Seed and Cone Insects of Ponderosa Pine

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Summary

At least five species of insects cause economic losses to the ponderosa pine seed crop in New Mexico. A seed chalcid, *Megastigmus albifrons* Walker, was found to destroy 42.6 percent of the potentially good seeds. *Conophthorus ponderosae* Hopkins, the pine cone beetle, destroyed an average of 24.8 percent of the cones in all samples. *Dioryctria auranticella* (Grote), the pine cone worm, destroyed an estimated 8.6 percent of the seed crop. The pine cone moth, *Laspeyresia piperana* (Kearfott), reduced the seed crop by 4.8 percent. Cecidomyiidae larvae, principally *Thomasiniana* sp. reduced the seed crop one percent. Collectively, these insects destroyed 82 percent of the potential seed crop, indicating that seed and cone insects may play an important role in preventing natural reforestation.

Many aspects of information about the biology of the more important species was developed. The times of emergence from the overwintering habitat and the times when developing cones are attacked in the spring were established for the more important species.

A key was developed for the identification of the insects most commonly found to damage ponderosa pine cones and seeds in New Mexico.

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Contents

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Seed and Cone Insects of Ponderosa Pine

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"No destructive agent short of climatic injury can so completely nullify a seed crop as insects" (Baldwin, 1942).

An extensive study of conifer seed and cone insects was undertaken by J.M. Miller, D.P. Sergent, J.E. Patterson, and F.P. Keen from 1912 to 1915. The work, published 40 years later by Keen (1958), showed that 38 species of western coniferous trees suffered from attack by seed and cone insects. Little additional research on seed and cone insects was conducted until after World War II, when increased emphasis on reforestation in the United States and Canada stimulated interest in factors affecting conifer seed production (Hedlin, 1961). With this stimulation, research agencies in the southeastern states, California, Washington, Idaho, western Canada, and the Great Lakes states began research on seed and cone insects. In the Southwest research on seed and cone insects has been mainly restricted to the recording of a few species by Keen (1958).

The present study was undertaken to identify the seed and cone insects of the ponderosa pine, and to develop information, where possible, on the biology of the most important insect species.

Procedures

Distribution and Economic Importance

A four-year survey was initiated to determine the species of insects attacking ponderosa pine cones in New Mexico and assess their importance.

Samples were collected primarily along passable roads through ponderosa pine (*Pinus ponderosae*) sites, using a truck-mounted ladder

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to reach the cones. Most samples were collected in the national forests in the state (fig. 1). To minimize sampling bias, all cones within easy reach of one side of the ladder were taken until a representative sample (minimum of 20 cones) had been collected. A few samples collected from trees felled at timber sales were taken from randomly-selected branches.

The 1964 and 1965 surveys were from the Lincoln and Gila national forests in southern New Mexico. The 1966 and 1967 samples were from all the national forests within the state. Forest Service personnel made all collections in the Cibola, Carson, Santa Fe, and Apache national forests in 1966. (Forest locations in appendix I)

After collection, each sample was randomly divided into two groups. One group was carefully dissected, and all the seeds in one-half of each cone as well as the scales and the

Fig. 1. Emergence device used in the laboratory to collect insects emerging from infested cone samples.

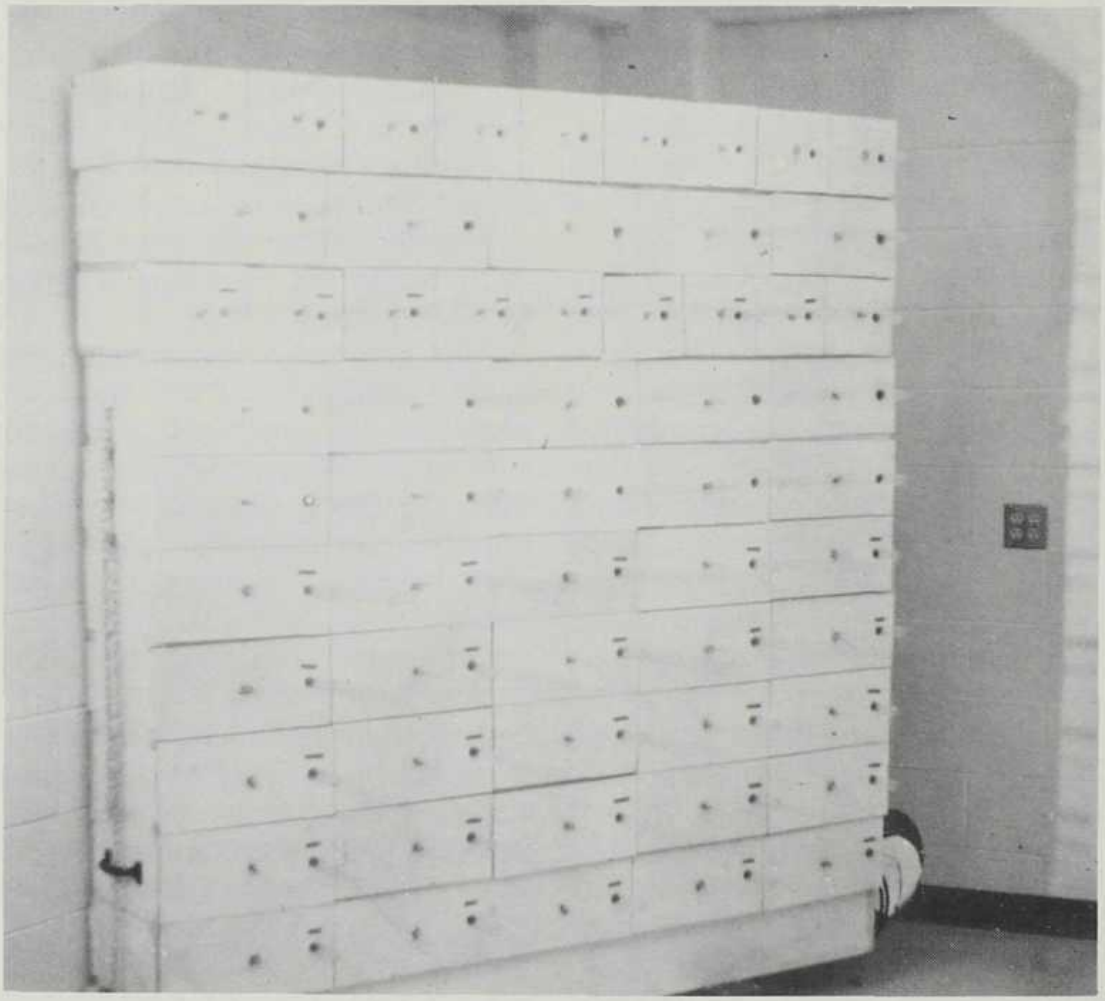
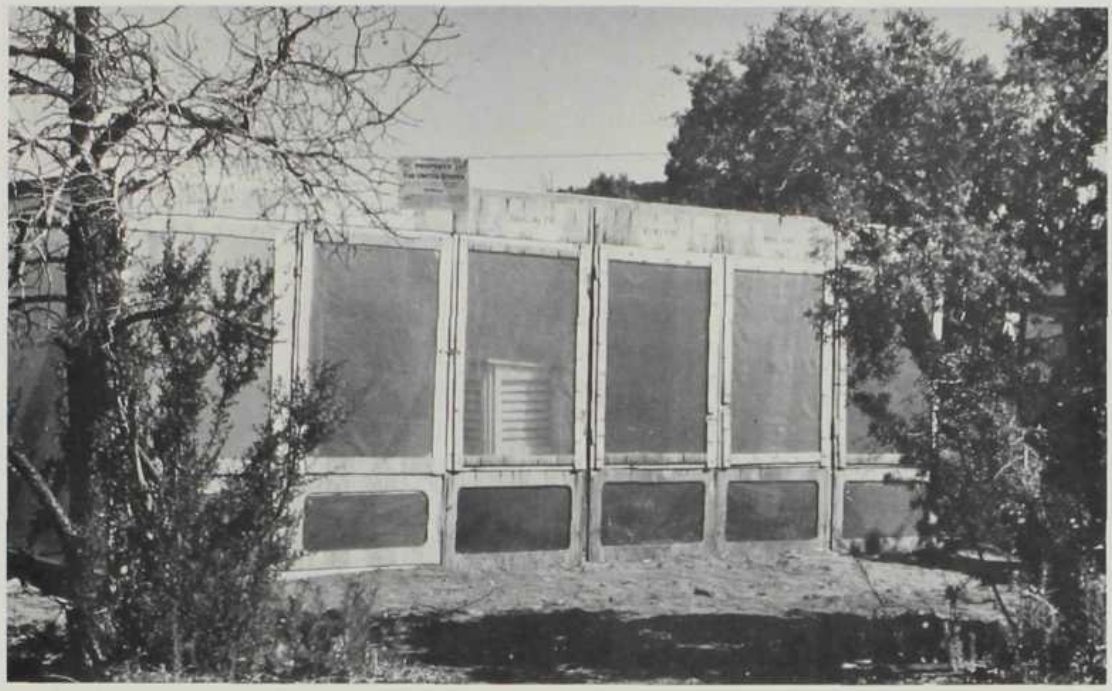


Fig. 2. Screened field cages used to determine the time of spring emergence of insects from infested cones in which they overwintered.



axis were examined. Typically, a ten-cone sample was examined, but sometimes this number was reduced to five. Existing damage was assigned to the responsible insects; this was determined by their presence or characteristic damage to the cones. The insects were removed and identified by station personnel or sent to specialists for identification.

The second group of cones was placed in an insect emergence cage consisting of a series of separate compartments (fig. 1). The compartments were sufficiently aerated to prevent the growth of surface mold. As the insects completed development and emerged from the cones, they were attracted to light admitted through a glass vial that extended into each compartment.

Emergence of Overwintering Forms

In 1966, 1967, and 1968, dates of first and maximum emergence and termination of emergence under field conditions were determined by routine observation of adults emerged from caged cones containing over-wintered insects. All collections were made in late March after the insects had overwintered in their natural habitat but before emergence began. Cones were placed in screened emergence cages (fig. 2) situated at 7100 feet elevation in the Gila National Forest near Kingston. Collections were made in the vicinity of the emergence cage at elevations from 6900 to 7100 feet in 1966 and 1967. The poor crop of new cones in 1967 caused the 1968 collections to be

made in the Lincoln National Forest and transported 117 miles to the emergence cage at Kingston.

Time of Cone Attack

The times at which various injurious species oviposited on the developing, second-year conelets were determined on caged branches where cones were protected from insect attack except for a brief, selected period during the spring and summer. Subsequent examination of the cones for the presence of insects or characteristic damage confirmed the occurrence of oviposition during the period of exposure.

Terminals bearing approximately 10 second-year conelets were caged in 2 feet x 4 feet sleeve cages made of 30 x 30 mesh Lumite screen and fitted with closeable (drawstring) canvas ends (fig. 3). Cages were installed in March before any detectable insect activity occurred. The cages were removed in turn from one of the terminals in each study tree for two-week periods and then replaced. In 1966, eight caged terminals were uncovered at two-week intervals. One cone-bearing branch was exposed continuously from April 11 until August 2. In 1967, six cages in each of two trees were used to evaluate the time of cone attack from March 21 to June 2.

Fig. 3. Plastic lumite screen cage (two by four feet) used to enclose cone-bearing ponderosa pine branches for observations.

Observations on Biology

The seasonal development of some of the more important ponderosa pine seed and cone insects was studied by routinely collecting and dissecting cones from a preselected sample area. The numbers, kinds, and developmental stages of the insects were noted, as well as the nature of damage to the cones and seeds.

In 1965, collections were made from five sample areas in the Gila National Forest and two from the Lincoln National Forest at two-week intervals from May 26 to Sept. 15. On each sample date, five cones were collected from each of five trees in each sample area. This procedure was continued in 1966 and 1967 in the Gila National Forest in each of four sample areas.

The sleeve cages described pre-

viously were used to exclude natural infestations, while allowing observations on individual species placed on cones. Trees used for these studies were located in the same area as the Gila Forest emergence cage, from which emerging insects were collected for introduction into the sleeve cages. This close location allowed for the timing of cage infestations to coincide with the time of natural emergence and thus insure that the cones were in the correct stage of development for insect attack. Various numbers of insects of known sex and age were introduced into the cages and subsequent examinations made.

Findings

A list of insects identified from ponderosa pine cones known or believed to feed on cones or seeds is given in table 1. All insects that feed on cones are included, even though the damage caused by some may be insignificant. The ones causing significant damage are denoted in the table by asterisks and discussed in subsequent sections. Table 2 lists all other insects (except predators and parasites) found in association with ponderosa pine cones. It could not be determined whether or not these were cone feeders.

Biology and Economic Significance of the More Damaging Species

A key for the identification of the more common insects that attack ponderosa pine cones is provided (see appendix II). It includes only those insects that were seen causing damage. This key was written so persons with little entomological training could identify insects that commonly damage seeds or cones of ponderosa pine in New Mexico. Simple characters and a minimum of technical terms were used in the key when possible so that the insects could usually be identified with a hand lens or, Lepidopterous larvae, with a dissecting microscope. Illustrations of the setal patterns useful in Lepidopterous identification are given (fig. 4), and a glossary of terms is included in appendix III. Tentative identification should be checked against the description of the insects in the text and correlated with the type of damage attributed to that particular species. As specific identifications were not always obtainable, many of those collected have not been described.

Conophthorus ponderosae Hopkins (ponderosa pine cone beetle) (*Coleoptera: Scolytidae*). *C. ponderosae* was found to be the species damaging ponderosa pine cones in New Mexico, rather than *C. scopulorum*, as previously reported by Keen (1958). The adults are 3.4-4 mm long, cylindrical, dark brown to black in color except that the elytra appear reddish brown. The larvae are small, curved, legless white grubs, 3.5-4

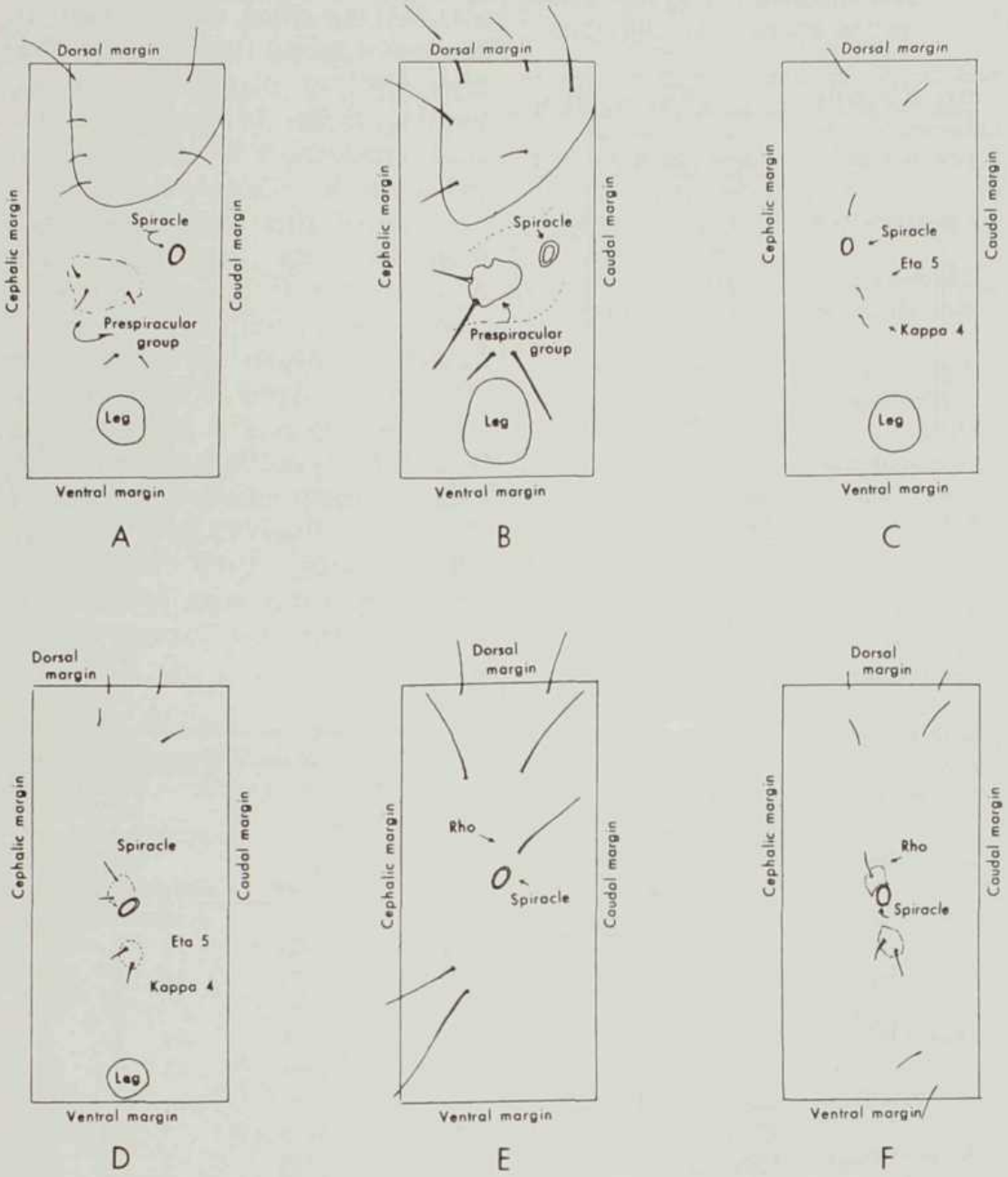
Table 1. Insects which feed on ponderosa pine cones and seeds in New Mexico, 1964-1967

Order & Family	Specific Name	Food Habits
Coleoptera		
Anobiidae	Ernobius alutaceus LeConte	Cone feeders
Anobiidae	Ernobius sp.	Cone feeders
Scolytidae	Conophthorus ponderosae Hopkins*	Cone feeders
Diptera		
Cecidomyiidae	Asynapta keeni (Foote)	Cone feeders
Cecidomyiidae	Cecidomyia sp.	Cone feeders
Cecidomyiidae	Contarinia sp.	Cone feeders
Cecidomyiidae	Lestodiplosis sp.	Cone feeders
Cecidomyiidae	Lestodiplosini genus prob. new	Cone feeders
Cecidomyiidae	Mycodiplosis near conicola	Cone feeders
Cecidomyiidae	Thomasiniana sp.*	Cone feeders
Chamaemyiidae	Leucopis sp.	Cone feeders
Chloropidae	Hapleginella conicola (Greene)	Cone feeders
Chloropidae	Oscinella new species	
Chloropidae	Tricimba new species	Cone feeders
Chloropidae	Conioscinella new species	Cone feeders
Lepidoptera		
Blastobasidae	Holcocera sp.	Cone feeders
Gelechiidae	Near or Chionodes sp.	Cone feeders
Gelechiidae	Exoteleia n. sp.	Cone feeders
Geometridae	Phengommataea niveostriata (Cockerell)	Cone feeders
Olethreutidae	Eucosma sp.*	Cone feeders
Olethreutidae	Laspeyresia piperana (Kearfott)*	Cone feeders
Olethreutidae	Laspeyresia sp. (not piperana)	Cone feeders
Olethreutidae	Laspeyresia toreuta (Grote)	Cone feeders
Olethreutidae	Laspeyresia youngana (Kearfott)	Cone feeders
Phycitidae	Dioryctria abietella (Denis/Schiffermuller)	Cone feeders
Phycitidae	Dioryctria auranticella (Grote)*	Cone feeders
Phycitidae	Possibly Vitula pinei Heinrich*	Cone feeders
Phycitidae	Zeiraphera diniana (Guenee)	Cone feeders
Yponomeutidae	Argyresthia sp.	Cone feeders
Hymenoptera		
Torymidae	Megastigmus albifrons Walker*	Seed infesting
Torymidae	Roptrocerus xylophagorum (Ratzeberg)	Seed infesting
Xyelidae	Xyela sp.	Catkins feeders
Homoptera		
Aphididae	Essigella sp.	Cone & leaf feeders

*Damaging to cones in New Mexico

mm long when fully developed and with a sclerotized, rounded head capsule. They were found within cones in which the axis was girdled by the female adult slightly above its junction with the stalk.

Fig. 4. Schematic illustration of differences in setal arrangements in Lepidopterous larvae encountered in the key. (Setal naming as used by Peterson, 1952).



A. Schematic drawing of prothorax illustrating trisetose prespiracular group of setae.

B. Schematic drawing of prothorax illustrating bisetose prespiracular group of setae.

C. Schematic drawing of abdominal segment illustrating Kappa 4 and Eta 5 placed vertically.

D. Schematic drawing of abdominal segment illustrating Kappa 4 and Eta 5 placed obliquely.

E. Schematic drawing of 8th abdominal segment illustrating seta Rho caudodorsad of spiracle.

F. Schematic drawing of 8th abdominal segment illustrating seta Rho cephalodorsad of spiracle.

Table 2. Insects associated with ponderosa pine seeds and cones in New Mexico for which feeding habits could not be determined, 1964-1967

Order & Family	Specific Name
Coleoptera	
Bruchidae	Acanthoscelides pulloides (Fall)
Chrysomelidae	Cryptocephalus atrofasciatus Jac.
Chrysomelidae	Glyptina sp.
Curculionidae	Smicronyx spretus Dietz
Figitidae	Aegilips sp.
Lathridiidae	Corticaria sp.
Diptera	
Drosophilidae	Drosophila sp.
Ephyridae	Allotrichoma sp.
Ephyridae	Philygria debilis Loew
Muscidae	Coenosa sp.
Sciaridae	Bradysia (new sp.)
Hemiptera	
Anthocoridae	Melanocoris nigricornis Van Duzee
Anthocoridae	Melanocoris (new sp.)
Anthocoridae	Tetraphleps sp.
Lygaeidae	Crophius schwartzi Van Duzee
Lygaeidae	Gastrodes pacificus (Provancher)
Lygaeidae	Geacorius pallens Stal.
Lygaeidae	Neacoryphis bicrucis (Say)
Lygaeidae	Neacoryphis lateralis (Dallas)
Lygaeidae	Nysius tenellus Barber
Pentatomidae	Dendrocoris neomexicanus Nelson

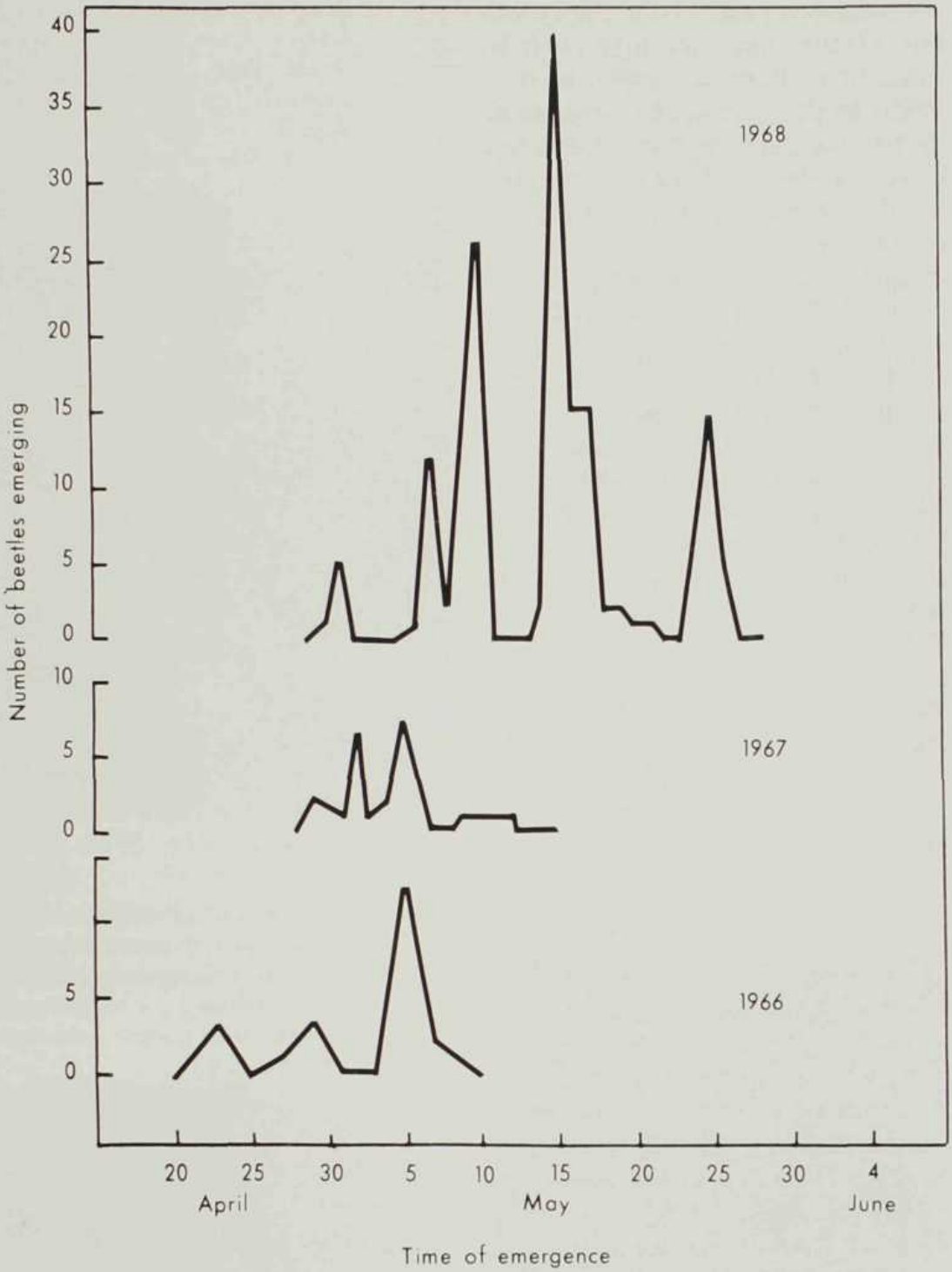
An estimate of the amount of damage to ponderosa pine cones in a four-year survey is shown in table 3. There was considerable variation in the level of infestation between sample areas (0-76 percent), with an average of 24.8 percent in 121 samples. The estimate of infestation reflects seed loss because all cones attacked are killed, a prerequisite to successful brood development. This high level of damage is a major limiting factor in ponderosa pine seed production in New Mexico (Kinzer et al. 1970).

Dates of first emergence, maximum emergence, and termination of emergence of the overwintering forms are presented in figure 5. Emergence began on April 21 in 1967 and on April 29 in 1968. Peak emergence occurred on May 5 in both 1966 and 1967; however, periods of heavy emergence occurred at irregular intervals over a 24-day period during 1968. Periods of heavy emergence were followed by one to three day periods during

Table 3. Damage to ponderosa pine cones from attack by Conophthorus ponderosae Hopkins in New Mexico

National Forest	Year	Samples	Cones Attacked
		number	percent
Lincoln	1964	10	60
Gila	1964	13	44
Lincoln	1965	19	4
Gila	1965	11	76
Lincoln	1966	3	47
Gila	1966	3	7
Apache	1966	1	0
Carson	1966	4	5
Santa Fe	1966	2	0
Lincoln	1967	13	13
Gila	1967	19	5
Apache	1967	2	0
Carson	1967	7	26
Cibola	1967	9	24
Santa Fe	1967	6	17

Fig. 5. Time of emergence of *Conophthorus ponderosae* (Hopk.) from the cones in which they overwintered in southern New Mexico.



which little or no emergence occurred. The emergence patterns did not correlate with daily changes in temperature and humidity (as indicated by hygromograph records taken in the emergence cage) either during or before the emergence peaks. Emergence was completed by May 9, 12, and 26, respectively, during the three years.

Sex ratio of the emerging beetles was 1:1.02 males to females, and 0.22 beetles emerged per cone. A small percentage (0.6 percent) of the population had a delayed emergence or extended dormancy and emerged the following spring.

Female of *C. ponderosae* attacked second-year ponderosa cones on the day they emerged from their overwintering habitat. They were not observed to attack first-year conelets or to feed on shoots or other plant parts before making the cone attack, as reported for *C. resinosae* Hopkins (Lyons, 1956). The period of heaviest cone attack occurred from May 5-25.

The female makes the initial attack, and the male subsequently gains entry through the burrow made by the female. The female penetrates the scales on the basal end of the cone, then bores to the cone axis, which she completely girdles at a point about 2 mm above its intersection with the stalk (fig. 6). The killed cone does not elongate further and rapidly takes on a characteristic withered, reddish appearance (fig. 7).

After the girdle is complete, the female begins to construct a straight gallery along one side of the cone axis. Only one female

Fig. 6. Female (above) and male (below) *Conophthorus ponderosae* (Hopk.) showing cone attack pattern. Cone has been girdled above stalk. Female is constructing egg gallery along one side of axis. Eggs are detectable on right side of gallery.

Fig. 7. Withered reddish appearance of second-year cone (bottom) killed by *Conophthorus ponderosae* (Hopk.) contrasted with appearance of normally developing cones (top).

attacks a cone. She is usually accompanied by a male. Eggs are laid singly in 1-2 mm deep niches along the gallery. An average of 6.7 eggs were laid per cone. The white, thin-walled ovid eggs average 908 μ long x 577 μ wide. They hatch within 5-6 days under optimum field conditions. A maximum of four cones are attacked by one female in cage tests. Typically three cones are attacked.

The larvae begin feeding on the surface of the cone scales. As they develop, they mine through the cone scales and seeds, leaving the cone cluttered with dry reddish frass and finely grated cone tissue that is free of resin.

There are two larval instars. The first pupae begin to form 16 days after the cones are attacked or an estimated 13-14 days after beginning of oviposition. Duration of the pupal stage is normally 8-12 days. Callow adults are found in the cone as early as 24 days after the cone is attacked. However, occasional individuals are observed to remain as pupae through the winter. The beetles overwinter as adults in the brood cone which remains on the tree.

Megastigmus albifrons Walker (the pine seed chalcid) (*Hymenoptera: Torymidae*). Adults are yellowish-brown, 6.0-6.5 mm long wasps with clear wings except for a well-defined club stigma below the anterior margin of the forewing. The females have a long (4.7 mm) curved ovipositor sheath. The larvae are creamy white, curved, legless, with strongly arched bodies composed of 14 segments. The larval head capsule is rigid. Larvae are always found within the seed capsule.

The infestation level of *M. albifrons* in 1965, 1966, and 1967 surveys is shown in table 4. Of all cones examined, 18.6 percent were infested with *Megastigmus;* within the infested cones, an average of 8 percent of the seeds were infested. The damage to the potentially good seed was relatively more severe, since a large percentage of the seeds within a cone normally do not develop into viable seed. Many seeds that appear normal have no viable embryo, even though the seed coat is fully formed and normal in appearance. An average of 42.6 percent of the seeds that developed a fully extended seed coat, in which an embryo was developing, were infested with *Megastigmus.* Thus, there is a seed

Fig. 8. Larval *Megastigmus albifrons* Walker within a ponderosa pine seed.

Table 4. Infestation levels of Megastigmus albifrons Walker in cones of ponderosa pine in New Mexico

Forest	Year	Total Samples	Total Cones Examined	Total Samples Infested	Total Cones Infested	Cones Affected	Seed Destroyed in Cones Infested	Potentially Good Seed Destroyed in Infested Cones
		----------number----------				----------percent----------		
Gila	1965	19	95	15	47	49.5	7.0	24.2
Lincoln	1965	11	55	3	13	23.6	7.8	100.0
Gila	1966	3	15	3	11	73.3	10.9	100.0
Lincoln	1966	3	15	2	2	13.3	2.7	25.0
Apache	1966	1	5	1	4	80.0	23.0	100.0
Carson	1966	4	20	1	4	20.0	9.5	92.7
Santa Fe	1966	2	10	0	0	0.0	0.0	0.0
Gila	1967	19	101	3	7	6.9	2.9	100.0
Lincoln	1967	12	80	0	0	0.0	0.2	100.0
Apache	1967	2	10	0	0	0.0	0.0	0.0
Carson	1967	7	70	1	7	10.0	6.0	30.0
Cibola	1967	9	55	1	1	1.8	0.2	4.3
Santa Fe	1967	6	62	2	4	6.4	3.0	15.8
All cones examined						16.8	8.0	42.6

loss of 42.6 percent of the potentially good seed because the *Megastigmus* larva completely consumes the developing embryo during its development (fig. 8). This is a conservative estimate of total infestation, however, because many infestations of *Megastigmus* were masked subsequently by *Conophthorus* beetle or *Dioryctria* infestations.

The record of emergence of overwintering adults from the cones is shown in figure 9. Adults emerged from April 9 until April 13 in 1966 (from 1965 matured cones), from March 23 until April 18 in 1967, and from March 26 to May 19 in 1968 indicating that April through early May is the time of greatest adult activity. A small percentage, 3 percent in 1965 and 2.9 percent in 1966, remained in diapause until the second year following maturation. Emergence of those adults with a two-year cycle occurred about the same time as those having a one-year cycle.

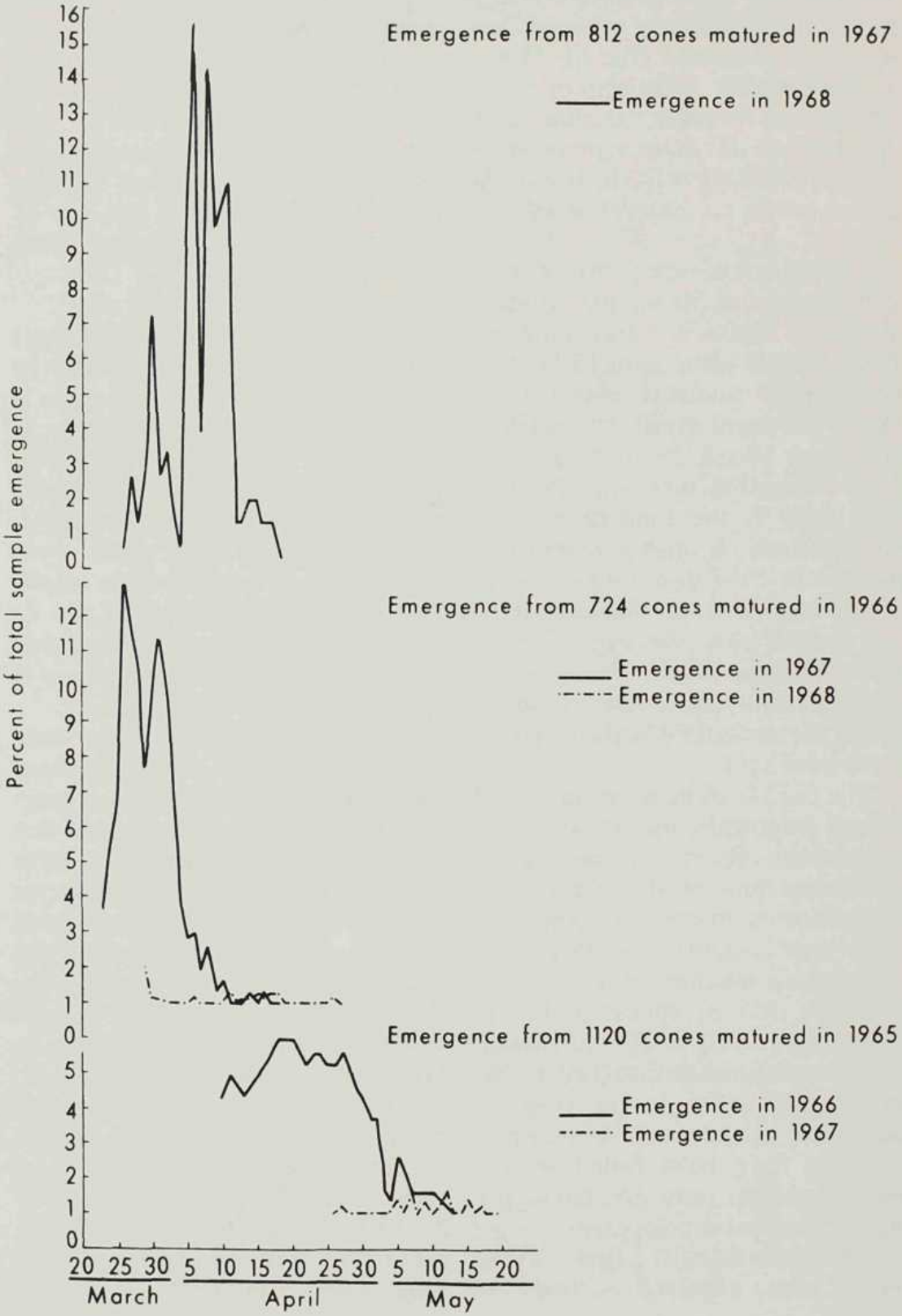
The female chalcid, by means of a long ovipositor, inserts her small, translucent eggs into the developing ponderosa pine seed embryo. The ovipositor is inserted through the scale that supports the seed. The eggs, which measure approximately 400 μ x 175 μ, appear to be enclosed in a strong gelatinous sheath. The sheath remains attached to the eggs for several days after they are deposited in the seed. As many as six eggs have been found in one seed; however, only one larvae per seed completes development.

The translucent, first instar larvae were observed as early as June 10. Larvae about one mm in length are common in the seed in the latter part of June. A fully developed larva occupies most of the space available within the seed coat. Pupation and transformation to the adult stage occurs in late summer and fall. They overwinter as adults within the seed capsule (fig. 7), which remains attached to the cone rather than falling when mature, as normal seed.

Laspeyresia piperana (Kearfott) (the pine cone worm) (*Lepidoptera: Olethreutidae*). *L. piperana* is common in ponderosa pine cones in New Mexico. A related *Laspeyresia* (not *piperana*) also attacks cones of this tree, however, in low incidence. *Laspeyresia* collected from ponderosa pine have also been identified as *L. toreuta* (Grote) and *L. youngana* Kearfott. Ponderosa pine is not generally recognized as a normal host for these insects.

Adult *L. piperana* are dark brown moths with an alar expanse of 17 mm. The hind wings are greyish brown in color. The eggs of this species, not seen during the course of this study, are, according to Keen (1958), attached rather insecurely to the surface of the cone. They are oblong, nearly cylindrical (0.75 x 0.50 mm), opaque and smooth of surface. The larvae are creamy white with a tan head, small circular, tan spiracles; minute body setae and with tan ventral proleg crochets arranged in a complete circle. They attain a length of 10-13 mm when full grown. Pupae are bright yellow, about 6.5 mm long, with prominent eye spots,

Fig. 9. Times of emergence of *Megastigmus albifrons* Walker adults from the cones in which they overwintered.



spiracles not exposed on the first abdominal segment, antennae shorter than wing, two rows of spines on abdominal segments 2-7, with anterior row larger and extending laterally to the spiracles and the caudal row not extending as far laterally as anterior row.

The larger larvae seem to prefer to feed within the developing seed, causing measurable damage to the developing embryos. The damage caused by smaller larvae was difficult to measure accurately because they mine through the scales as well as seeds and undoubtedly cause tissue damage to the cone which could not be readily evaluated by the technique used. The significance of injury in this stage was not measured. Older larvae move into the pith of the cone (fig. 10), where they later pupate. An average of at least 9.4 seeds were destroyed in *Laspeyresia* infested cones.

The infestation level of *Laspeyresia* for 1965, 1966, and 1967, shown in table 5, averaged 14.8 percent in all cones examined. The direct damage caused by one *Laspeyresia* per cone was evaluated by comparing seed production from cones containing one *Laspeyresia* larva at dissection with insect-free cones from the same sample. The infested cones had 32.3 percent fewer potentially-viable seeds per cone than uninfested cones. Taking this estimated single larva loss per cone and the estimated three-year infestation rate of 14.8 percent, the seed loss attributable to *Laspeyresia* was 4.8 percent. As *Laspeyresia* infested cones usually contain more than one larva, this estimate may be low and needs confirmation, as the sample size was not sufficient to show statistical difference at the .05 level.

Fig. 10. Advanced stage larvae of *Laspeyresia piperana* (Kft.) in the pith of a ponderosa pine cone.

Spring emergence of *L. piperana* ranged from May 13-17, 1966, to May 3-29, 1967. Delayed emergence was observed in one individual which remained in the larval stage until the second spring after the cone had matured. Keen (1958) noted that as many as 35 percent of the larvae may remain in diapause for more than one winter. Hedlin (1967) showed that 80 percent of the population diapaused and did not emerge until the second spring.

Oviposition occurred on cones that were made available to females during May 23 to June 6 and June 6 to June 20. Larvae were first noted around July 20 in routine cone dissections. They were mostly

Table 5. Infestation levels of Laspeyresia sp. in cones of ponderosa pine in New Mexico

Forest	Year	Total Samples	Total Cones Examined	Total Samples Infested	Total Cones Infested	Cones Affected	Average Seeds Destroyed per Attacked Cone	Average Larvae per Cone in Infested Cones
		number				percent	number	number
Gila	1965	19	95	11	27	28.4	*	1.3
Lincoln	1965	11	55	1	3	5.4	*	1.0
Gila	1966	3	15	1	1	6.6	7	*
Lincoln	1966	3	15	1	2	13.3	2	*
Apache	1966	1	5	1	3	60.0	13	*
Carson	1966	4	20	2	5	20.0	5	1.0
Santa Fe	1966	2	10	1	1	1.0	*	1.0
Gila	1967	19	101	3	3	2.97	7	1.3
Lincoln	1967	12	80	2	5	6.25	10	1.8
Apache	1967	2	10	0	0	0.0	*	*
Carson	1967	7	70	4	21	30.0	15	3.5
Cibola	1967	9	55	1	5	9.0	9	2.0
Santa Fe	1967	6	62	5	12	19.4	10	1.7
All cones examined						14.8	9.4	

*Not determined in this particular sample.

3-5 mm long at this time and reached their maximum length (10-13 mm) around the middle of August. Then they entered the pith of the cone and became heavy-bodied, with accumulation of fat bodies. They passed the winter as mature larvae, and pupation occurred the following spring.

Dioryctria auranticella (Grote). (the pine cone worm)(*Phycitidae: Lepidoptera*). The larvae are large green to purple caterpillars with dorso-lateral stripes darker extending the length of the body. They may reach a length of up to 26 mm when full grown. The head is dark brown with the cervical shield paler. The body setae are short. Pupae are brown, without readily apparent eye spots, with antennae as long as wings, without body setae or sharp spines, and with recurved spines on terminal segment of abdomen.

Adults are rusty red moths with darker bands across the forewing and one zigzag band across the wing near the tip. Posterior wings are light brown. They have a wing expanse of approximately 31 mm.

Infestation levels of *D. auranticella*, shown in table 6, indicate an average annual infestation of 8 percent. Damage and infestation levels are the same because cones attacked are completely destroyed and do not produce viable seeds. Infestation is usually extensive in individual trees, while adjacent trees may be unaffected.

The time of oviposition was not determined in this study. Larvae were seen feeding in the cones from May 31 to the end of July, after which they were no longer found. In the laboratory, they pupated outside the cone, and adults emerged shortly thereafter. The location of pupation in nature was not determined in this study. They may overwinter as first instar larvae in a hibernaculum as noted for *D. reniculella* (McLeod and Daviault, 1963), *D. zimmermani* (Carlson and Butcher, 1967) and *D. disclosa* (Lyons, 1957). They apparently do not overwinter as advanced larvae, pre-pupae, and pupae, as do *D. abietella* (Lyons, 1957).

Sometimes *Dioryctria* may have left the cone before the damage survey was finished. So, similar damage caused by other species may have been erroneously tabulated and thus allowed an overestimate of *Dioryctria* damage. Any such error, however, was minimal.

Dioryctria larvae tunnel through the scales and seeds in an indiscriminate manner (fig. 11). These tunnels may be 6 mm wide and often 30 mm in length. Feeding results in severance of a large number of the scales near their point of attachment to the cone axis. The galleries are usually relatively free of resin. Larvae characteristically make one or more holes to the outside of the cone, and these often are surrounded by dry, reddish frass held together by a small amount of webbing. The surface appearance of cone scales that have been damaged initially take on a characteristic tan appearance. The entire cone is affected by the time larval feeding is complete and has a bronze appearance. Attacked cones seldom

Table 6. Estimation of cone damage levels attributable to Dioryctria auranticella (Grote) in New Mexico

Forest	Year	Total Samples	Total Cones Examined	Total Samples Infested	Total Cones Infested	Cones Affected
		number				percent
Gila	1965	19	95	5	10	5.2
Lincoln	1965	11	55	1	1	1.8
Gila	1966	3	15	0	0	0
Lincoln	1966	3	15	0	0	0
Apache	1966	1	5	1	1	20
Carson	1966	4	20	0	0	0
Santa Fe	1966	2	10	0	0	0
Gila	1967	19	101	5	11	10.9
Lincoln	1967	12	80	4	17	21.3
Apache	1967	2	10	1	5	50.0
Carson	1967	7	70	1	1	1.4
Santa Fe	1967	6	63	1	1	1.6
Weighted Average						8.6

Fig. 11. Typical feeding of *Dioryctria* larvae in ponderosa cones usually resulting in complete loss.

produce viable seed nor do they open normally.

The time at which adults emerge from the overwintering habitat to attack developing second-year cones was not adequately evaluated in this study. One adult emerged on May 7, 1967, from a forest litter sample collected in early spring for the overwintering study. This may have been an abnormal occurrence, however, as examination of forest litter from beneath infested trees during the winter did not yield viable pupae.

Cages containing cones exposed to newly emerged adults during the periods of May 23-June 6 in 1966 and April 17-May 1 and May 29-June 2 in 1967 contained *Dioryctria* when examined in the fall. This was not conclusive proof of the oviposition period because *Dioryctria* are often foliage and terminal feeders and could have been feeding in or on such tissue when the cage was placed on the tree. None of the cages exposed earlier or later were infested with this insect.

The larvae develop rapidly and individuals 11-16 mm long were seen by the third week of June. Pupae began to form as early as July 19.

Thomasiniana sp. (Diptera: Cecidomyiidae) Cone Midge. At least four species of *Cecidomyiid* larvae were found in ponderosa pine. The small pink or orange larvae occur in large numbers on cones in occasional trees. Infestation levels as given in table 7 indicate that members of this group occurred in only 4 percent of the cones sampled. *Cecidomyiid* infestation had little effect on the seed crop except in isolated trees where heavy populations of *Thomasiniana* were occasionally seen. Larvae of *Thomasiniana* sp. (fig. 12-A) are relatively large, pale-pinkish and reach 4.5 mm in length when full grown. They have small setae on each segment, elevated spiracles, and a breastbone that is uniformly light brown in color and T-shaped in older larvae. They are very active and may jump as far as six inches when placed on a flat surface.

Larvae feed on the surface of the scales, causing a heavy resin flow. As many as 120 larvae were observed in a single cone. The external surface of cone scales on which the larvae have fed usually appear pale green rather than the normal bright green. The upper and lower surfaces of the part of each damaged scale

Table 7. Incidence of Cecidomyiiae-larvae in cones of ponderosa pine in New Mexico

Forest	Year	Total Samples	Total Cones Examined	Total Samples Infested	Total Cones Infested	Cones Affected
		number				percent
Gila	1965	19	95	3	10	10.5
Lincoln	1965	11	55	0	0	0
Gila	1966	3	15	1	1	6.7
Lincoln	1966	3	15	0	0	0
Apache	1966	1	5	0	0	0
Carson	1966	4	20	1	1	5.0
Santa Fe	1966	2	10	0	0	0
Gila	1967	19	101	1	8	7.9
Lincoln	1967	12	80	2	2	2.5
Apache	1967	2	10	0	0	0
Carson	1967	7	70	1	1	1.4
Cibola	1967	9	55	1	2	3.6
Santa Fe	1967	6	60	0	0	0
All cones examined						4.2

Fig. 12. Schematic drawing of Cecidomyiidae larvae found in cones of ponderosa pine in southern New Mexico. A. *Thomasiniana* sp. B. *Asynapta keeni*. C. *Mycodiplosis* sp. D. *Cecidomyia* sp.

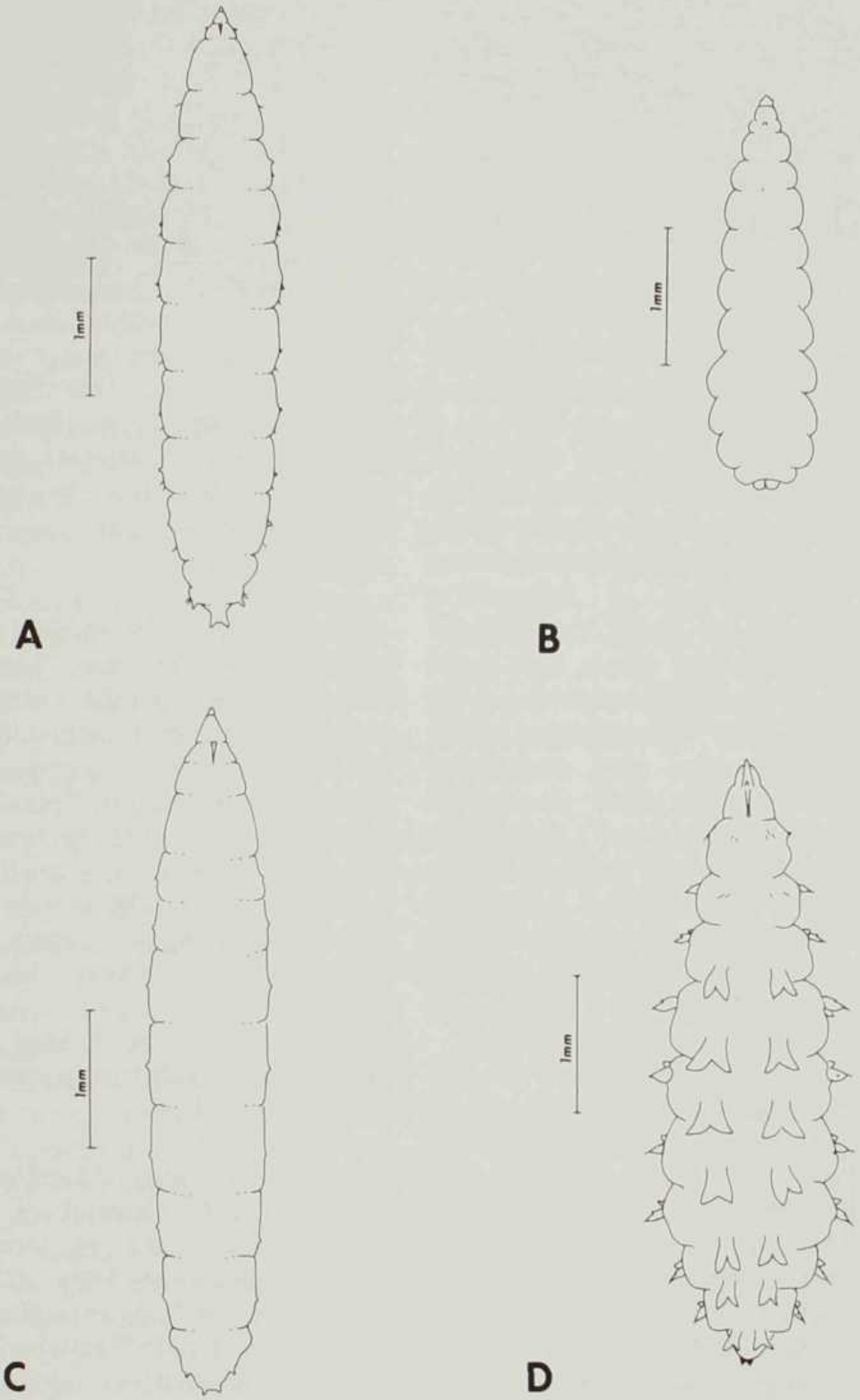
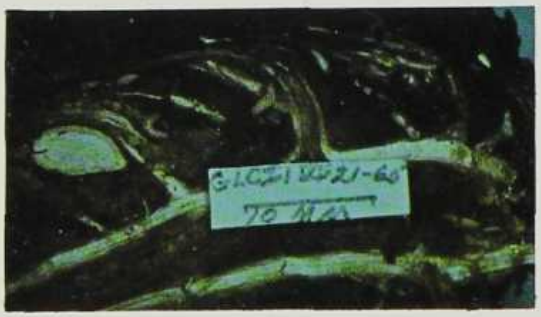


Fig. 13. Cone with heavy resin flow on surface of scales caused by feeding of *Thomasiniana* sp. larvae.



that is inside the closed cone is discolored pinkish red and later turns dark brown (fig. 13).

Neither time of spring emergence from the overwintering habitat nor the time the adult attacks cones was determined for *Thomasiniana* sp. The period of oviposition appears to be quite variable, as larvae from 1 to 4 mm long were found in cones dissected the third week in June. The larvae or pupae apparently do not overwinter within the cone since no insects emerged from cages containing large numbers of cones. These insects probably do not have a significant effect on seed production except when very heavy populations occur in individual trees.

Notes on Insects Rarely Encountered

Eucosma sp. (Lepidoptera: Olethreutidae). Larvae of *Eucosma* sp. were occasionally found damaging cones. The larvae are pinkish caterpillars with a few prominent body setae on each segment. The cervical shield is as dark as the head and widely separated from it. There is a conspicuous pinaculum above and below abdominal spiracles 1-8, and the prespiracular bristle arises from a distinct pinaculum. *Eucosma* larvae feed indiscriminately on seeds and scales and in the process construct burrows that wind through and between scales, often spiraling around the cone axis. The smaller larvae also construct burrows along the apical periphery of individual cone scales. Infested cones have sparce webbing in damaged area. One larva was found in a cone from which adults were excluded except for the period June 6 to June 20 and probably indicates that oviposition occurred then.

Vitula sp. (possibly pinei) (Lepidoptera: Pyralidae). Larvae of this insect are purplish caterpillars with bisetose prespiracular bristles which arise from a prominent sclerotized pinaculum. The sides of the head are uniformly brown in color and the body has small circular tan spiracles. The larvae forage through the cones, causing heavy resin flow. They attain a length of about 8.5 mm, then construct a tough cell of white webbing within the cone in which they pupate (fig. 14).

Holcocera spp. (Lepidoptera: Blastobasidae). Caterpillars designated as *Holcocera* spp. occasionally damage cones. They are small caterpillars reaching approximately 10 mm in length, have trisetose prespiracular bristles, and seta Rho

Fig. 14. Larva of *Vitula* sp. in preparation for pupation.

on eighth abdominal segment are caudo-dorsal of spiracle. Information obtained on damage caused by these species was inadequate to determine their effect. One specimen reached a length of 10 mm in a cone killed by *Conophthorus* beetles when it was only 38 mm long, suggesting that some species may be secondary invaders. They were, however, also collected from normally developing second-year cones. In two cases, *Holcocera* developed and pupated in caged cones, but cone damage was not detected. The pupae seen were about 5.5 mm long, eye spots were not readily apparent, spiracles on first abdominal segment were not exposed, antannae were as long as wings, and abdominal segments 4-8 possessed a row of spines on caudal margin that encircled the abdomen.

Asynapta keeni (Foote) (Diptera: Cecidomyiidae). Larvae of this species are red, reaching a length of 2.4-2.8 mm when fully developed. The body is without setae, the spiracles are not conspicuous, and the faint breastbone is I-shaped (fig. 12-B).

They apparently feed on the seeds and scales within the developing, closed cone. A high population causes considerable resin flow in the infested area of the cone, and occasionally an external appearance is characteristic of that caused by *Thomasiniana* sp., although this situation is rarely seen. Adults were observed to emerge from cones in which they overwintered from May 7 to June 23; however, most emergence was May 1-5. Larvae 1-2 mm long were observed in cones by late June. In the fall caged larvae crawled from cones into soil placed in the bottom of the cage, although some remained in the cones.

Mycodiplosis sp. near conicola Foote (Diptera: Cecidomyiidae). Larvae of *Mycodiplosis* sp. were found occasionally in ponderosa pine cones. They attain a length of 4.5-5 mm when fully developed (fig. 12-C). They have a T-shaped breastbone that is almost uniformly brown in color expect that the caudal end is slightly darker. Setae are absent, and spiracles are slightly elevated.

The effect of this insect on cones was not determined. The low infestation rate observed during this study indicated that it is of little economic importance in New Mexico.

Cecidomyia sp. (Diptera: Cecidomyiidae). An undetermined species of *Cecidomyia* was found on rare occasions in ponderosa pine

cones. The few larvae encountered were about 4 mm long and had characteristic large bilobed papillae on segments 6-12 (fig. 12-D). The effect of this insect on seeds and cones was not determined, although its rarity suggests that it is not of significant economic importance.

Essigella sp. (Homoptera: Aphididae). An undetermined species of this genus was occasionally seen feeding on the basal end of green cones near the stalk. It was not considered to cause economic damage. The aphids were attended by the ant *Liometopum occidentale luctuosum* Wheeler.

Ernobius alutaceus LeConte (Coleoptera: Anobiidae). This insect was found occasionally in ponderosa cones. The larvae are curved, tapering, curled grubs with 6 thorasic legs and yellowish brown heads. Keen (1958) indicates *E. punctulatus* (LeConte), *E. pallitarsis* Fall and *E. montanus* occur in ponderosa pine cones and that all are secondary invaders that feed on cones already killed by other insect species. *Ernobius granulatus* was shown (Ebel, 1964) to be a secondary invader of long leaf pine even though it was commonly found in dead first-year cones. In this study, however, *E. alutaceus* was found feeding in green cones. Whether or not they made the primary attack as suggested for *Ernobius* spp. in ponderosa and Jeffrey pine by Ruckes (1958) was not determined. They appear to be of little consequence to seed production in New Mexico.

Eurytoma sp. (Hymenoptera: Eurytomidae). An undetermined species of this genus was reared from one cone sample. The biology of this species or its effect on the cone was not determined. Some members (species also undetermined) of this group are apparently phytophagous, according to Keen (1958). He reported that one in Douglas fir fed, developed, and pupated within the seeds in a manner similar to that of *Megastigmus*. Another seed feeding species was reared from seeds of Oregon Ash.

Parasitic Insects

A list of parasitic insects associated with ponderosa pine cones is given in table 8. Determination of their parasitic relationship was beyond the scope of this study.

Phanerotoma sp. (Hymenoptera: Braconidae) were often reared from cones damaged by *Dioryctria auranticella*. This probably indicates that it is parasitic on this species, although the association was not definitely established. Similarly, *Exeristes comstockii* (Cresson) (Hymenoptera: Ichneumonidae) was reared from cones containing mumified *Laspeyresia* larvae on which it is likely parasitic.

An undetermined species of adult *Tetrastichus* (Hymenoptera: Eulophidae) emerged from a number of cone samples. The larval stage was not observed. The pupal stage was found to occur in large numbers within the seeds of cones that were also infested with the pine seed chalcid. The presence of a

Table 8. Parasitic insects, of the order Hymenoptera, associated with *ponderosa* pine cones in New Mexico, 1964-1967

Family	Specific Name	Family	Specific Name
Braconidae	Agathis cupressi Muesebeck & Walkley	Eulophidae	Tetrastichus longicorpus (Girault)
Braconidae	Apanteles sp.	Eulophidae	Tetrastichus strobilus Burks
Braconidae	Bracon rhyacioniae		
Braconidae	Bracon sp.	Eulophidae	Tetrastichus sp.
Braconidae	Eubadizon sp.	Eurytomidae	Eurytoma sp.
Braconidae	Heterospilus sp.	Figitidae	Aegilips sp.
Braconidae	Leiophron sp.	Ichneumonidae	Campoplegini
Braconidae	Macrocentrus sp.	Ichneumonidae	Campoplex sp.(phaedroctonus group)
Braconidae	Phanerotoma sp.prob. erythrocephala Rohwer	Ichneumonidae	Dolichomitus new sp.
Braconidae	Phanerotoma sp.	Ichneumonidae	Exeristes comstockii (Cresson)
Braconidae	Protomicroplitis sp.		
Braconidae	Rogas sp. prob. autographae Viereck	Ichneumonidae	Exeristes sp.
		Ichneumonidae	Tromatobia variabilis (Holmgren)
Ceraphronidae	Atritomellus sp.		
Ceraphronidae	Lygocerus sp.	Ichneumonidae	Venturia sp.
Cynipidae	Cynipinae sp.	Ichneumonidae	Venturia sp. diff. sp. from above)
Encyrtidae	Copidosoma sp.		
Encyrtidae	Homalotylus terminalis californicus	Platygasteridae	Platygaster sp.
		Pteromalidae	Acerocephala atroviolacea (Crawford)
Epipaschiidae	Tetralopha sp.		
Eulophidae	Galeopsomyia columbiana (Ashmead)	Pteromalidae	Amblymerus sp.
		Pteromalidae	Habrocytus sp.
Eulophidae	Hyssopus evetriae Girault	Pteromalidae	Habrocytus quinquefasciatus Girault
Eulophidae	Hussopus novus Girault	Pteromalidae	Merisus atriscapus Gahan
Eulophidae	Tetrastichus barbarae Burks	Pteromalidae	Pachyneuron sp.
		Pteromalidae	Pteromalini

dead seed chalcid larvae in the same seeds with *Tetrastichus* sp. suggested the possibility that this insect might be predaceous on *M. albifrons*, as suggested by Keen (1958) for *Tetrastichus* sp. in California. *Tetrastichus* sp. adults apparently overwinter in the seeds which remain attached to the cone scales. Adult emergence from the overwintering habitat occurs from March 27 to May 6.

Predaceous Insects

A list of predaceous insects associated with ponderosa pine cones in New Mexico is presented in table 9. Limited observations on their relationship to insects damaging seeds and cones were made incidental to the other studies.

Cymatodera sp. (Coleoptera: Cleridae) were occasionally seen in *L. piperana* tunnels, suggesting that

Table 9. Predaceous insects associated with ponderosa pine cones in New Mexico, 1964-1967

Order & Family	Specific Name	Order & Family	Specific Name
Coleoptera		Chrysopidae	Chrysopa near carnea Stephens
Cleridae	Cymatodera sp.		
Cleridae	Enoclerus sp.	Hemerobiidae	Hemerobius pacificus Banks
Coccinellidae	Mulsantina picta (Randall)	Hemerobiidae	Hemerobius stigmaterus Fitch
Coccinellidae	Scymnus sp.		
Neuroptera		Raphidiidae	Agulla sp.
Chrysopidae	Chrysopa comanche Banks	Raphidiidae	Agulla minuta Banks

this insect is predaceous on *Laspeyresia*. An unidentified *Ichneumonidae* adult of the tribe Campopleg-ini was observed feeding on a *Laspeyresia* larva that was within a ponderosa seed.

Discussion

At least 69 different insects were found associated with ponderosa pine cones. The inability of taxonomic specialists to provide specific identification for many of the insects suggests the possibility that many of them may be undescribed. Twenty-five were believed to be seed or cone feeders capable of causing some degree of damage. Five species were commonly encountered which did significant damage to the cone or seed.

Collectively this group was responsible for an average seed loss of 82 percent in all cone samples collected, indicating that seed and cone insects greatly limit the regeneration of ponderosa pine in New Mexico. A high level of damage may often be experienced in areas where fewer cones are available for the emerging insects to attack (Hedlin, 1964), and therefore seed and cone insects are relatively more severe during years of poor cone crops. On the other hand, it has been pointed out by Hedlin (1964) that variables other than the cone crop may affect the insect population, e.g., the percentage of diapausing individuals.

This study attempted to measure losses by insects only during the spring and summer of the second year of development. Other losses in ponderosa pine, namely strobilus abortion and overwintering losses due to insects, mechanical damage, frost, and squirrel cutting, have been shown to be important elsewhere (Barnes et al., 1962), and unquestionably add to the losses cited for insects in New Mexico.

This study marks only a beginning of an understanding of seed

and cone insects of ponderosa pine in New Mexico. It exposes the uncertain taxonomy of some of the pest and related species and the relative void of knowledge on host, parasite, and predator relationship, on diapause, behavior, and biology of pest species.

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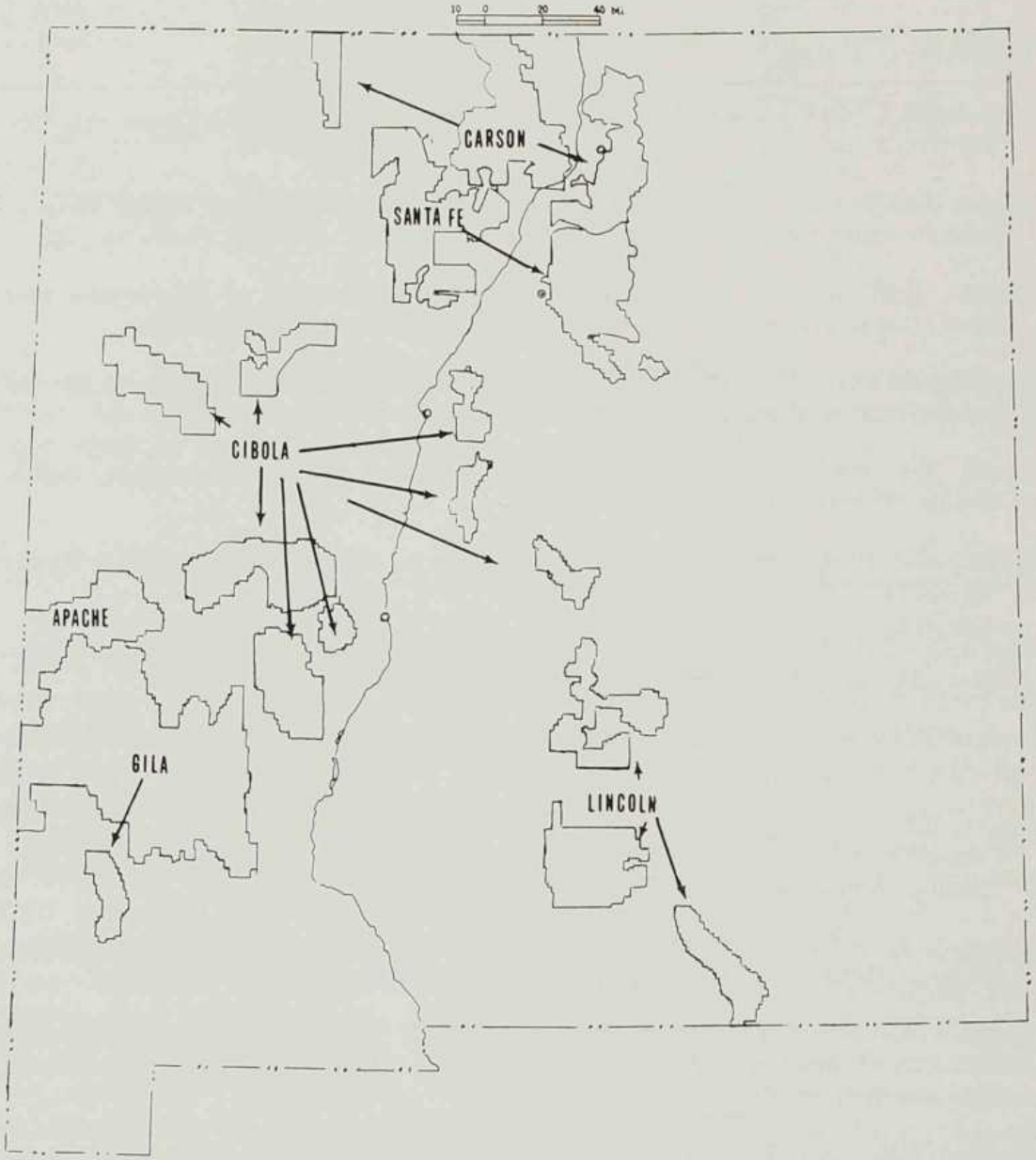
Location of national forests in New Mexico



A Key to the More Common Insects Feeding on Second-Year Ponderosa Pine Cones in New Mexico

1 Small yellow-green, soft bodied insects, pear-like in shape with a pair of cornicles near the posterior end of the abdomen (Aphids) . . . . *Essigella* sp.

1′ Not pear-like, without cornicles 2

2 Insect in larval stage 3

2′ Insect in pupal or adult stage 12

3 With a distinct sclerotized head, or if head capsule indistinct, possessing chitonized, opposable mandibles 5

3′ Without a distinct sclerotized head and without opposable mandibles. Tiny maggots, tapering toward both ends, head poorly developed with schlerotized structure (breastbone) usually visible on the ventral side of the prothorax, light pink to orange 4

4 Breastbone prominent (and "T" shaped, not "I" shaped) and uniform brown in color, spiracles slightly elevated, approximately 4.5 mm long when full grown, very active (Fig. 12-A) . . . . . *Thomasiniana* sp.

4′ Breastbone faint (and "I" shaped) and spiracles not raised, approximately 3mm long when full grown (Fig. 12-B) . . . . . *Asynapta keeni* (Foote)

5 Larvae legless 6

5′ Larvae with legs 7

6 Larvae tapering toward both ends with head capsule (very lightly chitonized) and distinctly "C" shaped, found within intact seed capsule . . . . . *Megastigmus albifrons* (Walker)

6′ Larvae grub-like, not distinctly tapered to both ends, with yellowish-brown, chitonized head capsule, not "C" shaped although may be slightly curved . . . . *Conophthorus ponderosae* (Hopkins)

7 With abdominal prolegs 8

7′ Without abdominal prolegs, body grub-like, with minute brownish spines in each segment, found in both wet and dry cones . . . . . *Ernobius alutaceus* (LeConte)

8 Lepidopterous larvae (caterpillars) with prespiracular group of setae on prothorax bisetose (Fig. 4-B) (Phycitids) 9

8′ Lepidopterous larvae (caterpillars) with prespiracular group of setae on prothorax trisetos (Fig. 4-A) (prespiracular bristles minute and larvae white and nearly naked) 10

9 Prespiracular bristles on prothorax arising from a prominent sclerotized pinaculum, sides of head uniform brown in color, cervical shield as dark as head. Kappa 4 and eta 5 placed vertically on abdominal segments 1-7, obliquely and in same pinaculem on 8, (Fig. 4-C and 4-D), spiracles small, circular, tan . . . . . *Vitula pinei* (Heinrich)

9′ Prespiracular bristles (stout) on prothorax not arising from distinctly dark brown sclerotized pinaculum. Sides of head slightly mottled or uniform brown, cervical shield often paler than head. Kappa 4 and eta 5 placed obliquely in all abdominal segments, spiracles medium in size, circular and brown to grey . . . . . *Dioryctria auranticella* (Grote)

10 Coxae on prothorax touching or nearly so. Setae Rho 3 (Fig. 4-E) on eighth abdominal segment caudodorsal of spiracle . . . . . *Blastobasis*

10′ Coxae on prothorax not touching. Setae Rho 3 (Fig. 4-F) on eight abdominal segment dorsal or cephalodorsad of spiracle 11

11 Nearly naked, white, smooth caterpillars with minute body setae. Circular tan spiracles, small but distinct. Cervical shield paler. Conspicuous pinaculum not present above and below abdominal spiracles, prospiracular bristles not arising from a very lightly chitonized pinaculum. Kappa 4 and eta 5 placed vertically on abdominal segments 1-8 (Fig. 4-C) . . . . . *Laspeyresia piperana* (Kearfott) (Common)
Laspeyresia youngana (Kearfott) (Rare)

11′ Pinkish caterpillars with a few prominent body setae on each segment, prothorasic shield nearly as dark as head capsule, conspicuous pinaculum above and below spiracles on 1-8th abdominal segment, prespiracular bristles arising from a distinct pinaculum, Kappa 4 and eta 5 placed obliquely on abdominal segments 1-8 (Fig. 4-D). Entire body covered with microsetae . . . . . *Eucosma* sp.

12 Insect in pupal stage 14

12′ Insect in adult stage 13

13 Small black beetles, approximately 3.5 mm long from stunted, withered, hard reddish brown cones containing fine shavings and little or no dried resin . . . . . *Conophthorus ponderosae* (Hopkins)

13′ Seed chalcid (Wasp-like) found within intact seed capsule . . . *Megastigmus albifrons* (Walker)

14 Hymenopterous (Wasp-shaped) pupae found within seed . . . *Megastigmus albifrons* (Walker)

14′ Lepidopterous or Coleopterous pupae found at other locations in cone 15

15 Lepidopterous pupae (yellow), approximately 6.5 mm long, light yellow, found usually in the cone axis . . . . . *Laspeyresia* sp.

15′ Coleopterous pupae approximately 3.5 mm long, found in stunted withered hard, reddish brown cone . . . . *Conophthorus ponderosae* (Hopkins)

Glossary

Alar–relating to the wings.

Anterior–in front–toward the front.

Apex–that part of a structure opposite the base.

Apical–at, near, or pertaining to the apex of a structure.

Axis–the center of a cone from which the scales arise.

Basal–at or pertaining to the base.

Bilobed–composed of two lobes.

Bisetose–with two bristles or setae.

Breastbone–(in Cecidomyiid larvae) a horny elongate process on the underside of the head and behind the mouth opening.

Callow adults–(in cone beetles) the condition of the adult after emergence when it is not fully of the mature color, i.e., light brown instead of dark brown.

Caudal–of or pertaining to the anal (rear) end of the insect.

Caudo–dorsal. Toward or in the direction of the rear and the top of the insect.

Cephalad–toward or in the direction of the head end of an insect.

Cervical shield–the chitinous plate behind the head (on the prothorax) of caterpillars, also called prothorasic shield.

Chitonized–filled in with or hardened by chitin.

Cornicles–erect or semierect tubules located on the top-rear of the abdomen of aphids.

Coxae–(plural for coxa) basal segments of leg, by which leg articututes with body.

Diapause–a period of suspended animation.

Dorso lateral strips–bands running along the insect body on either side and just below the topline.

Gallery–a tunnel in the tissue of the host in which the female deposits her eggs.

Hibernaculum–a protective covering in which a larva hibernates.

Papillae–a small soft projection.

Pith–the softer, fibrous area within the axis of a cone.

Pinaculum–an enlarged seta–bearing *soft projection* forming a flat plate.

Posterior–toward or pertaining to the rear.

Prespiracular–in front of the spiracle.

Sclerotized–pertains to a definite hardened area of the insect's body wall.

Spiracle–*a breathing* pore through the lateral aspect of the segments of the insect's body.

Stigma–(in *Megastigmus albifrons*) a club shaped discoloration in the anterior margin of the front wings, about one third of length from end of wing.

Stalk–the supporting structure of a cone.

Trisetose–with three bristles or setae.

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