, and *P. oregonensis* have a smooth, dull surface. They are white in color with a slight yellowish tinge, and ellipsoidal in shape (Figure 5). As the eggs become older they increase in length and width, some becoming almost spherical. As observed by other workers, the chorion is very tough.

Recently laid eggs of *P. crinita* and *P. minor* were nearly equal in size (Table 1). Eggs of four *P. crinita* females, (found July 8 and

Table 1. EGG SIZES OF THREE SPECIES OF *Pleocoma*

Species	Eggs		Length		Width		Average	
	Number	Age	Max.	Min.	Max.	Min.	L.	W.
<i>P. crinita</i>	16	64	5.2	4.3	3.4	2.9	4.7	3.3
	40	unknown	5.7	3.1	4.6	2.8	4.6	3.9
<i>P. minor</i>	8	63	4.9	4.4	3.6	3.3	4.7	3.4
	49	unknown	5.6	4.3	4.6	3.1	4.7	3.4
<i>P. oregonensis</i>	61	unknown	6.5	4.9	5.0	3.9	5.9	4.6

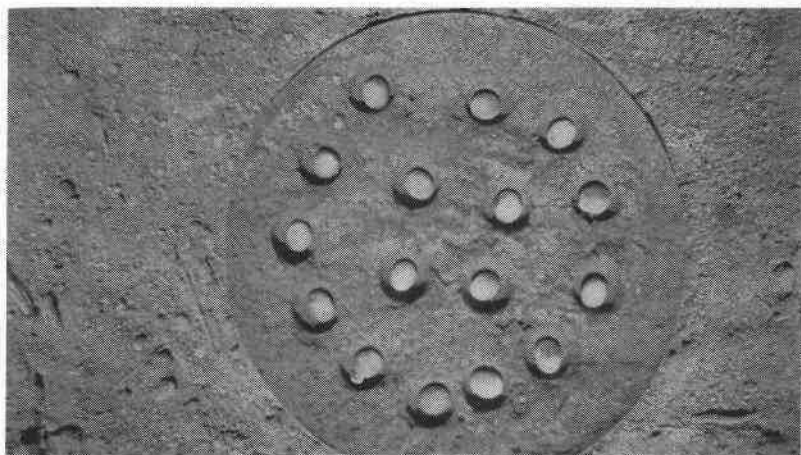


FIGURE 5. Eggs of *Pleocoma*.

11, 1955) and eggs from two *P. minor* females (found June 27, 1956 and June 17, 1957) were also of nearly equal size (Table 1). The eggs of *P. oregonensis* are larger than those of the other two species. Eggs (soil cages July 20, 1955) from two females averaged 5.9 mm. in length and 4.6 mm. in width (Table 1).

Egg Development

Egg development is very slow in *P. crinita* and limited observations indicate the same is true of *P. minor* (Table 2). Measurements taken of developing *P. crinita* eggs in 1954, 1955, and 1957 show that eggs measured in March were smaller than those measured in April and May.

Table 2. EGG DEVELOPMENT OF TWO SPECIES OF *Pleocoma*

Species	Mated	Dissected	Range in egg	
			Length	Width
<i>P. crinita</i>	Fall 1953	March 14, 1954	1.6-3.1	1.3-2.0
		March 20, 1954	2.3-3.9	1.5-2.6
		April 12, 1954	2.5-4.4	1.8-2.8
		April 15, 1954	1.6-4.1	1.1-2.8
	November 1954	April 6, 1955	1.6-3.3	1.3-2.5
		May 14, 1955	2.9-4.4	2.0-3.6
		April 30, 1957	3.1-4.6	2.8-3.6
<i>P. minor</i>	Fall 1956	April 30, 1957	3.1-4.6	2.8-3.6
	October 1956	April 18, 1957	2.1-4.1	1.3-3.1

Time of Deposition

Females of *P. crinita* and *P. minor* mating in October and November do not deposit eggs until May, June, and into July of the following year. Limited observations indicate that *P. oregonensis* females mating in November deposit eggs in June.

On June 4, 1954, a *P. crinita* female and 47 eggs were found in the soil in the McKeown orchard near Odell, Oregon. This female later deposited 5 additional eggs in the laboratory.

In 1955, *P. crinita* began egg deposition the latter part of May. In the laboratory, one individual had deposited three eggs by May 27. Two females, discovered in the field on May 30, had deposited 2 and 3 eggs respectively. Another individual, dug on June 9, had laid 20 eggs, and upon dissection 12 additional eggs were found. On June 21, a female with 14 eggs was taken from the McKeown orchard, and dissection revealed 28 unlaidd eggs.

Two *P. crinita* females taken from soil cages on May 17, 1956, were found to have deposited 6 and 10 eggs respectively. These females failed to deposit additional eggs in the laboratory.

Five *P. crinita* females taken in the B. Hukari orchard on April 30, 1957, were placed in earth-filled quart jars and when examined May 22, were found to have deposited 19, 24, 26, 29, and 32 eggs respectively. All five females continued egg laying in the laboratory during the remainder of May, with one female continuing egg deposition until June 24.

Pleocoma minor begins egg deposition in mid- to late May and continues through June. One female discovered in the G. Ogden orchard June 27, 1956, had a clutch of eggs intact in the soil beneath her. This individual was still alive, but later dissection revealed egg deposition was completed.

Three *P. minor* females mated October 22, 1956, were kept in a temperature cabinet in soil-filled quart jars at temperatures approximating those in the soil where eggs are laid (37-56° F.). Examination of the jars on May 22, 1957, revealed the females had deposited 2, 8, and 10 eggs respectively. Disturbance apparently disrupted egg deposition because these females failed to continue egg laying. Two other individuals, mated at the same time as the preceding three, were allowed to remain in the soil under natural conditions. On May 27, 1957, these females were dug from the soil and found to have deposited 22 and 30 eggs respectively. Both females failed to deposit additional eggs. A female discovered on June 17, with 48 eggs, deposited one additional egg in the laboratory. Another individual dug from an orchard on June 25, was found to have deposited 46 eggs and she also deposited one egg in the laboratory.

Limited observations indicate egg laying by *P. oregonensis* occurs in June. Two females were mated November 6, 1954, and placed in soil cages. The soil cages were examined July 20, 1955, and both females were found dead after having deposited 35 and 48 eggs respectively. On November 8, 1955, three females were mated and retained in soil cages at The Dalles. The three cages and contained females were examined June 20, 1956. One individual (dead) had deposited no eggs. Another (dead) had deposited 9 eggs. The third individual was alive and had deposited 41 eggs. She later laid 7 additional eggs in the laboratory.

Number of Eggs

Under laboratory and field conditions, 17 *P. crinita* females deposited a total of from 20 to 62 eggs. Seventeen *P. minor* females deposited from 2 to 63 eggs under the same conditions. Five *P. oregonensis* females deposited 9 to 48 eggs under laboratory and field conditions. In several instances some eggs had begun hatching, but the newly hatched larvae had not dispersed from the small cavities in which the eggs had been laid. In such cases, eggs and larvae were considered a unit of eggs (Table 3).

In 1957, individual *P. crinita* and *P. minor* females were isolated in the laboratory in an attempt to ascertain the number of eggs laid in a given period. The number of eggs deposited varied from 2 to 8 in a 48-hour period, to 6 in a 64-hour period. Often, only one egg was laid in a 72-hour period. As the frequency of handling increased, the number of eggs decreased. A female of *P. oregonensis*, after depositing 41 eggs in the field by June 20, 1956, continued laying eggs in the laboratory. She laid 7 eggs between June 20 and June 30.

Place and Manner of Deposition

Females of the three species deposit their eggs in the soil in rather a characteristic manner. Ritcher and Beer (1956) found that a *P. dubitalis dubitalis* female deposited her eggs individually, beginning at the bottom of a burrow and moving upward in a spiral fashion within a vertical core of pulverized soil.

Females of *P. crinita*, *P. minor*, and *P. oregonensis* deposit their eggs in the same manner. Eggs are deposited individually, each in a cavity slightly larger than the egg. The female moves upward in a spiral fashion, pulverizing a core of soil and depositing eggs therein. After deposition of her eggs, the female dies and can be found in the soil, usually immediately above the topmost egg.

The bottom-most egg or eggs are found at varying depths in the soil (Table 3). The depth at which *P. crinita* females deposit the first eggs was found to range from 14.5 to 28.5 inches. *Pleocoma minor* females were found to begin egg deposition at depths ranging from

Table 3. DEPTH RANGE OF EGGS AND NEWLY HATCHED LARVAE FOR THREE SPECIES OF *Pleocoma*

Species	Range	Eggs	Larvae	Total in clutch	Vertical distribution
	<i>Inches</i>				<i>Inches</i>
<i>P. crinita</i>	13.0-14.5	14	.....	14	1.5
	11.0-16.0	1	36	37	5.0
	*13.0-16.0	20	.....	20	3.0
	*14.0-18.0	50	.....	50	4.0
	14.5-18.5	.....	20	20	4.0
	15.5-18.5	3	23	26	3.0
	19.5-20.0	.....	20	20	1.5
	20.5-20.5	2	.....	2	0.0
	16.0-21.0	1	31	32	5.0
	*18.0-23.0	43	.....	43	5.0
	22.5-23.0	3	.....	3	0.5
	20.5-24.5	47	.....	47	4.0
	*21.0-27.0	9	53	62	6.0
	22.0-28.5	17	44	61	5.5
<i>P. minor</i>	14.5-17.0	.....	34	34	2.5
	14.5-17.5	1	35	36	3.0
	15.5-18.0	1	32	33	2.5
	14.0-19.0	.....	data lost	.....	5.0
	17.5-20.5	45	.....	45	3.0
	23.0-24.0	14	.....	14	1.0
	23.0-26.5	46	.....	46	3.5
	24.0-27.0	63	.....	63	3.0
	24.0-27.0	41	.....	41	3.0
	26.5-28.5	31	.....	31	2.0
	26.5-28.5	42	.....	42	2.0
	26.0-29.5	34	.....	34	3.5
<i>P. oregonensis</i>	*46.0-48.0	9	.....	9	2.0
	*43.0-48.0	35	.....	35	5.0
	*43.0-48.0	48	.....	48	5.0
	*43.0-48.0	48	.....	48	5.0
	..... 23.0	35	.....	35	.....

* From soil cages

17 to 29.5 inches. On June 28, 1956, one clutch of *P. oregonensis* eggs dug from the field disclosed the deepest egg at 23 inches. Females of this species, when isolated in soil cages, burrow to the bottom of the cages (4 feet) before beginning egg deposition.

The vertical distance occupied by eggs in the pulverized core of soil depends to a degree on the number of eggs (Table 3). In several instances when females were in the process of depositing eggs, counts and measurements of the space occupied were nonetheless

made. If part of the clutch had already hatched, but the larvae had not yet dispersed from the cavities in which the eggs were laid, the eggs and larvae were considered as a unit of eggs.

The vertical distance occupied by *P. crinita* eggs ranged to 6 inches. The vertical distribution of *P. minor* eggs varied from 1 inch to 5 inches. Under laboratory conditions 4 egg masses of *P. oregonensis* occupied a vertical distance of from 2 inches to 5 inches.

Length of Egg Stage and Time of Hatching

Eggs were incubated in a constant temperature cabinet at 54°-60° F., from May 22 to August 18, 1957. The temperature in the incubator was changed weekly to correspond with the rise in the outdoor soil temperature at the 18-inch level.

Laboratory observations indicate that the egg stage of *P. crinita* may average 7 days longer than for *P. minor*. The length of the egg stage for 24 *P. crinita* eggs of known age averaged 69 days (Table 4). These eggs hatched between August 4 and 18. Sixteen *P. minor* eggs of known age averaged 62 days in the egg stage (Table 4). The hatching period began August 1 and extended to August 10.

Eggs of the three species collected in the field during May, June, and July were incubated in the laboratory to determine the onset of hatching. Temperatures in the constant temperature cabinet ranged from 54° F. in late May to 60° F. in early September.

Table 4. LENGTH OF EGG STAGE FOR *P. crinita*

Date deposited	Maximum age	Eggs	Date of hatch	Days in egg stage
	<i>Hours</i>			
May 22-25	64	6	August 4	71
	64	3	August 6	73
May 25-27	48	3	August 6	71
	48	2	August 4	69
May 27-30	72	1	August 6	67
	72	1	August 5	66
June 1-4	72	1	August 8	65
June 4-7	72	2	August 11	67
June 7-10	72	1	August 13	65
	72	1	August 14	66
June 10-13	72	1	August 15	64
	72	1	August 17	66
June 13-15	48	1	August 18	65
Total		24		
Average days				69

Records for a period of four years (1954, 1955, 1956, and 1957) show the hatching period of *P. crinita* eggs to extend from July 21 to September 2. The records of 1956 and 1957, show a hatching period for *P. minor* eggs to be from July 15, to August 21 (Table 5). Two years' records (1955 and 1956) for *P. oregonensis*, show a hatching period from July 25 to August 27.

Table 5. LENGTH OF EGG STAGE FOR *P. minor*

Date deposited	Maximum age	Eggs	Date of hatch	Days in egg stage
	<i>Hours</i>			
May 27-28	48	5	August 1	64
	48	2	August 2	65
May 29-June 1	63	2	August 1	61
	63	2	August 2	62
June 4-7	72	2	August 4	58
	72	2	August 5	60
June 10-13	72	1	August 10	58
Total		16		
Average days				62

LARVAL STAGE

This is the stage of economic importance when associated with cultivated plants. Four descriptions of *Pleocoma* larvae have appeared in the literature. While two of these papers, Osten Sacken (1874) and Hayes and Chang (1947), were based on only single specimens, Ritcher (1947 a and b) based his description on a series of specimens and a cast larval skin. A late instar of *P. crinita* is illustrated in Figure 6.

Soil as a Factor Affecting Vertical Distribution of Larvae

The distribution of orchard tree roots is largely a matter of the character of the soil in which the tree grows. The character of the subsoil is one of the most important factors influencing the depth of rooting. In the Hood River Valley, the soil and its effect on penetration of tree roots directly affects the vertical distribution of *Pleocoma* larvae. Indications are that this effect also controls the vertical distribution of *P. oregonensis* larvae in cherry orchards surrounding The Dalles.

In certain districts of the Hood River Valley, roots of apple and pear do not penetrate the soil more than 24-30 inches because

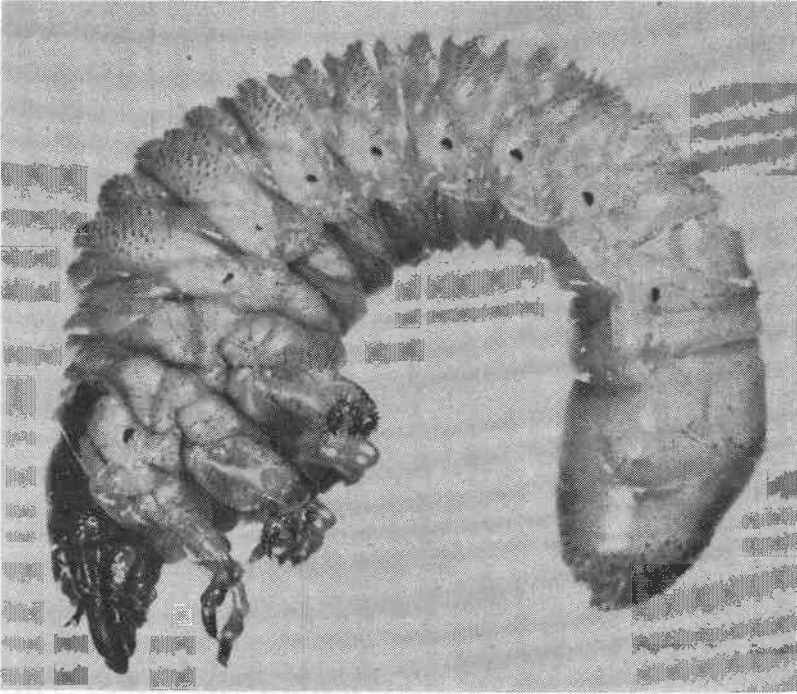


FIGURE 6. Larva of *P. crinita* (late instar).

of the restrictive sub-soil layer. In other districts, the loose, open subsoil allows root penetration to a depth of 60 inches. In some districts surrounding The Dalles, cherry roots penetrate the soil to depths exceeding 60 inches.

Larvae of *P. crinita* found in those districts with the root zone limited to a 24- to 30-inch depth have a vertical distribution ranging from 3.5 to 29 inches (Table 6). The greatest number of grubs occurs in the 8- to 24-inch level in orchards with a 30-inch root zone. In those orchards with roots occupying only 24 inches, the greatest number of grubs are found from 8 to 16 inches. Larvae of *P. crinita* are not known to occur in districts with loose, open subsoils so it was not possible to determine larval distribution of this species in situations where the roots go deeper.

Grubs of *P. minor* occur in localities where roots are restricted to a 24-inch zone and also where root penetration is to a depth of 60 inches (Table 7). Larvae of this species occurring in localities with a 24-inch root zone are found in greatest numbers in the 8- to 20-inch level, while grubs in the districts with a 60-inch root zone are found

Table 6. VERTICAL DISTRIBUTION OF *P. crinita* LARVAE

Depth range	Apple root depth		Pear root depth
	30 inches	24 inches	24 inches
<i>Inches</i>	<i>Larvae</i>	<i>Larvae</i>	<i>Larvae</i>
0- 3.5	0	3	0
4- 7.5	19	38	16
8-11.5	24	71	42
12-15.5	23	115	40
16-19.5	15	116	37
20-23.5	4	51	9
24-27.5		18	
28-29		2	

in the greatest numbers at the 16- to 44-inch level. The overall depths at which grubs of *P. minor* are found in the Hood River Valley vary greatly, ranging from 3.5 to 59 inches. Trees with roots restricted to a 36- to 38-inch zone by a plate of solid rock were encountered at the G. Ogden apple orchard southwest of Odell, Hood River County. Larvae of *P. minor* were discovered within one inch of this plate of rock. In another instance a tree growing on the edge of a plate of rock was found to have some roots restricted to a 40-inch zone while other roots extended to a depth of over 55 inches. Larvae were found confined by the plate of rock and also to a depth of 59 inches in the area occupied by roots.

Table 7. VERTICAL DISTRIBUTION OF *P. minor* LARVAE

Depth range	Apple root depth			Pear root depth
	24 inches	40 inches	60 inches	57 inches
<i>Inches</i>	<i>Larvae</i>	<i>Larvae</i>	<i>Larvae</i>	<i>Larvae</i>
0- 3.5	0	0	2	0
4- 7.5	4	0	3	0
8-11.5	13	0	6	0
12-15.5	14	2	18	1
16-19.5	26	5	20	0
20-23.5	5	3	18	3
24-27.5		11	21	4
28-31.5		28	26	2
32-35.5		7	22	6
36-39.5		7	19	5
40-43.5			15	3
44-47.5			3	7
48-51.5			4	0
52-55.5			2	2
56-59.5			1	

At The Dalles, *P. oregonensis* larvae are associated with cherry roots to a depth of 48 inches. Several samples dug from beneath Ponderosa pine in Sorosis Park, The Dalles, were found to contain grubs to a depth of 38 inches.

Seasonal Soil Temperatures

A study of soil temperatures during a 4-year period, 1954-1957, indicates that larvae of *P. crinita* live in an environment with limited fluctuations in temperature. This is illustrated by Figure 7, which shows the seasonal soil temperatures for 1955 in an infested Hood River orchard at the 6- and 18-inch level.

The greatest monthly temperature fluctuation at the 6-inch level occurred in June and September. In June the fluctuation was 12° F., while in September it was 13° F. The yearly change at the 6-inch level was 32° F. The minimum temperature at the 6-inch level occurred in December with a reading of 35° F., and the maximum for December was 40° F. The maximum temperatures occurred in the months of June, July, August, and September with readings of 66°, 67°, and 66° F. respectively.

Monthly changes at the 18-inch level were not as pronounced as at the 6-inch level. The greatest fluctuation, occurring in May and October, was 70° F., and the yearly change was 27° F. The minimum temperatures at the 18-inch level occurred in January, February, March, and December when the temperatures were 38°, 38°, 38°, and 39° F. respectively. The maximum temperatures occurred in July, August, and September with readings of 64°, 65°, and 63° F. respectively.

On two occasions, soil temperatures were recorded at the time of digging for *P. oregonensis* larvae at The Dalles. Soil temperatures beneath Ponderosa pine, Sorosis Park, on August 16, 1956, were found to be 67° F. at 9 inches, and 63° F. at the 30-inch level. On June 12, 1957, soil temperatures beneath a sweet cherry tree on Sky-line Road, The Dalles, were 63° F. at 24 inches and 60° F. at 30 inches.

These seasonal changes in soil temperatures do not influence the overall distribution of grubs in the soil. A few *P. crinita* and *P. oregonensis* grubs were discovered close to the soil surface on several occasions in late fall and winter. Comparison of the vertical distribution of *P. crinita* larvae in November, December, and January with the distribution during July, August, and September disclosed no significant differences in distribution. Possibly a scattered few of those in the 3- to 4-inch level move upward closer to the soil surface once the high soil temperatures of June, July, August, and September have moderated.

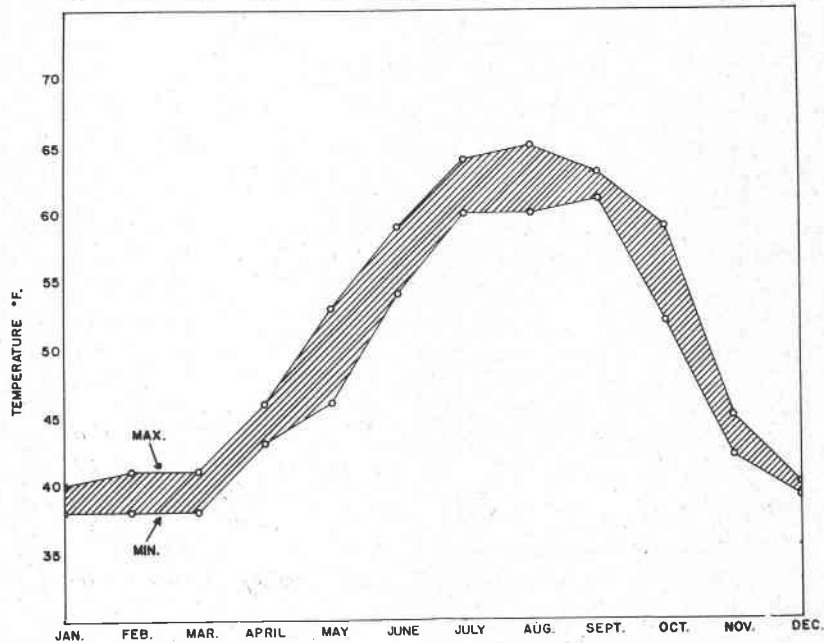
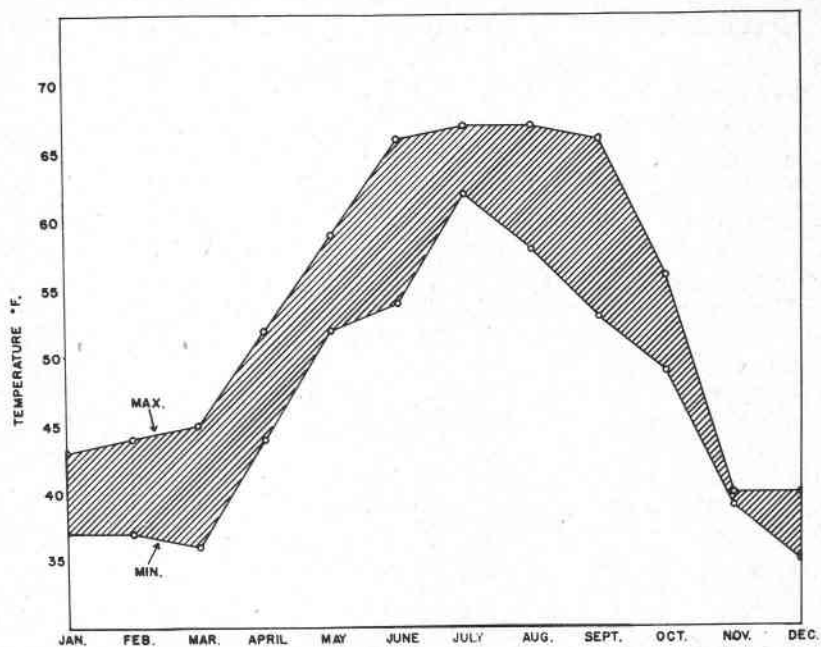


FIGURE 7. Top, soil temperatures (1955) at the 6-inch level. Bottom, soil temperatures at the 18-inch level from the D. McKeown apple orchard, Odell, Hood River County.

Periods of Feeding

In general, larvae of *P. crinita* and *P. minor* feed throughout the greater part of the year. The feeding period of small larvae is difficult to determine because they are usually found in close proximity to fibrous roots. Only when numerous larger larvae are discovered in samples dug from beneath fruit trees can one readily determine if the larvae are feeding. These larvae attack the larger roots and are easily detected while feeding, or are still close to freshly gouged-out areas on the roots. Fewer large larvae were found feeding during the moult period and in late January to mid-February.

Larvae of *P. oregonensis* feed on sweet cherry roots at The Dalles during March, April, May, and June, but no larvae were found feeding on roots in September. No samples have been taken during the remainder of the year.

Possibly late instars of *Pleocoma* feed sparingly or not at all since Areekul (1957) found that the epithelial cells were reduced and degenerated in late instars of *P. crinita*.

Moultng

Most larvae of *P. crinita*, *P. minor*, and *P. oregonensis* moult during the summer months. Prior to moulting, each larvae prepares a cell and moults therein, often consuming its cast skin soon after.

Sample diggings made in orchards every month of the year disclosed that larvae of *P. crinita* moult but once a year. The earliest moulting occurred August 11, 1955, and the latest September 27, 1954. Recently-moulted larvae with cast skins are most commonly found in mid-September. Larvae kept in the laboratory for a period of one year moulted during August and September.

Pleocoma minor larvae sampled for a period of two years (1956 and 1957) in the same manner as the previous species, were also found to moult once a year in a cell constructed by the larvae. The earliest moulting larvae were found on June 12, 1956, and the last on August 31, 1956. Limited observations indicate *P. oregonensis* larvae moult during August. A large number of larvae found in the soil on August 16, 1956, were moulting, or moulted in the laboratory within one week.

Instars

All other Scarabaeidae have only three instars, but *P. crinita* and *P. minor* have many instars and indications are that *P. oregonensis* follows the same pattern. This, together with the fact that *Pleocoma* larvae moult but once a year, indicates an exceedingly long life cycle of perhaps 9 to 13 years.

The following methods were employed in determining the number of instars. Eggs of *P. crinita* and *P. minor* were incubated in the laboratory (54°-60° F.). A large number of the newly hatched larvae were preserved shortly after hatching and measurements were made of head capsule widths to establish a range for the first instar. Other newly hatched larvae were allowed to undergo a moult which occurred about 21 days later. These were then preserved and measurements made of head capsule widths to establish a range for the second instar. First instars can be distinguished by the distinct shape of their mandibles.

Head capsules of larvae dug in the field were measured, larvae then placed individually in soil-filled, 3-ounce salve boxes and stored in a constant temperature cabinet (37°-60° F.). Larvae were checked monthly for moulting and head capsule width re-measured. Also large numbers of larvae were dug before the moulting period, measured, then re-measured after the moult. In many cases it was possible to obtain three separate head capsule measurements for a single larvae. Head capsule widths of prepupae were also determined, which gave a range of measurements for known mature larvae.

The range in head capsule measurements for laboratory-reared first instars of *P. crinita* was 1.99-2.26 mm. The head capsules of first instar grubs collected in the field measured 2.02-2.33 mm. Second instars reared in the laboratory had head capsules measuring 2.29-2.53 mm. Those discovered in the field ranged from 2.29-2.53 mm. *Pleocoma crinita* does not pupate before the ninth instar. Some larvae may continue moulting past the ninth instar and have what appear to be 13 instars before pupating (Table 8).

The same techniques were employed in establishing the instars of *P. minor* as were used in the case of *P. crinita*. Maximum widths of head capsules of the first instars reared in the laboratory ranged from 1.85-2.26 mm., while newly-hatched larvae, collected in the field from cavities in which eggs had been deposited, measured 1.89-2.23 mm. Head capsules of second instars reared in the laboratory ranged from 2.23-2.45 mm. in width. Those collected in the field measured 2.33-2.45 mm. *Pleocoma minor* is in at least the ninth instar before pupation occurs. Some larvae of this species continue moulting after the ninth instar and may have what appear to be 13 instars. (Table 8). Limited investigation of *P. oregonensis* larvae indicate they also have a large number of instars.

In comparing the range of measurements of respective instars it was found that the measurements of *P. crinita* larvae were larger than those for *P. minor* larvae. Also it is to be noted that larvae of both species may pupate during any of the instars following the ninth.

Table 8. MAXIMUM WIDTH OF HEAD CAPSULE FOR THE INSTARS OF *P. crinita* AND *P. minor*

Instar	Grubs	<i>P. crinita</i>		Remarks	Grubs	<i>P. minor</i>		Remarks
		Min.	Max.			Min.	Max.	
		<i>Mm.</i>	<i>Mm.</i>			<i>Mm.</i>	<i>Mm.</i>	
1.....	94	1.99	2.26	Reared	60	1.85	2.26	Reared
1.....	40	2.02	2.33	Field	31	1.89	2.23	Field
2.....	42	2.29	2.53	Reared	30	2.23	2.45	Reared
2.....	37	2.29	2.53	Field	25	2.33	2.45	Field
3.....	62	2.53	3.10	Field	48	2.46	2.94	Field
4.....	92	3.27	4.09	Field	88	3.10	3.43	Field
5.....	53	3.59	4.74	Field	44	3.43	3.92	Field
6.....	73	4.74	5.39	Field	59	4.09	4.58	Field
7.....	101	5.39	6.38	Field	92	4.58	5.39	Field
8.....	93	6.05	7.03	Field	88	5.39	6.21	Field
9.....	67	7.03	7.68	Pupated	52	6.05	6.70	Pupated
10.....	69	7.52	8.18	Pupated	55	6.70	7.36	Pupated
11.....	54	8.01	8.83	Pupated	30	7.19	7.52	Pupated
12.....	50	8.67	9.48	Pupated	37	7.68	8.67	Pupated
13.....	32	9.16	10.14	Pupated	11	8.83	10.63	Pupated

Larval Populations

Some orchards or portions of orchards in the Hood River Valley have large populations of grubs, but the number of grubs per square foot beneath individual trees varies. To determine the population of grubs beneath a tree, soil from a sample area was removed layer by layer with a hand trowel. The sample area, within the "drip" portion of the tree, was 36 inches square and extended 4 or 6 inches below the depth at which the last larva was found.

Samples dug from one 3-acre apple orchard near Odell revealed that the population of *P. crinita* grubs varied from .44 to 7.78 grubs per square foot, or from 19,350 to 338,800 grubs per acre. Another 1-acre plot of apple trees was found to have .78 grubs per square foot. Two acres of pears, sampled in 1955 and 1956, was found to average 2.67 grubs per square foot.

Pleocoma minor grubs are also abundant in certain localities. A 3-acre apple and pear orchard southwest of Odell had an average of 3.66 grubs per square foot. Another apple orchard southeast of Odell had 21 grubs per square foot, distributed to a depth of 60 inches.

At present, *P. oregonensis* larvae are not known to occur in large numbers at The Dalles. Four samples, taken from beneath Ponderosa pine in Sorosis Park, revealed grubs to be present in

limited numbers. The sample ranged from 0 to 1.67 grubs per square foot. Three samples taken from beneath three cherry trees on Sky-line Road, disclosed a range of .06 to .33 grubs per square foot.

PREPUPAL STAGE

Pleocoma crinita and *P. minor* were found to have a rather distinct prepupal stage (Figure 8) but the time of onset is difficult to determine.

In this stage, larvae are creamy-white in color, flaccid, immobile, and may be found stretched out on their dorsa in a cell constructed by the last larval instars. The larvae do not feed during this stage and indications are that the stage may be over 30 days in length.

Prepupae of *P. crinita* may be discovered in the soil from late June to early July, followed by pupation in late July and early August. *Pleocoma minor* prepupae were commonly found on June 17 and 25, 1957. Some of these did not pupate until July 12-20, 1957, but some pupated at an earlier date.

PUPAL STAGE

Description of Pupa and Pupal Cell

The white, exarate pupae of *P. crinita* and *P. minor* have no processes on the pronotum such as are found in certain other scarabaeid pupae. Sex of *Pleocoma* pupae can be determined by examination of the antennae and apical horn. In the males, the antennal club

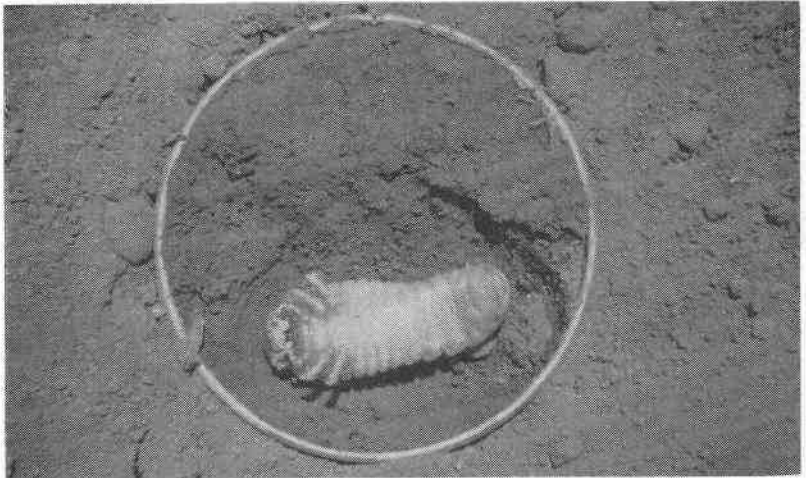


FIGURE 8. Prepupa of *P. crinita*.

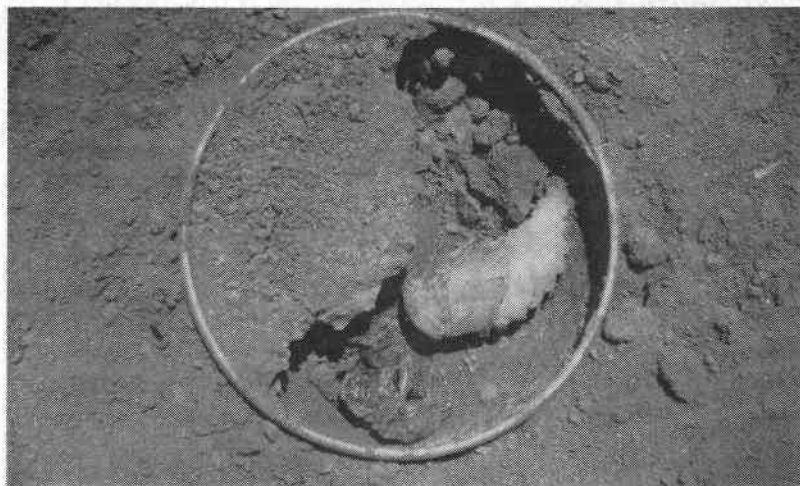


FIGURE 9. Pupa of *P. crinita*.

is prominent while the apical horn is pointed; in females the antennal club is not prominent and the apical horn is rounded.

As in the adults, there is a considerable range in size of *Pleocoma pupae*. Only a limited number of pupae have been measured to give approximate size. Male pupae of *P. crinita* are approximately 41 mm. in length; the female pupae are 44 mm. in length. Pupae of *P. minor* are smaller, males being 33 mm. in length and females being 35 mm.

Pupae are found in pupal cells prepared by the last larval instars, lying on their dorsa and occasionally on their sides, but rarely on their venters (Figure 9). The pupal cells are 2 to 2.5 inches in length, .75 to 1 inch in diameter, and are horizontal to the soil surface. The cast larval skin is posterior to the pupa in the cell.

Depth of Pupation

Pupae of *P. crinita* and *P. minor* are found scattered in the soil at depths which correspond closely to the vertical distribution of larvae. Fifty-six *P. crinita* pupal cells were observed at depths ranging from 5.5 to 24 inches (See also Ritcher and Olney, 1953, and Ellertson, 1955). Sixty-five pupal cells of *P. minor* were found at depths ranging from 6 to 42 inches. Measurements are recorded only for those in which a prepupa, a live or dead pupa, or a cast pupal skin was found (Table 9).

Table 9. DEPTHS OF PUPATION FOR *P. crinita* AND *P. minor*

Depth range	<i>P. crinita</i> root zone	<i>P. minor</i> root zone	
	30 inches	24 inches	60 inches
<i>Inches</i>	<i>pupae</i>	<i>pupae</i>	<i>pupae</i>
5.5-12	14	14	10
12.5-18	29	7	12
18.5-24	13	....	7
24.5-30 .....	....	....	6
30.5-36 .....	....	....	5
36.5-42 .....	....	....	4

Two pupal cells of *P. oregonensis* have been found in the vicinity of The Dalles, Oregon. One dead male with pupal skin was taken at a depth of 33 inches from the J. J. Foster cherry orchard near Mill Creek, September 13, 1954. The other pupal cell, containing a dead female and pupal skin, was discovered at 37 inches in Sorosis Park on August 22, 1956. These two records fall within the range at which larvae of this species are known to occur.

Time and Duration of Pupal Stage

The onset of pupation is difficult to ascertain in the field and can be determined only by frequent digging during the summer or by use of a temperature cabinet indoors. *Pleocoma minor* pupates and transforms into the adult stage at an earlier date than does *P. crinita* (Tables 10 and 11). This is further correlated with the time of adult flight activity.

Approximate beginning dates for pupation of *P. crinita* in the field were secured in each of four years. These dates were August 5, 1954; July 27, 1955; August 10, 1956; and July 24, 1957.

In 1955, 26 *P. crinita* larvae pupated in a constant temperature cabinet where temperatures simulated outdoor soil temperatures at the 18-inch level (58°-60° F.). Under these laboratory conditions pupation began July 27 and continued to August 14. Two *P. crinita* larvae pupated July 19, 1957 under laboratory conditions. The length of the pupal stage for *P. crinita* ranged from 39 to 53 days with an average of 44 days.

The first pupa of *P. minor* was discovered during 1956 in the W. Gale apple orchard on Dethman Ridge near Odell, Oregon. This single female pupa was discovered August 1, at a depth of 10 inches. On August 8, 1956, one male pupa at a depth of 24 inches was collected in the G. Ogden orchard southwest of Odell, Oregon. On June

Table 10. TIME AND DURATION OF PUPAL STAGE FOR *P. crinita*, 1955 AND 1957

Date of pupation	Became adult	Duration in days	Sex
July 27, 1955.....	September 16, 1955	53	Female
July 29, 1955.....	September 9, 1955	43	Female
July 31, 1955.....	September 15, 1955	47	Male
July 31, 1955.....	September 16, 1955	48	Male
August 1, 1955.....	September 14, 1955	45	Female
August 2, 1955.....	September 17, 1955	47	Male
August 2, 1955.....	September 17, 1955	47	Male
August 2, 1955.....	September 17, 1955	47	Male
August 3, 1955.....	September 19, 1955	48	Male
August 3, 1955.....	September 14, 1955	43	Female
August 3, 1955.....	Pupa died	....	Female
August 5, 1955.....	September 21, 1955	48	Male
August 6, 1955.....	September 18, 1955	44	Female
August 7, 1955.....	September 19, 1955	44	Female
August 9, 1955.....	September 21, 1955	44	Female
August 9, 1955.....	September 22, 1955	45	Female
August 12, 1955.....	September 19, 1955	39	Female
August 12, 1955.....	September 19, 1955	41	Male
August 13, 1955.....	September 21, 1955	40	Male
August 13, 1955.....	September 21, 1955	40	Male
August 13, 1955.....	September 21, 1955	40	Male
August 13, 1955.....	September 21, 1955	40	Male
August 13, 1955.....	September 21, 1955	40	Male
August 13, 1955.....	September 21, 1955	40	Male
August 13, 1955.....	September 22, 1955	41	Male
August 13, 1955.....	September 23, 1955	42	Male
August 14, 1955.....	Pupa died	....	Female
July 19, 1957.....	September 9, 1957	52	Male
July 19, 1957.....	August 28, 1957	41	Female
Average.....		44	

14, 1957, a single male pupa at a depth of 8 inches was dug from the W. Laraway apple orchard at the junction of East Side and Whiskey Creek roads.

A total of 4 *P. minor* pupae were reared in a constant temperature cabinet from grubs taken March and June, 1956, in the Ogden orchard. Of the 119 live grubs taken in March, one became a pupa June 28. The June collection yielded 62 grubs, of which 3 pupated on the following dates; June 26, July 21, and July 23, 1956.

Thirty-six prepupae of *P. minor* were dug from the Laraway and Hagen orchards on June 14, 17, and 25, 1957. Under laboratory conditions 17 of them pupated, beginning June 17 and continuing to August 1. The length of the pupal stage for *P. minor* ranged from

Table 11. TIME AND DURATION OF PUPAL STAGE FOR *P. minor*, 1956 AND 1957

Date of pupation	Became adult	Duration in days	Sex
June 26, 1956.....	Pupa died	....	Male
June 28, 1956.....	Pupa died	....	Male
July 21, 1956.....	September 1, 1956	42	Female
July 23, 1956.....	September 2, 1956	41	Female
June 17, 1957.....	Pupa died (1957)	....	Male
June 19, 1957.....	August 3, 1957	45	Female
June 22, 1957.....	August 7, 1957	46	Male
June 25, 1957.....	Pupa died	....	Male
June 27, 1957.....	Pupa died	....	Male
June 27, 1957.....	Pupa died	....	Male
June 30, 1957.....	August 15, 1957	46	Male
July 2, 1957.....	August 20, 1957	49	Male
July 12, 1957.....	Pupa died	....	Female
July 12, 1957.....	August 27, 1957	46	Female
July 17, 1957.....	September 3, 1957	48	Male
July 17, 1957.....	Pupa died	....	Female
July 18, 1957.....	Pupa died	....	Female
July 18, 1957.....	September 3, 1957	47	Female
July 20, 1957.....	September 9, 1957	51	Male
July 28, 1957.....	September 10, 1957	44	Female
August 1, 1957.....	September 14, 1957	44	Female
Average.....		47	

44 to 51 days and averaged 47 days. The mortality rate of *P. minor* pupae was rather high since 9 of 21 pupae died.

The average length of the pupal stage for *P. crinita* was 3 days shorter than that for *P. minor* (Tables 10 and 11). The length of the pupal stage did not vary with sex of either species and all transformed into adults the same year that pupation occurred.

KEYS TO THE PLEOCOMA OF WASCO AND HOOD RIVER COUNTIES, OREGON

Linsley, in 1946, published a key to the species of male and female *Pleocoma*. Only males of *P. crinita*, *P. minor*, and *P. oregonensis* were characterized in this key since the females were unknown. The following keys include females as well as males of all three species.

SEXES

- Antennal lamellae long. Vertical horn prominent, pointed at apex.
Hind wings entire and functional.....males
- Antennal lamellae short. Vertical horn not prominent, rounded at
apex. Hind wings vestigial.....females

MALES

1. Antennal club with four long lamellae. Pronotal hairs usually
absent. Bicolourous: pronotum dark brown; elytra light red-
brown*oregonensis*
Antennal club with six or seven long lamellae. Pronotal hairs
nearly always present. Unicolorous or bicolorous; if bicolor-
ous, pronotum lighter in color 2
2. Median longitudinal impression of pronotum with long erect hairs
present along the entire length and scattered over other por-
tions of pronotum; pronotal puncta coarse. Color red-brown
to black-brown*crinita*
Median longitudinal impression of pronotum with short erect
hairs limited to the anterior one-third to one-half and usually
absent from other portions of pronotum; pronotal puncta fine.
Brown-black to black; pronotum often reddish-black.....*minor*

FEMALES

1. Antennal club with four short lamellae. Pronotal hairs usually
absent*oregonensis*
Antennal club with five or six short lamellae. Pronotal hairs
present 2
2. Median longitudinal impression of pronotum with hairs present
along entire length; a few minute hairs scattered over other
portions of pronotum. Body unicolorous; pronotum and elytra
red-brown*crinita*
Median longitudinal impression of pronotum with hairs limited
to anterior one-third to one-half; hairs usually absent from
other portions of pronotum. Body unusually unicolorous,
occasionally bicolorous; pronotum usually red-brown, occa-
sionally black-brown; elytra red-brown.....*minor*

ADULT STAGE

Period of Transformation

Pupae of *P. crinita* begin transforming into adults in late August and continue until late September. Transformation of *P. minor* pupae begins in late July and continues to early September.

Under laboratory conditions (58°-60° F.), *P. crinita* pupae began transforming into adults on August 28 and continued to do so until September 23 (Table 10). In the field, the first new adults have been found in their pupal cells on August 25; however, the majority of pupae transform in early to mid-September. Pupae are rarely found after September 25.

Pleocoma minor pupae began transforming into adults on August 3, 1957, under laboratory conditions (of 58°-60° F.) (Table 11). Newly formed adults and pupae were collected in the field from pupal cells on August 1, 1956; no pupae were found in a sample digging on August 31, 1956. The earliest that new adults had been found in the field was July 26, 1957. The majority of pupae transform in August, with pupae rarely being found after the first week of September.

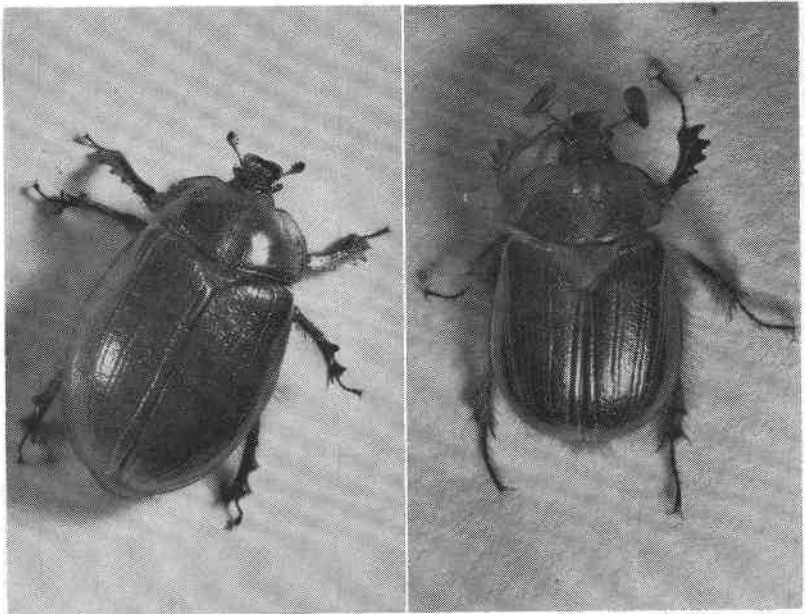


FIGURE 10. Left, female of *P. crinita*. Right, male of *P. crinita*.

Table 12. MATING PERIODS FOR THREE SPECIES OF *Pleocoma*

<i>P. minor</i>		<i>P. crinita</i>	<i>P. crinita</i>
Year	Hood River County	Hood River County	Wasco County
1930	October 23		
1931			January 29
1953		November 13-March 8, 1954	
1954	October 19	October 22-January 29, 1954	
1955	September 27-October 27	October 22-March 10, 1956	
1956	September 10-November 13	October 17-March 4, 1957	
1957	September 17-October 30	October 20-January 15, 1958	
1958			January 17

<i>P. oregonensis</i>		<i>P. oregonensis</i>
Year	Wasco County	Sherman County
1953	October 17-November 6	
1954	October 8-November 6	Prior to November 27
1955	October 4-November 28	November 7
1956	October 6-November 9	October 19-November 9
1957	September 30-November 18	November 14

Movement From the Pupal Cell

Within a few days after transformation, adults of *P. crinita* (Figure 10) and *P. minor* begin burrowing from their pupal cells. The burrow, one-half to three-quarters of an inch in diameter, turns gradually upward from the end of the pupal cell. Rarely, adults begin the tunnel at 90° to the pupal cell. During the process of burrowing, pupal cells become filled with tightly-packed, pulverized soil. The last larval exuvia and pupal skin are compressed in this soil at the end opposite the exit tunnel.

In the early stage of burrowing, there is usually a space of 2 to 2.5 inches between pulverized soil and soil through which the adults are tunneling. This space diminishes in length as burrowing progresses. Upon attaining the soil surface, or near the soil surface, adults are closely confined in the pulverized soil.

Season of Adult Activity

The three species of *Pleocoma* in Wasco and Hood River Counties mate during the fall and winter seasons. Periods when mating of the three species was observed are given in Table 12.

Mating of *P. minor* begins in early September and may extend to mid-November, the peak of activity being in late September and

early October. *Pleocoma oregonensis* begins mating in late September or early October and in certain years may continue to late November.

Pleocoma crinita has the longest mating period. Adult activity begins in mid- to late October and is at its height in November and December, with sporadic activity during January, February, and early March. Since activity of adults begins so late in the season, inclement weather in mid- to late November and December often disrupts the normal emergence. During these periods, soil is frozen or covered with snow; however, these disruptions only prolong the period of adult activity. This could be a case of a species not too well adapted to its environment.

Effect of Moisture and Light On Adult Activity. The autumn and winter seasons with their rain and saturated atmosphere have long been associated with flight of *Pleocoma* males. Light, or absence of light, seems to influence the time flight occurs. Males and females of *P. crinita*, *P. minor*, and *P. oregonensis* in Oregon are also influenced by moisture and light or absence of light.

In 1953, Ritcher and Olney recorded flight of *P. crinita* males under the following conditions: November 13, flight finished before 8:00 a.m.; November 14, flight from 5:50-7:25 a.m.; and November 18, one male collected in flight at 6:05 a.m. These same writers stated that November 13 was the first flight of males. A check of the precipitation data for that year showed 1.66 inches of rain fell between September 1 and November 13 inclusive. Observations for the years 1954, 1955, 1956, and 1957 indicate at least 1.00 inch of rain falls between September 1 and the first flight of *P. crinita* males and activity of females near the soil surface.

Flight, in the peak of *P. crinita* activity (November and December), begins at 6:00-6:30 a.m. and continues to 7:00-7:50 a.m. Males rarely fly after 7:45 a.m. and are not known to fly in the late evening hours or at night. Males have been collected during predawn and early dawn under a wide range of climatic conditions, which includes drizzling rain, radiation fog, and an overcast sky with a few broken clouds.

Though *P. minor* belongs to the seven-lamellate group, its flight habits differ from *P. crinita*. Two *P. minor* males were collected October 19, 1954, between 6:00-6:30 a.m. in a drizzling rain, and on October 27, 1955, a male was taken in flight during a slight drizzle at 9:30 a.m. (Linsley, 1956 a). Records for two years (1956 and 1957) indicate male and female activity begins after nearly .50 inches of rain has fallen.

The largest flights of *P. minor* occur in predawn (5:00-5:30 a.m.) and may continue to 7:45 a.m., but males are commonly observed flying in midmorning (11:00 a.m.) and midafternoon (3:00

p.m.). Limited observations indicate that this species has some flight activity during the night hours, since one male was collected at a lighted window in the Oak Grove district at 10:30 p.m. during October, 1957.

Irrigation of orchards with sprinklers during early September apparently influences emergence of *P. minor*. In early September, 1957, two adjoining orchards were observed for emergence of this species. One orchard sprinkled in early September had a large flight of *P. minor* several days before the first limited activity occurred in the unirrigated orchard.

Pleocoma oregonensis belongs to the four-lamellate group. Males of this species have been collected under the same wide range of climatic conditions as males of the other two species. On October 8, 1954, males were collected during the first rain of the season, and flight was noted as occurring at 6:30 a.m. and 4:30 p.m., either in the rain or at times when the atmosphere was saturated (Ellertson, 1956). Four years' observations (1954, 1955, 1956, and 1957) show adult activity begins when nearly .50 inches of rain has fallen. The largest flights occur in predawn (4:45 to 5:15 a.m.) and may continue to 7:00 a.m., but males have been observed and collected in flight at 9:30 a.m. and at 1:00, 2:30, 3:00, and 4:30 p.m.

Adult Populations

As a whole, large flights of *P. crinita*, *P. minor*, and *P. oregonensis* occurred each year during the time the habits of these species were investigated. However, in specific areas there have been differences in size of flight from year to year.

In an orchard where *P. crinita* has been observed since 1953, there has been a decrease in the emergence of adults. In two other orchards large flights were noted in 1956, but in 1957, only an occasional male was seen in flight or found digging down to the few scattered females.

During two years' observations in three orchards where *P. minor* occurs in large numbers, there has been no yearly difference in size of flight. The flight of *P. oregonensis* in Sorosis Park, The Dalles, for 1955, 1956, and 1957 has not fluctuated noticeably.

Adults of all three species are abundant in wooded areas and flights are as large as those that occur in orchard lands. From all indications, *Pleocoma* are restricted to rather localized areas and occur as colonies in the wooded districts, the same as in the orchards.

Behavior of Female During Mating Season

Following transformation, females of three species burrow to the soil surface and upon reaching the surface, turn, re-enter the

old burrow a short distance and await the males. *Pleocoma crinita* females are an exception since they, more commonly than *P. minor* or *P. oregonensis*, may dig a new burrow within inches of the old one.

During mating season, a large number of unmated females of all three species were observed in their burrows. They occurred at depths ranging from .50 to 14 inches. The majority, however, were less than 5 inches deep, head down and covered by pulverized soil.

A female burrow can be detected by the presence of a small mound of pulverized soil which is pushed up in the process of breaking through the thin crust of soil and digging back through the pulverized soil in the old burrow. The plug of pulverized soil beneath which the female is hidden may extend from the soil surface to the depth at which the female is hidden or it may be only one-half inch in thickness.

Males, upon locating a female burrow, begin digging through the plug of pulverized soil and upon finding the female, mate in the burrow. Often two, or as many as nine, males have been observed entering a burrow occupied by a female, with two or more males being crushed in the process (Ellertson, 1956). Under laboratory conditions females of the three species will copulate with more than one male.

Behavior of Female Following Mating

After copulation, females of *P. minor* and *P. oregonensis* soon retreat to lower depths in the soil; *P. crinita* females, however, remain near the soil surface for as long as 5 months.

During November and December, 1953, numerous *P. crinita* females were dug from burrows. Depth, position, and amount of pulverized soil covering the individual was recorded, then the females were returned to the soil and the location marked with a numbered stake. Those marked burrows examined March 4, 1954, showed that some females had retreated to a depth of 8 inches while others were at the same level (2.5-6.5 inches) as when observed during November and December, 1953.

On December 10, 1954, numerous mated *P. crinita* females were placed in the soil at depths of 2 to 3 inches. These places of introduction were marked for further examination and on March 16, 1955, eight of these marked females were dug and found to be at 2, 2.5, 2.5, 3.5, 4, 4.5, 4.5, and 5 inches respectively.

Again on January 25, 1955, mated *P. crinita* females were placed in the soil at a depth of 2-3 inches. Twelve of these females were examined April 6, 1955, and found at 2.5, 3, 3.5, 3.5, 3.5, 4, 5, 6, 6, 6, 7,

and 19 inch depths. While digging for grubs on March 15, 1956, a single female beetle was found at a 4-inch depth.

Observations indicate that by mid- to late April and early May, *P. crinita* females are approaching the depths at which eggs are known to be deposited. Three mated females placed in the soil on January 25, 1954, and dug on May 14, 1955, were found at 13, 14, and 18 inches respectively. Two females discovered April 16, 1956, were at a depth of 20 inches, and 5 females discovered April 30, 1957, were 17, 21, 22, 23, and 23 inches in the soil.

Limited observations indicate *P. minor* females are near the depths known for egg deposition by mid-April. Five mated females placed in the soil on October 17, 1956, were removed April 17, 1957, and found to be at 16.5, 20.5, 21, 22, and 23 inches respectively. On April 18, 1957, two females were found at 18 and 22.5 inches.

Behavior of Males During Mating Season

Flight of Male. Numerous large flights of *P. crinita*, *P. minor*, and *P. oregonensis* have been observed during predawn (5:30-6:30 a.m.) in the beams of automobile headlights or during early daylight (6:30-7:30 a.m.). In general, the flight patterns of the three *Pleocoma* species found in Hood River and Wasco Counties agree with those cited by other workers (Ricksecker, 1886, Fall, 1911, Davis, 1935, Hazeltine, 1953, Smith and Potts, 1945, and Ritcher and Beer, 1956).

The undisturbed flight while seeking females is slow and meandering, males flying close (2 inches or less) to 12 or 18 inches above the soil surface. Mixed among the slow flying are others flying straight and swiftly at heights of 3 to 6 feet. When disturbed, flight becomes swift, erratic, and often escape is made by soaring 10 or more feet into the air.

Flight is clumsy and blundering, as males often collide with weeds and clumps of tall grass. Upon colliding with obstructions of this nature, males tumble through the tangled stems and, with wings vibrating, crawl a short distance before becoming airborne. A large flight of beetles flying through or out of tall grass creates a noticeable, loud, buzzing sound.

The manner in which *Pleocoma* males locate the female is not easily explained, because the female is usually in a burrow and covered by a small mound of pulverized soil. Several workers have advanced the thought that a sensory mechanism may be involved (Ricksecker, 1886, Rivers, 1890, and Davis, 1918 and 1935).

Attraction to Light. Certain species of *Pleocoma* are reported to be attracted to light (Rivers, 1889, Davis, 1935, and Hazeltine, 1953) while others are not (Smith and Potts, 1945). Also, some

species are reported as being attracted to light at some seasons but not at others (Hazeltine, 1950).

Males of *P. crinita*, *P. minor*, and *P. oregonensis* are not attracted to light from a Coleman lantern, kerosene light trap, or automobile headlights. However, two specimens of *P. crinita* were taken at a lighted window at 6:30 a.m. on January 15, 1958. Furthermore, *P. minor* males have repeatedly been collected on a window sill beneath a lighted window near Oak Grove, Hood River County.

LONGEVITY

Although the longevity of male and female beetles was not known to early workers, several writers presented data which indicated females lived for considerable time (Hopping, 1920, and Davis, 1935). Beginning with the time of transformation, females of two species under study were found to live for nearly 12 months, while males live a shorter period.

Transformation of *P. crinita* pupae is known to occur in late August and early September. Females of this brood have been discovered alive with their eggs as late as August 19 of the following year. The latest that males have been found alive was March 10 of the year following transformation.

Pleocoma minor pupae transform in late July and early August. Females from this brood have been discovered alive on August 9 of the following year. Males have been collected only as late as November 13 of the same year as transformation.

Limited observations indicate females of *P. oregonensis* may live for a considerable period. One female mated November 8, 1955, and kept outdoors in a soil cage was found still alive with her clutch of eggs on June 20, 1956. The latest male flight for this species was known to occur November 27, the same year as emergence.

At no time do adults feed. This is phenomenal, considering the burrowing habits of the adults, flight of males and mating, the length of time for egg development and the number of eggs deposited by an individual female.

NATURAL ENEMIES

Of all stages, the adults are the most vulnerable to attack by natural enemies. This occurs mainly during the mating period when male and female beetles are near the soil surface, or when the males are in flight. At this time the adults are preyed upon by birds, domestic fowl, chipmunks, squirrels, mice, skunks, coyotes, foxes, dogs, and other animals (Davis, 1918, Smith and Potts, 1945, Linsley,

1942 and 1957, Hopping, 1920, Ricksecker, 1886, and Von Blocker, 1935).

In Hood River Valley orchard lands, skunks (*Mephitis*) are the greatest enemies of *P. crinita* and *P. minor* adults. On numerous occasions skunks have been observed seeking and digging beetles from the soil in the early dawn hours. The skunks actively feed on the adults whenever the beetles are near the soil surface. In the case of *P. crinita*, beetles remain near the soil surface for a long period of time. On March 27, 1956, skunks were noted feeding on female beetles of this species. These female beetles were from the brood which began emerging in early November of 1955. In instances of this nature, skunks are capable of reducing a beetle population. In some Hood River Valley apple orchards, as high as 15 separate skunk diggings can be found near a single tree.

In Sorosis Park, The Dalles, where a large population of *P. oregonensis* occurs, evidence of skunk digging is very common during the period of adult beetle activity. The excavations made by the skunks may be only an inch or two in depth. However, the majority of holes are 4 to 6 inches deep, with an occasional hole 10 inches deep.

SUMMARY

Two species, *Pleocoma crinita* Linsley and *P. minor* Linsley are associated with apple, pear, and sweet cherry trees in Hood River County, while a third species, *P. oregonensis* Leach is associated with sweet cherry trees in Wasco County. In the Hood River Valley, pome fruit trees, particularly apples, were seriously affected.

Larvae feed on fibrous roots, main roots, and underground portions of the trunk of bearing and nonbearing trees at depths ranging from 3.5 to 60 inches, depending on depth to which roots have penetrated the soil.

P. crinita and *P. minor* larvae feed throughout the entire year, with the possible exception of the moulting period. Moulting of *P. crinita* and *P. minor* occurs once a year, during the summer months. Indications are that *P. oregonensis* also moults once per year, in the month of August. Other Scarabaeidae normally have only three instars; however, *P. crinita* and *P. minor* have many instars and indications are that *P. oregonensis* follows the same pattern. *Pleocoma crinita* and *P. minor* have at least 9 instars before pupation occurs and there may be as many as 13.

Larvae of *P. crinita* live in an environment with limited fluctuations in temperature. Of the temperatures recorded at 6, 12, 18,

and 24 inches, the greatest monthly and yearly fluctuations occurred at the 6-inch level.

The wingless female beetles deposit from a few to more than 60 dull-white eggs in the soil at depths ranging from 29.5 to 14.5 inches. Egg deposition begins in mid- to late May and continues through June. The egg stage for *P. crinita* averages 69 days, while *P. minor* has an egg stage averaging 62 days. The egg hatching period for *P. crinita* begins in late July and extends to early September, and *P. minor* eggs begin hatching in mid-July and continue to late August. *Pleocoma oregonensis* eggs begin hatching in late July and continue to late August.

The pupae of *P. crinita* and *P. minor* are located at depths closely corresponding to the vertical distribution of larvae. Pupation of *P. crinita* begins in late July and early August, while pupation of *P. minor* occurs in mid- to late June and early July.

Pupae of *P. crinita* begin transforming in late August and early September, and *P. minor* pupae transform in late July and early August. Mating activity of the three species occurs during the fall and winter rainy periods. Males search for the wingless females, which are usually hidden in burrows at depths of .50 to 14 inches. The largest flight of males usually occurs during predawn and dawn, in a drizzling rain, or when the atmosphere is saturated with moisture.

Dispersion of this genus is mainly by larvae moving through the soil or movement of the wingless females over the soil surface. Females, however, are rarely found on the surface. No insect parasites or predators are known. Skunks, which feed on adults, are the greatest enemy of *Pleocoma* in Wasco and Hood River Counties.

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