Mountain Pine Beetle in Southwestern White Pine in the Pinaleño Mountains

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Abstract—*Mountain pine beetle has rarely been found in the Madrean Sky Island Archipelago and has not been reported from the Pinaleño Mountains until recently. This insect began killing southwestern white pine in 1996 or earlier, with additional mortality each year since. Activity has increased in the last 2 years. The life cycle in the Pinaleños during this time has been univoltine, with some females surviving the winter to produce a second brood in the spring. Stain fungi are evident in most killed trees, but not all. In infested areas, total stocking and the abundance of southwestern white pine has been significantly reduced, creating small openings in the stand canopies. The future course of this outbreak is uncertain.*

Introduction

Mountain pine beetle (*Dendroctonus ponderosae* Hopkins (Coleoptera: Curculionidae, Scolytinae)) is a native bark beetle infrequently found in the Madrean Sky Island Archipelago, and there is no record of it in the Pinaleño Mountains (32.4^0 latitude). Scattered mountain pine beetle-infested southwestern white pines (*Pinus strobiformis*) were found in 2007 near Soldier Creek in the Pinaleño Mountains (USDA Forest Service 2008). Additional individual and small groups of southwestern white pines have been infested each year since. Mortality each year is minor, but the outbreak has persisted, damage appears to be increasing, and mortality has accumulated to significant levels that affect resource values. Values at risk include recreation, as some of the infestations are in the vicinity of developed recreation sites, and wildlife, as the seeds, large trees, and snags are utilized by the endangered Mount Graham red squirrel, *Tamiasciurus hudsonicus grahamensis* (Benkman and others 1984; Frank and Cox 2009), among others. Though mountain pine beetle is the most significant insect disturbance agent in lodgepole pine (*Pinus contorta*) forests, and is well studied elsewhere, little is known about its biology and effects in southern Arizona or on southwestern white pine. We undertook investigations to characterize the effects of infestation, determine tree and site characteristics associated with mountain pine beetle infestation, and establish a timeline of outbreak development

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Background

Though well distributed throughout much of western North America (Gibson and others 2009; Safranyik and others 2010; Wood 1982), records of mountain pine beetle and related tree mortality are sparse in southern Arizona. Hopkins (1909) reported finding it in the Chiricahua Mountains in 1907, but reported no further information from that location. A tabulated Forest Service record of forest insect activity during the 1960s in Arizona and New Mexico (USDA Forest Service 1971) indicates that an infestation occurred on the Coronado National Forest (N.F.) in the 1960s, at the same time that outbreaks occurred on the Cibola N.F. and Carson N.F. in New Mexico. Though survey records from individual years in the 1960s are no longer available, the information indicates that infested trees were on these three National Forests and included ponderosa pine (*Pinus ponderosa*) and southwestern white pine in 1961-1965, 1968, and 1969. The only other insect activity recorded for the Coronado N.F. during that time period was roundheaded pine beetle (*Dendroctonus adjunctus* Blandford) in 1967-1970. No further reference to mountain pine beetle activity in southern Arizona was found until 2007.

The historical range of mountain pine beetle extends from northern Baja, California, and the northern border of Mexico (31^0 latitude) to central British Columbia (56^0) (Cibrián-Tavar and others 1995; Safranyik and others 2010; Wood 1982). As a result of rising temperatures, the geographic range has recently expanded northward to eastern Alberta (Safranyik and others 2010) and to higher elevations (Bentz and others 2011; Logan and Powell 2009). Activity within the historical range has also increased in recent years, and outbreaks are occurring in areas where they either were not recorded or were recorded infrequently (Bentz and others 2011; Bentz and Schen-Langenheim 2007; Gibson and others 2009). The current outbreak in British Columbia and Alberta is likely one of the largest in history (Kurz and others 2008; Taylor and others 2006). All *Pinus* species within the mountain pine beetle range except Jeffrey pine (*Pinus jeffreyi*) can be successfully attacked, including white pines and piñons.

Temperature regimes play a significant role in determining when and where mountain pine beetle outbreaks occur (Gibson and others 2009; Logan and others 2010), and rising temperatures may have contributed to recent changes (Bentz and others 2011; Safranyik and others 2010) by influencing seasonal aspects of life history (Logan and Bentz 1999). In order to overcome tree defenses, adult mountain pine beetles must mass-attack trees with large numbers of beetles. Synchronized adult emergence and aggregation pheromones make it possible for sufficient numbers of beetles to be present at one time to overcome tree defenses. Mountain pine beetle can adapt its development rates seasonally to optimize likelihood of synchronized emergence (Logan and Bentz 1999). Throughout its wide geographic range, mountain pine beetle has adapted to local temperature regimes and has the capacity to exhibit different seasonal life histories (Amman and Bartos 1991; Gibson and others 2009). Mountain pine beetle does not have a winter diapause, and the life history is very responsive to temperature. Mountain pine beetle is typically univoltine, but in portions of its range with cooler summers (especially at high elevations), it is semivoltine (Safranyik and Carroll 2006). Outbreaks occur during warm periods, particularly when winter temperatures are mild enough to allow survival of all life stages, and there is sufficient summer thermal energy to allow a univoltine life cycle (Logan and others 2010) and when temperature regimes facilitate synchronous adult emergence (Bentz and others 1991; Safranyik and Carroll 2006); suitable thermal windows may be quite narrow. The northern part of the Madrean archipelago is the southern extreme for the mountain pine beetle range, and the thermal habitat is probably marginal for the species. Most of the time, activity is probably minimal because synchronization of adult emergence is insufficient to allow mass-attack, a univoltine life cycle is infrequent, or mortality occurs to one or more life stages because summer temperatures are too warm or because an overwintering stage is susceptible to cold. One or more of these conditions has probably changed recently.

Approach

Our objectives were to characterize the effects of infestation, determine tree and site characteristics associated with mountain pine beetle infestation, and establish a timeline of outbreak development. Our approach was to establish plots in infested areas, compare the character of those plots to randomly located southwestern white pine-inhabiting plots, and date mortality of mountain pine beetle-attacked trees using tree-ring analysis.

Infested areas were located by reconnaissance both on foot and by vehicle. Plots were located completely within infested areas. Where infested areas were large, plots were located 100 m apart, and along an elevation gradient where possible. Trees larger than 20 cm DBH were measured on a 0.05-ha plot fixed-radius plot while trees smaller than 20 cm DBH but 3 cm DBH or larger were measured on a 0.02-ha fixed-radius plot. At each plot, spatial coordinates, elevation, aspect, slope, and species of trees in the vicinity were recorded. Data recorded for each tree included species, diameter (DBH, or DIB if bark was absent), dwarf mistletoe rating, canopy position, needle color and abundance on live and dead trees, presence of bark and limbs of various sizes on dead trees, evidence of bark beetle attack, species of attacking bark beetle, and evidence of stain fungi. When recording canopy position we distinguished between small suppressed trees and healthy understory trees. There are many bark beetle species that attack *Pinus* in southern Arizona, but mountain pine beetle galleries are distinctive and easily distinguished from those of other species (fig. 1a; Fairweather and others 2006). We had little difficulty finding evidence of mountain pine beetle activity in trees that had been dead for 15 years (fig. 1b), as mountain pine beetle scores the wood surface and these scars are evident after much weathering. Increment cores were taken from mountain pine beetle-killed trees that had been dead long enough that the attack year could not be determined from visual inspection of snag condition, as well as from some recently-killed trees. The outer ring dates of these cores were determined in the laboratory using standard tree-ring procedures (Stokes and Smiley 1968). We also opportunistically sampled individual mountain pine beetle-killed trees found during reconnaissance to assist in determining the outbreak timeline.

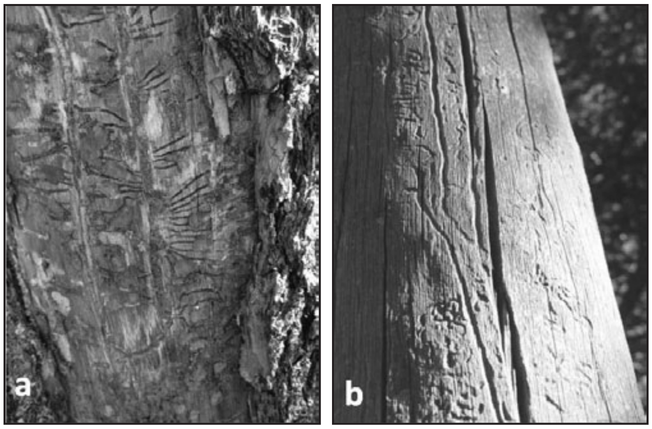

Figure 1—(a) Fresh mountain pine beetle galleries, and (b) gallery scars from a tree killed in 1997 and photographed in 2011; both are southwestern white pine in the Pinaleño Mountains. Mountain pine beetle females construct long nearly-linear galleries with J- or L- shaped hooks at the bottom, along which eggs are laid; larvae feed in the phloem and construct galleries that initially are horizontal and do not score the wood (photos by A.M. Lynch).

Characteristics of mountain pine beetle-infested trees and plots were compared to tree and plot characteristics of systematically located plots in a Pinaleño Demography study (Falk and others 2009) on which southwestern white pine was found. The Pinaleño Demography plot system consists of two sampling grids across the mountain range above 2134 m elevation. The first grid is spaced at 1000 m, and the second grid is offset east and south by 500 m. Plots consist of nested 0.017- and 0.05-ha plots for small and large trees, respectively. At each plot, site and stand characteristics data were collected in 2009 and 2010 similar to what is described above for live and dead trees of all species. Additionally, increment cores were collected from each tree and cross dated and measured to establish demographics, mortality events, growth release events, and recruitment events.

We did not set out to investigate the life cycle and seasonal history of mountain pine beetle in the Pinaleño Mountains. However, during the last several years the first author has repeatedly visited infested trees and plots several times to monitor the situation, assist other investigators in the collection of genetic material and infested bolts for life history studies, train local managers in identifying mountain pine beetle, and to develop this study. These observations are also reported here.

Mountain pine beetle-infested areas were located below the Riggs Lake campground, in and above the Treasure Park campground, on the upper slopes of Webb Peak, and in the Soldier Creek campground. District personnel had removed many dead and infested trees at the latter location for safety reasons, and we sampled six plots in the other locations. Here we report the results from those plots, and are careful to not over interpret the limited data, restricting our observations to what we think can be supported by the data. In 2012, we will sample additional plots and determine the causal agents of dead southwestern white pine found in the Pinaleño Demography study.

Results

Insect Biology

The majority of the mountain pine beetle population was clearly univoltine with mass-attacks in the autumn. A small number of trees were successfully mass-attacked in spring. This was evidenced by very tight bark in trees with excessive sap flow on the outer bark in spring, presence of pupae in early June 2011 (indicative of spring attacks the previous year [B.J. Bentz, personal communication]), noticeable fading of foliage in some trees in autumn (fading from autumn attacks usually occurs early in the subsequent growing season), and formation of a partial growth ring in the outer ring of a few dead trees. Our data is not sufficient to accurately determine the proportion of trees that were attacked in spring (it was low, perhaps 10-15%) or if a portion of the population was semivoltine.

Evidence of stain fungi was found in most trees, but not all. We did not record the presence of staining at the beginning of the study. Twenty-five percent of sampled southwestern white pine and ponderosa pine (on the plots or not) and 12% of the cored trees did not have stain fungi. Stain-free trees were killed in a range of years from 1998 to 2011.

Outbreak Development

We originally thought that the outbreak originated at the summit of Webb Peak in lightning-struck trees, but this was not the case. Individual dead trees with outer ring dates of 1996 and 1997, which for autumn-attacked trees would be the year-of-attack, were found scattered across the landscape. Larger numbers of trees were attacked in 2001 and especially 2010. This is typical of mountain pine beetle—randomly distributed impaired trees are attacked when population densities are low, but once population density increases beetles select clustered populations of larger resource-rich trees (Boone and others 2011).

Character of Infested Trees

Fifty-four mountain pine beetle-attacked trees were found, including 14 opportunistically sampled (off-plot) trees. All were southwestern white pine except for two ponderosa pine and one Douglas-fir (*Pseudotsugae menziesii*). The Douglas-fir probably represents a mistake by attacking beetles, as it was growing tightly intertwined with a similarly sized southwestern white pine (both were 13 cm DBH). Brood developed in the southwestern white pine, but not in the Douglas-fir. All attacked trees were larger than 17 cm DBH except for these two trees, and the majority were larger than 20 cm.

On infested plots, a greater proportion of larger size classes were attacked (fig. 2). Over 70% of trees 40 cm or larger in diameter were killed by mountain pine beetle.

Character of Infested Plots

The Pinaleño Demography plot system (Falk and others 2009) represents a random sample of sites in the Pinaleño Mountains above 2134 m. On plots with southwestern white pine, it is most commonly associated with Douglas-fir, white fir (*Abies concolor*), and ponderosa pine (89, 51, and 49% of plots, respectively). Engelmann spruce (*Picea engelmannii*), corkbark fir (*A. lasiocarpa* var. *arizonica*), and aspen were less frequently found (31, 31, and 26% of plots, respectively), and Gambel oak (*Quercus gambelii*) and Arizona willow (*Salix arizonica*) were found occasionally. Southwestern white pine inhabited sites with slopes less than 65% with a wide range of aspect, though few faced west.

Species composition, slope, and aspect of mountain pine beetle-infested plots were very similar to those of the Pinaleño Demography plots. Elevation ranged from 2670 to 3050 m. Southwestern white pine stocking of infested plots varied considerably, between 5 and 36 sq m/ha, and stocking of all species varied between 34 and 73 sq m/ha. Douglas-fir was found on all infested plots

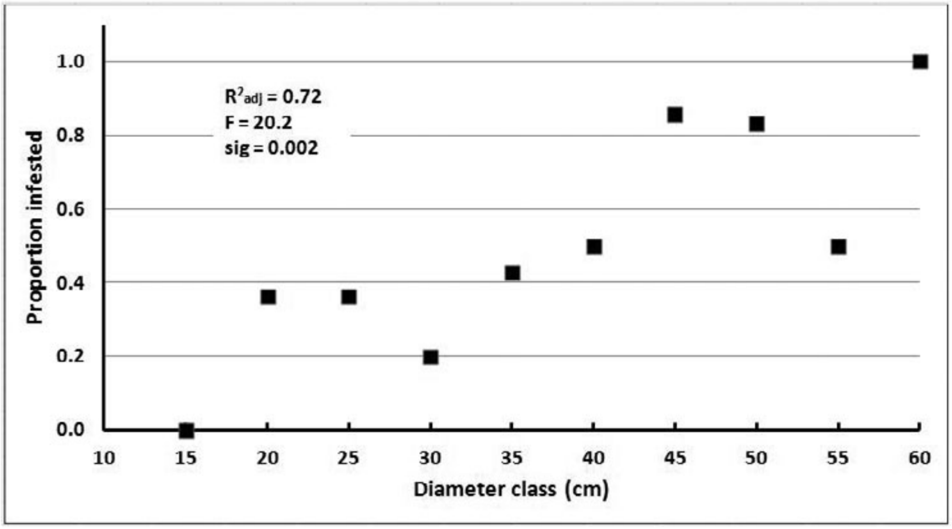

Figure 2 –Proportion of southwestern white pine infested with or killed by mountain pine beetle on infested plots. Each size class, 15-50 cm, had 6 or more trees.

Table 1—Characteristics of study plots before and after mountain pine beetle infestation, and plots in the Pinaleño Demography study where southwestern white pine was present.

	Before	After	Change (%)	Demography
All species				
stocking (sq m/ha)	49 ± 17	19 ± 5	-61	96 ± 39
density (tph)	660 ± 214	537 ± 193	-19	698 ± 335
Southwestern white pine				
stocking (sq m/ha)	27 ± 9	14 ± 11	-48	20 ± 19
density (tph)	360 ± 135	240 ± 153	-33	152 ± 102
dominance (% stocking)	55 ± 9	37 ± 18	-32	22 ± 20
mean dbh (cm)	29.2 ± 7.5	28.0 ± 8.7	-4	39 ± 11

On average, infested plots had similar densities but half the basal area compared to the random Pinaleño Demography plots. There was a higher representation of southwestern white pine that were, on average, smaller in diameter than those in the Pinaleño Demography study (table 1).

Effects of Infestation

Mountain pine beetle infestation significantly reduced total stocking and density, and the abundance of southwestern white pine (table 1). Mean basal area was reduced approximately 60%, creating small openings in the canopy. Resulting species composition favored Douglas-fir, with mean dominance by that species increasing from 22 to 56%.

Discussion

Some conclusions can be made from the study at this point. In the Pinaleño Mountains, mountain pine beetle preferred areas dominated by southwestern white pine indicates that insect attacks occur where the host is more abundant. We found few ponderosa pine that were attacked by mountain pine beetle, even in areas where ponderosa pine was common.

The overall impacts of this insect have been modest, creating small openings in mixed-conifer stands. Southwestern white pine is prolific in the Pinaleño Mountains, with abundant reproduction. It is one of the preferred species for several resource objectives, and has been a stable component of the mixed-conifer forest. Though damage has been modest to date, it increased significantly in 2010 and 2011.

Uncertainty regarding the future course of the outbreak is the largest concern. Mountain pine beetle has aggressive population dynamics once population densities are high enough that the defenses of healthy trees can be overcome (Boone and others 2011; Gibson and others 2009), and once started, outbreaks can deplete the host resource over large areas. The initial stages of outbreaks are marked by a change in attack behavior from individual impaired trees to groups of healthy trees, which appears to be the case in the Pinaleños. Attacks in the last 2 years have clearly favored groups of healthy trees; however, the scale of activity in the Pinaleños is rather small, so it is too soon to conclude that a high-intensity outbreak has begun. Outbreaks occur in warm periods when the population can sustain a univoltine life cycle (Logan and others 2010), and that appears to be the situation in the Pinaleños. On the other hand, the temperature regime needed to sustain that life cycle in southern Arizona is unknown. The thermal habitat for mountain pine beetle may be marginal, and it is possible that small changes in the temperature regime could disrupt the univoltine life cycle and synchronization of adult emergence, which would subsequently dampen outbreak dynamics. Activity in the 1960s apparently subsided without catastrophe. Too little is known about the course of that outbreak to assist in projecting mountain pine beetle activity during the current outbreak. We cannot determine if the mountain pine beetle population in the Pinaleños is at an incipient outbreak stage or in the initial stage of an intense outbreak.

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References

Amman, G.D.; Bartos, D.L. 1991. Mountain pine beetle offspring characteristics associated with females producing first and second broods, male presence, and egg gallery length. Environmental Entomology 20: 1562-1567.

Benkman, C.W.; Balda, R.P.; Smith, C.C. 1984. Adaptations for seed dispersal and the compromises due to seed predation in limber pine. Ecology 65(2): 632-642.

Bentz, B.J. 2006. Mountain pine beetle population sampling: inferences from Lindgren pheromone traps and tree emergence cages. Canadian Journal of Forest Research 36: 351-360.

Bentz, B.; Campbell, E.; Gibson, K.; [and others]. 2011. Mountain pine beetle in high-elevation five-needle white pine ecosystems. Pp. 78-84 *in* Keane, R.E.; Tomback, DF.; Murray, M.P.; Smith, C.Y. (editors). The future of high-elevation five-needle white pines in western North America: Proceedings of the High five Symposium; 28-30 June 2010; Missoula, MT. Proceedings RMRS-P-63. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 376 p.

Bentz, B.J.; Logan, J.A.; Amman, G.D. 1991. Temperature-dependent development of the mountain pine beetle (Coleoptera: Scolytidae) and simulation of its phenology. The Canadian Entomologist 133: 375-387.

Bentz, B.J.; Schen-Langenheim, G. 2007. The mountain pine beetle and whitebark pine waltz: Has the music changed? Pp. 43-50 *in* Proceedings of the conference Whitebark Pine: A Pacific coast perspective. R6-NR-FHP-2007-01. Portland OR: U.S. Department of Agriculture, Forest Service.

Boone, C.K.; Aukema, B.H.; Bohlman,n J.; [and others]. 2011. Efficacy of tree defense physiology varies with bark beetle population density: A basis for positive feedback in eruptive species. Canadian Journal of Forest Research 41: 1174-1188.

Cibrián-Tovar, D.; Méndez-Montiel, J.T.; Campos-Bolaños, R.; [and others]. 1995. Insectos Forestales de Mexico. Universidad Autonoma Chapingo, Secretaría de Agricultura y Recursos Hidraulicos, United States Department of Agriculture, Natural Resources Canada y Comision Forestal de America del Norte. 455 p.

Fairweather, M.L.; McMillin, J.; Rogers, T.; [and others]. 2006. Field guide to insects and diseases of Arizona and New Mexico forests. Albuquerque, NM: U.S. Department of Agriculture, Forest Service, Southwestern Region. 271 p.

Falk, D.A.; Lynch, A.M.; O'Connor, C.; [and others]. 2009. Growth and demography of Pinaleño high elevation forests. Performance Report RJVA 07-JV-11221615317. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 25 p.

Frank, C.L.; Cox, S.R. 2009. The adaptive significance of seed hoarding by the Mt. Graham red squirrel. Pp. 256-273 *in* Sanderson, H.R.; Koprowski, J.L., (editors). The last refuge of the Mt. Graham Red Squirrel: Ecology of endangerment. Tucson: The University of Arizona Press. 427 p.

Gibson, K.; Kegley, S.; Bentz, B. 2009. Mountain pine beetle. Forest Insect & Disease Leaflet 2. FS-R6-RO-FIDL#2/002-2009. U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. 12 p.

Hopkins, A.D. 1909. Practical information on the Scolytid beetles of North American forests. I. Barkbeetles of the genus Dendroctonus. Bulletin No. 83, Part I. Washington, DC: U.S. Department of Agriculture, Bureau of Entomology.

Kurz, W.A.; Dymond, C.C.; Stinson, G.; [and others]. 2008. Mountain pine beetle and forest carbon feedback to climate change. Nature 452: 987-990.

Logan, J.A.; Bentz, B.J. 1999. Model analysis of mountain pine beetle seasonality. Environmental Entomology 28: 924-934.

Logan, J.A.; Powell, J.A. 2009. Ecological consequences of forest insect disturbance altered by climate change. Pp. 98-109 *in* Wagner F.H. (editor). Climate warming in western North America: evidence and environmental effects. Salt Lake City: University of Utah Press.

Logan, J.A.; MacFarlane, W.W.; Willcox, L. 2010. Whitebark pine vulnerability to climate-driven mountain pine beetle disturbance in the Greater Yellowstone Ecosystem. Ecological Applications 20: 895-902.

Safranyik, L.; Carroll, A.L. 2006. The biology and epidemiology of the mountain pine beetle in lodgepole pine forests. Pp. 33-66 *in* Safranyik L., Wilson B. (editors). The mountain pine beetle: A synthesis of biology, management and impacts in lodgepole pine. Victoria, BC: Canadian Forest Service, Natural Resources Canada.

Safranyik, L.; Carroll, A.L.; Régnière, J.; [and others]. 2010. Potential for range expansion of mountain pine beetle in the boreal forest of North America. The Canadian Entomologist 142: 415-442.

Six, D.L.; Adams, J. 2007. White pine blister rust severity and selection of individual whitebark pine by the mountain pine beetle (Coleoptera: Curculionidae, Scolytinae). Journal of Entomological Science 47:345–353.

Stokes, M.A.; Smiley, T.L. 1968. An introduction to tree-ring dating. University of Chicago Press. 73 p.

Taylor, S.W.; Carroll, A.L.; Alfaro, R.I.; Safranyik, L. 2006. Forest, climate and mountain pine beetle outbreak dynamics in western Canada. Pp. 67-94 *in* Safranyik, L., Wilson, B. (editors). The mountain pine beetle: A synthesis of biology, management and impacts in lodgepole pine. Victoria, BC: Canadian Forest Service, Natural Resources Canada.

USDA Forest Service. 1971. Major forest insect and disease losses 1961-70. Prepared by I&D Staff, December 1971. Insect and disease surveys are completed every year by the Forest Service. Reports from the 1960s are lost or were never published, but a tabulated summary of activity in Arizona and New Mexico is available at the USDA Forest Service, Region 3, Forest Health Protection office, Albuquerque, NM.

USDA Forest Service. 2008. Forest insect and disease conditions in the Southwestern Region, 2007. R3-08-01. Albuquerque NM: U.S. Department of Agriculture, Forest Service, Southwestern Region, 41 p.

Wood, S.L. 1982. The bark and ambrosia beetles of North and Central America (Coleoptera: Scolytidae), a taxonomic monograph. Great Basin Naturalist Memoirs No. 6. 1359 p.
