CONE AND TWIG BEETLES (COLEOPTERA: SCOLYTIDAE) OF THE GENUS *CONOPHTHORUS*: AN ANNOTATED BIBLIOGRAPHY

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by

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FOREWORD

Beetles (Coleoptera: Scolytidae) of the genus *Conophthorus* infest cones and twigs of pine, *Pinus* spp. and rank among the most destructive of North American cone and seed insects (Hedlin *et al.* 1980). The genus was erected by Hopkins (1915) to accommodate 15 species found in North America. McPherson (1970b) and Wood (1962, 1971, 1977a, 1978a, 1978b, and 1980) have since added new species, and Wood (1977b) has synonymized several species named by Hopkins. The present day total is 14 species (Wood 1982); namely: *apachecae Hopkins*; *banksianae* McPherson; *cembroides* Wood; *conicolens* Wood; *coniperda* (Schwarz) synonyms *clunicus Hopkins and* taedae *Hopkins;* echinatae *Wood;* edulis *Hopkins;* mexicanus *Wood;* michoacanae *Wood;* *monophyllae* Hopkins; *ponderosae* Hopkins synonyms *contortae* Hopkins, *flexilis* Hopkins, *lambertianae* Hopkins, *monticolae* Hopkins and *scopulorum* Hopkins; *radiatae* Hopkins; *resinosae* Hopkins, synonym *virginianae* Hopkins; and *teocotum* Wood.

This annotated bibliography contains 91 references on *Conophthorus*. These references address some aspect of biology, control, ecology, or taxonomy. Some references are general, or include other insects; for these, the annotations were confined to the subject. Although several species have been synonymized, the annotations give the species names as they were reported.

Three indices are included at the end of the bibliography: author; species; and subject.

The literature review was completed in December 1985 and includes publications abstracted in *Bibliography of Agriculture* and *Forestry Abstracts*.

ACKNOWLEDGEMENTS

My appreciation to A. Obarymskyj and library staff for obtaining some of the reprints; K. Griffiths, G.E. Miller, and J. Turgeon for reviewing the manuscript; and S. Stitt, all of the Canadian Forestry Service, for the artwork on the front cover.

BIBLIOGRAPHY

1. Barnes, B.V.; Bingham, R.T.; Schenk, J.A. 1962. Insect-caused losses to western white pine cones. USDA For. Serv., Intermountain For. Range Exp. Stn., Res. Note 102, 7 pp.

The western white pine cone beetle, *Conophthorus monticolae*, destroyed more than 90% of the cones during a six-year period in northern Idaho.

2. Bedard, W.D. 1966. High temperature mortality of the sugar-pine cone beetle *Conophthorus lambertianae* Hopkins (Coleoptera: Scolytidae). Can. Ent. 98:152-157.

Broods in 66 of 110 cones exposed to full sunlight for one week or more appeared to have been killed by high temperatures, whereas broods in only 9 of 114 cones died when placed in the shade. In the laboratory, high beetle mortality occurred when exposed to temperatures of 47.1 to 48.2°C, but not when exposed to 46.2 to 46.7°C. Internal cone temperatures in beetle-killed cones in the field exceeded 50°C in 11 of 20 cones. Factors influencing internal cone temperatures are discussed.

3. Bedard, W.D. 1968a. Additions to the knowledge of the biology of *Conophthorus lambertianae* Hopkins (Coleoptera: Scolytidae). Pan-Pacific Entomol. 44:7-17.

Adults overwinter in twigs either on the tree, on the ground, or in fallen cones. Overwintering females did not have sperm in their spermathecae. After penetrating the peduncle of the cone, the female constructs a circumferential gallery, and excavates a longitudinal gallery along the cone axis. No more than 3 females were found ovipositing in a single cone, and where multiple attacks occurred, the females constructed individual or nearly individual egg galleries. Parent adults emerge from the cones within 10 days of the attack. Both sexes emerged in flight condition: males did not undergo complete reduction of wing muscles, while females did. Attacked cones fell to the ground a month or two after they were attacked. Callow adults appeared fully pigmented 10 days after transforming from pupae, but could not fly until 3 weeks later. Some brood adults left cones, flew, and mined individually in twigs. Beetles may mine more than one twig between September and late May. There appears to be only one generation per year. The internal condition of the beetles suggested quiescency which would allow the beetles to survive when cones are not available for insect reproduction.

4. Bedard, W.D. 1968b. The sugar pine cone beetle. USDA For. Serv., For. Pest Leafl., 112, 6 pp.

This leaflet provides a description of the life history and habits; a distribution map of the beetle and its host and photographs of the insect's life stages, and cone damage.

5. Bright, D.E. Jr.; Stark, R.W. 1973. The bark and ambrosia beetles of California Coleoptera: Scolytidae and Platypodiae. Bull. Calif. Insect Survey, Vol. 16, Univ. Calif. Press, 169 pp.

This bulletin shows the geographic distribution and provides basic information on the biology of *Conophthorus contortae, C. flexilis, C. lambertianae, C. monophyllae, C. monticolae, C. ponderosae,* and *C. radiatae* in California.

6. Chamberlin, W.J. 1958. The scolytidae of the northwest: Oregon, Washington, Idaho and British Columbia. Oregon State Monographs: Studies in Entomology No. 2, 208 pp.

A key to five species of *Conophthorus* in the Pacific northwest: *C. ponderosae, C. lambertianae, C. flexilis, C. contortae,* and *C. monticolae* is provided. Descriptions of these species are given (based on Hopkins 1915 paper), as well as the type locality, distribution, hosts, and habits.

7. Dale, J.W.; Schenk, J.A. 1978. Cone production and insect-caused seed losses of ponderosa pine in Idaho and adjacent Washington and Montana. Bull. For. Wildlife Range Exp. Stn. 24. Univ. of Idaho, Moscow, 15 pp.

Gregarious attacks were not observed for *Conophthorus ponderosae*. Single *C. ponderosae* females were found mining in conelets and in new lateral shoots in late May and June. Twig attacks generally occurred in the upper, westerly portion of the crown. Three types of lateral shoot damage occurred: (1) mining of a conelet or bud with extension down the twig for 3 to 4 cm, (2) construction of a spiral mine well below the bud, with extension distally, or (3) construction of a spiral mine 4 to 15 cm below the bud with no extension of the mine. Neither egg niches nor larvae were found in any shoots or conelets. Crop losses from *C. ponderosae* ranged from 10.8% to 97.9% between 1967 and 1969. The severity of damage appeared to be related to crop size and stand structure.

8. Dale, J.W.; Schenk, J.A. 1979. Bionomics and natural control of the cone and seed insects of ponderosa pine in Idaho and adjacent Washington and Montana. Bull. For. Wildlife Range Exp. Stn. 29. Univ. of Idaho, Moscow. 24 pp.

Emerging females of *C. ponderosae* were more numerous than males, with a male:female ratio of 1:1.18 and 1:1.95 in 1968 and 1969, respectively. Cone attack was observed from the second week of May until early July. Adult females are significantly larger than males. The female usually attacks the cone first and then is joined by a male. Single ovipositing females were commonly encountered in cones. Occasionally a single male that had initated an attack was found in a cone. Females leave the cone usually through the entrance hole, occasionally from the cone tip and rarely from the side of the cone. No more than 2-4 cones are attacked by a female. Beetles survived almost 2 years in cones stored at 3°C. The most common predator of *C. ponderosae* was a clerid, *Phyllabaenus* sp. The coneworm *Dioryctria auranticella* (Grote) not only competes with *C. ponderosae,* it also destroys a portion of the beetle population. Increased stand density is likely to reduce losses to the beetle.

9. DeBarr, G.L.; Barber, L.R.; Maxwell, A.H. 1982. Use of carbofuran for control of eastern white pine cone and seed insects. For. Ecol. Manage. 4:1-18.

Carbofuran granules applied to the soil at rates of 4.5, 9.0, or 13.5 g active ingredient (a.i.)/cm of tree diameter at breast height reduced the number of successful *Conophthorus coniperda* attacks. Mean percent of beetle-killed cones per tree was 92, 25, 3, and 3 for carbofuran rates of 0, 4.5, 9.0 and 13.5 g ai/cm of tree diameter, respectively.

10. Dell, T.R.; Robertson, J.L.; Haverty, M.I. 1983. Estimation of cumulative change of state with the Weibull function. Bull. ent. Soc. Am. 29: 38-40.

This report illustrates the application of the three parameter Weibull function, which can project the amount of time required to achieve a desired level of mortality after application of insecticides. Time trends for *Conophthorus ponderosae (= C. monticolae)* mortality after application of permethrin and chlorpyrifos are shown.

11. Forcella, F. 1980. Cone predation by pinyon cone beetle *(Conophthorus edulis;* Scolytidae): dependence on frequency and magnitude of cone production. Am. Nat. 116:594-598.

The number of *Conophthorus edulis* beetles per cone averaged 3.8 (range 1-18). The highest beetle density, 6.4 beetles per square meter of ground area, was found in a stand where annual cone production was most consistent. It is suggested that extraordinarily large cone crops followed by meagre ones or consistently poor crops would be a viable mechanism for pinyon pine to elude predation.

12. Forcella, F.; Harvey, S.J. 1983. Host selection by pine cone beetles in North America (Coleoptera: Scolytidae). Coleopt. Bull. 37:343-347.

The relative decomposition (weight loss) rate of pine cones of several species was used to test the hypothesis that the continual warm/moist climate of the southeastern United States hastened microbial decomposition of cones to such that the quantity and quality of cone material would be jeopardized for pine cone beetles. The study assumed that quality is affected in the same way as cone quantity. Pine species whose cones are attacked by cone beetles have "decay-resistant" cones for at least one year. Pine species whose cones are not attacked have cones that decompose rapidly. Microbial interference with the quality and quantity of cone resources for beetle brood chambers and food is suggested as a possible explanation for host selectivity and the geographic distribution of *Conophthorus* in North America.

13. Godwin, P.A.; Odell, T.M. 1965. The life history of the white-pine cone beetle, *Conophthorus coniperda*. Ann. ent. Soc. Am. 58:213-219.

Adult beetles emerge in the spring from brood cones on the ground or from the petioles of conelets either on the tree or on the ground. Female beetles initiate cone attack. Beetle attack in the spring is usually directed towards the second-year cones, but conelets, new shoots, male flowers, and buds are also attacked. When accompanied by a male, the female bores down the cone axis; if unaccompanied, she bores through the side of the cone or leaves through the entrance. Mating may take place in the first cone attacked. Male beetles do not initiate cone attacks; they usually follow behind the female, widen the gallery and apparently pack frass into the proximal chamber. Eggs are deposited singly in niches cut along the sides of the gallery and are covered with frass. Oviposition usually occurs in the second cone attacked. Larvae feed indiscriminately on cone and seed tissue, and pass through two instars. The larval stage lasts about 2 weeks. Callow adults appear 7 to 10 days after pupation. Oviposition was only observed in the second-year cones.

14. Graber, R.E. 1964. Impact of the white-pine cone beetle on a pine seed crop. J. For. 62:499-500.

The number of fallen cones per acre was estimated by counting the cones in two hundred 0.0001-acre plots. The average number of cones per plot was 2.7, or 27,000 cones per acre. Not a single mature cone was observed on the trees. Of the 200 cones dissected to determine the cause of mortality, the white pine cone beetle, *Conophthorus coniperda*, was responsible for 98% of the damage. The average number of adult beetles per cone was 2.1. The seed potential of the destroyed cone crop was estimated to be about 45 pounds per acre.

15. Hall, D.J.; Wilson, L.F. 1974a. Within-tree distribution of the jack pine tip beetle, *Conophthorus banksianae* McPherson, on jack pine. Great Lakes Entomol. 7:89-93.

Almost 50% of the shoots attacked by *Conophthorus banksianae* occurred within the top 10 inches of the tree crown, and all attacks were confined to the top 3 feet of the crown. Shoot tips well-exposed to the sky are most likely to be attacked. Few shoots less than 3.0 mm are attacked, with the greatest shoot damage occurring in the 3.0 to 4.0 mm diameter class.

16. Hall, D.J.; Wilson, L.F. 1974b. Within-generation mortality of the jack pine tip beetle, *Conophthorus banksianae* McPherson, in Michigan. Great Lakes Entomol. 7:151-162.

Parasitism accounted for 15 to 40% of second-instar mortality and up to 25% of pupal mortality. The hymenopterous parasitoid, *Cecidostiba dendroctoni* Ashmed, was responsible for over 95% of the parasitism and was the only factor to be important in influencing total generation mortality. Other factors such as sibling cannibalism, dessication, "pitching out", and predation were encountered; however, their impact was too low to evaluate.

17. Hamilton, J. 1893. List of Coleoptera taken at Sparrow Lake, Ontario. Can. Ent. 25:272-279.

This paper lists a species of beetle inhabiting the cones of white pine as "? Dryocoetes, sp.". The author notes: "This insect by difference of antennal club and tibial form does not appear to be a true Dryocoetes; neither by colour nor elytral striation and punctuation does it conform to Mannerheim's description of *affaber*." Cones opened on September 10 and contained 20 or more mature adults in each.

18. Hard, J.S. 1964. The identification of primary red pine cone insects. USDA For. Serv., Lake States For. Exp. Stn., Res. Pap., LS-12, 10 pp.

This publication provides keys to the primary red pine cone insects by characteristic damage to mature cones, and to the mature larvae of the insects. A chart showing the periods of larval occurrence for the primary insects is included. *Conophthorous resinosae* is considered to be the most important pest of red pine cones.

19. Harrington, W.H. 1902. Note on *Pityophthorus coniperda,* Schwarz. Can. Ent. 34:72-73.

Beetles were found in the shoots and cones of both red and white pine. The beetles found in red pine were larger but were identified as the same species attacking white pine.

20. Haverty, M.I.; Wood, J.R. 1981. Residual toxicity of eleven insecticide formulations to the mountain pine cone beetle, *Conophthorus monticolae* Hopkins. J. Georgia Ent. Soc. 16:77-83.

Adult beetles were placed on filter papers treated with solutions of either resmethrin (encapsulated), fenvalurate, lindane, permethrin, carbaryl, chlorpyrifos, m-parathion (encapsulated), diazinon (encapsulated), diazinon, fenitrothion, or fenitrothion (encapsulated). The numbers of dead and moribund insects were recorded at 12 and 24 hours after the beetles were placed on the filter paper. Toxicity data was analyzed by probits. LC 50 and LC 90 values at 12 and 24 hours were calculated, and selected regression lines compared by likelihood ratio tests for each insecticide. After 24 hours exposure, encapsulated resmethrin and fenvalurate were the most toxic, with LC 50 values 325 and 65 times as toxic as encapsulated fenitrothion (the least toxic formulation).

21. Haverty, M.I.; Dell, T.R. 1984. Time trends in mortality of *Conophthorus ponderosae* (Hopkins) exposed to insecticide residues. Pestic. Sci. 15:369-374.

Conophthorus ponderosae adults were exposed to residues of insecticide formulations for 24 hours. LT 90 values were estimated using a 3 parameter Weibull function. Regression of the time to 90% mortality as a function of concentration (g a.i./L) for the insecticides permethrin, gamma-HCH, diazinon, fenitrothion, res-

methrin, and chlorpyrifos are given. The usefulness of the Weibull function for the evaluation of insecticides is discussed.

22. Hedlin, A.F.; Yates, H.O. III; Tovar, D.C.; Ebel, B.H.; Koerber, T.W.; Merkel, E.P. 1980. Cone and seed insects on North American conifers. Can. For. Serv., USDA For. Serv., Secr. Agric. Recur. Hidraul, Mexico. 122 pp.

Maps showing the distribution of *Conophthorus apachecae*, *cembroides*, *conicolens*, *coniperda*, *echinatae*, *edulis*, *monophyllae*, *ponderosae*, *radiatae*, and *resinosae* are provided. Included in this general publication is a brief description of their life history, habits, and damage, as well as a key to the genus by host tree species.

23. Henson, W.R. 1960. An effect of aggregation on the behavior of a beetle *(Conophthorus coniperda* Sz.) in a temperature gradient. Yale J. Biol. and Med. 33:128-132.

Stable and immobile thigmotrophic aggregations are formed in an open arena as a sequel to accidental collision. Aggregations are more frequent at higher temperatures because of activity and greater likelihood of encounter. It is suggested that the thigmotrophic fixation holds insects immobile when preferred temperatures are exceeded.

24. Henson, W.R. 1961a. Laboratory studies on the adult behavior of *Conophthorus coniperda* (Schwarz) (Coleoptera: Scolytidae). I. Seasonal changes in the internal anatomy of the adult. Ann. ent. Soc. Ann. 54: 698-701.

The entire gut of each callow adult examined was empty or filled with only small amounts of reduced materials from the time of first appearance of adults after pupation until the following spring. Thereafter, the gut continued to show evidence of food. The gonads of both sexes remained slightly developed from time of emergence as new adults to the following spring. Testes began to increase in size the following spring, reduced about the middle of May and began to reach a maximum size again in July. Ovarian development became evident during late April and reached a peak about early June. Flight muscles did not reduce in size until about the beginning of June. Degeneration of flight muscles corresponded to the onset of reproductive activity and occurred to the same extent and at the same time in both sexes. About 25% of the insects obtained from the time of first adult emergence to spring emergence were starved. This percentage increased to 50%

during the later part of June. It is suggested that the increasing numbers of starved insects may be due to severe competition for food. No evidence of disease or parasitism was found in more than 1000 adults examined.

25. Henson, W.R. 1961b. Laboratory studies on the adult behavior of *Conophthorus coniperda* (Schwarz) (Coleoptera: Scolytidae). II. Thigmotropic aggregation. Ann. ent. Soc. Am. 54:810-819.

Conophthorus coniperda adults form strong and immobile thigmotrophic aggregations when confined in an open arena in the laboratory. Aggregation is complete within 30 min and involves about 80 to 85% of the population. The extent of aggregation appears to be a functional relationship between density and probability of collision between moving beetles. High humidity also promotes aggregation. At low densities, the probability of collision is increased when temperatures and the amount of light are increased. The only time when the thigmotrophic response is greatly reduced is during the emergence from overwintering cones. Feeding, extended exposure to drying, free water, high and low temperatures, continuous light or dark, starvation, antennal amputations, blinding, and other surgical treatments failed to suppress the thigmotropic reaction. It is suggested that this reaction would prevent high temperatures and perhaps other unfavourable influences from driving the insects from their cones.

26. Henson, W.R. 1962. Laboratory studies on the adult behavior of *Conophthorus coniperda* (Coleoptera: Scolytidae). III. Flight. Ann. ent. Soc. Am. 55:524-530.

Maximum flight takes place between 27 and 35°C, after about 9 hours of light, and after a period of high humidity. Based on the laboratory studies it is predicted that flight should take place on clear days when the insects have been warmed enough to move to the surface of the duff into exposed conditions where they would stay while temperatures increased through the day. The greatest intensity of flight should take place in the heat of the mid-afternoon. Insects mounted on flight mills revealed several interesting features. First there appeared to be very large numbers of very short flights with periods of short duration between them. These short bursts of flight took place both before and after more normal longer flights. A second interesting feature was that flight velocity was constant throughout individual flights and also between insects, with the exception of one insect. When exposed to a point source of light, the insects always flew directly to the light whether it was overhead or at any vertical angle down to the horizon. It is suggested that

69. Santamour, F.S., Jr. 1965. Insect-induced crystallization of white pine resins. II. White-pine cone beetles. USDA For. Serv., Northeast. For. Exp. Stn., Res. Note NE-39, 5 pp.

Crystallization of oleoresin of white pine, *Pinus strobus,* was induced by the presence of macerated head and thorax, macerated abdomen, whole live insects, or fresh frass of *Conophthorus coniperda*.

70. Schaefer, C.H. 1962. Life history of *Conophthorus radiatae* (Coleoptera: Scolytidae) and its principal parasite, *Cephalonomia utahensis* (Hymenoptera: Bethylidae). Ann. ent. Soc. Am. 55:569-577.

Conophthorus radiatae eggs are ellipsoid, milky white, and pass through recognizable stages before eclosion. The larvae pass through two instars, are apodous, soft-bodied and are white with a brown head capsule. Pupae pass through four distinct developmental stages: (1) solid white colour; (2) eye pigments darken; (3) mandibles become brown followed by the graying of the elytra; and (4) distal third of the elytra appears black. Parent adults can be distinguished from the newly emerged adults, by the reddish body color of the "new" adults versus the dark black color of the "old" adults. Adult females are larger than males. The 7th and 8th abdominal tergites are fused in the female, but separate in the male. Emergence of overwintering adults is generally synchronized with the beginning of cone development. Some mating may occur prior to emergence since some females taken out of an overwintering cone laid eggs from which progeny developed. The female initiates cone attack and constructs a spiral gallery around the cone axis. Eggs are placed singly in niches cut alongside of the gallery as well as in the frass of the main gallery. Some parent females emerge from the cone to make a second attack: usually those that emerged first in the season. In years where there are not enough cones, several females may oviposit in one cone. Eggs require about 25 days for development. The first larval instar lasts 15 to 20 days and the second lasts 30 to 40 days. The pupal stage begins in June and lasts 15 to 20 days. Most of the callow adults overwinter in the brood cones, others emerge to attack and overwinter in conelets or mature cones. Eggs, larvae, and pupae reared in the laboratory under constant temperatures from 10 to 40°C, with 5°C increments, survived best at temperatures of 20°C. A detailed description of the biology of *Cephalonomia utahensis* is provided.

71. Schaefer, C.H. 1963. Factors affecting the distribution of the Monterey pine cone beetle, *(Conophthorus radiatae* Hopkins) in central California. Hilgardia 34:79-103.

Adult beetles enter the base of the cone of *Pinus radiata* just above the junction of the cone and peduncle. In all cones examined, the female precedes the male. The female constructs a gallery along the cone axis, and deposits her eggs either singly or in pairs in niches made in the seeds. The parent beetles leave the cone through the entrance hole and plug it with resin and boring dust. There appear to be two periods of attack; however, it was not determined if the second attack was by the overwintering parent adults or by the brood produced by them. The larvae fed first on the seeds in which the eggs had been deposited, and then on other tissues of the cone. A pupal cell is constructed in the area where the larva fed last. Brood adults leave the cones by mining through the cone scales. Some adult beetles overwinter in the brood cones while others overwinter in first-year conelets.

67. Ruckes, H.R. Jr. 1959. Two new records for the cone beetle genus *Conophthorus* Hopkins in California. Pan-Pacific Entomol. 35:94.

Conophthorus monticolae were reared from western white pine, *Pinus monticola* cones collected in Lassen County, California. *Conophthorus contortae* were reared from lodgepole pine, *P. contorta* var. *latifolia,* cones collected from several locations in the Sierra Nevada Mountains.

68. Ruckes, H.R. Jr. 1963. Cone beetles of the genus *Conophthorus* in California. Pan-Pacific Entomol. 39:43-50.

Three species of cone beetles, *Conophthorus lambertianae, C. ponderosae,* and *C. radiatae,* were reared from egg to adult on cone tissues other than their selected host. A chalcid parasite, *Tomicobia tibialis* Ashmead, was obtained from overwintering adults of *C. lambertianae,* and unidentified nematodes were recovered from the Malpighian tubules in the larvae of *C. ponderosae, C. lambertianae,* and *C. monophyllae.* A key to the California species of *Conophthorus* is provided along with a description of their biology. California *Conophthorus* species include: *C. monophyllae, C. ponderosae, C. lambertianae, C. monticolae, C. contortae,* and *C. radiatae. C. monophyllae* appears to have 2 generations per year. *Pinus ponderosa, P. jeffreyi, P. washoensis* and sometimes *P. attenuata* are hosts for *C. ponderosae.* Some brood adults of *C. ponderosae* remain in the brood cone for more than one year. Two generations of *C. lambertianae* may occur during heavy cone crop years. *C. contortae* overwinter as pupae in lodgepole pine, *P. murrayana.*

61. Poinar, G.O. Jr.; Caylor, J.N. 1974. *Neoparasitylenchus amvlocercus* sp. N. (Tylenchida: Nematodea) from *Conophthorus monophyllae* (Scolytidae: Coleoptera) in California with a synopsis of the Nematode genera found in bark beetles. J. Invert. Path. 24:112-119.

From a sample of 21 adult beetles randomly collected from the cones of the single leaf pinyon pine, *Pinus monophylla,* 13 (62%) were parasitized by *Neoparasitylenchus amvlocercus;* 6 (28%) were parasitized by a species of *parasitaphelenchus;* and 3 (14%) had a double infection by the two nematode species. As many as 7 adults of *N. amvlocercus* were recovered from a single beetle. All larvae examined were free from nematode infection. A description of *N. amvlocercus* is provided.

62. Rauf, A.; Benjamin, D.M.; Cecich, R.A. 1985. Insects affecting seed production of jack pine, and life tables of conelet and cone mortality in Wisconsin. For. Sci. 31:271-281.

The red pine cone beetle, *Conophthorus resinosae,* destroyed 0.76 and 1.17% of the jack pine cones in 1980 and 1981, respectively.

63. Ross, D.A. 1958. A list of cone and seed insects of interior British Columbia. Proc. Ent. Soc. B.C. 55:30-31.

Notes the occurrence of *Conophthorus monticolae* on *Pinus monticola.*

64. Ruckes, H.R. Jr. 1956. A bethylid parasite of cone beetles. Pan-Pacific Entomol. 32:184-185.

Adults of *Cephalonomia utahensis* Brues were collected from pine cones infested with *Conophthorus lambertianae* and *C. ponderosae.*

65. Ruckes, H.R. Jr. 1957. The overwintering habitat of the sugar-pine cone beetle. J. Econ. Ent. 50:367-368.

Mature adults of the sugar-pine cone beetle, *Conophthorus lambertianae,* enter twig tips at the base of the vegetative bud and mine through to the current year's growth where they overwinter.

66. Ruckes, H.R. Jr. 1958. Some observations on the Monterey pine cone beetle, *Conophthorus radiatae* Hopkins (Coleoptera: Scolytidae). Ann. ent. Soc. Am. 51:214-215.

Overwintered adults emerged from late April to mid-May. First attacks were for feeding and occurred in both twigs and cones. Feeding attacks were often gregarious, while attacks for oviposition were usually produced by one female. There were 4 periods of oviposition. The mean total fecundity is about 27 with a range of 6-45. Life tables constructed for *C. coniperda* indicate that the mortality for eggs, larvae, pupae, and adults was 2.17, 18.62, 1.70, and 63.0%, respectively. Most of the adult mortality was due to insects that dispersed or emigrated in the fall, or to drowning in waterlogged cones in the spring. The life table ignored the effect of variation in cone crop. It is suggested that hibernation by the cone beetle is a temperature controlled quiescence. The cone beetles appeared to prefer withered cones for feeding and fresh cones for oviposition. Various control measures are discussed.

59. Odell, T.M.; Godwin, P.A. 1964. White-pine cone beetle. USDA For. Serv., Forest Pest Leafl. 83, 7 pp.

This leaflet provides a description of the life stages, life history, and habits of *C.coniperda*. Photographs of cone, shoot and conelet damage, and of larvae are included. A map showing the distribution of the beetle is given.

60. Odera, J.A. 1971. The effect of solar radiation on cone insects of eastern white pine *(Pinus strobus)* in the Fredericton area, New Brunswick. Can. Ent. 193:605-609.

Internal cone temperatures of uniformly sized cones placed on the ground were compared between a sunny cleared site and a mixed conifer shaded site. Cone temperatures were recorded, 3 days a week at 10 a.m. and at 3 p.m., from 21 May to 27 Sept. Ground and ambient air temperature were recorded concurrently with cone temperatures. Differences in cone temperature at the two sites were highly significant. High and low cone temperatures coincided with high and low ground temperatures. There was a highly significant correlation coefficient of cone temperature and ground temperature. The correlation coefficient for cone temperature and cone size was not significant. High temperature mortality, expressed as a percentage of the total number of *Conophthorus coniperda* present, ranged from 29.0% in early June to 100% during the summer at the sunny site, compared to 2.0 to 17.0% during the same period at the shady site.

Conophthorus lambertianae constructs an egg gallery that is straight and close to the axis of the cone. In large cones from 6 to 8 inches long, 15 to 30 eggs may be deposited. It is probable that a pair of parent adults may attack more than one cone. Pupae may be found in the cones within 4 weeks after the first cone attack. All sugar-pine cones which are attacked fall to the ground. Broods complete their development within the fallen brood cones. New adults remain in the brood cones throughout the winter. The most successful attacks are found in cones 4 to 6 inches in length. Cones that are larger appear to resist the beetles by "drowning" them out. There appears to be one generation per year. In some areas of the beetle's range no appreciable damage to the cone crop is found, while in other areas over 90% of the cone crop is destroyed. The life cycle of *C. ponderosae* does not differ "...in any important respect..." from that of *C. lambertianae*. The method of cone attack does however differ. *C. ponderosae* constructs a spiral tunnel around the axis of the cone before beginning the egg gallery through the axis. It is suggested that the beetles might be controlled if the fallen infested cones were raked up and burned during September, October, or November.

56. Miller, W.E. 1978. Use of prescribed burning in seed production areas to control red pine cone beetle. Environ. Entomol. 7:698-702.

Infestations by *Conophthorus resinosae* can be reduced by prescribed burning between October 22 and May 10 when beetles are on the ground. Increased populations of *Eucosma monitorana* Heinrich and *Dioryctria disclusa* Heinrich may offset any gains from prescribed burning. Furthermore, weather suitable for burning is as little as one week, and therefore requires prompt action and tight scheduling.

57. Miller, W.E.; Taylor, A.H. 1968. How to control red pine cone beetle. USDA For. Serv.,North Central For. Exp. Stn., Station pamphlet.

A non-technical pamphlet that advocates a light prescribed burn be conducted sometime between October 15 and May 1 in seed orchards to destroy overwintering populations of red pine cone beetles.

58. Morgan, F.D.; Mailu, M. 1976. Behaviour and generation dynamics of the white pine cone beetle *Conophthorus coniperda* (Schwarz) in central Wisconsin. Ann. ent. Soc. Am.69:863-871.

53. Mattson, W.J.; Tabashnik, B.E.; Miller, J.R. 1984. Developing a conceptual model of cone-finding behavior by the red pine cone beetle, *Conophthorus resinosae* Hopkins (Coleoptera: Scolytidae). *In* Proceedings of the IUFRO workshop on seed and cone insects. (H.O. Yates III, ed) USDA Southeastern For. Exp. Stn. pp. 65-76.

Using available information on dispersal mechanisms (see Henson 1967) of *Conophthorus* and some of the authors' own preliminary laboratory data on the phototactic and geotactic behavior of *C. resinosae*, it is hypothesized that, after beetles fly upward and toward tree silhouettes, they either discriminate among tree species before or after landing. Once a red pine tree has been found, the beetles may either find cones by cues such as volatiles, color or shape, that is, cone-directed alightment, or by random alightment. The null hypothesis (random alightment) that beetles land on branches without regard to the distribution of cones per branch is examined. It is suggested that even at very low cone densities of 5 cones per branch a beetle has an 80% chance of finding a cone-bearing branch on its first landing. Furthermore, the null hypothesis predicts that branches will receive beetles in direct proportion to their surface ratio. The authors argue that since damaged cones do not increase non-linearly with available cones, the beetles do not use long range cues to find cones. Twenty-five recently emerged beetles were released near a red pine tree to observe their flight behaviour. Of the 18 beetles which were tracked, only one beetle landed on the tree but did not land on or near the four cones available to it. The evidence presented suggested that cone-directed alightment is to be rejected.

54. Miller, J.M. 1914. Insect damage to the cones and seeds of Pacific coast conifers. USDA Bull. 95, 7 pp.

Notes that several species of cone beetles are very common in western yellow pine and sugar pine, and that damage by the beetles resulted in a 25 to 75% reduction of sugar pine cones in some seasons. A general account of "retarded emergence" (a portion of the brood overwintering for more than one season) is provided, and it is noted that retarded emergence has not been observed for cone beetles. This retarded emergence is considered as an adaptation by cone insects to the intermittent nature of cone crops.

55. Miller, J.M. 1915. Cone beetles: Injury to sugar pine and western yellow pine. USDA Bull. 243, 12 pp.

50. Mattson, W.J. 1968. The impact of insects on second-year cone crops in red pine seed production areas. USDA For. Serv., North Cent. For. Exp. Stn., Res. Note NC-53, 2 pp.

Cone damage by *Conophthorus resinosae* ranged from 12 to 28% in red pine seed production areas over the 6-year period, 1962-1967.

51. Mattson, W.J. 1978. The role of insects in the dynamics of cone production of red pine.Oecologia (Berl) 33:327-349.

Twenty-three complete and six partial life tables of red pine cones were constructed for 8 study areas located in northern Michigan, Wisconsin, and Minnesota. In 18 of the 23 lifetables the generation survival (number of survivors/number flowers initiated) was less than or equal to 20%. The greatest mortality for red pine cones was during the first and last 3 months of development. Almost all losses, except overwintering mortality, were caused by insects. *Conophthorus resinosae* killed young conelets by tunnelling into their supporting branch shoots as well as the cones. In some study areas, the cone beetle is the dominant species; and in areas that were dominated by *Dioryctria disclusa*, the cone beetle was in a secondary or codominant position. Annual variations in cone survival (those in the last 3 months of development) were largely due to variations in predation by *C. resinosae* and *D. disclusa* in areas with an abundance of pine within a one-third mile radius, and by *C. resinosae* and *Eucosma monitorana* in areas with less pine. Insects were likely responsible, along with late summer weather, in influencing the rate of initiation and differentiation of flower bud primordia. It is suggested that insects may actually enhance flower primordia production.

52. Mattson, W.J. 1980. Cone resources and the ecology of the red pine cone beetle, *Conophthorus resinosae* (Coleoptera: Scolytidae). Ann. ent. Soc. Am. 73:390-396.

Between 1967 and 1978, *Conophthorus resinosae* destroyed an average of 79% of the annual cone crops in red pine seed production areas in Wisconsin. Conelet mortality can occur when beetles attack new shoots. The number of eggs laid per cone was found to increase linearly with cone length. Also, the length of the egg gallery and the number of eggs laid per completed gallery are linear functions of cone and gallery length, respectively. From laboratory studies on gallery construction rates, it was found that a female beetle spends approximately 2.39 h/mm of gallery built. By using the linear growth rate of red pine cones, it was estimated that each beetle could "handle" (digging, ovipositing, tunnelpacking etc.) from 16 to 20 cones during the summer. Since red pine cones are small in size and seed load, the female adult may need 20 cones to find enough suitable material for their egg loads.

Weekly collections of shoots and cones injured by *Conophthorus* were made to compare the life history of *C. resinosae* with the life history of a *Conophthorus* sp. attacking the shoots of jack, scotch, ponderosa, and coneless red pine. *Conophthorus resinosae* was found to differ from tip-infesting beetles in three ways. First, the immature stages of *C. resinosae* appeared earlier than the tip-infesting beetles. Second, the immature stages of the tip-infesting beetles last much longer than *C. resinosae*. Third, *C. resinosae* is univoltine, while the tip beetles appear to be bivoltine. Bivoltinism is suggested because eggs were abundant in late August after an absence of one month (mid-July to mid-August), and because teneral adults appeared in late July after most old adults were dead. Differences in adult body length and width were significant between *C. resinosae* and the tip beetles; however "...the overlap is sufficient to make the measurements useless (except at extremes) for distinguishing cone from tip beetles."

49. McPherson, J.E.; Stehr, F.W.; Wilson, L.F. 1970b. A comparison between *Conophthorus* shoot-infesting beetles and *Conophthorus resinosae* (Coleoptera: Scolytidae). II.Reciprocal host and resin toxicity tests; with a description of a new species. Can. Ent. 102:1016-1022.

A new species, *Conophthorous banksianae* McPherson is described as a separate and distinct species from *Conophthorus resinosae* on the basis of two tests reported herein: (1) reciprocal host and (2) resin toxicity, and behavioral differences reported earlier (see ref. 48). In the reciprocal host test, *Conophthorus resinosae* beetles (collected from overwintering red pine shoot tips) and jack pine tip beetles (collected shortly after they began feeding on tips of jack pine) were placed separately in cages containing one of the following types of red or jack pine branches: (1) cones and shoots, (2) shoots only, or (3) cones only (shoot tips removed). *Conophthorus resinosae* attacked shoots and cones of both tree species whereas *C. banksianae* attacked only the shoots of both trees. In the resin toxicity test, the beetles were exposed to saturated atmospheres of an "appropriate" resin formulated of pure pine monoterpenes. The percentage of monoterpenes used for the resin formulations is not provided. *Conophthorus resinosae* survived equally well in vapours of the simulated red and jack pine shoot resin. On the other hand, *C. banksianae* appeared to survive "best" when exposed to jack pine resin vapour (12 dead beetles when exposed to red pine resin compared to 8 dead beetles exposed to jack pine resin; exposure time 120 h). Regarding the resin toxicity test the authors state: "The overall results, though far from conclusive, seem to reflect each insect's behaviour pattern in nature".

mate or oviposit during the first few weeks. Cone attack is usually initiated by the female who constructs evenly spaced blind egg niches along the sides of a tunnel bored through the centre of the cone axis. Males apparently contribute nothing towards the cone attack process. Mating may take place in a widening constructed at the base of the axial tunnel. The parent beetles leave the cone via the entrance tunnel, and before leaving the female fills the base of the tunnel with a plug of resin and debris. Using the interval between peaks of successive stages, the duration of the immature stages was estimated to be: eggs - 17 days; instar I - 13 days; instar II - 22 days; and pupa - 19 days. New adults leave the cone either from the base of the axial tunnel, or by boring through the top or sides of the cone. Adults prepare for overwintering by entering a current year's shoot of pine and tunnelling distally through to the pith of the vegetative bud. The infested shoots eventually break off the tree and drop to the ground. Adults remain in these shoots over the winter. No adults were found to overwinter in the cones. Extended dormancy does not appear to occur in *C. resinosae*. Parasitism and disease were negligible. Mortality of *C. resinosae* larvae was estimated to be about 97% when the cones were also infested with *Eucosma monitorana* Hein., and about 18% when they occurred alone.

47. Lyons, L.A. 1957. Insects affecting seed production in red pine. IV. Recognition and extent of damage to cones. Can. Ent. 89:264-271.

Keys to insects based on cone damage and mature larvae are provided. Cones infested by *Conophthorus resinosae* can be identified where the "Cone (is) easily detached from the branch, leaving a traversely grooved stub, most often dry and hard, with a waxy accumulation of resin covering scales at one side near base; with small circular holes mostly at stem end but sometimes in sides and top; containing dry brown powder". Mature larvae of *C. resinosae* have a well developed head, and a stout, white curved body about 4 mm long. Feeding by *C. resinosae* tended to be the dominant cause of cone loss. In general, the relative intensity of damage by the beetle was shown to vary inversely with the fluctuation in cone production. Whereas a decrease in cone abundance may result in detrimental competition between different species, *C. resinosae,* in contrast, is well-fitted to the cone habitat since it can rapidly render the cone unsuitable for other species and is often the first species to attack.

48. McPherson, J.E.; Wilson, L.F.; Stehr, F.W. 1970a. A comparison between *Conophthorus* shoot-infesting beetles and *Conophthorus resinosae* (Coleoptera: Scolytidae). I. Comparative life history studies in Michigan. Can. Ent. 102:1008-1015.

42. Kulhavy, D.L.; Dale, J.W.; Schenk, J.A. 1975. A checklist of the cone and seed insects of Idaho. Forestry, Wildlife and Range Exp. Stn., Univ. Idaho, Current Inf. Ser. 6, 28 pp.

This checklist is presented in two parts: (1) the insects by host tree, the life stages of insects collected, and the specialist who identified the specimens, and (2) by insects and their host tree. This list reports *Conophthorus flexilis* on *Pinus flexilis, C. ponderosae* on *P. ponderosa,* and *C. monticolae* on *P. monticola.*

43. Little, E.L. Jr. 1943. Common insects on pinyon pine *(Pinus edulis).* J. N.Y. Ent. Soc. 51:239-252.

This general paper notes that pinyon cone beetles, *Conophthorus edulis,* were very destructive to second-year cones. The beetles were observed to enter the cones by boring into the stalk at the base, and were active in the cones in June and July.

44. Little, E.L., Jr. 1944. Destructive insects on pinyon *(Pinus edulis).* USDA For. Serv., Southwest. For. and Range Exp. Stn., Res. Note 110, 4 pp.

In the words of the author, this paper is a summary of "The author's longer journal article (see 1943 paper) from which the information in this Research Note is taken...".

45. Lyons, L.A. 1951. Insects affecting seed production in red pine. Can. Dep. Agric., For. Biol. Div., Bi-Mon. Prog. Rep. 7(3):1.

In 1950, *Conophthorus resinosae* was the most important cause of seed loss in red pine at Chalk River and Sault Ste. Marie, Ontario.

46. Lyons, L.A. 1956. Insects affecting seed production in red pine. I. *Conophthorus resinosae* Hopk. (Coleoptera: Scolytidae). Can. Ent. 88:599-608.

Conophthorus resinosae eggs are ovoid, white and translucent; larvae are apodous, soft-bodied, white with light brown heads, and have two instars; pupae are white when newly formed and darken later; and adults are shiny, black, cylindrically shaped with an unsculptured elytral declivity. Female adults are generally larger than the males. After emergence in the spring, adult beetles feed in either current-year's shoots or cones, and do not

0.1 mL 1% resin for treatment (i), and 0.1 mL ethanol for the remaining treatments. The number of beetles entering the vials containing the test substance was compared with the number entering the control vials as a measure of their response. A significant response was recorded for female beetles to treatments a, c, and e; whereas, males only had a positive response to treatment a. Both males and females were attracted to the combined odours of ¼ cut conelet containing the opposite sex, but were not tested against the same sex.

39. Kinzer, H.G.; Ridgill, B.J.; Watts, J.G. 1970. Biology and cone attack behaviour of *Conophthorus ponderosae* in southern New Mexico (Coleoptera: Scolytidae). Ann. ent. Soc. Am. 63:795-798.

Adult beetles of *Conophthorus ponderosae* emerged from late April to late May to attack second-year cones of *Pinus ponderosa*. Emergence patterns did not correlate with daily changes in temperature and humidity either before or during peak emergence. The sex ratio of emerging beetles was 1:1.2 male to females. A small proportion (0.06%) of the beetle population remained in the cones for two winters. Cone attack is initiated by the female who enters the cone by boring through the scales at the basal end of the cone. The female then bores through to the cone axis and girdles the cone about 2 mm above its interception with the petiole. Once the girdle is complete, the female constructs a straight gallery along one side of the cone axis. Eggs are laid singly in niches cut along the gallery. Only one female attacks a cone and is usually accompanied by a male. There are two larval instars. The beetles overwinter as adults in the brood cone that remains on the tree. Occasionally some individuals remain as pupae through the winter.

40. Kinzer, H.G.; Ridgill, B.J.; Watts, J.G. 1972b. Seed and cone insects of ponderosa pine. New Mexico Agric. Expt. Stn., Bull. 594, 36 pp.

A more general publication that contains essentially the same information about *Conophthorus ponderosae* as reported by Kinzer *et al*. 1970 (see above), except that the sex ratio of emerged beetles is reported as 1:1.02 not 1:1.2 as reported earlier.

41. Knull, J.N. 1932. Notes on Coleoptera. - No. 3. Entomol. News 43:62-67.

Dead adults of *Conophthorus coniperda* were found in the small immature cones of pitch pine, *Pinus rigida* Miller.

a gallery along the axis of the cone, while *C. flexilis* bore a gallery through the centre of the axis and do not girdle the cone. Only one *C. ponderosae* female attacks each cone, whereas 2 or 3 *C. flexilis* females may attack a single cone. The feeding behavior of both species is similar: larvae feed on cone scales and seeds leaving the cone filled with frass and finely grated cone tissue. Cross-mating studies indicated that, under controlled conditions, *C. ponderosae* males x *C. ponderosa* females attack and produce broods in both ponderosae and southwestern white pine. Male-female crosses of *C. flexilis* also attacked both pine species but brood development only occurred in the normal host, southwestern white pine. Brood establishment occurred in both species of pine when *C. ponderosae* females were mated with *C. flexilis* males. *C. flexilis* females produced successful broods only in southwestern white pine when mated with *C. ponderosae* males. These results suggested that *C. flexilis* is unlikely to produce viable brood in *Pinus ponderosa*. Life table studies indicated that only about 7% of *C. ponderosae* adults survive the winter, while 28% of the original population of *C. flexilis* successfully emerged the following spring. Laboratory olfactometer tests showed that both male and female *C. flexilis* were attracted to ethanol dilutions of alpha pinene.

37. Kinzer, H.G.; Ridgill, B.J. 1972. A rapid field method for sexing the ponderosa pine cone beetle. J. Econ. Ent. 65:1188-1189.

Beetles will voluntarily rotate their abdomen and reveal their terminal tergites when picked up with a curved vacuum pencil and rotated so that the beetle is held downward. Approximately 120 beetles can be sexed per hour with this technique. A diagram showing the fusion of the 7th and 8th tergites in the female, and the two distinct tergites in the male is provided.

38. Kinzer, H.G.; Ridgill, B.J.; Reeves, J.M. 1972a. Response of walking *Conophthorus ponderosae* to volatile attractants. J. Econ. Ent. 65:726-729.

The attraction of male and female adults of *Conophthorus ponderosae* to the following treatments was determined: (a) 0.1 mL frass and tunnel shavings extract, (b) 1 female equivalent in 0.1 mL ethanol + 0.1 mL 1.0% resin, (c) 0.1 mL of 1.0% ponderosa pine resin, (d) 0.1 mL of 1% alpha pinene in ethanol, (e) 0.1 mL of 1% beta pinene in ethanol, (f) 0.1 mL of delta 3 carene in ethanol, (g) 0.1 mL myrcene in ethanol (h) 0.1 mL limonene in ethanol, and (i) 0.1 mL transverbenol to 5 mL pentane + 0.1 mL 1% resin. Controls were 0.1 mL 1% resin for treatment (b), 0.5 mL pentane +

tles, and as much as 60% of the cone crop may be infested. *Conophthorus lambertianae* attacks both the cones and twigs of *Pinus lambertiana* and *P. monticola*. A description of the life history (based on Miller's 1915 paper) is presented. A braconid *Eubadizon* sp, and a chalcid *Spathius* sp were found associated with *C. lambertianae;* however, it could not be conclusively demonstrated if these two species were preying on the cone beetle. Several collections of *C. monophyllae* were made from cones of singleleaf pine in southern California, and it is probable that it has a life history like that of other members of the genus. The life history of *C. monticolae* is very similar to that of *lambertianae*. It is suggested that *monticolae* and *lambertianae* may be races of the same species. *Pinus ponderosa* commonly, and *Pinus jeffreyi,* rarely, are the host for *C. ponderosae*. The damage caused by this species is extensive but varies among trees and seasons. The adult beetles overwinter in killed cones on the tree. From 1 to 20 beetles may be found attacking second-year cones through May and early June. Small first-year cones are rarely attacked and eggs are not deposited in these conelets. No predators or parasites were recorded. *Conophthorus radiatae* were collected from the Monterey peninsula, California, but appeared to be an unimportant species. *Conophthorus scopulorum* is superficially indistinguishable from *C. ponderosae* and attacks *Pinus ponderosae* var. *scopulorum*. The life cycle is similar to *C. ponderosae,* and adults of *scopulorum* were found hibernating in the bark of a tree in November. Unidentified species of *Conophthorus* were collected from bristlecone, knobcone, foxtail, and Washoe pine cones.

36. Kinzer, H.G.; Reeves, J.M. 1976. Biology and behavior of cone beetles of ponderosa pine and southwestern white pine in New Mexico. New Mexico State Univ. Agric. Expt. Stn., Bull. 641, 28 pp.

"This bulletin expands these earlier results (see Kinzer *et al.* 1970, 1972a,b) and elucidates many other aspects of the biology of the two species *(C. ponderosae* and *C. flexilis).*" An average of 22% of the ponderosa, and 28% of the southwestern white pine cone crop was destroyed in New Mexico by *Conophthorus ponderosae* and *C. flexilis,* respectively. First emergence of *C. flexilis* occurred between April 7 and 14, peaked April 15, and by April 25, 90% of the adults had emerged. Peak numbers of emerged *C. ponderosae* occurred around May 5 during the first two years and May 7 to 18 during the third year of monitoring. All immature stages of *C. flexilis* occurred several weeks later than those of *C. ponderosae,* even though the adults of *C. flexilis* emerged earlier. The female of both species makes the initial attack on second-year cones and enters the cone by boring through the scales at the basal end. *Conophthorus ponderosae* girdle the cone and construct this group of beetles have been in the Fitch collection since 1850, in the Hubbard and Schwarz collection since 1877, two species in the Harrington collection since 1885, and one species in the Hamilton collection since 1893.

33. Jenkins, M.J. 1983. Relationship between attacks by the mountain pine cone beetle (Coleoptera: Scolytidae) to clone and cone color in western white pine. Environ. Entomol. 12: 1289-1292.

The level of attack by *Conophthorus ponderosae* differed significantly between clones. It is suggested that clonal variability in terpene levels (implicated in primary host attraction) is a likely explanation for differences in beetle attack. During the 5-year study, intermediate and purple cones were attacked at higher levels than green cones in 1977 and 1978; however, differences in beetle attack could not be related to cone color in 1980 and 1981. No data were available for 1979 because almost no cones were produced. The author suggests that dark cones (purple or intermediate) maximize silhouette perception and have higher temperatures; both effects which may enhance attraction of the beetle to cones.

34. Keen, F.P. 1928. Insect enemies of California pines and their control. Calif. Dept. Nat. Resour., Div. For., Bull. 7, 113 pp.

Lists *Conophthorus ponderosae* in western yellow and Jeffrey pine cones, *C. lambertianae* in sugar and western white pine, *C. radiatae* in Monterey pine, *C. monophyllae* in single leaf pine, and *C. contortae* in beach pine cones.

35. Keen, F.P. 1958. Cone and seed insects of western forest trees. USDA For. Serv. Calif. For. and Range Exp. Stn., Tech. Bull. 1169, 168 pp.

Ten western species of *Conophthorus* are described. *C. apachecae* "...similar in most respects to *C. ponderosae* and like *C. scopulorum* is doubtfully distinct from *C. ponderosae.*" *Conophthorus contortae* were found on cones of *Pinus contorta* var *contorta*, but not found in lodgepole pine, *P. contorta* var *latifolia*. From 5 to 20 adults of *Conophthorus edulis* may be found overwintering in the cone. A small black wasp *Acerocephala atrovolacea* Crawf. was reared from cones infested with *C. edulis* and presumed to be a parasite of this cone beetle. More than one cone of *Pinus flexilis* may be attacked by a pair of *C. flexilis* beesuppresses thigmotropism and flight inhibition. After emerging from the cone, the photopositive beetles climb through to exposed portions of the duff, and after a period of warming in dry air, they fly upwards to the diffuse sky light. Once above the trees adults are exposed to the point light source of the sun whereupon they become disoriented, fly horizontally, and orient to dark silhouettes of the tree leaders. Chemical stimuli are probably used to locate the cones after landing on the leader of the tree.

30. Herdy, H. 1959. A method of determining the sex of adult bark beetles of the genus *Conophthorus*. Can. Dep. Agric., For. Biol. Div., Bi-Mon. Prog. Rep. 15(3):1-2.

The seventh and eighth tergites of the female appear as a single plate, whereas the tergites are separate and distinct in the male. This method was tested for *Conophthorus coniperda, C. resinosae,* and a *Conophthorous* spp. taken from jack pine shoots.

31. Herdy, H.; Thomas, J.B. 1961. The seasonal development of a species of *Conophthorous* (Hopkins) (Coleoptera: Scolytidae) in the shoots of jack pine, *Pinus banksiana* (Lamb.) in Ontario. Can. Ent. 93:936-940.

The adult beetle bores an entrance hole in the previous year's shoot. Attack by the beetles in early May does not result in oviposition and may be feeding sites. The eggs are placed singly in niches cut into a tunnel that extends distally to the entrance hole. There are two larval instars. The pupal period lasts 6 to 13 days. The development period from larva to adult ranged from 13 to 32 days. The parent beetles produce a second brood in late June or early July. New adults from both broods emerge from July to September and feed on jack pine buds. The beetle overwinters in buds which have usually dropped to the ground. Two parasites, *Eurtytoma pini* Bugbee, and *Habrocytus* sp. were reared from the beetle larvae.

32. Hopkins, A.D. 1915. A new genus of Scolytid beetles. J. Wash. Acad. Sci. 5:429-433.

The author erects the genus *Conophthorus* to include 15 species. *Pityophthorus coniperda* is renamed *Conophthorus coniperda* Schwarz, and is the type species. Brief descriptions of distinguishing features for the species *edulis, taedae, virginianae, resinosae, ponderosae, scopulorum, apachecae, clunicus, coniperda, radiatae, contortae, monticolae, monophyllae, flexilis,* and *lambertianae* are provided. The author notes that representatives of insects leaving the forest floor would fly in the direction of the most intense illumination, and, as they flew above the trees, they would orient towards dark silhouettes.

27. Henson, W.R. 1964. Laboratory studies on the adult behavior of *Conophthorus coniperda* (Coleoptera: Scolytidae). IV. Responses to temperature and humidity. Ann. ent. Soc. Am. 57:77-85.

Adults moved within the cone to avoid flooding, but did not move to avoid overheating. The beetles responded to increased temperature by increased activity (taken as the length of travel within 3 min) in both dry and wet air, but when the temperature reached 35°C at 40% RH their activity dropped off. Maximum walking speed was reached at 40°C in dry air (RH 40%) and at 35°C in moist air (RH 100%). At 45°C insects rapidly died in either dry or moist air. The "preferred" temperature of adult beetles is about 30°C in both wet and dry gradients after 20 or 60 min exposures. The insects chose saturated conditions at all temperatures (temperature intervals of 2.5°C from 15 to 35°C) when offered a choice between saturation and 75% RH. By contrast, the beetles chose dryer conditions or became disoriented to humidity at lower humidity choices, especially at higher (30°C+) temperatures.

28. Henson, W.R. 1966. *Conophthorus coniperda* (Coleoptera: Scolytidae) and the seed production of *Pinus strobus*. *In* Breeding Pest Resistant Trees. Gerhold, R.D., E.J. Schreider, R.E. McDermott, and F.A. Winieski (eds.) pp 185-187.

This paper is essentially a summary and overview of the studies conducted by Henson (see ref. 23-27). The author suggests an interesting method for control of *Conophthorus coniperda*. It is suggested that if the intermittent seeding habit (considered to be an adaptive response of white pine to the seed-infesting insects) were manipulated in such a way as to suppress seed production for a year, the local beetle population would be reduced to very low levels. Subsequent seed production would remain relatively free from cone beetles until local populations were restored through immigration and local population increase.

29. Henson, W.R. 1967. The analysis of dispersal mechanisms in *Conophthorus coniperda* Sz. Biometerology 2:541-549.

Increased day length (approaching 12 h) and warmer temperatures initiate beetle emergence from cones in the spring. As beetles move towards the surface of the cones, they fill their guts which

Conophthorus radiatae is apparently restricted to stands of *Pinus radiata* D. Don. within a few miles of the Pacific Coast. East of the coastal fog belt, the survival of this beetle is greatly reduced. The results from several field and laboratory studies support the conclusions that in inland areas infrequent high summer temperatures is the major mortality factor of immatures, whereas, a combination of low humidity, warm to high temperatures, and no precipitation reduces adult survival.

72. Schaefer, C.H. 1964. Physical and physiological changes in the adult Monterey-pine cone beetle, *Conophthorus radiatae* (Coleoptera: Scolytidae). Ann. ent. Soc. Am. 57:195-197.

It is suggested that the respiration rate could be used as an index of the physiological condition of adults, since, the adult respiration rate is significantly lower during the overwintering or "inactive" period than during the post-emergence of "active" period. The flight muscles and ovaries of overwintering adults are underdeveloped until just prior to emergence. Sperm was found in the spermathacae of some overwintering females which suggested pre-emergence mating and perhaps inbreeding. Adult beetles will emerge after 10 days from cones held at 25°C and high humidity. Termination of adult dormancy does not require a period of low temperature or a given photoperiod, but is dependent on a favorable temperature and humidity.

73. Shea, P.J.; Jenkins, M.J.; Haverty, M.I. 1984. Cones of blister-rust resistant western white pine protected from *Conophthorus ponderosae* Hopkins *(=C. monticolae* Hopkins). J. Georgia Ent. Soc. 19:129-138.

Seven treatments consisting of 0.3, 0.6, and 1.2 g/L permethrin applied once, the same concentrations applied twice (14 days apart), and an untreated check were evaluated for control of *Conophthorus ponderosae*. All permethrin treatments had levels of infested cones that were significantly different from untreated cones (p= 0.05). A benefit-cost ratio ([$value/tree with treatment - $value/tree without treatment]/treatment cost/tree) was calculated to provide another basis for prescribing treatments. Permethrin applied at 0.6 g/L once provided the most favourable benefit-cost ratio, even though it was the next to least effective treatment. A simple decision matrix concerning treatment or no treatment relative to cone crop size and expected beetle population is provided and briefly discussed. Degree-day data collected during the study to predict beetle emergence was considered to be too variable to accurately determine when pesticide spraying should begin. Monitoring the emergence of caged beetles is suggested to determine when to spray.

74. Schenk, J.A.; Goyer, R.A. 1967. Cone and seed insects of western white pine in northern Idaho: Distribution and seed losses in relation to stand density. J. For. 65:186-187.

Conophthorus monticolae damaged 0.2 and 0.0% of the total seed examined in 1963 and 1964, respectively.

75. Schmid, J.M.; Mitchell, J.C.; Carlin, K.D.; Wagner, M.R. 1984. Insect damage, cone dimensions, and seed production in crown levels of ponderosa pine. Great Basin Nat. 44:575-578.

Second-year cones were collected in September from 10 locations in the Coconino and Kailiab national forests, in northern Arizona. The mean percentage of damaged cones by *Conophthorus ponderosae* was not significantly different between upper, middle, or lower crown levels, but was significantly different among areas and among trees within areas. Areas that produced cone crops every year may sustain greater damage than those areas where cone crops are produced every 3-5 years. On an area basis, the mean percentage of cones infested by the cone beetles ranged from 0 to 39%.

76. Schwarz, E.A. 1895. Description of the pine-cone-inhabiting Scolytid. Proc. Ent. Soc. Wash. 3:143-145.

A description of the new species *Pityophthorus coniperda* is provided. The author states that, "This new species differs from the generic description of *Pityophthorus* as given by Eichhoff (Ratio, etc, p. 173) in the structure of the antennae and the anterior tibiae...", but felt that "...it would be premature to erect a new genus for an isolated species". An interesting account of the previous confusion of names e.g. *Dryocoetes affaber* for this scolytid is given.

77. Struble, G.R. 1947. Twig damage in sugar pine caused by the cone beetle. J. For. 45:48-50.

Reports the discovery of the twig-mining habit by *Conophthorus lambertianae*. Adult beetles enter just behind the terminal bud and bore down the centre of the stem. Only one adult to each twig was observed. The twig-mining habit caused limited damage throughout the crowns of sugar pines of various ages and vigour. Differences in the extent of twig-killing appeared to be associated with cone attack; areas where cone attack was severe suffered the most twig damage. Twigs examined late in the fall indicated that about 90% of them were abandoned, even though the twigs were still attached to the trees.

78. Swaine, J.M. 1918. Canadian bark-beetles. Part II, A preliminary classification, with an account of the habits and means of control. Can. Dept. Agric., Entomol. Br., Bull. 14, 143 pp.

Provides a key (pages 92-93), adapted from Hopkins 1915 paper, to the *Conophthorus* species: *resinosae*, *ponderosae*, *scopulorum*, *coniperda*, *contortae*, and *monticolae*.

79. Tabashnik, B.E.; Mattson, W.J.; Miller, J.R. 1985. Host acceptance behavior of the red pine cone beetle *(Conophthorus resinosae)*. Entomol. exp. appl. 37:3-7.

Eighty-seven percent of adult female *Conophthorus resinosae* placed on red pine cones stayed for 3 minutes, but only 15% remained on white pine cones. When presented cone slices, the beetles did not walk any faster to red pine than to white pine. Furthermore, the beetles were equally likely to bore into red and white pine cones. Interestingly 40% of the beetles bored into twigs rather than cones of white pine. The short term (3 min) and long term (24 h) responses of individual beetles to either host indicated that beetles left white pine cones more readily than red pine cones; however, after remaining for 3 min they were not more likely to stay on red pine than white pine for the next 24 h. These findings suggest that the beetles may attack white pine in nature.

80. Thomas, J.B. 1957. The use of larval anatomy in the study of bark beetles (Coleoptera: Scolytidae). Can. Ent. 89 (Suppl. 5), 45 pp.

Thirty species of bark beetles, including *Conophthorus coniperda* and *C. resinosae*, were examined to determine whether larvae could be identified to genus or species on the basis of their external anatomy. A key to the genera and species examined is provided. It was not possible to separate the two species of *Conophthorus*. The close link between *Conophthorus* and *Pityophthorus* is discussed in terms of their anatomy.

81. Thomas, J.B. 1967. A comparative study of gastric caeca in adult and larval stages of bark beetles (Coleoptera: Scolytidae). Proc. Ent. Soc. Ont. 97:71-83.

The different types of gastric caeca (globular only, globular and elongate, elongate only, intermediate, or none) and the patterns of distribution are described and illustrated for 83 species of bark beetles representing 27 genera. Included in this treatise

are descriptions of the gastric caeca of *Conophthorus coniperda, C. flexilis, C. lambertianae, C. monophyllae, C. radiatae, C. resinosae,* and a *Conophthorus* species collected from jack pine. The gastric caeca of the larvae and adults of the *Conophthorus* examined are similar in structure. The globular caeca are arranged in an irregular band on opposite sides of the midgut and are preceded by groups of 3 or 4 elongate caeca. The elongate caeca are usually in a continuous row in the adult, partially encircling the midgut; whereas, in the larvae they are in two groups.

82. Thomas, J.B. 1971. The immature stages of Scolytidae: the genus *Conophthorus* (Coleoptera: Scolytidae). Can. Ent. 103:1021-1026.

The external anatomy of larvae and pupae of the *Conophthorus* species *banksianae, resinosae, coniperda, ponderosae, flexilis, monophyllae, monticolae, radiatae;* and of larvae of *C. lambertianae* is given. Minor intraspecific variations in the larval anatomy are evident. No consistent differences were found that would separate one *Conophthorus* species from another. Pupae were similar in structure, and again it was not possible to separate the species.

83. Thomas, J.B.; Lindquist, O.H. 1956. Notes on bark beetles and associated insects feeding in pine shoots. Can. Dep. Agric., For. Biol. Div., Bi-Mon Prog. Rep. 12 (4):2.

Tentative identification of bark beetles collected from damaged shoots of jack, red, or Scots pine was inconclusive. Some specimens were identified as "*Conophthorus coniperda, C.* possibly *coniperda, C. resinosae, C.* probably *resinosae, Pityophthorus carinceps* Lec., *P. pulicarius* (Zimm.) and *Pityophthorus* spp." Shoot damage is most prevalent in small trees 1 to 5 inches (dbh) growing in the open where reproduction is not dense. Damage is more frequent on the terminal shoots of lateral branches than on the main tree leaders. The adult beetle cuts an entrance hole into the terminal portion of the previous year's growth about the time the new shoots begin to elongate in the spring. Eggs are deposited singly in niches cut into the gallery located above the entrance hole. New adults appear about mid-July. Some newly emerged adults mined into the shoots of jack pine directly below the new bud and fed there. Larvae of *Cimberis elongatus* were found in nearly all shoots attacked by the bark beetles.

84. Williamson, D.L.; Schenk, J.A.; Barr, W.F. 1966. The biology of *Conophthorus monticolae* in northern Idaho. For. Sci. 12:234-240.

Conophthorus monticolae overwinters as mature adults in aborted cones. Emergence of the adults in the spring appears to coincide with the initiation of cone elongation. The adult female constructs a straight gallery along the cone axis with laterally positioned egg niches. Oviposition lasts from late May to late June, and eggs hatch in 5 to 10 days. The larval stage, which has 2 instars, lasts about 4 weeks. Larvae feed indiscriminantly on the cone tissues without forming distinct larval mines. Pupation occurs within the cone, and transformation to mature adults requires about 3 weeks. Some adults may spend 2 years in the cone before emergence. Seven parasites were found to be associated with cones infested with *C. monticolae* and/or *Dioryctria abietella* and *Eucosma rescissoriana;* however, specific host determinations for the parasites were not obtained.

85. Wood, S.L. 1962. Miscellaneous taxonomic notes on Scolytidae (Coleoptera). Great Basin Nat. 22:76-82.

Describes the new species *Conophthorus mexicanus* which is "...very closely allied to *ponderosae* Hopkins but is larger and has the elytral declivity much more strongly impressed". The type locality is Necaxa, Puebla, Mexico.

86. Wood, S.L. 1971. New species of bark beetles (Scolytidae: Coleoptera) from western North America. Great Basin Nat. 31:69-76.

Conophthorus cembroides is a new species to science. "This species is closely related to *edulis* Hopkins, but is distinguished by the slightly smaller, shallower punctures on the pronotum and elytra and by the flattened, very feebly impressed interstriae 2 on the declivity." The female is indistinguishable from the male by external characteristics. The type locality is Miller Canyon, Huachuca Mts., Arizona, USA.

87. Wood, S.L. 1977a. New synonymy and new species of American bark beetles (Coleoptera: Scolytidae), Part IV. Great Basin Nat. 37:207-220.

The author names a new species of *Conophthorus: Conophthorus conicolens*. "This species is distinguished from *apachecae* Hopkins and *ponderosae* Hopkins by the slightly stouter body form, by the more strongly, more broadly impressed declivity, with the tubercles on interstriae 3 longer, by the larger punctures on declivital striae 3, and by the smoother elytral disc, with the punctures averaging larger and somewhat confused". The type locality is 13 km W. Texmelucan, Puebla, Mexico.

88. Wood, S.L. 1977b. New synonomy and new species of American bark beetles (Coleoptera: Scolytidae), Part V. Great Basin Nat. 37:383-394.

Conophthorus clunicus Hopkins and *C. taedae* Hopkins are declared synonyms of *C. coniperda* Schwarz, and *C. virginianae* Hopkins synonymous with *C. resinosae* Hopkins. *Conophthorus coniperda* is distinguished from *C. resinosae* by the smaller size, steeper elytral declivity and tuberculate declivital interstriae 1. The author also declares *C. monticolae, C. scopulorum, C. contortae, C. flexilis* and *C. lambertianae* as *C. ponderosae*. It is suggested that there is a possibility that sibling species occur in the material treated as *C. ponderosae;* however, biological studies would be required to determine whether or not this is the case.

89. Wood, S.L. 1978. New synonomy and new species of American bark beetles (Coleoptera: Scolytidae), Part VII. Great Basin Nat. 38:397-405.

A description of the new species *Conophthorus echinatae* is provided. *Conophthorus echinatae* is distinguished from *C. coniperda* "...by the smaller size, by the more slender form, by the more strongly arched elytral declivity, by the coarser pronatal and elytral punctures, and by the weaker transverse frontal impression." The type locality is Winona, Missouri.

90. Wood, S.L. 1980. New genera and new generic synonomy in Scolytidae (Coleoptera). Great Basin Nat. 40:353-358.

Two new species are named: *Conophthorus michoacanae* and *C. teocotum*. *Conophthorus michoacanae* "...is distinguished from *apachecae* Hopkins by the more slender body, by the less densely punctured, smoother basal half of the elytral disc, by the broader, more gradual elytral declivity..." This species was collected from *Pinus michoacana* cones. The type locality is Urapan, Michocan, Mexico. The female is similar to the male in all respects. *Conophthorus teocatum* "...is distinguished from *ponderosae* Hopkins by the subacutely elevated median carina on the lower totally obsolete punctures on declivital striae 2 except near base..." The female is "...similar to the male except transverse frontal impression more extensive, slightly more conspicuous, carina slightly shorter." This species was collected from *Pinus teocote* cones, and the type locality is Urupan, Michoacan, Mexico.

91. Wood, S.L. 1982. The bark and ambrosia beetles of North and Central America (Coleoptera: Scolytidae). A taxonomic monograph. Great Basin Nat. Mem. 6, 1359 pp.

A general introduction and key to the 14 species of *Conophthorus*, i.e. *monophyllae, cembroides, edulis, radiatae, echinatae, coniperda, banksianae, resinosae, mexicanus, conicolens, apachecae, michoacanae, ponderosae* and *teocotum* is provided. For each species, this monograph gives diagnostic characteristics, descriptions of the male and female adults, distribution, and miscellaneous notes. In addition, the host(s) for each species, except *mexicanus*, and a brief description of the biology of each species, except *cembroides, echinatae, mexicanus, michoacanae* and *teocotum*, is given.

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