REVIEW OF THE 1992-1995 DENDROCTONUS BARK BEETLE OUTBREAK IN THE PINE FORESTS OF SIERRA DE LAS MINAS, GUATEMALA

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SUMMARY

From 1992 to 1995, an outbreak of bark beetles (Coleoptera: Scolytidae) occurred in the pine forests of the Sierra de las Minas in eastern Guatemala, primarily in the Departments of El Progreso and Zacapa. The main bark beetle species involved was Dendroctonus frontalis Zimmermann, which is commonly called the southern pine beetle in the United States. The most affected species of pine was Pinus oocarpa Schiede. Apparently, the outbreak was initiated by the severe drought conditions that prevailed during 1992 and 1994. However, by the time of my visit in August 1995, the outbreak appeared to be collapsing. The most severe infestations were in areas administered by Fundacion Defensores de la Naturaleza (= Defensores), a nongovernmental organization headquartered in Guatemala City. Early in 1995, I was informed about the outbreak by Defensores staff members Andreas Lehnhoff, Oscar Nuñez, and Gerardo Paiz. It was during those discussions that plans were initiated for me to visit as part of the USFS Sister Forest Partnership. Overall, I spent about two weeks in Guatemala (6-22 August 1995), evaluating the situation and making recommendations to Defensores. This report provides a summary of my initial findings and recommendations.

BACKGROUND INFORMATION

Bark beetle outbreaks in the Guatemalan highlands have been recorded since the late 1800's, but not until 1932 were any of the beetles involved identified. Bates (1932) recorded that Dendroctonus adjunctus Blandford and Dendroctonus mexicanus Hopkins had killed large areas of pine in the Department of Totonicapan. In 1936, Guatemalan President Ubico signed an order mandating that the "death of the pines in the western highlands be investigated" (Schwerdtfeger 1955). This presidential order was carried out and soon thereafter Alvarado (1939) reported that burning and overgrazing had been the two principal causes for the outbreak. Another major bark beetle outbreak occurred in Guatemala in the 1950s, primarily in stands of Pinus rudis Endlicher in the Departments of Huehuetenango and Totonicapan. Again, Dendroctonus adjunctus was the principal pest involved (Becker 1954, 1955, Schedl 1955, Schwerdtfeger 1955, 1956, 1959, 1961). Later, in the 1970s and early 1980s, another major outbreak occurred in the western highlands of Guatemala, affecting pine stands in the Departments of Chimaltenango, Huehuetenango, Quetzaltenango, Quiche, Sacatepequez, San Marcos, Solola, and Totonicapan. Again, Pinus rudis was the most severely affected pine species, but also attacked were Pinus montezumae Lambert, Pinus oocarpa, Pinus pseudostrobus Lindley, and Pinus tenuifolia Bentham (now = Pinus maximinoi H.E. Moore) (Clark 1974, INAFOR 1978). Many outbreaks occurred in stands that were overmature and overstocked. In addition, many of these sites suffered from drought stress, frequent fires, overgrazing, and "ocote" production.

In neighboring Honduras, several major outbreaks have occurred this century. However, the most severe outbreak took place during the 1960s, when about 20% of all pines were killed, primarily Pinus oocarpa. The principal bark beetle species involved was Dendroctonus frontalis (Beal et al. 1964, Billings 1972, 1982, FAO 1968, Fox et al. 1964, Hernandez 1975, Ketcham and Bennett 1964, Wilkinson and Haack 1987). As in Guatemala, the contributing factors to these outbreaks in Honduras included poor forest management, overmature stands, frequent fires, and drought (Beal et al. 1964, Billings 1982, Carr 1950, Ketcham and Bennett 1964).

OBJECTIVES

The objectives of this mission included (1) evaluation of the current bark beetle outbreak, (2) evaluation of Defensores' current forest management practices that were relevant to pest control, (3) training of key Defensores staff in bark beetle biology and management, and (4) collection of life history data concerning the bark beetle complex infesting pines in eastern Guatemala.

MISSION DURATION AND ITINERARY

The mission began on 6 August 1995 and ended on 22 August 1995. Approximately 9 days were spent visiting sites in the Sierra de las Minas. Throughout my stay, I worked closely with Gerardo Paiz Schwartz, a forester with Defensores. A brief itinerary follows.

DAY	DATE	ACTIVITY
Sunday	6/Aug/95	Traveled from Michigan to Guatemala. Was met by Gerardo Paiz (GP) of Defensores. Stayed at Hotel Dorado, Guatemala City. Discussed plans for the entire trip.
Monday	7/Aug/95	GP and I visited the main office of Defensores. I met with several members of the Defensores staff. Then, we visited the office of CONAP to obtain permits to (1) conduct a scientific study in a protected area, (2) collect insects, and (3) export these insects to the US. Then we visited the US-AID offices and met with Gerry Bauer. Later that evening, we went to the home of Gerry Bauer to pick up six Lindgren funnel traps that I had shipped to Guatemala a few weeks earlier. These traps were for use in collecting bark beetles.
Tuesday	8/Aug/95	GP and I traveled from Guatemala City to San Agustin Acasaguastlan (referred to hereafter as San Agustin), Department of El Progreso. We traveled to our first field site (near Morazan), which was close to San Agustin. We collected several scolytids from a recently attacked Pinus oocarpa tree. We stayed the night in San Agustin.
Wednesday	9/Aug/95	GP and I traveled to a nearby outbreak site in El Progreso (Finca Las Delicias) where we worked with two field staff for the day (Rudi del Cid and Israel Albizures). We inspected several infested pine trees and collected scolytids. A few currently infested trees had been felled, and on these, we examined the within-tree colonization pattern. We installed 2 funnel traps here to collect bark beetles.

Thursday	10/Aug/95	GP and I traveled from San Agustin to another outbreak area in El Progreso. We traveled through El Cimiento to Albores. We stayed the night in Albores at the home of Carlos Mendez. We visited the field site of Defensores known as "La Cabaña" which is located near La Trinidad. This is near the top of the Sierra de las Minas in a cloud forest. At the field site, we met with 4 forest guards. We also met a Peace Corps Volunteer at this site: Jamelle Schlangen.
Friday	11/Aug/95	GP and I visited a few field sites during the morning in Albores and then traveled to near Rio Hondo in the Department of Zacapa. We sampled dead pine trees along the way. We visited with Defensores staff in Rio Hondo and Zacapa.
Saturday	12/Aug/95	GP and I traveled to Santa Rosalia, Zacapa, with Aurelio Gallardo, a forest guard. We hiked to a nearby outbreak site, which crossed a river (Rio El Chorro). We sampled several trees in this area, and elsewhere along the trail and the road. Returned to Rio Hondo.
Sunday	13/Aug/95	GP and I traveled from Rio Hondo to Jones where we worked with Jose Morales of Defensores. We visited two outbreak sites and sampled several trees. Later that day, we hiked to a nearby waterfall. Returned to Rio Hondo at night.
Monday	14/Aug/95	GP and I traveled to Vista Hermosa, which is on the eastern edge of the Sierra de las Minas. From this location, it was possible to view Lake Izabal. This area was much lower in elevation with the predominant pine being Pinus caribaea Morelet. A few recently killed pines were inspected. Returned to San Agustin for the night.
Tuesday	15/Aug/95	GP and I traveled to nearby sites in the Rio Comaja watershed towards Moro. We saw several outbreak sites, which included both Pinus oocarpa and Pinus tecunumanii.
Wednesday	16/Aug/95	GP and I returned to Guatemala City. Visited IGM (Instituto Geografico Militar) and purchased topographical maps of the Sierra de las Minas area. Made several phone calls and prepared slide talk for the Universidad del Valle. Stayed at Hotel Dorado.

Thursday	17/Aug/95	Moved from Hotel Dorado to Hotel Princess in Guatemala City. Presented lecture in Spanish on pine bark beetles at the Universidad del Valle in Guatemala City. Hosted by Drs. Michael and Margaret Dix. GP and I visited the offices of CONAP to obtain the final forms to permit taking some of the pine bark beetles to the US so that they could be positively identified by experts. Visited the offices of Defensores.
Friday	18/Aug/95	Traveled from Guatemala City to Huehuetenango. Just a few scattered, recently dead pines were observed along the Pan-American Highway. Met Gerry Bauer by chance along the highway near the entrance to Quetzaltenango.
Saturday	19/Aug/95	Traveled from Huehuetenango to La Libertad. Visited a few forest nurseries and reforestation projects that I had worked in as a Peace Corps Volunteer during 1975-1977.
Sunday	20/Aug/95	Traveled from La Libertad to Huehuetenango. Visited a few old work sites. No signs of bark beetle damage in the Department of Huehuetenango, at least in areas close to the Pan-American Highway.
Monday	21/Aug/95	Traveled from Huehuetenango to Guatemala City. Visited with GP. Prepared materials for return trip. Stayed at Hotel Princess.
Tuesday	22/Aug/95	Traveled from Guatemala to Michigan.

OUTBREAK SITUATION

Areas Visited

During the nine days in the field, Gerardo Paiz and I traveled in a Defensores-owned 4-wheel-drive pickup and visited several outbreak sites along the southern slopes of the Sierra de las Minas Mountains in the Departments of El Progreso and Zacapa. Most of the sites occurred in ecological associations that could be described as lower montane wet forests of Pinus and Quercus species and lower montane moist forests of mostly Pinus oocarpa. Most outbreak sites occurred between 500 and 2100 meters elevation.

Causal Agents

Several bark beetle specimens were collected in the field from Pinus oocarpa and P. caribaea. A few more were specimens were collected from pine trees tentatively identified as P. maximinoi and P. tecunumanii; pine taxonomy follows Perry (1991). The three required permits to conduct this study were

obtained from CONAP (Comission Nacional de Areas Protegidas), including permits to conduct a scientific study in a protected area, to collect insects in a protected area, and to export insects to the US. Upon my return to the US, I sent several specimens to Dr. Stephen Wood at Brigham Young University, Provo, Utah, so that they could be positively identified by him. The names used in this report are based on Dr. Wood's identifications and Wood (1982).

At all sites dominated by Pinus oocarpa, P. maximinoi and P. tecunumanii, the primary mortality agent encountered was a species of bark beetle belonging to the genus Dendroctonus. This species is currently considered to be Dendroctonus frontalis Zimmermann. However more specimens are needed to make sure that a vary similar species, Dendroctonus mexicanus Hopkins, was not also involved. Dendroctonus mexicanus is similar in size to Dendroctonus frontalis but is usually found at elevations slightly higher than those occupied by D. frontalis (Wood 1982). In sites dominated by Pinus caribaea, the bark beetle Ips calligraphus (Germar) was the only scolytid encountered.

Overall, six species of scolytids were collected from pine trees in the Sierra de las Minas in 1995. They were:

Dendroctonus frontalis Zimmermann,
Dendroctonus parallelocollis Chapuis
Ips calligraphus (Germar)
Ips grandicollis (Eichhoff)
Pityophthorus confusus Blandford
Xyleborus intrusus Blandford

The primary species of bark beetle involved in the pine mortality appeared to be Dendroctonus frontalis. However, in some trees, Ips calligraphus appeared to be primary as well. The most common secondary bark beetle species included Ips calligraphus, Ips grandicollis, Dendroctonus parallelocollis and Pityophthorus confusus. As for ambrosia beetles (xylem-infesting scolytids), Xyleborus intrusus was the only species collected.

All six of these scolytid species were encountered in the lower trunks of the infested pines. We were not able to determine the within-tree distribution of these bark beetles in a detailed fashion because felling of trees was usually not practical. However, several recently fallen pines were encountered and inspected for bark beetle galleries, and on these trees, galleries similar to those of Dendroctonus frontalis were found along the entire trunk from groundline to the upper crown. In the crown and canopy branches, Ips and Pityophthorus galleries were commonly seen. Galleries of Dendroctonus parallelocollis were only seen along the lower 2-3 meters of the trunk. On a few currently infested pine trees, Ips calligraphus appeared to be the principal mortality agent, since no Dendroctonus-like galleries were found. Within-tree distribution of bark beetles in Pinus oocarpa has been studied in Honduras (Wilkinson and Haack 1987).

There is still some taxonomical controversy within the genera Ips and Dendroctonus. For example, Lanier (1972) recognized Ips interstitialis (Eichhoff) (mostly Central American in distribution) as distinct from Ips calligraphus (mostly North American) based on morphology, cross-mating studies, and karyology. However, Wood (1982) synonymized Ips interstitialis under the name Ips calligraphus, stating that the two were basically identical morphologically and that further investigation was still needed before the two could be distinguished reliably. Similarly, there has been much controversy

between the 5-spined Ips beetles -- Ips cribricollis (Eichhoff) and Ips grandicollis. These two species were placed in synoymy by Wood in 1977 (Wood 1982), but later they were shown to be distinct species and that both occur in Central America (Lanier 1987). Overall, I will follow Wood (1982) in the present report and use the identifications that he provided me with. Nevertheless, readers should realize that many older papers will refer to only Ips cribricollis and Ips interstitialis (see Becker 1955, Schedl 1955, Schwerdtfeger 1956). Similar problems have existed in the literature with reference to Dendroctonus frontalis, Dendroctonus mexicanus, and Dendroctonus vitei Wood (Lanier et al. 1988), all of which are similar morphologically and occur in Guatemala

Dendroctonus frontalis ranges from the southeastern United States through Mexico to Honduras (Cibrian et al. 1995, Wood 1982). Adults are 2 to 4 mm long. It attacks several species of pine, including Pinus maximinoi, P. oocarpa and P. tecunumanii in Mexico and Central America (Cibrian et al. 1995, Wood 1982). Few reports exist of D. frontalis in Guatemala (Lanier et al. 1988), but this may reflect some of the taxonomic difficulties described above. Females initiate attack along the trunk of standing trees, and they produce an aggregation pheromone that results in mass attack of the tree. Trees exude resin at the sites where the adult females are attacking, resulting in a "pitch tube." Soon a single male joins each female. After mating, the female constructs a zig-zag (S-shaped) gallery, called an egg gallery, within the cambial region. The egg gallery etches both the inner bark (phloem) and the outer sapwood (xylem). As the females extend their tunnels, they chew niches along the gallery walls and lay a single egg in each niche. After a few days, larvae hatch from the eggs and begin to feed away from the egg gallery, primarily within the phloem. After making a tunnel about 1-cm long, each larva creates an oval feeding area. Third and fourth instar larvae tunnel into the outer bark and create individual pupal chambers. After pupation, the new adults exit the tree by chewing their way through the bark and thereby leave a visible exit hole on the bark surface. All life stages can be found at any one time in the field. Depending on ambient temperatures, one generation will often require 5 to 10 weeks. In parts of Honduras, it is estimated that D. frontalis completes as many as 8 to 9 generations per year. Similarly, in the Sierra de las Minas in Guatemala, D. frontalis could potentially complete 6 to 9 generations per year depending on local temperatures. In Mexico, D. frontalis is usually found at elevations below 2000 m.

Dendroctonus parallelocollis ranges from Mexico to Honduras (Cibrian et al. 1995, Wood 1982). Adults are usually 5 to 6 mm long. It has been recorded from four species of pine, including Pinus oocarpa (Becker 1955, Cibrian et al. 1995, Schedl 1955, Wilkinson and Haack 1987, Wood 1982). Adults are black, with the sides of the pronotum being almost parallel. Attack by this beetle is usually associated with D. frontalis and D. mexicanus (Cibrian et al. 1995). Females initiate attack in the lower trunk and major roots of pine trees that are greater than 10 cm in diameter. It can also infest stumps of recently cut pine trees. Females construct vertical egg galleries that can extend 1 to 2 m in length. Trees exude large quantities of resin at the attack sites. Little is known about the developmental time of this species. In Mexico, it is usually found at elevations below 2700 m (Cibrian et al. 1995).

Ips calligraphus has a geographic range that includes eastern North America; southern and southwestern United States; Mexico south to Nicaragua; and the Caribbean islands of the Dominican Republic, Bahama Islands, and Jamaica (Wood 1982). Adults are 4 to 6 mm long and have 6 spines along the

elytral declivity. It attacks several species of pine, including Guatemalan species such as Pinus caribaea, P. maximinoi, P. oocarpa and P. pseudostrobus (Cibrian et al. 1995, Schedl 1955, Wood 1982). In the genus Ips, males initiate attack along the trunk and branches of standing or fallen pine trees. Trees exude resin at the attack sites. Males produce an aggregation pheromone. Usually, 2 to 5 females join each male (see Kirkendall 1983). After mating, the females construct individual egg galleries that tend to go vertically, up or down, following the wood grain. As the females tunnel, they chew niches along the gallery walls and lay a single egg in each niche. As in Dendroctonus, Ips egg galleries score both the inner bark (phloem) and the outer sapwood (xylem). After hatching, larvae tunnel away from the egg gallery and feed primarily in the inner bark. Pupation occurs in the phloem. Because of overlapping generations in warm climates, all life stages can be found at any one time in the field. Depending on ambient temperatures, one generation will usually require 4 to 10 weeks. In Florida, Ips calligraphus completes 8 to 12 generations per year (Haack 1985). Similarly, in the Sierra de las Minas in Guatemala, Ips calligraphus could complete 6 to 10 generations per year. A few papers that deal with Ips calligraphus and its associates include Billings (1972), Garraway (1986), Haack (1985), Haack et al. (1987a, 1987b), Haack and Slansky (1987), Renwick and Vite (1972), Schmitz (1972), Slansky and Haack (1986), Wood and Stark (1968), and Yates (1972a. 1972b).

Ips grandicollis has a geographic range that includes eastern North America; the southern United States to Texas; Mexico south to Nicaragua; and various Caribbean islands (Wood 1982). Adults are usually 3 to 4.5 mm long and have 5 spines along the elytral declivity. It attacks several species of pine, including Guatemalan species such as Pinus caribaea, P. oocarpa and P. pseudostrobus (Cibrian et al. 1995, Wood 1982). Ips grandicollis has habits that are similar to those of Ips calligraphus, except that it often concentrates its attack in the upper trunk and crown branches. Nevertheless, the Ips grandicollis adults that we collected were from lower trunk samples of Pinus oocarpa. Ips grandicollis usually arrives at trees that are already under attack by more vigorous bark beetles such as Dendroctonus frontalis or Ips calligraphus. Ips grandicollis is polygamous, with usually 1 to 4 females joining each male. After mating, the females construct individual egg galleries that tend to radiate transversely from the nuptial chamber.

Pityophthorus confusus has a geographic range that extends from the southern United States through Texas, to Mexico, and south to Nicaragua (Wood 1982). Adults are usually 2.0 to 2.9 mm long. It has been recorded from at least seven species of pine throughout its range, with Pinus oocarpa being the primary host in Central America (Becker 1955, Bright 1981, Schedl 1955, Wood 1982). Beetles in the genus Pityophthorus breed in either the phloem area of the trunk and branches or in the pith of shoots. Like Ips beetles, Pityophthorus confusus breeds in the phloem. Males initiate attack and are believed to use pheromones. It is polygamous, with usually 2 to 5 females joining each male. Galleries may extend in any direction. Pityophthorus confusus usually infests the trunk and branches of trees that are already under attack by species of Dendroctonus or Ips (Bright 1981, Wilkinson and Haack 1987). Bright (1981) recognizes two subspecies: Pityophthorus confusus confusus Blandford from southern Mexico and Central America, and Pityophthorus confusus bellus Blackman from northern Mexico and the United States. However, Wood (1982) did not recognize these two subspecies.

Xyleborus intrusus has a geographic range that extends from Canada to Honduras (Wood 1982). Adults are usually 2.2 to 2.7 mm long. It has been

recorded from several species of pine, but no specific host records were given for Guatemala by Wood (1982). Little is known about the biology of Xyleborus intrusus. In general, beetles in the genus Xyleborus construct their galleries within the sapwood of the host tree, often making many branched galleries. An ambrosial fungus is cultivated on the gallery walls. Larvae feed primarily on this fungus within the parental galleries. These scolytids are commonly called ambrosia beetles. Males are rare in the genus Xyleborus, and when they do occur, they are flightless. Typically, Xyleborus females mate with their brothers before leaving the host trees. Thus, only females fly in search of new host material. Wood (1982) reports that Xyleborus intrusus usually attacks the base of recently killed, standing pine trees.

Current Outbreak Conditions:

At the time of my visit in August 1995, the outbreak appeared to be collapsing. Of all the attacked trees observed, the bark beetles had already emerged from over 99% of them. As a result, almost every pine stand that we visited consisted of a mixture of green, apparently healthy trees, and dead trees on which most needles had turned red or dropped. Only rarely did we encounter currently infested pines, those typically had fading green to yellow foliage. I was told that most pines were attacked and killed during 1993, 1994, and the first half of 1995.

As of early 1995, Gerardo Piaz estimated that there were over 50 major outbreak sites in the Sierra de las Minas, killing over 900 ha of pine forests. However, practically no live specimens of Dendroctonus frontalis were encountered during my August 1995 visit. The outbreak may end in 1996 if the dry season is not too severe. Moreover, during a conversation with Oscar Nuñez at a Sister Forest Meeting in Milwaukee, Wisconsin, in November 1995, he told me that the 1995 rainy season in the area of the Sierra de las Minas was among the wettest in history. Given that information it seems likely that the bark beetle outbreak will stop in 1996 or at least be much less severe.

Contributing factors:

Apparently, the outbreak was initiated by the severe droughts that prevailed during 1992 and 1994. Gerardo Piaz plans to obtain historical temperature and precipitation records for one or more sites along the southern slopes of the Sierra de las Minas -- sites closest to the current outbreak areas. Such data would allow comparing the 1992 and 1994 temperature and precipitation records to historical average values, and thereby the severity of the 1992 and 1994 droughts could be better appreciated.

Knowledge of the average annual temperature can be used to predict the pattern of beetle voltinism, that is, the number of generations they complete per year. For example, in Florida, Haack (1985) determined that Ips calligraphus completes, on average, one generation every 457 degree days above a threshold temperature of 10 C. This information was used during a study in the Dominican Republic to predict the number of generations that Ips calligraphus could complete there (Haack et al. 1989). It was found that the average annual temperature in the outbreak area was 24.1 C. With that value it was possible to predict that Ips calligraphus could theoretically complete more than 11 generations per year in the Dominican Republic:

$$\frac{(24.1\ C - 10\ C) \times 365\ \text{days/year}}{457\ \text{degree-days/generation}} = 11.3\ \text{generations/year.}$$

Because average temperatures decline with increasing elevation, beetle populations should complete fewer generations per year at elevations above the site where the temperature data is obtained, and conversely, more generations at lower elevations.

Throughout the world, outbreaks of pine bark beetles often occur during or soon after periods of drought for a variety of reasons as discussed by Mattson and Haack (1987a, 1987b). Basically, water-stressed pines are (a) more attractive to bark beetles because of changes in certain volatile compounds, (b) more susceptible to attack because of their lowered defenses, and (c) more suitable for bark beetle growth and development because concentrations of soluble nitrogen and sugars increase in tree tissues in response to stress.

Almost all of the outbreak sites that we visited consisted of nearly mature or mature stands that were growing on apparently nutrient-poor, shallow soils. Typically, mature to overmature trees are more susceptible to insect attack during periods of stress than are younger, vigorously growing trees. Several outbreak areas consisted of overstocked stands. Beetle activity was observed on terrain that ranged from nearly flat to very steep. Other possible contributing factors include frequent fires and overgrazing. For example, we found evidence of recent fires in nearly all outbreak sites. The outbreak situation observed in Guatemala was similar to that reported elsewhere in Central America and the Dominican Republic where epidemics were most severe in overstocked, overmature stands growing on relatively poor soils (Beal et al. 1964, Ketcham and Bennett 1964, Billings 1982, FAO 1968, Haack et al. 1989, Hernandez 1975, Schwerdtfeger 1955, Wilkinson and Haack 1987).

PHEROMONE STUDY

Prior to my arrival in August 1995, I had shipped six Lindgren funnel traps to Guatemala, using the APO address of Gerry Bauer at the US AID Office in Guatemala City. The traps arrived in good condition. Gerardo Piaz and I picked them up soon after my arrival in Guatemala. In addition to the traps, I hand carried 24 pheromone lures to use with the traps -- about a 6-month supply of lures for each traps. Prior to my arrival, it was thought that Dendroctonus adjunctus was responsible for the current outbreak and therefore I brought lures that were made especially for D. adjunctus: exo-brevicomin and frontalin (Borden 1982). Fortunately, frontalin is the primary ingredient in the pheromone of Dendroctonus frontalis (Borden 1982), and therefore these lures may still be attractive to local beetle populations -- both bark beetles and natural enemies.

On 9 August 1995, working with Rudi del Cid and Israel Albizures, Gerardo Piaz and I installed 2 of the 6 funnel traps at an outbreak site near Las Delicias in the Department of El Progreso. These two traps are being monitored by Rudi del Cid and Israel Albizures on a regular basis. Both bark beetles and natural enemies are being collected. Periodically, groups of these beetles will be shipped to experts for positive identification. Additional trapping sites will be selected in the future. As this study continues, additional pheromone lures and collecting materials will be supplied as needed.

Trapping for at least one year will result in a good understanding of the seasonal flight patterns for the various bark beetles and their natural enemies (especially the predatory beetles). Placing traps at different elevations would be especially informative.

BARK BEETLE WITHIN-TREE DISTRIBUTION

As mentioned above, we found no trees that were currently under attack by large numbers of Dendroctonus frontalis beetles, but we encountered hundreds of pine trees that had recently died as a result of Dendroctonus attack as evidenced by the egg galleries located along the trunk. The gallery pattern observed on the bark surface of nearly every dead pine tree was similar to that created by Dendroctonus frontalis, but in Guatemala, Dendroctonus mexicanus and Dendroctonus vitei also occur, and all three species make similar galleries. Therefore, what I report as Dendroctonus frontalis attack could include one or two other Dendroctonus species. However, based on the areas and elevations sampled in Guatemala and Dr. Stephen Wood's examination of the beetles collected during this study, the principal damaging agent is considered to be Dendroctonus frontalis.

During my visit, we inspected the trunks and branches of more than 100 dead pine trees for bark beetle galleries. For almost every Pinus oocarpa tree that had died during the past few years (mostly 1993-1995), we found only Dendroctonus frontalis galleries along the trunk from groundline into the lower crown. Occasionally, Ips and Pityophthorus galleries were seen along the lower trunks of these same trees. Along the trunk in the upper crown and on the crown branches, Ips and Pityophthorus galleries were common. Along the trunks of already dead Pinus caribeae trees, we found only Ips galleries.

When we inspected the lower trunks of currently infested pines, we found primarily Ips attacks. Most of these beetles were later found to be Ips calligraphus. During my visit, Ips calligraphus was the most consistently encountered beetle on all species of pine that were currently under attack by bark beetles. This shift in the beetle complex, from Dendroctonus frontalis to Ips, may be further evidence that the current Dendroctonus outbreak is subsiding.

It is very common to find one species of bark beetle attacking the lower trunk of a pine tree, while other beetle species attack the upper trunk or the branches. This type of specialization in where bark beetles attack a tree is called resource partitioning. Several papers exist that describe resource partitioning by pine bark beetles in North America (Flamm et al. 1987, Foltz et al. 1985, Paine et al. 1981, Wagner et al. 1985), Mexico (Perry 1951), Central America (Billings 1972, Vite et al. 1975, Wilkinson and Haack 1987), and the Caribbean (Haack et al. 1989).

ASSOCIATED NATURAL ENEMIES

Overall, because of the short duration of my visit and the scarcity of currently infested trees at that time, little information was gathered on the biological control agents of bark beetles in the Sierra de las Minas. However, we were able to make a few observations. For example, larvae and some adults of several predatory beetles (Cleridae, Histeridae, Tenebrionidae, Trogositidae) and flies (Dolichopodidae) were found under the bark of the currently infested pines. In addition, we observed some adult clerid beetles on the bark surface. It appeared that these agents could have contributed to the current collapse of the outbreak. There was also evidence (cocoons in the cambial region) of parasitism by various hymenopteran wasps, possibly braconids. A list of insects associated with Dendroctonus frontalis in

Honduras was reported by Clark (1974). Similarly, a list of insects associated with beetle-killed pines in Guatemala was reported by Becker (1955). A full-color guide to insects associated with Dendroctonus frontalis in the southeastern United States (Goyer et al. 1980) will be mailed to Gerardo Piaz for his investigations in Guatemala.

HOST TREES

The species of pine trees killed by bark beetles in the Sierra de las Minas was primarily Pinus oocarpa. Gerardo Paiz said that P. maximinoi was the second most affected pine species in the area. In addition, several P. tecunumanii trees were also attacked and killed during this outbreak. At the eastern edge of the Sierra de las Minas, at lower elevations, a few recently killed Pinus caribaea trees were also seen. Outbreak sites were found between 500 and 2100 meters in elevation. In one internal report (Navarro and Paiz 1994) in which 43 outbreak sites were listed in 13 separate watersheds, their average elevation was 1200 m. The diameter at breast height of the bark beetle-killed trees tended to range between 10 and 40 cm, but both larger and smaller trees were attacked. Individual tree diameter records for some of the affected stands would be useful.

CONTROL EFFORTS EMPLOYED AT SIERRA DE LAS MINAS

Few to no control efforts were employed during the recent bark beetle outbreak in the Sierra de las Minas. Basically, the outbreak was allowed to run its course. This situation is understandable because of the difficulty in obtaining the permits to cut pine trees legally, even if the trees are currently attacked or dead. One reason to require permits prior to logging is to reduce the rate of deforestation.

Three techniques that are commonly used to control Dendroctonus frontalis outbreaks include salvage, cut-and-leave, and cut-pile-and-burn (Billings 1982, Thatcher et al. 1980). Because of legal restrictions, none of these control methods were available to the staff of Defensores during the recent outbreak. I was told that Defensores was recently granted permission by CONAP to do some limited salvage of beetle-killed trees. Unfortunately, it took several months to receive this permission, which is too long during an outbreak situation compared with the short generation time of pine bark beetles.

RECOMMENDATIONS

Several recommendations were presented to Defensores staff members that related to control of the present outbreak as well as to future outbreaks. Several of these comments are presented here for consideration by all parties that deal with the Sierra de las Minas.

Control of active infestations should be a first priority. Infestation size, rate of expansion, and accessibility should be considered when evaluating sites for control efforts (Billings 1982). Large, expanding infestations should have priority over smaller, non-expanding outbreak sites. Rapid utilization of infested and killed trees will reduce additional losses to fungi and secondary invaders such as ants, termites, wood borers, and ambrosia beetles. Because the current outbreak has diminished in severity, salvage

efforts should be Defensores' top priority. After salvaging beetle-killed stands, these areas should be reforested as soon as possible.

Because many forest stands in the Sierra de las Minas are overstocked and overmature, management techniques should be implemented that reduce stand volume and age, for example by thinning or clear-cutting. This is important because overstocked, overmature stands are believed to be very susceptible to bark beetle attack (Thatcher et al. 1980). This practice should be implemented by Defensores through their forest management plans for each of the major watersheds that contain pine in the Sierra de las Minas. Younger stands, if maintained at a proper stocking level, should be more vigorous and therefore more resistant to bark beetle attack during future droughts (see Nebeker and Hodges 1983). Of course, to fully implement forest management plans, many current laws and regulations will have to be modified.

Defensores and CONAP employ several forest guards throughout the Sierra de las Minas. These forest guards should be trained to recognize signs and symptoms of bark beetle attack, and upon encountering infested trees, they should be instructed to provide details to key personnel, such as Gerardo Paiz, a forester with Defensores.

Each year, Defensores offers extension courses to local communities throughout the Sierra de las Minas. At such times, instruction should be offered on bark beetle biology and control, and encouragement should be given to report all infestations to their local forest guards. In this way, Defensores will enlist the aid of the local citizens.

If salvage operations occur in the affected pine stands, or if laws change in the future to allow thinning of overstocked stands, there will likely be an increased need for additional sawmills. It may be useful to consider now where future sawmills should be located, or if existing sawmills should be expanded.

Because bark-beetle outbreaks usually follow environmental stresses such as drought and fire (see Haack and Slansky 1987, Mattson and Haack 1987a, 1987b, Haack et al. 1989, Wilkinson and Haack 1987), it is important that Defensores personnel anticipate an increase in bark beetle activity during and for a year after such events. If infestations are discovered and controlled early, losses will be reduced. Early detection is especially important in countries like Guatemala where Dendroctonus and Ips populations can build quickly, completing one generation in 1-2 months.

Although several insecticides have proven effective against bark beetles, they are usually not recommended because (a) they are expensive to apply under forest conditions, and (b) they kill the bark beetles' natural enemies that are in the sprayed host material (Billings 1982). Similarly, pheromone lures cannot be recommended as a means to prevent or stop outbreaks. In addition, pheromone lures are somewhat costly, with current values at US $5-10 each, and a field life expectancy of 6-10 weeks depending on ambient temperatures.

Overall, Defensores should establish a program that provides for (a) training of their personnel and local citizens on bark beetle biology and control, (b) regular surveys, and (c) record keeping of all outbreak sites, including size, beetle activity level, control priority level, date of detection, date and method of control, and an estimate of the timber loss. In addition, Defensores should aggressively develop forest management plans and

put them into action to improve the overall health of the pine forests throughout the Sierra de las Minas.

Defensores should consider developing a protection plan as part of their overall forest management plan. The protection plan should include aspects of fire management and pest management. The pest management plan should have a list of steps and control measures that will be followed during future bark beetle outbreaks.

Defensores, in cooperation with local universities and other interested parties, should conduct basic biological studies on the life histories of the major forest pests and their natural enemies.

At the national level, it will be necessary for CONAP and DIGEBOS to consider legal modifications that will enable groups like Defensores to more effectively deal with future outbreaks. For example, allowing cutting of currently infested pine trees in a timely manner will help reduce local beetle populations during future outbreaks.

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MESSAGE SCAN FOR ROBIN VORA

To sisfor sc:r09f10a
To sisfor net:r09f10a
CC r.bridges:wo
CC t.hofacker:wo
CC j.hayes:r08f06a
CC p.shea:s27a
CC ncet:s23a

From: ROBERT A. HAACK:S23L03A
Postmark: Dec 06,95 1:30 PM Delivered: Dec 06,95 1:04 PM

Subject: Haack's Trip Report - Guatemala, Aug 1995

Comments:
Here, at long last, is my Trip Report for the visit I made to Guatemala back in August. This document is 18 pages long and somewhat technical, so you may wish to think twice before printing it! This report deals with an outbreak of pine bark beetles in the Sierra de las Minas in eastern Guatemala. I was hosted by "Fundacion Defensores de la Naturaleza" -- who we are partners with in the Sister Forest Program. Defensores is a NGO that administers the Biosphere Reserve in this region of Guatemala. The tentative ID of the principal bark beetle involved is Dendroctonus frontalis -- the southern pine beetle -- a "good" friend to many of us, especially to those working in the southern US. Regards, Bob
(I will try to e-mail this document Defensores in Guatemala.)

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