BIOLOGY OF SOME OREGON RAIN BEETLES, PLEOCOMA SPP., ASSOCIATED WITH FRUIT TREES IN WASCO AND HOOD RIVER COUNTIES

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INTRODUCTION

In September, 1953, a decline of apple trees in the Hood River Valley was partly solved 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 (19, p. 441 and 48, p. 114) noted grubs of this genus attacking roots of pear and apple. Virtually nothing was known concerning the biology of this group. Until recently, the genus Pleocoma has been a scientific curiosity, because of the strange habits of the adults and their primitive characters. Consequently they have been collectors' items and publications on the group dealt primarily with taxonomy and morphology. Several articles have been published, concerning the morphology of Pleocoma larvae occurring in California (55, p. 84-87; 60, p. 11-20; 26, p. 117-127 and 61, p. 14-17).

Credit for discovering and associating the grubs with injury belongs to Mr. Vernon Olney, then Research Assistant in Entomology, Mid-Columbia Branch Experiment Station, Hood River, Oregon. A survey by Mr. Olney in

the fall and winter of 1953, disclosed injury to be widespread in twenty or more orchards in the Hood River Valley. Dr. Paul O. Ritcher, Chairman, Department of Entomology, Oregon State College, Corvallis, Oregon, identified the grubs to genus.

An economic problem of considerable magnitude presented itself, as there are 12,000 acres of pome fruit trees in the Hood River Valley, which potentially could be hosts of these grubs. Following this, in March 1954, the grubs of Pleocoma were found attacking roots of sweet cherries at The Dalles. Approximately 6,000 acres of tree fruits are grown in this area.

One species, P. minor Linsley was known to occur in the Hood River Valley, since Hood River was cited as the type locality of this species (44, p. 52-53). Male beetles, identified as P. crinita Linsley were collected in November, 1953, at the locality where grub injury was first found. The species at The Dalles was identified as P. oregonensis Leach. Identifications were made by Dr. E. G. Linsley, Department of Entomology and Parasitology, University of California, Berkeley, California.

Research was needed to establish basic facts about these insects so that intelligent control measures could be devised. Investigation of their biology was begun in

1953, by Mr. Vernon Olney under the supervision of Dr. Paul O. Ritcher. Upon the resignation of Mr. Olney in 1954, I continued the study on *Pleocoma* in the Hood River Valley and The Dalles.

Position of the genus Pleocoma in the Scarabaeidae has been a controversial subject for many years. Though not settled, the opinion of many workers is that it should follow the Geotrupini in a separate tribe. Early workers had difficulty in studying the position of Pleocoma because of the poor and limited material for both adult and larval forms.

In 1856, LeConte (34, p. 24) established the genus and described P. fimbriata. LeConte said of Pleocoma, "apparently belonging to Dynastidae", followed by some pondering concerning resemblance to Syrichthus and Athyreus, he stated, "Doubt must, therefore, be entertained whether the genus should be placed with the Dynastidae or Geotrupidae".

This is remarkable, as the descriptions and placement of the genus were based on a single mutilated male, found at an unknown locality in California by Dr. Heermann. In the words of Horn (30, p. 12) "The original specimen was badly mutilated, having been partially eaten by a bird. The oral organs were destroyed, the abdomen entirely gone; one antennae and part of the legs remained". Possibly the type locality is somewhere in El Dorado County, California, as Horn (30, p. 6) stated he had obtained specimens of P. fimbriata from El Dorado County. Fall (22, p. 66) added further, "Three males

in my collection from El Dorado Co. are undoubtedly typical representatives of fimbriata".

In another article, LeConte said (36, p. 40), "as the oral organs and the abdomen are destroyed I cannot tell whether this genus belongs to the Dynastides or Geotrupides; in either case, the four-jointed antennal club is equally remarkable. The affinities, so far as I can understand them, seem to be rather with Geotrupes". LeConte in a foot-note to this article mentioned having specimens resembling P. fimbriata. However, the specimens had seven segmented antennal clubs. In this foot-note is written, "Although agreeing with Geotrupidae in the eleven-jointed antennae, the form of the antennae is entirely anomalous in that and allied groups, and the small size of the oral organs would seem to indicate a new group between Geotrupidae and Copridae".

An additional note by LeConte (37, p. 71) described oral organs (taken from a woodpecker's stomach) that he believed belonged to P. fimbriata. In summarizing, he thought the detailed characters were sufficient to establish Pleocoma as a new group related to the Geotrupidae and Copridae, but with a strong tendency toward the Dynastidae group. Horn (30, p. 6) thought the description may belong to some other species. After placing Pleocoma in the Dynastidae group in 1859,

LeConte changed its status in 1861 by erecting the tribe Pleocomini and placing it lower than the Geotrupini (38, p. 128).

In a review of the systematic position of the genus Pleocoma (15, p. 126-127) Davis wrote, "Motschulsky, who had seen five specimens in the museum at St. Petersburg, and with whom LeConte corresponded, regarded the genus as allied to Ceratophys Fisher a division of Geotrupes. Schaufuss..... concurred in this opinion, but noted a similarity to Antichira Esch."

Osten Sacken (55, p. 84-87) described a Pleocoma larva found deep in the soil by Mr. Behrens of San Francisco. After comparing this larva with an analytical table of lamellicorn larvae and a few larval descriptions of Geotrupidae, Aphodiidae, Copridae and Trogidae, Osten Sacken stated, "I soon perceive that the choice will lie between Geotrupidae and Trogidae". After some speculation he favored a relationship of Pleocoma with Trogidae rather than Geotrupidae. Osten Sacken's closing remarks were, "Altogether, the material at hand for comparison are too meagre for a final decision upon the relationship of the larva". LeConte (40, p. 82) noted the characters of this Pleocoma larva, justified the placement of the genus as a distinct tribe near Trox and Geoptrupes.

Gerstaecker (24, p. 436-450 and 72, p. 202-211) took issue with LeConte and the early work with Pleocoma adults. Gerstaker stated he would place Pleocoma with Melolonthidae, or at least in a group remote from Geotrupini. Later (72, p. 210-211) Gerstaker had grave doubts concerning Osten Sacken's description of a Pleocoma larva, stating he thought the larva described was a larva belonging to the Lucanidae.

Horn immediately came to the defense of LeConte and confirmed the position of Pleocoma near the Geotrupini. He also stated that the larva described by Osten Sacken was truly a Pleocoma larva (30, p. 1-18; 31, p. 144 and 32 p. 233-235)

Pleocoma was placed in the subfamily Pleocominae by Arrow (2, p. 484).

Leng (42, p. 252) favored the position that Pleocoma should follow Geotrupini and placed the genus accordingly.

Based on larval characteristics, Böving and Craighead (6, p. 53) considered the genus as a subfamily, Pleocominae of the Scarabaeidae.

Paulian (56, p. 151-155) after studying external adult characters and the male genitalia of Pleocoma, believed the genus should be placed in a distinct subfamily, Pleocominae in the family Geotrupidae. In the same

publication, Paulian pointed out the lack of detail in the larval characters and figures as described by Osten Sacken. Because of this there is no indication of the position of Pleocoma. Paulian further noted this larva does not approach the Lucanidae as suggested by Gerstaeker.

Based on their study of one Pleocoma larva, Hayes and Chang (26, p. 117-127) are of the opinion this genus should be placed as a separate family, Pleocomidae.

In 1947, Ritcher (60, p. 11-20) described the larva of P. hirticollis vandykei Linsley after comparing numerous larvae of this species with larvae of four other Pleocoma species. At this time, Ritcher considered placing Pleocoma in a subfamily close to, but distinct from Geotrupinae.

Following the study of some unknown geotrupid larvae, Ritcher (61, p. 3-27) concurs with Paulian in that Pleocoma is a geotrupid genus.

REVIEW OF PLEOCOMA SPECIES IN WASCO AND HOOD RIVER COUNTIES, OREGON

The three species, P. crinita Linsley, P. minor Linsley and P. oregonensis Leach were described from either one or two male specimens. Females of the three species were unknown.

Pleocoma crinita was described (44, p. 53-54) from two males, collected near Glenwood, Klickitat County, Washington, in May 1936. Though the type specimen is labelled as collected in May, a long series collected by the writer were found only from October into March.

Prior to 1953, P. crinita was known from one locality in Oregon (51, p. 145). The two males were collected January 29, 1931 at Mosier, Wasco County, by W. W. Lawrence. Males of P. crinita collected and submitted to Linsley were misidentified as P. minor. Ritcher and Olney (62, p. 42) were in error when reporting four males of P. minor being collected at Mosier, Oregon on October 23, 1930, by D. C. Gillespie. They further reported two of these specimens were used when the species P. minor was described. Actually the collection date of October 23, 1930, is associated with two specimens of P. minor collected near Hood River, Oregon, by D. C. Gillespie. The other two specimens were P. crinita and are associated with the data, January 29, 1931,

Mosier, Wasco County, collected by W. W. Lawrence (51, p. 145). The brief note appearing in Coleopterists Bulletin (63, p. 16) is in reference to P. crinita and not P. minor.

Linsley (51, p. 145-146) published a paper based on over 100 male and 80 female P. crinita from two localities in the Hood River Valley, Oregon and a locality near Husum, Klickitat County, Washington. Linsley modified the original description and noted differences in local populations. He also mentioned a female beetle collected at Pine Grove, Hood River County, by Olney, which differed from the other females in the series. Comparison of this single female with a long series of P. minor collected by the writer at Pine Grove and other localities, indicate that it is the later species.

Males and females of P. crinita from widely separated sites in the Hood River Valley vary greatly in size. Males range from 19 to 24 mm., with an average of 21.5 mm. in length and females range from 22-28.5 mm., with an average of 24.7 mm. in length.*

Two males served as the basis for the description of P. minor by Linsley (44, p. 52-53). These two males

* Measured from the tip of one clypeal horn to the apex of the elytron on the same side.

were collected near Hood River, October 23, 1930 by D. C. Gillespie. At the time of the description, type specimens were noted as being of small size (18 mm.).

In 1956, Linsley (50, p. 122) briefly reviewed the species P. minor on the basis of 15 males collected from a woodland site in 1954 and 1955 and 7 females collected from the same locality. Many more males and females from this and other sites in Hood River County were collected in 1956 and 1957. Males range in length from 17.5-23 mm. and average 19.8 mm., with length of females ranging from 21 to 29 mm. and averaging 24 mm.

Pleocoma oregonensis Leach (33, p. 186) was described in 1933, from a single male taken at Wasco, Sherman County, Oregon, in 1908. A long series of males collected in Wasco and Sherman County, range in length from 19 to 27.5 mm. and average 22.8 mm. Thirty eight females collected from these same localities range from 22.5 to 30.5 mm. in length and average 26.7 mm.

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

Linsley (49, p. 61-65) 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. Bicolorous: 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 bicolorous pronotum lighter in color 2

2. Median longitudinal impression of pronotum with long erect hairs present along the entire length and scattered over other portions 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 unsually unicolorous, occasionally bicolorous: pronotum usually red-brown, occasionally black-brown: elytra black ..... minor

DISTRIBUTION ON THE NORTH AMERICAN CONTINENT

All known species of the genus Pleocoma (45, p. 101-104; 46, p. 145-152; 48, p. 110-114; 49, p. 61-65 and 52, p. 102-104) occur in western North America. Members of the genus are known from Utah and from Aloma in Baja California, northward through California and Oregon to glenwood in southern Washington. At this point the distribution records are disjunct, with the next record (P. trifoliata Linsley) being from Seward, Alaska. Altogether some 29 species have been described.

From these records, a large region including western Washington, Nevada, Idaho, Montana, British Columbia and Alberta should be suspected of having Pleocoma.

The climate and vegetation of western Washington, northward along the slopes of the Cascade Range into southern British Columbia are similar to those of northwestern Oregon. Collecting in this region should extend the range of some species found in Oregon or result in the discovery of new species.

Two species are recorded from Utah; namely P. ulkei Horn and P. remota Davis, both based on single males. With this in mind, other States in the Rocky Mountain region could conceivably contain Pleocoma.

DISTRIBUTION IN OREGON

Six species of Pleocoma are known in Oregon; P. dubitalis leachi Linsley, P. dubitalis dubitalis Davis, P. simi Davis, P. carinata Linsley, P. crinita, P. minor and P. oregonensis. These species are found in approximately one-fourth the total land area of the State. No species are recorded from the coastal region or the western slopes of the Coast Range. A few scattered sites are known on the western slopes of the Cascade Mountains southeast of Salem. The area from Hood River, westward to Portland, is devoid of records. With the exception of Wasco and Hood River Counties, the eastern flank of the Cascade Mountains and eastward to the Idaho border is devoid of records. The Umpqua and Fremont National Forests east of Medford and Roseburg could harbor species of Pleocoma. Other localities of special interest where unknown species may occur, are near Prineville in the Ochoco National Forest or in the Blue and Wallowa Mountains and surrounding areas.

Linsley (44, p. 51-52) reported the subspecies P. dubitalis leachi, from West Linn and Colton in Clackamas County. The subspecies P. d. dubitalis, is listed from Dilley and Forest Grove in Washington County, Salem, Corvallis and McMinnville (45, p. 99; 46, p. 151 and

48, p. 113). Ritcher and Beer (64, p. 181) further recorded this subspecies from localities on the eastern slopes of the Coast Range, in the Willamette Valley and southeast of Salem on the western slopes of the Cascade Mountains.

Davis, (12, p. 24) described P. simi, giving the type locality as Cleveland in Douglas County. According to Ritcher and Beer (personal communication) specimens of this species have been collected near Grants Pass and at Spencer Butte, south of Eugene.

Pleocoma carinata is found only in southern Oregon, being described from specimens taken at the base of Mt. McLoughlin, near Butte Falls, in Jackson County (44, p. 56-57). The species is also recorded from Dead Indian Soda Springs in Jackson County (46, p. 151). Both of these localities are east of Medford.

Pleocoma crinita occurs at Mosier, Wasco County, Oregon; (51, p. 145) in many Hood River Valley orchards and woodlands, Hood River County, Oregon (51, p. 145 and 62, p. 41-42); Glenwood and an apple orchard north of Husum, Klickitat County, Washington (44, p. 53-54 and 51, p. 146).

Bailey (4, Frontpiece) shows Mosier to border on the semihumid division of the Transition Zone. Forest trees in the area are yellow-pine, Douglas fir and Oregon

oak (Quercus garryana). Fruit growers in the area surrounding Mosier, state they receive 21 inches of moisture annually.

Hood River Valley with an average of 30.1 inches of moisture annually is in the humid division of the Transition Zone (4, Frontpiece). Some of the native trees include Douglas fir, white fir (Abies concolor), black cottonwood (Populus trichocarpa), Oregon maple, vine maple and "islands" of yellow-pine and Oregon 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 southward to Odell and southwest to Oak Grove at elevations ranging to 1150 feet (Figure 5). 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 (44, p. 52-53 and 50, p. 122). This species occupies the same kind of habitat and is often found within one-fourth mile of areas occupied by P. crinita (Figure 2). 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 2000 feet (Figure 5).

The third species, P. oregonensis has been recorded from The Dalles, Wasco County; 15 miles east of Wasco, Sherman County (18, p. 431) and Wasco, Sherman County (33, p. 186). 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 (4, Frontpiece). The ground cover in these zones ranges from mixed stands of Douglas fir and yellow-pine to pure stands of yellow-pine or yellow-pine and Oregon oak, or sagebrush and short grass (Figures 3 and 4).

Specimens collected near The Dalles, are from cherry orchards, pure stands of yellow-pine or associations of yellow-pine and Oregon oak at elevations ranging from 350 to 600 feet. The known range extends south from The Dalles to Friend (2430 feet) and Wamic (1664 feet), thence northwest to Camp Baldwin (Boy Scout camp) at 3700 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 moisture in this area ranges from 13.6 inches at The Dalles, 15.3 inches at Wamic, to over 30 inches at Camp Baldwin. Wasco in Sherman County has

11.8 inches of moisture annually.

ECONOMIC IMPORTANCE AND HOST PLANTS

Early reports which associate *Pleocoma* grubs with roots of orchard trees are uncommon in the literature. 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.

Two unpublished reports, made known to the writer by Dr. Paul O. Ritcher, concern larvae now in the U. S. National Museum collection. In one instance, larvae were reported by Mr. G. P. Weldon as injuring young fruit trees near Sacramento, California. On March 5, 1936, Mr. Steward Lockwood collected larvae from soil in a young pear orchard at Caminio, El Dorado County, California. These larvae were suspected of causing serious injury to newly planted fruit trees.

In Insects of Western North America by Essig (19, p. 441) there is an illustration of a *P. fimbriata* grub and the injury it caused on roots of a young pear tree. In 1945 (48, p. 114) Mr. H. H. Keifer was cited as reporting grubs injuring roots of apple trees at Leona Valley, Palmdale, Los Angeles County, California.

Hayes and Chang (26, p. 119) referred to a larva of *Pleocoma* in their collection as being discovered at

the roots of a pear tree near Caminio, El Dorado County, California.

Mr. Fred Platt (personal communication with Dr. P. O. Ritcher) wrote that Pleocoma grubs were injuring roots of orchard trees in Butte and perhaps northeastern Shasta County, California. Later Mr. Platt reported P. edwardsii LeConte grubs were attacking roots of apple trees in an abandoned orchard at De Sabla, Butte County, California (52, p. 102).

Two records known to the writer, associate Pleocoma grubs with roots of plants, other than orchard trees. Larvae of P. hirticollis vandykei Linsley (60, p. 11) are noted as feeding on grass roots, near Patterson Pass, California. The other report concerned roots of a strawberry plant being attacked by a Pleocoma grub at Newberg, Oregon (personal communication with Dr. P. O. Ritcher).

The first recorded instance of Pleocoma injury to orchard trees in Oregon occurred at Hood River in 1953 (62, p. 41-42). 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 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. In December of 1953, damage was known to be widespread in approximately twenty, Hood River orchards. The writer has also observed P. crinita larvae feeding on roots of apple trees near Husum, Klickitat County, Washington (51, p. 146).

The writer (17, p. 13) suggested that possibly other species of Pleocoma grubs were attacking roots of fruit trees in Hood River Valley and at The Dalles. Following this report, I (18, p. 431) noted grubs of P. oregonensis as injuring roots of sweet cherries at The Dalles.

One other species, P. minor, was known to occur in Hood River County (44, p. 52-53). It was not until mid-October 1955, that I collected adults in Hood River orchards. Further investigation in 1956 and 1957, revealed P. minor to be as common and widespread as P. crinita and causing the same type of injury.

Fibrous, main roots and underground portions of the trunk of bearing and non-bearing 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 (Figures 6 and 7). This injury may occur throught the entire root

zone, and there is no relationship between variety (above ground portion of tree) and grub injury.

Affected bearing apple trees in the Hood River Valley are low in vigor, with foliage being sparse, small and yellow (Figure 8). Pear trees infested with grubs lack terminal and sucker growth. The leaves are yellow and sparse with little or no fruiting (Figure 9). Large populations of grubs may be causing injury in only small areas of 5 or 6 trees or may be spread over 10 or more acres. The 10 acre plot may be one-fourth of one grower's entire holdings.

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

It is difficult to determine if grubs are responsible for decline of cherry trees at The Dalles. Other factors, such as drought, gopher injury to roots, winter injury and viruses are contributing to the unthrifty condition of many cherry trees in that area.

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 the roots of apple (Malus), pear (Pyrus) and sweet cherry (Prunus avium rootstock). I have found that grubs of P. crinita and P. minor can shift their feeding habits from roots of Prunus to Malus and from Malus to Pyrus. Grubs of P. oregonensis at The Dalles, are feeding on rootstock of cherry (Mazzard or Mahaleb) and on apple clonal rootstock, Malling II and VII. This species has also shifted feeding habits from Prunus to Malling II and VII.

A grower at Hood River, after removing three acres of cherries, planted the plot to apple trees on seedling rootstock. When leaves of the young trees began wilting in May 1957, investigation revealed one to

4 grubs feeding on the root systems. One-third of the trees in this three acre planting were severely damaged or died as a result of this feeding (Figure 10). Pleocoma minor was involved in this instance. The writer has also followed the history of one, 5 acre planting of 12 year old Bartlett trees in Hood River. The original planting was Newton apples with pears interplanted. 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.

At The Dalles, a grower after removing seven acres of 40-50 year sweet cherries in 1956, replanted this area with apples on Malling II and VII rootstock. Pleocoma oregonensis grubs immediately began feeding on these Malling rootstocks.

THE EGG STAGE

Virtually nothing was known concerning the egg stage or egg laying habits of *Pleocoma* for a period of 97 years after the description of the genus and type species by LeConte in 1856 (34, p. 24).

Davis, in 1918 (10, p. 117) dissected 50 eggs from a females of *P. badia* Fall, which were light yellow in color, oval and about 1 mm. long. He further stated in 1935 (15, p. 129), "Oviposition must take place deep in the ground, but of this nothing is known".

In 1953, Ritcher and Olney (62, p. 129) reporting the first information on egg laying of *P. crinita* state, "Some time after mating the females descend deeper in the soil and there wait until the following summer before depositing their eggs. This is substantiated by finding of one "nest" on September 17 which contained five unhatched eggs and fourteen newly hatched larvae, and other finds from then on of groups of small larvae. In every case the dead female was found in the midst of her brood and at from 13.5 to 15 inches in depth. The number of progeny from one female is about 20 to 25".

Three papers, one in 1955 and two in 1956, added further to our knowledge of the egg stage of *Pleocoma*. The writer in 1955 (17, p. 14) found the eggs of *P. oregonensis* were a quarter of an inch in length to

three-sixteenth of an inch in width, while those of P. crinita were slightly smaller. Also some females of P. crinita deposited over 50 eggs, during June, with the clutch being vertical to the soil surface and grouped in a space of 3 to 7 inches.

In 1956, (18, p. 431) two P. oregonensis females, under laboratory conditions, deposited 35 and 48 eggs respectively. These eggs hatched between July 25 and August 2, 1955.

Ritcher and Beer in 1956 (64, p. 182) wrote "It was found that Pleocoma dubitalis dubitalis has egg laying habits similar to those of Pleocoma behrensi LeConte as observed by J. W. MacSwain of the University of California (personal communication) and similar to those of Pleocoma crinita Linsley ...." . In the same paper Ritcher and Beer discussed number of eggs, size, depth and period of egg deposition for P. dubitalis dubitalis. On July 23, 1954, they found a female in the soil with 50 eggs between 12 and 17.5 inches in depth. Ten eggs from one to three days old ranged from 3.9 to 5.1 mm. in length and 2.7 to 3.5 mm. in width. In 1954, they incubated 24 eggs at 60°F. with hatching occurring between August 28 and September 8. Under laboratory conditions in 1955, five female P. dubitalis dubitalis

deposited 59, 61, 51, 33 and 53 eggs during the period of May 25 through June 18. These eggs hatched between September 1 and September 24. The egg stage for 13 eggs of known age ranged from 83 to 95 days.

A. 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 12). As the eggs become older they increase in length and width, some becoming almost spherical. The chorion is very tough. In discussing the chorion of P. dubitalis dubitalis eggs, Ritcher and Beer (64, p. 183) wrote, "The chorion is so tough that eggs can be dropped on a wooden floor without apparent injury".

Recently laid eggs of P. crinita and P. minor were nearly equal in size (Table 1).

Eggs of four P. crinita females (found July and 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).

Table 1. Egg sizes of three species of Pleocoma.

Species	No. of eggs	Age of eggs	Length in mm. Max.	Length in mm. Min.	Width in mm. Max.	Width in mm. Min.	Average l.	Average w.
P. crinita	16	64 hrs.	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
P. minor	8	63 hrs.	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
P. oregonensis	61	unknown	6.5	4.9	5.0	3.9	5.9	4.6

B. EGG DEVELOPMENT

When the initial life history studies were begun in 1953, nothing was known concerning development and time of egg deposition. To investigate these points, Mr. Olney placed recently mated P. crinita females in soil cages during the fall months of 1953. Periodically, during March and April, 1954, the writer dissected ovaries and developing eggs from these females.

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

Table 2. Egg development of two species of *Pleocoma*.

Species	Mated	Dissected	Range in egg length in mm.	Range in egg width in mm.
P. crinita	Fall, 1953	Mar. 14, 1954	1.6 - 3.1	1.3 - 2.0
		Mar. 20	2.3 - 3.9	1.5 - 2.6
		Apr. 12	2.5 - 4.4	1.8 - 2.8
		Apr. 15	1.6 - 4.1	1.1 - 2.8
	November 1954	Apr. 6, 1955	1.6 - 3.3	1.3 - 2.5
		May 14	2.9 - 4.4	2.0 - 3.6
	Fall, 1956	Apr. 30, 1957	3.1 - 4.6	2.8 - 3.6
P. minor	October, 1956	Apr. 18, 1957	2.1 - 4.1	1.3 - 3.1

C. TIME OF DEPOSITION

All data indicate that females mating in October and November do not deposit eggs until May, June and into July of the following year. Pleocoma crinita and P. minor begin egg deposition in mid-to late May and continue deposition through June. Limited observation indicates that P. oregonensis females 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 unlaid 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-fill quart jars. Upon examination May 22, these females 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 to do so 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.). These females were examined May 22, 1957, and found to have deposited 2, 8 and 10 eggs respectively. Disturbance apparently disrupted egg deposition as these females failed to continue egg laying. Two other individuals, mated at the same time as the preceeding 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.

From limited observations, 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. 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.

D. PLACE AND MANNER OF DEPOSITION

Females of the three species under study deposit their eggs in the soil in rather a characteristic manner. Ritcher and Beer (64, p. 183) found that a P. dubitalis dubitalis female deposits her eggs individually, beginning at the bottom of a burrow and moves 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 cavity slightly larger than the egg. The female moves upward in a spiral fashion, pulverizing a core of soil and depositing eggs therein.

The distance from the outer portion of one egg to the outer portion of another egg, across the diameter of the core of pulverized soil, varies slightly. In P. crinita the distance ranged from 1 to 1.75 inches, with P. minor being in the same range of measurements. Four egg clutches of P. oregonensis have been measured, with the distance across the diameter being 1.75 inches.

After deposition of her eggs, the female dies and is found in the soil, usually immediately above the top-most egg.

E. NUMBER OF EGGS

There is considerable variation in the number of eggs deposited by females of the three species. Under laboratory and field conditions seventeen 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 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, counts were made of eggs and larvae and 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 with a high of 6 in a 64 hour period. Often, only one egg was laid in a 72 hour period (Tables 4 and 5). 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.

F. DEPTH AND VERTICAL DISTANCE OCCUPIED

The bottommost egg or eggs are found at varying depths in the soil (Table 6). 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 17 to 29.5 inches. On June 28, 1956, one clutch of P. oregonensis eggs dug from the field disclosed the

Table 3. Number of eggs deposited by three species of Pleocoma.

Species	No. by one individual	Species	No. by one individual	Species	No. by one individual
P. crinita	20	P. minor	* 2	P. oregonensis	* 9
	20		* 8		* 35
	* 24		* 10		35
	26		14		* 48
	* 30		* 22		* 48
	32		* 30		
	* 33		* 31		
	* 36		33		
	37		34		
	* 43		* 34		
	44		35		
	* 45		* 41		
	50		* 42		
	52		* 45		
	* 52		* 47		
	61		* 49		
	62		63		

* Eggs from females under laboratory conditions

deepest egg at 23 inches. Females of this species, when isolated in soil cages, burrowed to the bottom of the cages (4 feet) before beginning egg deposition.

Table 4. Number of eggs deposited in given period by *P. crinita*.

Female	Eggs deposited before disturbance.	Date	No. eggs	No. hours
1	24			
		May 22-25	6	64
		May 25-27	4	48
		May 27-30	2	72
		May 30-June 1	1	48
		June 1-4	2	72
		June 4-7	2	72
		June 7-10	3	72
		June 10-13	2	72
		June 13-15	1	48
		June 15-18	0	72
2	19			
		May 22-25	3	64
		May 25-27	0	48
		May 27-30	1	72
		May 30-June 1	0	48
		June 1-4	0	72
		June 4-7	0	72
		June 7-10	0	72
		June 10-13	0	72
		June 13-15	0	48
		June 15-18	0	72
		June 18-21	0	72
		June 21-24	1	72
3	29			
		May 22-25	4	64
		May 25-27	0	48
		May 27-30	1	72
4	26			
		May 22-25	4	64
5	32			
		May 22-25	1	64

Table 4. (continued)

Female	Eggs deposited before disturbance.	Date	No. eggs	No. hours
6	47	May 25-27	2	48
		May 27-30	1	72
		June 4-6	2	48
		June 6-8	3	48

The vertical distance occupied by eggs in the pulverized core of soil depends to a degree on the number of eggs (Table 6). In several instances a female was in process of depositing eggs, however, an egg count was made and a measurement made of the space occupied. In some instances it was not possible to measure a clutch of eggs as some had begun hatching. In such cases the newly hatched larvae had not dispersed from the cavities in which the eggs were laid. Subsequently a measurement was made of vertical distance occupied by the eggs and newly hatched larvae and considered as the distance occupied by a clutch of eggs.

Table 5. Number of eggs deposited in given period by *P. minor*.

Female	Eggs deposited before disturbance.	Date	No. eggs	No. hours.
1	22			
		May 27-29	0	48
		May 29-June 1	0	63
2	30			
		May 27-29	0	48
		May 29-June 1	0	63
3	Unknown			
		May 27-29	8	48
		May 29-June 1	4	63
		June 1-4	0	72
		June 4-7	4	72
		June 7-10	0	72
		June 10-13	0	72
		June 13-15	0	48
		June 15-18	1	72
		June 18-21	1	72
4	48			
		June 18-21	1	72
5	46			
		June 26-July 1	1	96

The vertical distance occupied by *P. crinita* eggs ranged from almost none (2 eggs) to 6 inches (62 eggs). The vertical distribution of *P. minor* eggs followed the same pattern with the distance varying from 1 inch (14 eggs) to 3.5 inches (46 eggs). In one case there was a distance of 5 inches; unfortunately the data on number of eggs were lost. Under laboratory conditions 4 egg masses of *P. oregonensis* occupied a vertical distance of 2 (9 eggs) to 5 inches (48 eggs).

Table 6. Depth range of eggs and newly hatched larvae for three species of Pleocoma.

Species	Range in inches	No. eggs	No. larvae	Total in clutch	Vertical distribution in inches.
P. crinita	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
P. minor	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
P. oregonensis	*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

C. 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 on the average the egg stage of P. crinita may be 7 days longer than P. minor.

The length of the egg stage for 24 P. crinita eggs of known age averaged 69 days (Table 7). These eggs hatched between August 4 and 18. Sixteen P. minor eggs of known age averaged 62 days in the egg stage (Table 8). 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 egg hatch. Temperatures in the constant temperature cabinet ranged from 54°F. in late May to 60°F. in early September.

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. Two years records (1955 and 1956) for P. oregonensis, show a hatching period from July 25 to August 27.

Table 7. Length of egg stage for P. crinita.

Date deposited	Maximum age in hours	No. of eggs	Date of hatch	No. days in egg stage
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 12	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

Table 8. Length of egg stage for P. minor.

Date deposited	Maximum age in hours	No. of eggs	Date of hatch	No. days in egg stage
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

THE LARVAL STAGE

Though this is the stage which is of economic importance when associated with cultivated plants, our knowledge of Pleocoma larvae has been limited. Four descriptions of Pleocoma larvae have appeared in the literature. While two of these papers, Osten Sacken (55, p. 84-87) and Hayes and Chang (26, p. 117-127) were based on only single specimens, Ritcher (60, p. 11-20 and 61, p. 14-17) based his description on a series of specimens and a cast larval skin.

A. DESCRIPTION

The larva is typically scarabaeiform with a whitish body and light yellow-brown head (Figure 12). The antennae are 3-segmented, with the first segment as long as the second and third segments together and the third segment small and about one-third the length of the second segment. Head narrower than the pro-thorax and the entire thoracic region with a larger diameter than the abdomen. The legs are well developed, 4-segmented, with stridulating organs on the meso-and metathoracic legs. The stridulatory organs appear as a finely striated area on the posterior surface of the mesothoracic coxae and a V-shaped row of sclerotized teeth on the metathoracic tronchanter. Anal opening Y-shaped and not surrounded

by fleshy lobes; with a narrow, transverse band of 50 to 70 unarranged, short, stout setae located cephalad of the lower anal lip.

B. 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, it has been found that the soil and its affect on penentration of tree roots directly effects the vertical distribution of Pleocoma larvae, since these roots are the source of food. Indications are that this effect also controls the vertical distribution of P. oregonensis larvae in cherry orchards surrounding The Dalles.

The Soil Conservation Service, at present is re-classifying the soils in the Hood River Valley. I am indebted to Mr. James Crane for graciously classifying the soil at a number of localities, where P. crinita and P. minor occur in the Hood River Valley. Pleocoma crinita larvae are found in the following soils: Transition series of Hood River silt of the Underwood type with a restrictive layer at 24 to 30 inches, Oak Grove series,

which is a medium textured soil with a restrictive layer at 24 inches and the Rockford series which has 0 to 3 feet of usable clay loam. Larvae of P. minor occur in the same Transition series of Hood River silt with a restrictive layer other than plates of rock in certain localities and a Residual type which has a higher clay content than the Chemawa series, but having no restrictive layer other than the clay content.

In certain districts of the Hood River Valley, roots of apple and pear do not penentrate the soil in excess of 24-30 inches because of the restrictive subsoil layer. In other districts, the loose, open subsoil has allowed 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 24-30 inch depth have a vertical distribution ranging from 3.5 to 29 inches (Table 9). 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 is found from 8 to 16 inches. Larvae of P. crinita are not now 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 10). Larvae of this species occurring in localities with a 24 inch root zone are found in greatest numbers in the 8-20 inch level, while grubs in the districts with a 60 inch root zone are found in the greatest numbers at the 16-44 inch level. The overall depths at which grubs of P. minor are found in the Hood River Valley varies greatly, ranging from 3.5 to 59 inches. While digging for P. minor grubs in the G. Ogden apple orchard southwest of Odell, Hood River County, the writer encountered trees with roots restricted to a 36-38 inch zone by a plate of solid rock. Larvae of this species 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 were 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.

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

Table 9. Vertical distribution of *P. crinita* larvae.

Depth range in inches	Apple root depths 24 inches	30 inches	Pear root depth 24 in.
	No. of larvae		No. of larvae
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	

Table 10. Vertical distribution of *P. minor* larvae.

Depth range in inches	Apple root depths 24 in.	40 in.	60 in.	Pear root depth 57 in.
	No. of larvae			No. of larvae
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	

C. SEASONAL SOIL TEMPERATURES

A study of soil temperatures during a four year period, 1954-1957 indicates that larvae of P. crinita live in an enviroment with limited fluctuations in temperature. This is illustrated by Figure 13 and 14, 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 Septmber with readings of 66, 67 67 and 66° F. respectively.

Monthly changes at the 18-inch level were not as pronounced as the 6-inch level. The greatest fluctuation occurring in May and October, was 7° 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.

On two occasions, soil temperatures were recorded at the time of digging for P. oregonensis larvae at The Dalles. Soil temperatures beneath yellow-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 Skyline Road, The Dalles, were 63° F. at 24 inches and 60° F. at 30 inches.

It was thought these seasonal changes in soil temperatures would influence the vertical distribution of grubs in the soil. On several occasions in the late fall and winter while digging for males of P. crinita and and P. oregonensis, grubs of these two species were discovered close to the soil surface (.50 to 1.5 inches). In the case of P. crinita, diggings in November, December and January disclosed no overall change in the vertical distribution of larvae when compared with the distribution for July, August and September. 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.

D. PERIODS OF FEEDING

In general, larvae of P. crinita and P. minor feed thoughout the greater part of the year. In the

case of small larvae it is difficult to determine their period of feeding, however, they are usually found in close proximity to fibrous roots. It is only when numerous larger larvae are discovered in samples dug from beneath fruit trees, that one can 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 numbers of 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, however, no larvae were found feeding on roots in September. No samples have been taken during the remainder of the year, nor for January and February.

Possibly late instar larvae of Pleocoma feed sparingly or not at all since Areekul (1, p. 563) found the epithelial cells were reduced and degenerated in late instar P. crinita larvae.

E. PERIOD OF MOULT

Prior to moulting, each larva prepares a cell and moults therein, often consuming its cast skin following the moult. Larvae of P. crinita, P. minor and

P. oregonensis moult during the summer months.

Sample diggings made in orchards every month of the year disclosed that larvae of P. crinita moult once a year. The earliest moulting occurred August 11, 1955, with the latest being September 27, 1954. Recently moulted larvae with cast skins are more 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 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.

Mature larvae of P. crinita and P. minor do not moult the year of pupation.

F. INSTARS

All other Scarabaeidae have only three instars, however, P. crinita and P. minor have many instars and indications are that P. oregonensis follow the same

pattern. Some authors have expressed an opinion that the larval stage of Pleocoma was possibly three or more years in length.

Davis (14, p. 266) expressed his opinion in the following manner, "Very little is known of the life history, and very few larvae have ever been collected, but indications are that the life of the insect may extend over 3 to 5 years".

While digging for P. hirticollis vandykei adults, Smith and Potts (73, p. 117-118) found 4 larvae of three distinct sizes. From these specimens, they thought this species had a life cycle of more than one year.

In the fall of 1953, Ritcher and Olney (62, p. 42) found P. crinita grubs of several sizes. They concluded that the life cycle may take several 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, then preserved, which established the second instar.

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 garner three separate head capsule measurements for a single larvae.

Head capsule widths of pre-pupae 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 11).

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 11).

Limited investigation of P. oregonensis larvae indicate it also has a large number of instars.

In comparing the range of measurements of respective instars it was found the measurements of P. crinita larvae were larger than 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 instar.

G. 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

Table 11. Maximum width of head capsule for the instars of P. crinita and P. minor.

Instar	No. grubs	P. crinita Min. in mm.	P. crinita Max. in mm.	Remarks	No. grubs	P. minor Min. in mm.	P. minor Max. in mm.	Remarks
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	"	48	2.46	2.94	"
4	92	3.27	4.09	"	88	3.10	3.43	"
5	53	3.59	4.74	"	44	3.43	3.92	"
6	73	4.74	5.39	"	59	4.09	4.58	"
7	101	5.39	6.38	"	92	4.58	5.39	"
8	93	6.05	7.03	"	88	5.39	6.21	"
9	67	7.03	7.68	Pupated	52	6.05	6.70	Pupated
10	69	7.52	8.18	"	55	6.70	7.36	"
11	54	8.01	8.83	"	30	7.19	7.52	"
12	50	8.67	9.48	"	37	7.68	8.67	"
13	32	9.16	10.14	"	11	8.83	10.63	"

with a hand trowel, The sample area, within the "drip" portion of the tree, was 36 inches square and to 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 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. Ahother, one 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 three 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 western-yellow pine in Sorosis Park, revealed grubs to be present in limited numbers. The samples ranged from 0 to 1.67 grubs per square foot. Three samples taken from beneath three cherry trees on Skyline Road, disclosed a range of .06 to .33 grubs per square foot.

THE PREPUPAL STAGE

Pleocoma crinita and P. minor were found to have a rather distinct prepupal stage (Figure 15) 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 the stage may be over 30 days in length.

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

THE PUPAL STAGE

Our previous knowledge of the pupal stage of Pleocoma was limited. Six papers are known to the writer in which there is information available concerning this stage. Davis in 1935 (14, p. 128) wrote the following, "Upon reaching its full size the larva approaches the surface of the ground, constructs a cell from three or four inches to a foot beneath it, and pupates. The pupa of Pleocoma has never been described. The only pupa in good condition that I have ever seen was that of a female P. behrensi Lec. which had been taken at a depth of about eight inches in the middle of a trail in Strawberry Canyon, Berkeley, Calif. This pupa was dug out while adults were emerging from burrows withing a few inches of it ... and the beetle probably would not have emerged until the following fall".

Pupal and larval skins of P. hirticollis vandykei females were found at the bottom of female burrows in five instances (73, p. 117), however no depth was noted. In the other paper on P. hirticollis vandykei (61, p. 17) seventeen females dug from burrows were found at depths of 3 to 10 inches with either a cast pupal or larval skin. A dead male was also found in its pupal cell at a depth of 5 inches.

In 1953, Ritcher and Olney (62, p. 42) found pupal cells of P. crinita between 7 and 21 inches in the soil. The authors noted that pupation must occur before the middle of September since fully colored adults were found from that time on. The writer (17, p. 15) described finding pupae of P. crinita at depths ranging from 5.5 to 21 inches. I further noted that pupation in the field and under laboratory conditions begins in late July and early August.

Ritcher and Beer (64, p. 184) on July 22, 1954, found three pupae of P. dubitalis dubitalis in the soil at depths of 7, 7.5 and 9.5 inches. One of these pupae became an adult on September 5, 1954. On October 1, 1952, the same authors also found one male beetle in its pupal cell at a depth of 5 inches.

A. DESCRIPTION OF PUPA AND PUPAL CELL

The white, exarate pupae of P. crinita and P. minor have no processes on the pronotum nor are the sex organs external as in certain other scarabaeid pupae. Sex of the pupae can be determined by examination of antennae and apical horn. In the males the antennal club is prominant while the apical horn is pointed; in females the antennal club is not prominant and the apical horn is rounded.

Like 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 16). 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 exuvia is located posterior to the pupa in the cell.

B. DEPTH OF PUPATION

Pupae of P. crinita and P. minor are found scattered at depths in the soil 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. 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 12).

Table 12. Depths of pupation for P. crinita and P. minor

Depth range in inches	P. crinita Root zone 30 in. No. pupae	P. minor Root zone 24 in. No. pupae	P. minor Root zone 60 in. No. pupae
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.

C. TIME AND DURATION OF PUPAL STAGE

The onset of pupation is difficult to ascertain in the field and can only be determined 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 (Table 13 and 14). 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 under laboratory conditions in 1957. 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 14, 1957, a single male pupa, at a depth of 8 inches was dug from the W. Larraway 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 Larraway 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 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 for P. minor (Tables 13 and 14). The length of the pupal stage did not vary with sex of either species and all transformed into adults the same year as pupation occurred.

Table 13. 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	September 9	43	"
July 31	September 15	47	Male
July 31	September 16	48	"
August 1	September 14	45	Female
August 2	September 17	47	Male
August 2	September 17	47	"
August 2	September 17	47	"
August 3	September 19	48	"
August 3	September 14	43	Female
August 3	Pupa died	--	"
August 5	September 21	48	Male
August 6	September 18	44	Female
August 7	September 19	44	"
August 9	September 21	44	"
August 9	September 22	45	"
August 12	September 19	39	"
August 12	September 21	41	Male
August 13	September 21	40	"
August 13	September 21	40	"
August 13	September 21	40	"
August 13	September 21	40	"
August 13	September 21	40	"
August 13	September 22	41	"
August 13	September 23	42	"
August 14	Pupa died	--	Female
July 19, 1957	September 9, 1957	52	Male
July 19,	August 28	41	Female
		44 day average	

Table 14. 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	Pupa died	--	"
July 21	September 1, 1956	42	Female
July 23	September 2	41	"
June 17, 1957	Pupa died (1957)	--	Male
June 19	August 3	45	Female
June 22	August 7	46	Male
June 25	Pupa died	--	"
June 27	Pupa died	--	"
June 27	Pupa died	--	"
June 30	August 15	46	"
July 2	August 20	49	"
July 12	Pupa died	--	Female
July 12	August 27	46	"
July 17	September 3	48	Male
July 17	Pupa died	--	Female
July 18	Pupa died	--	"
July 18	September 3	47	"
July 20	September 9	51	Male
July 28	September 10	44	Female
August 1	September 14	44	"
		47 day average	

THE ADULT STAGE

A. 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 13). 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-Deptember. Pupae are rarely found after September 25.

Pleocoma minor pupae began transforming into adults on August 3, 1957, under laboratory conditions (58-60° F.) (Table 14). 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 have been found in the field was July 26, 1957. The majority of pupae transform in August, with pupae being rarely found after the first week of September.

B. MOVEMENT FROM THE PUPAL CELL

Within a few days after transformation, adults of P. crinita and P. minor begin burrowing from their pupal cells. The burrow, one-half to three-quarter of an inch in diameter, turns gradually upward from the end of the pupal cell. Rarely, adults begin the tunnel at 90 degrees 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 1/2 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.

C. SEASON OF ADULT ACTIVITY

The three species of Pleocoma in Wasco and Hood River Counties, mate during the fall and winter seasons. Period when mating of the three species was observed is given in Table 15.

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 extend 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 well be a case of a species not too well adapted to its environment.

(a) 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.

Table 15. Mating periods for three species of *Pleocoma*

Year	*P. minor* Hood River County	*P. crinita* Hood River County	*P. crinita* 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

Year	*P. oregonensis* Wasco County	*P. oregonensis* 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

Two of the earliest observations on occurrance of Pleocoma activity were written by Ricksecker. Both citations concerned P. fimbriata. In 1886 (57, p. 201-202) he noted emergence began after the autumn rains soaked the soil to a depth of 4 to 6 inches, with flight being diurnal and of short duration. A note in 1888 (58, p. 212) stated a few Pleocoma emerged after a slight rain, but after a storm lasting about a week the whole brood emerged.

Other early observations appeared in the literature in 1889 and 1890. Rivers (65, p. 17) credited Mr. Baron as observing and collecting P. fimbriata flying in the rain during the evening. Two other notes by Rivers in 1890, are concerned with the flight habits of P. behrensii. Specimens (67, p. 70) were collected on 19, 20 and 22 of October, while the second period of heavy rain was at a peak. The other note (68, p. 21-26) stated that adults are found during the first heavy rains of the season, which often is in the month of October.

Davis (9, p. 11-12) wrote "After the first rains of the year ..... the beetles come to the surface. The males come out and fly ...."

Following this early period, collectors began noting the time or period of day when flight occurred

and atmospheric conditions at the time of collection.

Pleocoma hirsuta Davis is recorded (13, p. 88-89) as being collected on January 22, 1933, at 5:00 a.m. while flying below the snowline.

Collection data on P. shastensis Van Dyke indicated this species flew during a variety of conditions. On October 22, 1932 (74, p. 184-185) males were collected, flying in a snowstorm. Flight (46, p. 151) also occurred in the early morning from about 6:00 a.m. to 10:00 a.m. and again in the afternoon and evening from about 3:00 p.m. to 9:00 p.m.

Two records of P. nitida Linsley flight were noted, both during pre-dawn and dawn. One occurred on December 19, 1940, three-quarter of an hour before sunrise during a period of radiation fog (46, p. 148). The other collection was made November 15, 1952, during the third rain of the season, between 4:55 p.m. and 5:25 p.m. in intermittant light rain (28, p. 202).

Two years observations on P. conjungens Horn as presented by Hazeltine (27, p. 188) showed males of this species are active shortly after sunset, during the night and the period prior to or shortly after dawn. During 1948, flight began between 7:50 and 8:00 a.m. on October 27 and at 8:30 a.m. on December 13 (Pacific

Daylight Saving Time). The largest flights occurred approximately one-half hour before dawn to one-half hour after dawn on rainy days or when the humidity was near the saturation point. Large flights were noted to begin at sunset and continue for 45 minutes under the same conditions as the morning flights. On November 6, 1949, flight began at 10:00 p.m. and continued to 6:00 a.m., with a steady light rain the entire time. The area was lighted by a nearly full moon shining through the fog-like clouds.

Pleocoma punticollis Rivers, (28, p. 202) is noted to fly both night and day in the second or third rain of the fall season. Males of P. sonomae (28, p. 202) were collected in flight on November 14, 1952, beginning at 2:00 p.m. and lasting about 15 minutes, with flight ending shortly after start of precipitation. A male was also observed flying at sunset in clear, cool weather in the same area on November 16.

Fall (28, p. 64-66) when describing P. australis noted he collected the specimens in a drizzling rain. This species was also recorded (48, p. 111) as flying at 3:00 p.m., October 24, 1941, in a drizzling rain.

Specimens of P. rickseckeri Horn (48, p. 112) were collected in the rain on November 9, 1940.

In 1920, Hopping (29, p. 126-128) wrote P. fimbriata, P. hoppingi Fall and P. behrensii males fly at dusk during a fine drizzle, but not during a rain. In the ensuing years numerous records of P. behrensi flight appear in print. On the two days following a heavy rain at Berkeley, California, October 15, 1925, a number of males were taken in flight or males and females were dug from their burrows. (11, p. 110). Von Bloeker (75, p. 288-289) wrote that P. behrensi males began flying as the sun disappeared behindMarin Point near Berkeley, California. This apparently was late afternoon since flickers and jays were observed capturing the male beetles in flight. In the fall of 1934, Linsley (42, p. 14) found P. behrensi had three flight periods. During the period of September 23 to October 6, there was .09 inches of rainfall, with no flight. The first flight occurred October 21 when there was .39 inches of rainfall. On October 31 and November 1, .62 inches of rain fell with a good flight of males and many females opened their burrows. The largest flight occurred November 17-18, when .77 inches of rain fell. During the week following this last flight, large number of both sexes were discovered in the soil.

In the Patterson Pass area of California (73,

p. 116-117), P. hirticollis vandykei was found to emerge after a soaking rain of about one-half inch or more. "Males were observed flying from 12:00 noon until 6:15 p.m. under conditions that varied from a heavy rain to late afternnoon sunshine to after dark, and from a slight breeze to a northwest wind. They appeared to be most abundant about the middle of the afternoon. On the whole, the weather was rather cold and threatening".

Males of the sub-species P. dubitalis dubitalis, commonly found in certain areas of the Willamette Valley of Oregon, have been observed or collected in flight under varying conditions. It has been observed (48, p. 113) flying near dusk, during the fall rainy period (October 23, 1938). Males have been collected (64, p. 181) during October and November in rain or when the air was saturated with moisture. Individuals were also observed flying at 10:00-11:40 a.m. and 2:05 p.m. On October 16, 1954, flight occurred between 6:53-7:40 a.m. with a light rain falling. The largest flights were observed during early morning hours shortly after dawn.

In 1953, Ritcher and Olney (62, p. 41) 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 pre-dawn and early dawn under a wide range of climatic conditions, which includes drizzling rain, radiation fog, overcast sky or a sky with a few broken cluds.

Though P. minor belongs to the seven lamellate group, its flight habits differ from P. crinita. Two P. minor males were collected in 1954 on October 19, 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. (50, p. 122). Two years records (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 pre-dawn (5:00-5:30 a.m.) and may continue to 7:45 a.m., however, males are commonly observed flying in mid-morning (11:00 a.m.) and mid-afternoon (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. I recorded (18, p. 431) collecting males on October 8, 1954, during the first rain of the fall season, and also noted male flight as occurring at 6:30 a.m. and 4:30 p.m., either in the rain or at times when the atmosphere was saturated. Four years observations (1954, 1955, 1956, 1957) shows adult activity begins when nearly .50 inches or rain has fallen.

The largest flights occur in pre-dawn (4:45 to

5:15 a.m.) and may continue to 7:00 a.m., however 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.

As with males of the other two species, males of this species have been collected under the same wide range of climatic conditions.

D. ADULT POPULATIONS

Taken as a whole, in the areas in which P. crinita P. minor and P. oregonensis occur, there have been large flights each year of adults during the time the writer has been investigating the habits of these species.

When a specific area is observed for a number of years, however, there are differences in size of flight from year to year. An orchard where P. crinita adults have been observed since 1953 (large flight that year) there has been a decrease in the emergence of adults since 1954. In two other orchards, large flights of P. crinita were noted in 1956, but in 1957, only an occasional male was seen in flight or found digging down to the scattered, few 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 during this period.

Adults of all three species are abundant in wooden 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.

E. BEHAVIOR OF MALES DURING MATING SEASON

Considerably more has been written concerning behavior of Pleocoma males than females. This is due in part to males spending limited time above ground, searching for the concealed, wingless females. Reports of male behavior include flight characteristics, attraction to water or light and the mechanics of locating a female.

(a) FLIGHT OF MALE

Two early collectors briefly noted flight characteristics of males. Ricksecker (57, p. 201-202) in 1886, while collecting P. fimbriata noted flight was slow and rarely attained a height of more than 6 or 8 feet. In 1911, Fall (22, 64-66) cited the flight of P. australis in the following manner, "Beetles flew slowly and apparently aimlessly, keeping as a rule a foot or two above the ground".

Davis (15, p. 129) says the flight of P. badia is slow and blundering with males keeping close to the ground, while the flight of P. beherensi was direct and and swift. Pleocoma nitidia males were said to be fast flyers (28, p. 202).

Smith and Potts (73, p. 117) described the flight of P. hirticollis vandykei in detail. Males, in search of female burrows, made slow sweeping flight of 50 to 200 yards into the wind. During this searching flight, males were 12 to 18 inches or less above the soil surface. Downwind flights were long, straight and swift, with males 10 to 15 feet above the ground. After this downwind flight another upwind search flight would begin. Frequently, flight was of long duration, with one male being followed for over a mile. When colliding with a plant, males fell to the ground, crawled a few inches, then took wing again.

Flight of P. dubitalis dubitalis cited by Ritcher and Beer (64, p. 181-182) was close to the ground (4 to 12 inches), however, when disturbed, males flew erratically and soared 20 or more feet into the air.

The writer has observed numerous, large flights of P. crinita, P. minor and P. oregonensis during pre-dawn (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 above.

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 air borne. A large flight of beetles flying through or out of tall grass create a noticeable,loud buzzing sound.

(b) ATTRACTION TO WATER

Reports of Pleocoma males being found in small streams and water filled ditches and puddles have been cited on several occasions.

Two early reports, one in 1888 and the other in 1889, are concerned with males of two species. Horn (30, p. 9) records P. hirticollis males being found,

drowned in a small stream of water. In 1889, Rivers (65, p. 17) reported a P. beherensii male being found drowned in a pool of water.

Davis (15, p. 130) in 1935, wrote the following, "Many males are attracted to pools of water, plunge into them, and drown".

Males of P. fimbriata have been taken from an irrigation flume and irrigation water (52, p. 102-103). Dr. E. G. Linsley (personal communication) noted P. behrensi males being commonly taken from a swimming pool in Strawberry Canyon, Berkeley, California and P. tularensis Leach from a flume and forebay in Sequoia National Park.

The writer had occasion to associate P. crinita with water in two instances. On the morning of March 8, 1954, a resident of Hood River, found a male, alive, in a puddle of water near her home. On December 7, 1955, a fruit grower near Odell, Hood River County, found Pleocoma males in water-filled ruts. Collections made at this locality during December 1956, revealed P. crinita to be present in the area.

Pleocoma minor males are also attracted to water. A grower near Oak Grove, Hood River County, found a male in a tub of water on September 24, 1956. Immediately after morning flights on September 20, 21 and October 10,

1956, I found P. minor males floating in water seeping from an irrigation line. Some of these males were alive, while others were drowned. On September 20, 1956, two males were discovered, burrowing into the soil within inches of this seepage.

The writer collected (October 22, 1956) five P. oregonensis males from puddles of water in Sorosis Park, The Dalles, Oregon. This apparently occurred during the pre-dawn hours of October 22, since all males were alive.

The association of Pleocoma males with water does not appear to be accidental, since these records now involve six species.

(c) ATTRACTION TO LIGHT

Certain species of Pleocoma are reported to be attracted to light, while other are not.

Rivers (66, p. 17) cited the experiences of Mr. Baron during a camping trip in the following manner, "while taking his evening meal was surprised by a visitation of a number of P. fimbriata entering his tent, charging upon his light and extinguishing it".

Davis (15, p. 129-130) made two reports on Pleocoma and their attraction to light and an interesting comment on light as an attractant. He said a Mr. Kenneth Monroe

told him of some large brown bugs flying into the fire during a rain at Pine Flats, near Pasadena. On the same pages, males of P. badia were reported as not being attracted to automobile headlights. Davis wrote further, "A light of low intensity such as lantern, a fire, or the reflection of light from a surface of water, is probably more attractive to them than is a stronger light.".

Pleocoma nitidia has been reported as not attracted to light (28, p. 202) and also as being collected three-quarters of an hours before sunrise at a light on the front porch of a house (45, p. 148).

Two other species (46, p. 151), P. shastensis and P. rickseckeri are noted as being attracted to light.

Smith and Potts (73, p. 117) found P. hirticollis vandykei males were not attracted to light from a Coleman lantern.

In 1950, Hazeltine (27, p. 202) reporting on a personal communication from Dr. J.A. Comstock says after dark, P. punctlcollis are strongly attracted to light. The same author (28, p. 188) reported P. conjungens males are attracted to light early in the season, but later in the seaon are not attracted to light.

Ritcher and Olney (62, p. 41) found P. crinita males were not attracted to light, however, two specimens

of this species were taken at a lighted window, at 6:30 a.m. on January 15, 1958.

Pleocoma minor males have repeatedly been collected on a window sill beneath a lighted window, near Oak Grove, Hood River County.

I have never found P. crinita, P. minor and P. oregonensis males to be attracted to light from a Coleman lantern, kerosene light trap or automobile headlights. While collecting males of these three species with the aid of automobile headlights, males have flown against the automobile near the headlights, but they have also flown against unlighted portions of the automobile. This flying into the automobile is probably due to clumsy, blundering flight and the inability to avoid large objects.

(d) LOCATING THE FEMALE

The manner in which Pleocoma males locate the female is not easily explained.

Four brief notes, advance the thought that a sensory mechanism may be involved. Ricksecker (56, p. 201-202) wrote, "where the flying males discover them by some acute sense and dig down to find their mates". Rivers (68, p. 25) suggested males found females by scent.

Davis (10, p. 117) cited, "I had heard Scarabaeidae smelled with the antennae, so I got all the strong smelling things I could think of such as acetic acid, vinegar, ether, chloroform, etc; to all of these the beetles paid no attention until the antennae were actually touched, and then they frantically tried to rub the antennae clean with the forelegs". Davis (15, p. 129) wrote, "The flying males are probably attracted to the female by scent".

During the period in which the female is near the top of the ground the burrow is covered by a small mound of pulverized soil. It is difficult to conceive of a male finding a female burrow by sight, particularly during pre-dawn darkeness. However, sight may be involved in finding females, as there is considerable activity on the ground surface when one or more males are burrowing to reach a female. In early morning, I have observed several P. minor males burrowing into soil at the same site. While observing these males, other males flying near these sites, alighted and joined the others. This has also been observed with P. oregonensis.

Odor and the sense of smell possible play a very important role. The small mound of damp soil may retain odor which attracts the males, since adult activity is during drizzling rain or when the air is saturated with

moisture. Skunks are also actively engaged in digging female beetles from the ground at this time and may also detect them by the female's scent. Male beetles are attracted to burrows from which females have been removed since males have been found in holes where skunks have dug females. To the writer, female beetles have a distinct odor, while males do not.

I have observed P. minor males flying near the ground in search of females on several occasions. On approaching or passing over a female burrow, males dropped to the ground and began crawling rapidly toward the burrow. The males held their antennae, with lamellae unfolded, in the same plane as the body and at right angles to the head.

F. BEHAVIOR OF FEMALE DURING MATING SEASON

Following transformation, females of the 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 burrow.

During mating season, a large number of unmated females of all three species were observed in their

burrows. The 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.

Male or 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 (18, p. 431).

Under laboratory conditions females of the three species will copulate with more than one male.

G. 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 considerable time.

Mr. Olney and Dr. P.O. Ritcher began investigations on P. crinita female activity during November and December, 1953. They dug numerous females from burrows, recorded depth, position and amount of pulverized soil covering the individual and then returned the females to the soil and marked the location with a numbered stake. Unfortunately the fruit grower cultivated the orchard and displaced nearly all stakes marking location of these burrows. Those few marked burrows found 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 December, 1953.

On December 10, 1954, I placed numerous mated P. crinita females in the soil at depth 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.

The writer placed known mated P. crinita females in the soil on January 25, 1955, 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.

Skunks (Mephitis) were actively digging out and feeding on P. crinita females during January, February and March of 1954, 1955 and 1956. This does not occur in the case of P. minor and P. oregonensis. The only time skunks feed on females of these two species is during the mating period when females are near the surface.

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. While digging for grubs of this species on April 18, 1957, two females were found at 18 and 22.5 inches.

H. 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. 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 (Figure 17).

In February, Hopping (29, p. 216-218) after finding the burrows which P. fimbriata females had opened to the soil surface, discovered these females at considerable depths in the soil (18-30 inches).

In their brief review of P. crinita life history, Ritcher and Olney (62, p. 41-42) stated by the time of male flight (November) many females had opened their burrows and retreated a short distance into the burrow to await males. They further remarked that following copulation females descended deeper into the soil and waited until the following summer before depositing their eggs.

Mating of P. dubitalis dubitalis occurs in October and November, however a live female of this species was found with her egg mass on July 23, 1954 (64, p. 181 - 183).

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, the year following, however 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 discovered 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. Energy for these activities apparently comes from stored fats.

DISPERSION

Obviously Pleocoma can only be spread, either by slow movement of the wingless females or larvae or they must be carried by some other agency.

Other workers make note of female beetles leaving the original burrow and digging a new one. Davis (10, p. 117) writes as follows, "The females of Pleocoma sometimes leave their burrows to dig new ones"... "Probably the beetles do their traveling at night". Hopping (28, p. 218) states, "The females seldom if ever come out of the ground". These writers in neither instance record the distance moved by females.

It is not uncommon to find where females of P. crinita have emerged from one burrow and dug a new one within an inch or at most 4 inches. On three occasions, in mid-morning, P. crinita females have been seen crawling over the soil surface in a Hood River apple orchard. On November 23, 1954, a female was seen 2 inches from an open burrow. Two females were seen on January 25, 1955 moving over bare ground. Of them, one female was a foot from an open burrow and the other female was 18 inches from an area were there might have been a burrow hidden in the grass. At 8:30, a.m., September

27, 1957 a P. minor female was seen crawling on a packed dirt road, 30 inches from a freshly opened burrow. A single female of P. oregonensis was seen moving over bare ground November 18, 1957. This female was 36 inches from a burrow. In one instance, a domestic cat has been observed carrying a live female beetle.

One means by which these beetles disperse is by movement of the larvae through the soil. Diggings in orchards and woodlands show larvae dispersed through the soil at various depths and distances from roots. A larva in the soil, feeding on the roots, could move a considerable distance in the course of seven or more years.

Man may also aid in dispersal. When orchardists remove trees, Pleocoma grubs are often found in the soil clinging to the root system. The usual practice is to drag the stumps and roots through the orchards to a point of disposal. Often, this distance is over a quarter of a mile. Larvae could be dislodged and drop by the wayside. The same could occur during a land clearing operation when the roots of forest trees are moved or the land leveled. Road builders could also move larvae and gravid females considerable distances when moving soil. Landslides and water may be another means of dispersal.

In spite of the above observations, it is still

difficult to understand how these species could spread from place to place.

NATURAL ENEMIES

Of all stages, the adults are the most vunerable 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 (10, p. 118) writing of P. badia Fall, from California reported finding elytra of this beetle in feces of some kind of animal and wrote, "The chipmunks and squirrels eat hundreds of the beetles. They must go out in the rain to dig them from their holes". Three elytra of Pleocoma were found at two ground squirrel middens near Patterson Pass, California, January 21, 1944 (73, p. 115).

Linsley (47, p. 165-166) from the vicinity of Yosemite National Park, recorded finding the remains of P. hoppingi Fall, in the nest of a white-footed mouse (Paremyscus sp.) and also remains of hundreds of the same species of beetle in coyote feces. Again in 1957, fragments of P. hoppingi males were reported as being taken from three coyote stomachs (52, p. 103).

Hopping (29, p. 218) reported foxes as preying on P. fimbriata in the following manner. "Suddenly I realized why I found so many holes in this red soil dug by foxes: "Mrs Pleocoma" undoubtedly made a fine part of Mr. Fox's meal". This transpired at a ranger station in the Sierra foothills five miles from Dunlop, in Fresno County, California.

Stellars and California Jays have been noted by Rickseeker (57, p. 202) as preying on male P. fimbriata. In Strawberry Canyon, Berkeley, California, Von Bloeker (75, p. 288-289) reports observing Coast Jays (Cyanocitta stelleri carbonacea), California Jays (Aphelocoma c. ooleptica) and Red Shafted Flickers (Colaptes cafer collaris)capturing male P. behrensi. This occurred at sunset while the male beetles were in flight.

In Hood River Valley orchard lands, skunks (Mephitis) are the greatest enemies of P. crinita and P. minor adults. On numerous occasions the writer has observed skunks 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. The deeper diggings in all probability yielded a female beetle.

To a limited extent, birds may also feed on Pleocoma adults in Hood River and Wasco Counties. On one occasion while collecting P. minor adults in the forest near Dee, Hood River County, an adult male was found with its abdomen sheared off. This had occurred shortly before being found, as the legs of the male were still moving. One other occurrence of the same nature was noted in an orchard near Odell, Hood River County. The abdomen of this male P. minor appeared as if it had been severed with a sharp instrument. Elytra and portions of

the prothorax of P. minor adults have been found lying in logging roadways near Dee. The remains were found within inches of disturbed soil, resembling that which a bird would make when feeding.

During October, 1956, a resident near Oak Grove, Hood River County, reported turkeys and a young dog pursuing and capturing flying beetles. The turkeys consumed the beetles. The dog, however, merely caught the beetles, crushed and dropped them to pursue another. Collections at this locality revealed the beetles to be P. minor.

Adults, particularly the females of P. crinita, P. minor and P. oregonensis are commonly infested with large numbers of mites[1] (Anoetidae, Histiostoma sp.). The mites are found congregated ventrally on the thorax and abdomen. Female beetles infested with these mites have been carefully observed. The mites caused no readily apparent injury and the female beetles later deposited fertile eggs.

A search of the literature reveals no parasites or predators being recorded from larvae of other species of Pleocoma. At Hood River and The Dalles, Collembola,

1 Determination by Dr. G.W. Wharton, Department of Zoology, University of Maryland.

Oligochaets and Acarina have been found associated with living or dead Pleocoma larvae. It could not be ascertained if the Collembola feeding on the dead larvae were the cause of death or not. In 1954, two "sick", living larvae of P. crinita were found infested with Oligochaetes.[2] Ordinarily Oligochaetes are found only in dead material and are not normally parasites. Larvae of all three species of Pleocoma are frequently infested with the same group of mites as the female beetles. The mites, often in large numbers, are found dorsally on the head capsule or beneath the dorsal fold of integument between the head capsule and prothorax. As far as can be determined, these mites have no adverse affect on the larvae.

No parasites or predators have been observed attacking the pupae and eggs of P. crinita or P. minor.

2 Determination by Dr. Ivan Pratt, Department of Zoology, Oregon State College.

MATERIALS AND METHODS

The writer had available a publication which proved of great assistance. A number of the techniques used in the white grub investigations in Kentucky by Ritcher (59, p. 100 - 149) were employed or modified in pursuing this study.

For the study of Pleocoma distribution, male and female beetles were collected from orchards, wooded areas within the orchard districts and surrounding forests throughout Wasco and Hood River Counties. Emphasis was placed on obtaining mating pairs of P. minor and P. oregonensis since females of these two species were unknown.

A number of methods were used in obtaining information regarding sites for collection of adult beetles. Fruit growers, field representatives of grower organizations, Boy Scouts, 4-H Club members and deer hunters contributed knowledge of sites where larval forms were present or male beetles had been seen in flight or where injury to fruit trees was suspected. On numerous occasions individuals brought beetles or larvae to the writer. Their localities were noted and collections made at appropriate times of the year.

The male beetles, especially of P. crinita and P. minor, were taken in flight during predawn hours with the aid of a flashlight and insect net. A search through orchards and woodlots seeking emergence holes or places where skunks were digging for adult beetles gave additional sites for later collecting. Another method was to drive slowly over country road watching for flying beetles in the beam of automobile headlights. Upon location of a male flight the automobile was stopped, with the lights and motor operating. The male beetles were collected in the illuminated area with the aid of an insect net.

Information on adult behavior was gained by investigating newly planted orchards where old apple and cherry orchards had previously grown. These newly planted orchards are usually under clean cultivation which leaves the soil surface smooth and devoid of grasses and other debris. On this bare soil it is easy to note male emergence holes, disturbed soil where females have opened burrows or where males have entered the soil.

Air and soil temperature records were obtained through use of 7-day recording instruments. All instruments were located in the McKeown apple orchard near Odell. Air temperatures were recorded by a hygrothermograph in a weather shelter. A four pen,

portable, recording thermometer was used to obtain soil temperatures. The bulbs were placed in the soil at 6, 12, 18 and 24 inch levels. The temperature data at the 18 inch level was then used in operating several incubators (constant temperature cabinets) in the laboratory. The incubators proved very satisfactory for detailed life history studies.

Eggs were obtained by confining mated females or copulating pairs in twelve-inch clay flower pots filled with packed, moist soil. The pots were placed in the ground and the tops covered with a screen. Mated females were also placed individually in wide mouth quart jars filled with moist soil. The jar lid was then screwed on the jars and the jars placed in a incubator where the temperature simulated outdoor soil temperatures. Another type of cage was utilized to confine adult beetles and larvae. This cage was constructed of 1 x 8 inch pine lumber. The boards were nailed together to form a rectangular box with a length of 3 or 4 feet. One end was closed with window screening. The top of the box was also fitted with a wire bail for lowering and raising. One board was nailed to the others with the nail heads protruding. This facilitated removal of a side for examination of the contents. A hole was made in the ground with a post hole auger. The soil cage was filled with

tamped soil and lowered in the hole by means of the bail.

Too frequent disturbance of female beetles disrupted egg laying and the females died or failed to deposit more than 5 or 6 eggs.

The clumps of soil containing eggs were broken and the eggs placed on packed soil in a three-ounce salve box. The best method found, was to place the eggs singly in small cavities made with the eraser end of a pencil (Figure 11). The eggs were incubated in a constant temperature cabinet at 54-60° F.

Within a week of hatching the larvae were transferred to two-ounce salve boxes containing firmed, moist soil. The sharpened end of a lead pencil was used to to make a hole in the soil. A single first-stage larva was dropped into the hole and the box closed.

The activities of larvae, adults and pupae in the soil were studied by means of samples dug in areas where populations of a given species occurred. When possible, samples were dug at two week or monthly intervals. The area examined was usually 36 inches square and to a depth 6 inches below the level of the deepest grub. The sod layer of about 4 inches was removed from the sample area and examined. Next, the soil was removed layer by layer with a hand trowel. Measurements of larvae, pupae, adults and eggs were made <u>in situ</u> to the

closest half inch.

The injured larvae were placed singly in numbered vials of 75% alcohol. The uninjured larvae were each placed singly in numbered salve boxes filled with soil. All data obtained in the field was noted and later transferred to bound notebooks under appropriate sections.

At the laboratory maximum width of the head capsules of the larvae were measured with a binocular microscope and ocular micrometer. After measurement the uninjured larvae were placed singly in three-ounce salve boxes filled with moist soil and bits of root for food. Every month or six weeks the larvae were removed, head capsules measurements made and fresh soil placed in the container.

SUMMARY

A biological study was made of three Pleocoma species (P. crinita, P. minor and P.oregonensis) and their relationship to fruit trees in Wasco and Hood River Counties, Oregon. The results of this investigation can be briefly summarized as follows.

Two species, P. crinita and P. minor are found associated with apple, pear and sweet cherry orchards and the Douglas fir association in Hood River County, while P. oregonensis is found in sweet cherry orchards, Douglas fir and yellow-pine forests of Wasco County. The later species is also known to occur in a sagebrush association in Sherman County and P. crinita in the Douglas fir and yellow-pine association surrounding Mosier, Wasco County.

The first authenticated records of Pleocoma grubs injuring roots of orchard trees in Oregon occurred in Hood River County in 1953, and Wasco County in 1954. These reports involved injury to roots of apple and pear in the Hood River Valley and roots of sweet cherry in the vicinity of The Dalles.

A detailed survey disclosed P. crinita and P. minor to be widely distributed in 6,000 acres of pome fruit orchards in the Hood River Valley and P. oregonensis was found widely scattered in over 6,000 acres of stone

fruit orchards surrounding The Dalles.

Larvae attack fibrous roots, main roots and underground portions of the trunk of bearing and non-bearing trees. The feeding injury is shallow or relatively deep, occurring as patches or winding bands and often girdling the roots. As a result of this injury bearing trees are low in vigor, with sparse, yellow foliage and produce small fruits. Young non-bearing trees die as a result of the destruction of the root system or growth of the above ground portion is inhibited.

After mating in the fall, egg laying begins in mid-to late May of the following year and continues through June. Eggs of the three species are dull white in color, averaging 4.6 to 5.9 mm. in length and 3.3 to 4.6 mm. in width, with the eggs of P. oregonensis being the largest.

Females deposit the first eggs at depths ranging from 29.5 to 14.5 inches and move upward in a spiral fashion, laying eggs singly each in a cavity slightly larger than the egg. Following the deposition of a small number to as high as 63 eggs, females die atop their egg mass.

In the laboratory (54-60°F.) the egg stage of P. minor averaged 62 days in length with egg hatch occurring between August 1 and 10. Eggs collected in the field

hatched between July 15 and August 21. Under laboratory conditions (54-60°F.) the egg stage of P. crinita averaged 69 days with hatch occurring between August 4 and 18, and eggs collected in the field hatched between July 21 and September 2. Pleocoma oregonensis eggs, collected in the field, hatched between July 25 and August 27.

Larvae are closely associated with roots of fruit trees. Soil affects the depth to which roots penetrate. Larvae of P. crinita and P. minor are distributed vertically from near the soil surface beginning at 3.5 inches to the total depth of root penetration, which may be nearly 60 inches. Pleocoma oregonensis larvae have been found to a depth of 48 inches beneath sweet cherry trees at The Dalles.

Soil temperatures recorded for 1955, at 6, 12, 18 and 24 inches indicate larvae of P. crinita live in an environment with limited fluctuations in temperature. The greatest monthly and yearly fluctuations are at the 6 inch level.

Feeding of P. crinita and P. minor larvae occurs throughout the entire year. The number of larvae feeding on fruit tree roots is less during the moult period and in late January to mid-February. Limited observations during March, April, May and June showed P. oregonensis

larvae to be feeding on roots of sweet cherry at The Dalles.

Larvae of the three species moult once per year, during the summer months. Pleocoma crinita moult from mid-August to late September and P. minor being in mid-June and are usually completed by late August. Larvae of the species at The Dalles have been discovered moulting in mid-August.

Larvae of the two Pleocoma species in Hood River County, have many instars. From a four year study it would appear larvae of P. crinita have at least 9 instars, but may have as many as 13. Pleocoma minor does not pupate before the ninth instar and also appears to have 13 instars. Larvae of these two species may pupate during any of the instars following the ninth. A limited study of P. oregonensis larvae indicate it also has numerous instars.

Pupae are found at depths closely corresponding to the vertical distribution of the larvae. Pupation of P. crinita begins in late July and early August, with an average pupal period of 44 days. The pupal period for P. minor starts in mid-to late June and early July, with an average pupal period of 47 days.

Pupae of P. crinita begin transforming into adults in late August to early September and those of

P. minor transform in late July and early August.

Shortly after transformation, adults burrow from one end of the pupal cell, turning gradually upward toward the soil surface.

Mating activity of the three species occurs during the fall and winter rainy periods. Flight of P. crinita males begins in mid-October, is at its heighth in November and December, with limited activity in January, February and early March. Mating flight of P. minor starts in early September and is completed by mid-November, while P. oregonensis mates in the short period of late September to mid-November.

Nearly .50 inches of rain is needed to start flight of P. minor and P. oregonensis males, while over 1 inch of rain falls before flight of P. crinita commences.

The wingless females open their burrows to the soil surface, retreat into the burrow to a depth of .50 to 14 inches and there await their mates. By early May, the females are at depths closely corresponding to depths at which egg deposition begins.

Pleocoma are restricted to rather localized areas and occur as colonies in the wooded districts, the same as in the orchards. Life of a male beetle is short when compared to the female, which may live for nearly 12 months.

Members of this genus are dispersed naturally only by movement of the grubs through the soil or by wingless females crawling over the soil surface. Grubs and gravid females may be dispersed by landslides, other movement of earth or by water.

Orchardists removing grub infested tree roots and then dragging the earth encrusted roots containing larvae through their orchards can disperse larvae. Animals and birds may also move female beetles accidentally.

The only enemies of Pleocoma in Wasco and Hood River Counties, are skunks which feed on adults during mating season. No insect parasites or predators were recorded.

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APPENDIX

Fig. 1

Native habitat of P. crinita,
Hood River County, Oregon.

Fig. 2

Native habitat of P. minor,
Hood River County, Oregon.

Fig. 3
Western yellow-pine habitat of
P. oregonensis, The Dalles, Oregon.

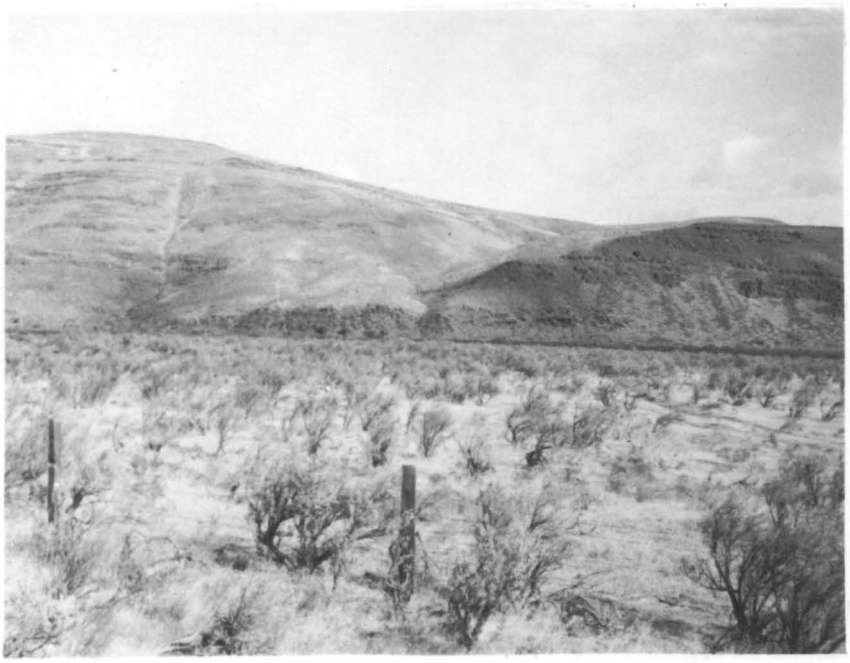

Fig. 4
Sagebrush habitat of P. oregonensis,
east of Wasco, Sherman County, Oregon.

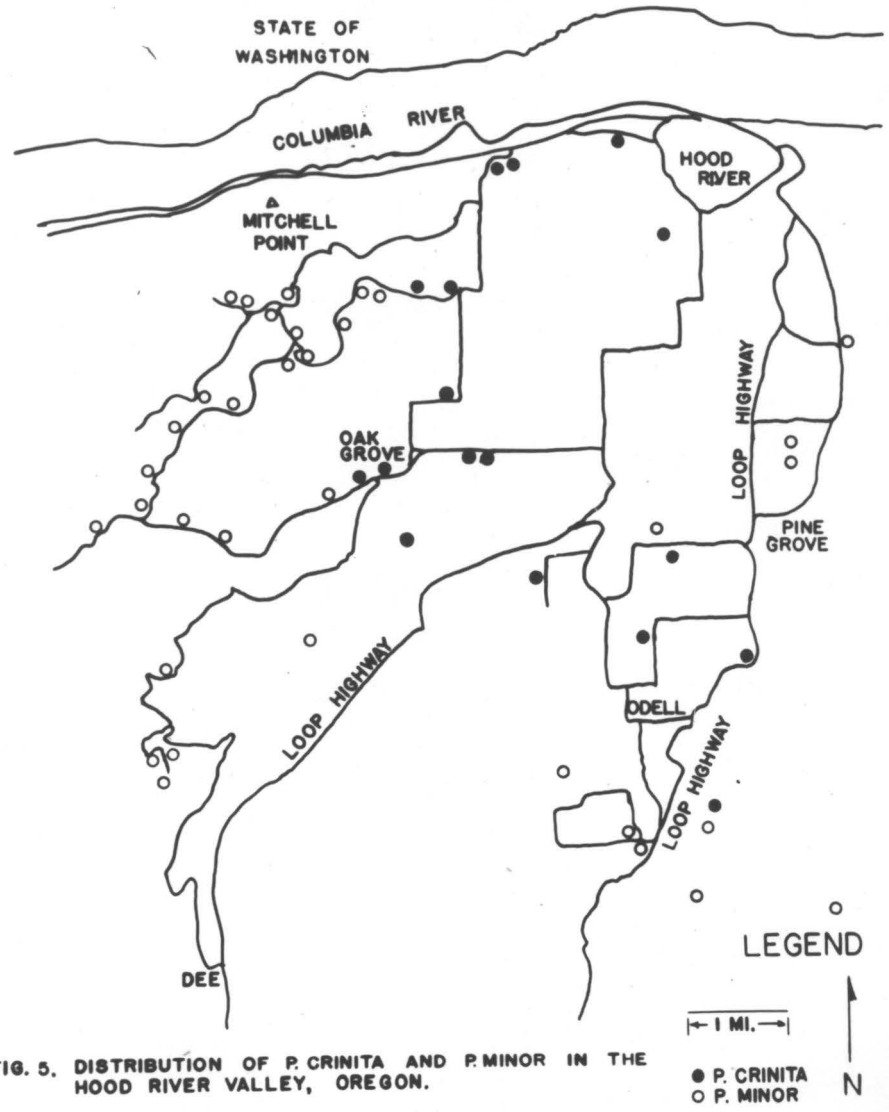

FIG. 5. DISTRIBUTION OF P. CRINITA AND P. MINOR IN THE HOOD RIVER VALLEY, OREGON.

Fig. 6

Larval injury on apple root.

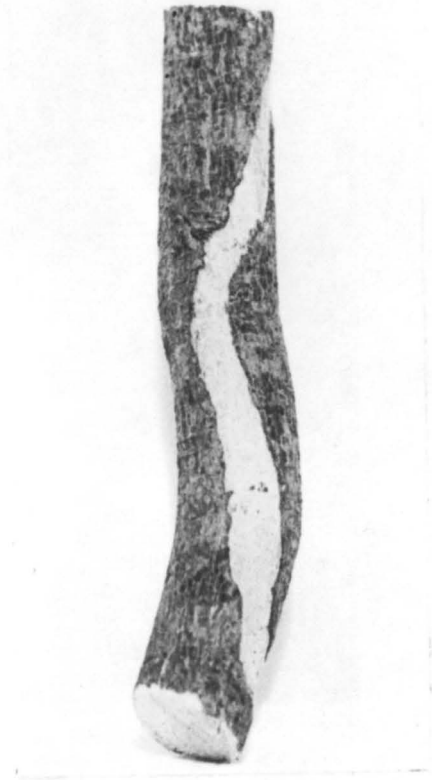

Fig. 7

Injury to root of sweet cherry by larva of P. oregonensis.

Fig. 8
Apple tree showing effects of grub injury to roots.

Fig. 9

Pear tree showing effects of grub injury to roots.

Fig. 10

Grub injury on root of young apple tree.

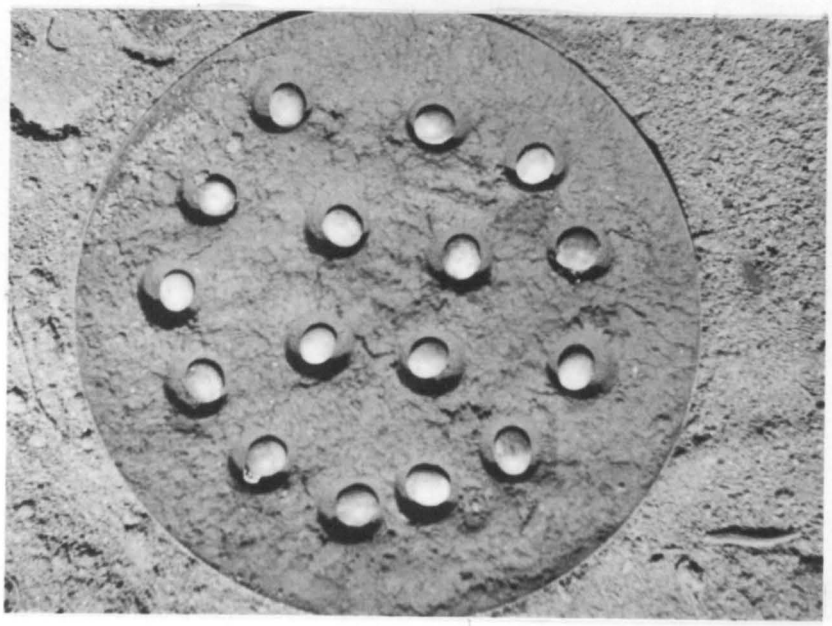

Fig. 11
Eggs of Pleocoma

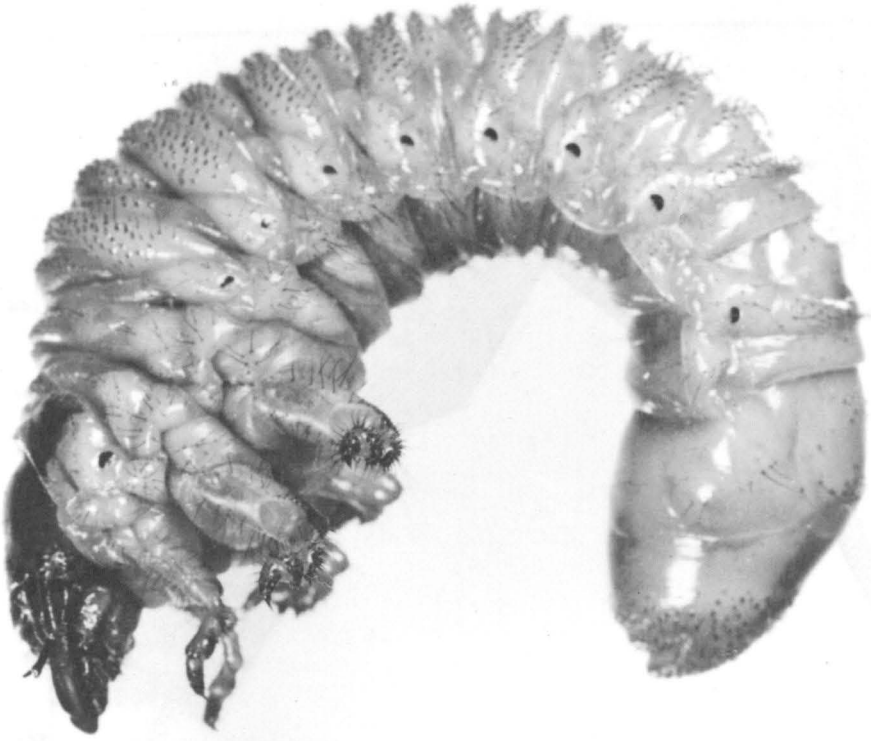

Fig. 12
Pleocoma larva.

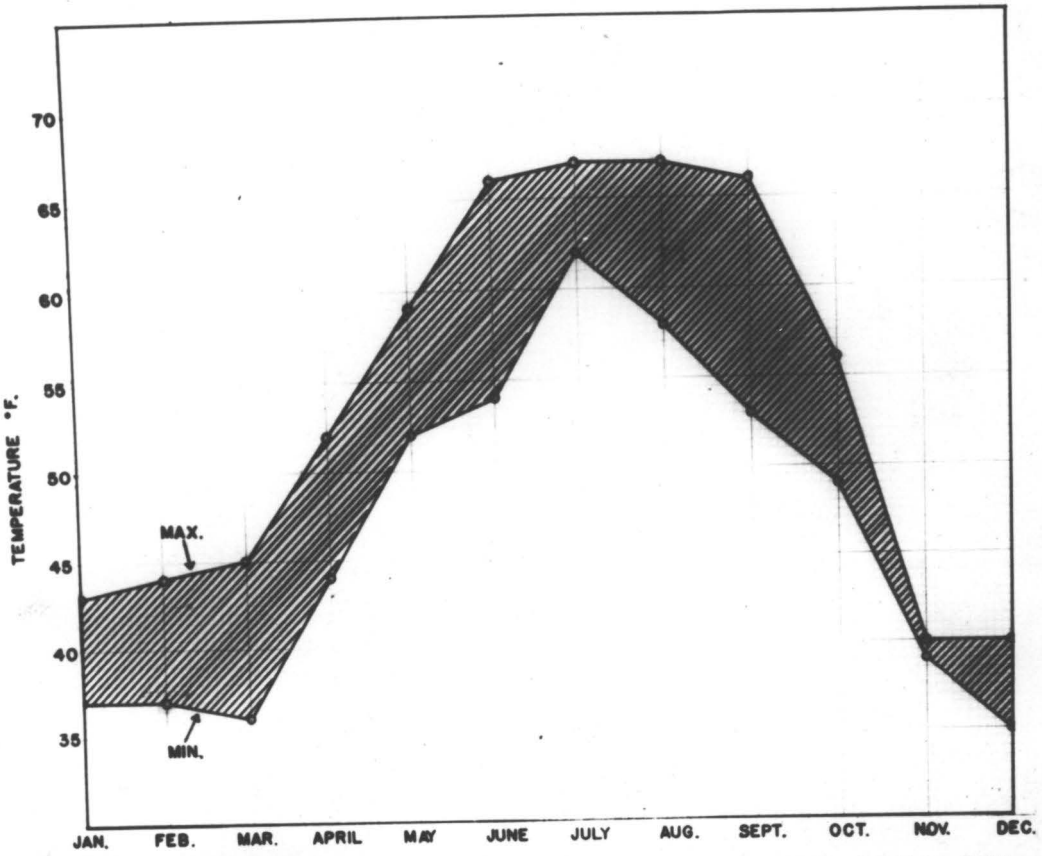

FIG. 13. SOIL TEMPERATURES (1955) AT THE 6 INCH LEVEL. D. MCKEOWN APPLE ORCHARD, ODELL, HOOD RIVER COUNTY, OREGON.

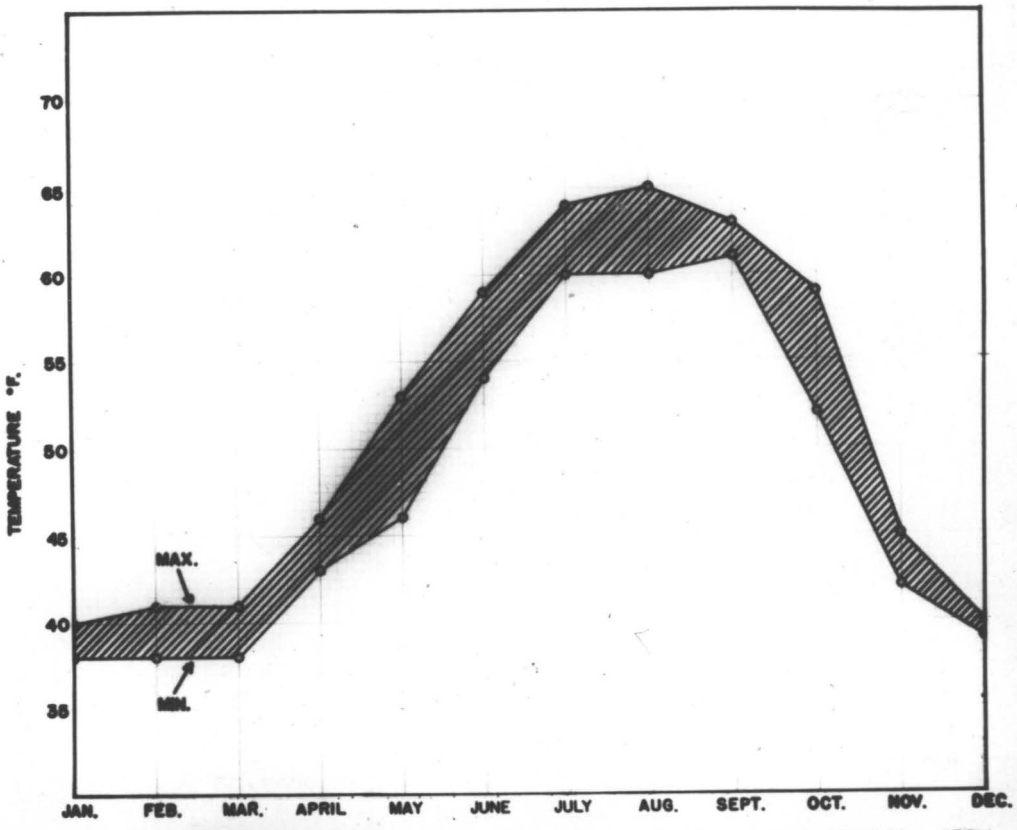

FIG. 14, SOIL TEMPERATURES (1955) AT THE 18 INCH LEVEL. D. MCKEOWN APPLE ORCHARD, ODELL, HOOD RIVER COUNTY, OREGON.

Fig. 15
Prepupa of Pleocoma.

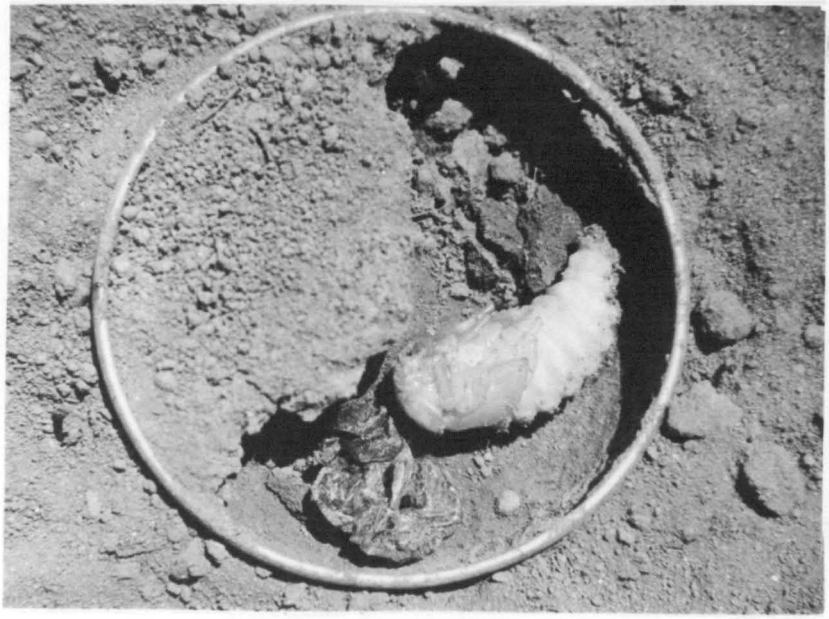

Fig. 16
Pupa of Pleocoma.