May 8, 2007

To Whom It Concerns:

Attached is the third report on the IAT-funded assistance to Mexico to evaluate *Ips* bark beetle outbreaks in the largest commercial pine plantation in Mexico. Previous site visits occurred 26 August- 2 September, 2005 and 10-18 February, 2006 (see previous progress reports). The third visit from 9-20 January, 2007 is reported here.

The Comisión Nacional Forestal (CONAFOR) requested USDA Forest Service-Forest Health Protection (FHP) expertise in assessing management options against *Ips* outbreaks recently occurring in the only large pine plantation in Mexico. Although CONAFOR committed a number of people to conduct much of the field work and data collection, additional expertise was needed to outline an assessment, oversee the data evaluation, and provide management recommendations to the managers involved. Specifically the goals of the project included:

1. Assess pheromone preference of species to determine the most effective combination for survey and management.
2. Determine flight periods for *Ips* spp. and possible changes in flight seasonality.
3. Develop a set of recommendations for managing pine plantations prone to ips bark beetle attack.

During the first visit we completed an initial assessment of the plantation and deployed an array of pheromone baited funnel traps. The second visit included laboratory time to examine the trap catches, identify species, and facilitate future direction of the study. At the conclusion of the second visit trap samples still remained to be collected and tallied, and species identification still needed to be verified. Thus, we were unable to complete our analysis of the data and provide final management guidelines. The third trip is allowed us to evaluate all the available data and provide recommendations in a formal presentation to the plantation land managers.

Additional issues of concern were raised in the project and would justify future collaboration with CONAFOR and specialists from other USA and Mexico institutions. In particular, additional efforts are needed to a) clarify the presence/range and morphological identification of *Ips* species found at the plantation; b) determine which *Ips* species are a significant threat to live, standing trees for all diameters expected through the life of the plantation (e.g. which species are causing mortality versus which are secondary arrivals); c) assess pheromone selection by the most aggressive *Ips* species (e.g. *I. lecontei*); d) evaluate slash use by *Ips* within the plantations (e.g. seasonal differences in attack, seasonal brood development time, slash diameter preference, host preference, etc.); e) assess the effect of pruning on *Ips* attacks; f) develop a monitoring program to track management activities and *Ips* outbreaks (e.g. data on the number, size, and species of trees lost, and their location and proximity to management activities) that could be used in an analysis of factors contributing to tree loss; and g) evaluate other stand management practices that affect tree resistance to *Ips* (e.g. other pests affecting tree health, proper trees species/site pairing, stand density levels). Additional items may be identified by CONAFOR as they compile, summarize, and identify gaps in information needed to support plans to change national regulations on harvesting and slash management in pine forests, particularly as it concerns *Ips* bark beetles.

This project has been an excellent opportunity for the Forest Service to provide needed assistance and expertise to Mexico, and to strengthen ties between the forest health programs of the two countries. In addition, information gathered on insects common to both countries benefits development of future management strategies. Opportunities for collaboration and experience may be particularly important as we look at the potential of inheriting "across-the-border" forest health problems (including changed behaviors of native pests) due to shifts in global climate patterns and increased international commerce.

Beth and I thank IAT for lending support to this project. Please feel free to contact us if there are any additional concerns or questions.

Sincerely,

/s/ Brytten Steed	/s/ Beth Willhite
Brytten Steed	Beth Willhite
Forest Entomologist	Forest Entomologist
Ogden Field Office-UT	Westside Forest I&D Service Center-OR
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TRIP REPORT ON IPS IN INTENSIVELY MANAGED PINE PLANTATIONS IN JALISCO, MEXICO

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Background

Large-scale, intensive even-age management of native pine forests using artificial regeneration is relatively new in Mexico. In 1997, Compañía Industrial de Atenquique (C.I. Atenquique) established the first industrial plantations of native pine in the State of Jalisco (Figs. 1, 2). C.I. Atenquique, owned by a large pulp and paper company that manages an assortment of pulp mills, paper plants, land concessions, and land holdings throughout Mexico and the southern United States, manages its southern Jalisco land commissions primarily for fiber production. Since 1997, the number of native pine plantations established by the company has steadily increased. C.I. Atenquique plans to manage for a continuous yield of high-quality fiber utilizing intensive forestry management techniques including planting, pruning, thinning, and short rotations.

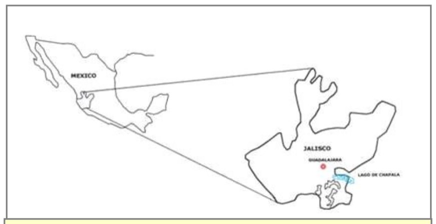


Figure 1. Project location in southern Jalisco.

Figure 2. Young pine plantation at C.I. Atenquique

In 2004, *Ips* outbreaks occurred in two young plantations that had been recently thinned and pruned. C.I. Atenquique personnel responded by promptly removing and burning any *Ips*-infested trees and on-site slash in the outbreak areas. Concerned about the implications of these outbreaks for the company's future intensive management program, C.I. Atenquique asked Comisión Nacional Forestal (CONAFOR) for help developing a monitoring program for *Ips* beetles in their pine plantations. Because relatively little is known about the biologies, semiochemicals, impacts, and management of the various *Ips* species associated with intensively managed pine plantations in Mexico, CONAFOR contacted Forest Health Protection for support in developing a bark beetle management program. At the time, it was suspected that *Pseudips (Ips) mexicanus* was the species of concern and that management might be obtained through pheromone-based trapping and timing of activities around this species' peak flights.

Purpose

The International Activities Team (IAT) provided funding during 2005 – 2007 for three trips for Brytten Steed and Beth Willhite to travel to the Mexican state of Jalisco, to assist CONAFOR in developing an *Ips* management program for young pine plantations in the areas managed by

C.I. Atenquique. The primary purposes of the first trip in August 2005 were to gather information about the history of the outbreaks, gain understanding of the goals and management of the plantations, roughly assess the health of the plantation trees, gather beetles for identification, and to establish field trapping sites. Trapping data was obtained to a) further determine the species present, b) test the attractiveness of several pheromone lure compounds to various *Ips* species and c) track *Ips* flight patterns over time.

The second trip, taken February 2006, included laboratory time to examine the trap catches, identify species, and facilitate future direction of the study. Due to the considerable amount of data that remained to be tallied and unresolved questions regarding the identification of some of the *Ips* species, we were unable to complete our analysis of the data and provide management guidelines at the conclusion of this second trip. After receiving confirmation on the species identifications and notification of completion of work on half the trap dates, we arranged a third trip, completed in February 2007, to visit with collaborating specialists, summarize the data, and give a presentation to Atenquique land managers.

Itinerary of 3rd trip

Jan. 9 Travel to Mexico City from USA.

Jan. 10 Visit bark beetle taxonomist/biologist Dr. Armando Equihua (Colegio de Postgraduados in Texcoco, D.F.) to discuss/verify species identification; visit with graduate students assisting with our project and related projects (Fig. 2).

Figure 2. Meeting with Dr. Amado Equihua and students who were assisting with this project and related studies.

Jan. 11 Visit with taxonomist in charge of trap collections in AM; Fly to Guadalajara and travel to Ciudad Guzman (actual location of traps) in PM.

Jan. 12 Work with technician in charge of trap collections in Ciudad Guzman; begin summary of data creation of presentation for meeting with Atenquique.

Jan. 13-15 OFF

Jan. 16-18 Continue data analysis and presentation creation at laboratory in Ciudad Guzman.

Jan. 19 Report on findings and management recommendations to Atenquique land manager (Fig. 3).

Figure 3. Final meeting with C. I. Atenquique and project cooperators: (from left to right: Hermelino Chavez [contractor], Francisco Bonilla [CONAFOR], Humberto Albarran [Atenquique], Jaime Villa [CONAFOR], Manuel Medina [Atenquique], Brytten Steed [USDA FS FHP], Francisco Ochoa [Atenquique], Comptroller [Atenquique], Beth Willhite [USDA FS FHP].

Jan. 20 Return to Guadalajara.

Jan. 21 Return to USA.

Results and Discussion

Ips: Field Collections and Trapping

Results of this project are still somewhat preliminary due to the lack of final counts and species identification for the first six months of trap collections (1 September, 2005 to 16 February, 2006). These initial trap catches were given (during our second visit) only 'estimated counts' for total numbers of bark beetles; no estimates were made for individual species. However, actual count data by species is available for later trap catches from 16 February to 1 August, 2006. Although not complete, these data do provide information on species presence, seasonal abundance, and pheromone response. Some results from our presentation to Atenquique land managers are provided here.

<u>Species Identified</u>

Using trap collections and collections directly from slash, six species of *Ips* were identified (Table 1). For several species this was the first official record of finding in the state of Jalisco and a first for some pine host species (Table 1). Both *P. mexicanus* and *I. bonansai* were obtained solely from trap catches. Slash pieces we collected from were not always identifiable to tree species, so some host records could not be confirmed. Of these six *Ips* species, literature and field evaluations of recent *Ips*-caused tree mortality in neighboring areas suggest that *I. lecontei* is the most aggressive of the species caught, followed by *I. cribricollis* and *I. calligraphus*.

Table 1. List of six species of *Ips/Pseudips* identified from trap collections and slash collections on Atenquique managed plantation lands. For several species, this was the first official record of collection from Jalisco state (=NEW). For the species collected in slash (all except *Pseudips mexicanus* and *Ips bonansae*) some host trees were also a first official record. Because slash was often difficult to identify to species, some host findings could not be verified (=POSSIBLE). (* compared with data from Cibrian et al. 1995 and Equihua y Burgos ~2001)

Species	# spines	Size (mm)	Previously noted in Jalisco state?*	Previously noted as a host species?*		
				Pinus douglasiana	*P. oocarpa*	*P. pseudostrobus*
Pseudips (Ips) mexicanus	3	3.6-5.0	**NEW**	n/a	n/a	n/a
Ips bonansae	4	2.9-3.4	Yes	n/a	n/a	n/a
I. integer	4	4.6-5.7	Yes	**(POSSIBLE)**	**(POSSIBLE)**	Yes
I. cribricollis	5	2.9-3.6	**NEW**	**NEW**	**(POSSIBLE)**	Yes
I. lecontei	5	4.0-4.7	Yes	**NEW**	Yes	Yes
I. calligraphus	6	3.8-5.9	Yes	**NEW**	Yes	Yes

During this project several issues have been raised about identification of *Ips* species in Mexico. Specifically, we have concerns over 1) differentiation of *Ips cribricollis* and *I.grandicollis* in Mexico, and 2) differences in *Pseudips (Ips) mexicanus* from the southern to northern (Canada) range.

Ips cribricollis vs. *I. grandicollis*: Large- and small-sized beetles from our *I. cribricollis* samples were sent to Anthony Cognato, bark beetle geneticist, Assistant Professor, Michigan State University, for species identification. Tests confirmed that the samples sent were *I. cribricollis* (see Cognato, 2000; Cognato and Sperling, 2000; and Cognato and Vogler, 2001 for related information) despite body sizes larger than those reported in Cibrian and others (1995) (>3.6 mm). Evaluation of the genitalia by Dr. Jorge Valdez Carrasco at Colegio Postgraduados also indicates that *I. cribricollis*, not *I. grandicollis*, is the species present in the trap catches from Atenquique. This information would support holding *I. cribricollis* as a unique species, different from *I. grandicollis* (see Hopping, 1965 and Lanier, 1987a; 1987b).

Pseudips mexicanus: Samples from our trapping in Mexico have been sent to Dr. Cognato. Additional samples from Utah (south of Evanston, WY) have been sent and we have requested samples from Canada and other locations in the Intermountain West to provide data from most of this beetle's range. Behavior information (colleague observations) and literature (Wood, 1982) suggest that northern populations in Canada may be different from southern populations in Mexico. Genetic analysis would indicate whether these differences have a genetic basis sufficient to consider the groups separate species, and if so, would help delineate the range of each. (See Hopping, 1963 for original synonymy.)

Three pheromone treatments were used for trapping beetles; 1) racemic ipsenol, 2) racemic ipsdienol, and 3) both the ipsdienol and ipsenol treatments combined (combo). Trapping occurred from 1 September, 2005 through 1 August, 2006. Only a few trap catches before 16 February have been sorted, identified to species, and counted. However, estimates of the total number of *Ips/Pseudips* in all bags have been made. Collections after 16 February have been fully sorted, identified, and counted.

Of the six species identified, five were found in the few bags examined from the first five months of trapping (bags from 8 September, 2005 and 26 January to 2 February, 2006). Our estimated numbers suggest that *I. lecontei* and *I .cribricollis* were the most abundant species with *I. cribricollis* predominating (Fig. 4-A). Four of the six species were common in counted trap catches from the final six months (23 February to 1 August, 2006). Again, *I. lecontei* and *I. cribricollis* were the most abundant species, but *I. lecontei* predominated (Fig. 4-B).

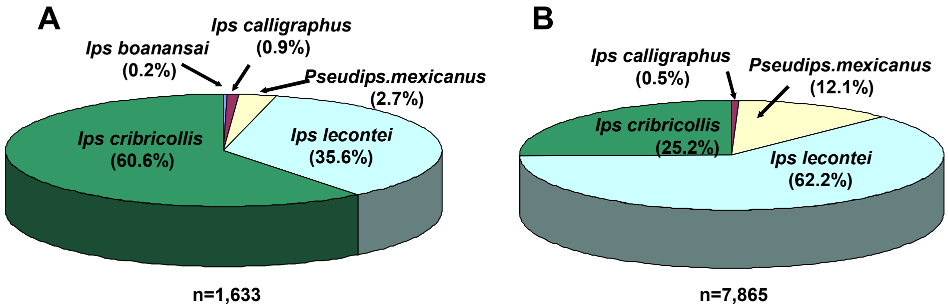


Figure 4. Percent of species in the subsample of bags examined from 8 September, 2005 and 26 January to 2 February, 2006 (A) and all bags from 23 February to 1 August, 2006 (B). In both sets *I. lecontei* and *I. cribricollis* were most abundant but with *I. cribricollis* dominating the early catches and *I. lecontei* the later.

Because the pheromone baits used were not equally attractive to all *Ips* species, we cannot say that one species is more prevalent in the environment than another, only that some are more attracted to the traps than others. However, trap data for a particular species considered over time and across an array of sites will provide a fairly good indicator of relative seasonal abundance.

Trap Treatment (Pheromone) Response

Ips lecontei and *I. cribricollis* clearly exhibited the highest attraction for treatments, followed by *P. mexicanus*. Conversely, *I. calligraphus*, *I. bonansai*, and *I. integer* demonstrated low to no attraction for the treatments (Fig. 4).

Average trap catch per site was calculated using data from 23 February to 1 August, 2006. Comparison of means was conducted using multiple response permutation procedures (MRPP). The MRPP analysis was chosen due to its insensitivity to data distribution or variance structure (Petrondas & Gabriel, 1983; Mielke & Berry, 2001). When all *Ips* species were considered together, the combined treatment caught significantly more beetles than did ipsdienol alone, but not more than ipsenol. Ipsenol and ipsdienol catches were not significantly different (P>0.05) (Fig. 5). Thus, it appears that the principle attractant is ipsenol and that ipsdienol does not interfere with that attraction. If ipsdienol had acted as an anti-attractant we would expect the combination treatment to have fewer beetles than the ipsenol alone.

Of the three principle beetle species captured in the traps, *Ips lecontei* demonstrated an attraction for treatments with ipsenol while *Pseudips mexicanus* demonstrated attraction for treatments with ipsdienol (P<0.05) (Fig. 5). Although treatments with ipsenol were most attractive to *Ips cribricollis*, they were not significantly different than the ipsdienol treatment (P<0.05) (Fig. 5).

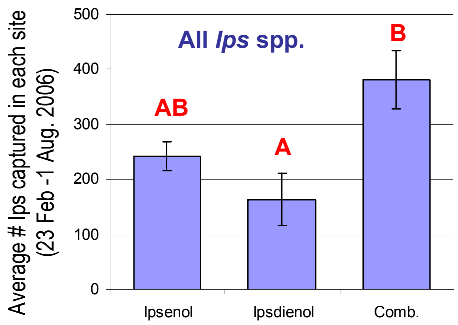
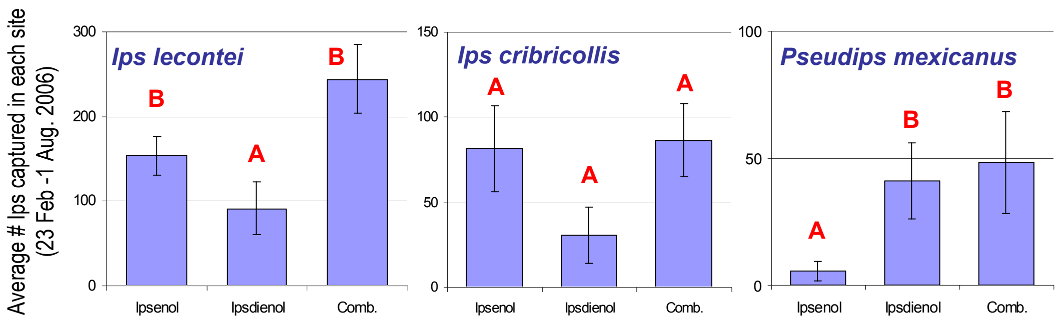


Figure 5. Average number of beetles captured at a site for each of the three pheromone treatments used (racemic ipsenol, racemic ipsdienol, and combination of ipsenol and ipsdienol). Within each graph, letters that are different indicate significant treatment differences as determined using MRPP (P<0.05).



Seasonality

Presence or absence of the four principle beetle species was calculated using data from 23 February to 1 August, 2006 for all trap sites (1 - 4) at the three locations (Coloradas, Corralitos, and Pinabetes/Sauces) (Table 2). *Ips lecontei* was present at all 10 trapping sites in all six months. *Ips cribricollis* was also present in all three locations during all six months, although not all sites caught all species in all months. *Pseudips mexicanus* was present in all three sites but rarely in Coloradas. *Ips calligraphus* was present in Coloradas and somewhat in Corralitos, but was either not present in Pinabetes/Sauces or in such low numbers as to not be measured.

Table 2. Presence (X) and absence (.) of four beetle species caught in pheromone traps from 16 February to 1 August, 2006 at all sites (1 - 4) in each location (Colo=Coloradas; Corra=Corralitos; PS=Pinabetes/Sauces). In PS, May and June data include the first week of June and July, respectively, due to 1x/mo collection periods.

Ips lecontei

Loc	Site#	Feb	March	April	May	June	July
Colo	1	X	X	X	X	X	X
	2	X	X	X	X	X	X
	3	X	X	X	X	X	X
Corra	1	X	X	X	X	X	X
	2	X	X	X	X	X	X
	3	X	X	X	X	X	X
PS	1	X	X	X	X	X	X
	2	X	X	X	X	X	X
	3	X	X	X	X	X	X
	4	X	X	X	X	X	X

Ips cribricollis

Loc	Site#	Feb	March	April	May	June	July
Colo	1	X	X	.	X	X	X
	2	X	X	X	X	X	X
	3	X	X	.	X	X	X
Corra	1	X	X	X	X	X	X
	2	X	X	X	X	X	X
	3	X	X	X	X	X	X
PS	1	.	X	X	X	.	X
	2	.	.	X	X	.	X
	3	X	X	X	X	.	.
	4	.	X	X	.	X	X

Ips calligraphus

Loc	Site#	Feb	March	April	May	June	July
Colo	1	.	X	X	X	X	.
	2	.	X	X	X	.	X
	3	.	X	X	.	.	X
Corra	1	.	X	X	X	.	.
	2	.	.	.	X	.	.
	3	.	.	.	X	.	.
PS	1	.	.	.	.	.	.
	2	.	.	.	.	.	.
	3	.	.	.	.	.	.
	4	.	.	.	.	.	.

Pseudips mexicanus

Loc	Site#	Feb	March	April	May	June	July
Colo	1	.	.	.	.	X	.
	2	.	.	.	.	.	.
	3	.	.	.	X	.	X
Corra	1	X	X	X	X	.	X
	2	X	X	X	X	X	X
	3	X	X	X	X	X	X
PS	1	X	X	X	X	X	X
	2	X	X	X	X	X	X
	3	X	X	X	X	X	X
	4	X	X	X	X	X	.

Using all data (all locations and sites) for all *Ips* species we graphed seasonal abundance for the entire trapping period (25 Aug, 2005 to 1 Aug, 2006) (Fig. 6). This data suggests that beetle populations may be higher during the wetter months (mid-June through mid-November) than during the drier months (mid-November through mid-June).

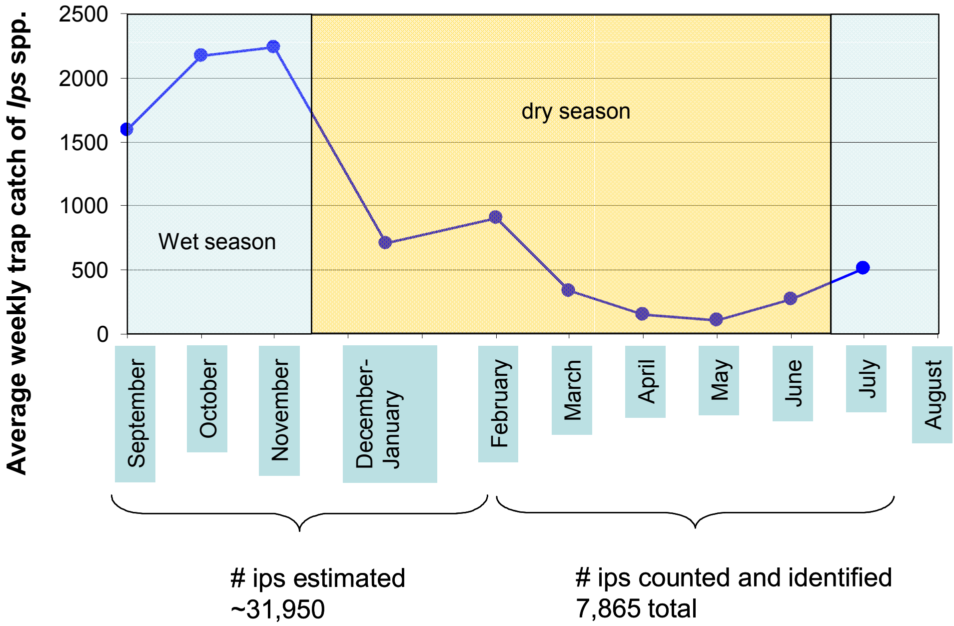


Figure 6. Seasonal abundance of all Ips species captured at all sites at all locations. Trap catches for the initial dates have been estimated while catches after February 18th have been sorted, identified, and counted.

However, seasonal abundance at individual sites show some of the variation present in the trap catches. Using additional data from complimentary studies currently being conducted by Rubén Ángel Hernández Livera, a graduate student of Dr. Equihua's at the Colegio de Postgraduados, we are able to extend the seasonal abundance graphs through November, 2006 for two areas (Fig. 7). Although Angel has several more sites, these were the only ones within a 1 km distance of our trapping sites.

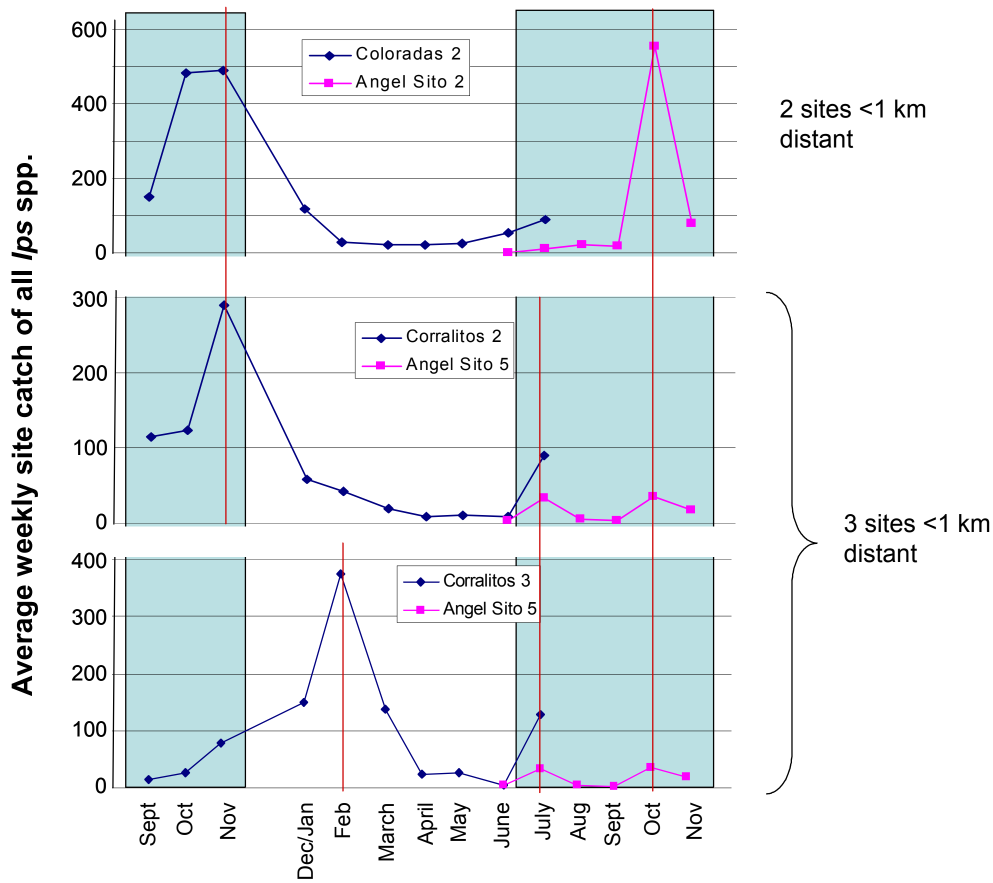


Figure 7. Seasonal abundance of all *Ips/Pseudips* species captured at sites in close proximity to each other. Blue lines indicate average weekly catch at sites from this study. Pink lines indicate average weekly catch at sites from a current study being conducted by Angel Hernandez at the Colegio de Postgraduados. Graphs assume that areas <1 km distant are sampling from similar beetle populations. Peak periods are noted with vertical red lines.

Once count data for individual beetle species is available for the initial trapping period of our study, we will be able to graph seasonal abundance of the principle *Ips* species of concern. However, it appears that *I. lecontei* and *I. cribricollis* constitute the greatest portion of *Ips/Pseudips* caught (>87%; Figs. 4-A and B). Our initial review of species in the earlier (between 1 September, 2005 and 18 February, 2006) trap catches also suggested that these two species were the most abundant. Thus, the seasonal peaks identified in Figs. 6 and 7 are likely indicative of the peaks of these two *Ips* species.

Site differences

Although *Pinus douglasiana* is the principle plantation tree in all three locations, trap catches differed among sites (see Table 2, Fig. 7). Using catch data for each species as a response variable, we used the multiple response permutation procedure for unreplicated block designs (MRBP) (Meilke and Berry, 2001) to compare the beetle communities at the three locations (Fig. 10). Results of comparisons with un-standardized columns were somewhat different from comparisons with standardized columns (B), due to the standardization's equal weighting of all four beetle species.

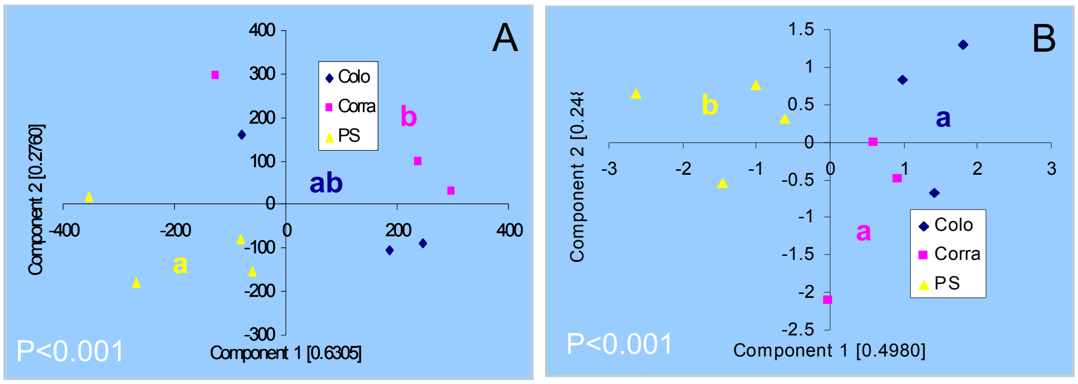


Figure 10. Comparison of the three locations (Colo=Coloradas; Corra-Corralito, PS=Pinabetes/Sauces) using multiple response permutation procedure with blocks (MRBP) without or with standardized columns (A and B, respectively). Trap catches for each of the four beetle species caught in pheromone baited traps were used as responses. Locations that contain similar letters are not significantly different (P>0.05).

The MRBP analysis indicates that trap catches in the Pinabetes/Sauces management unit differ more from those at Corraltitos or Coloradas than trap catches at Corralitos or Coloradas differ from each other. It must be kept in mind, however, that trap catches are not necessarily indicative of actual beetle flight or likelihood of attack on possible hosts (see Bentz 2006). For example, one potential effect on trap catches at individual sites is proximity to slash (Fig. 8). Slash may serve to 1) draw beetles away from traps if it is more attractive than the pheromone treatments and/or 2) provide high population numbers as brood emerges from the created slash that might not be indicative of the landscape population trend. Trap catches could also be affected by seasonal changes in an individual species attraction to the pheromones used (B. Steed, unpublished data).

Figure 8. Note small amounts of pine slash near pheromone trap array, created when thinning activities in a nearby plantation extended beyond plantation boundaries. This slash may affect trap catches at this site.

Management: Findings

Plantation Management Regime

C.I. Atenquique regenerates harvested areas principally with *Pinus douglasiana* and to a much lesser extent, with *Pinus pseudostrobi*s. Preference of *P. douglasiana* is based on its fast growth, high quality fiber, and resistance to *Dendroctonus* bark beetle attack. Out of the ten or so species of pine native to this area, these two species are considered most desirable for fiber production. Current management projections call for a first-entry weeding at age four to six years, a second-entry thinning and pruning at age seven to eight years, two commercial thinnings, and final harvest at approximately 28 years of age.

Timing of Forest Management Activities

The annual climate in this part of Mexico is temperate, and characterized by a wet season and a dry season. The wet season extends from June through September, transitioning to the dry season during October through November. Very little rain falls from December through May, with February through April being the driest months. May and June experience the highest temperatures, and November through February are the coolest months. C.I. Atenquique conducts cleaning operations (equivalent to clearcut or seed tree regeneration harvest) and planting activities during the wetter season (approximately mid-June through mid-November). Weeding of seedling plantation trees (<2cm dbh, 4- to 6-years-old) usually occurs during winter at the beginning of the dry season and during the coolest period of the year (mid-November through the end of January), and thinning and pruning of sapling plantation trees (2-8cm dbh, 7- to 8-years-old) usually occurs during the hot, dry months of March and April. Other slash-creating activities by private non-industrial entities commonly occur throughout the year in mature forests near the plantations.

Treatment of slash

Slash is generally left untreated on the site, although in some cases larger pieces are peeled and removed once the bark has dried out and loosened (usually >3 months).

Ips Outbreak history: In summer, 2004, *Ips* outbreaks were detected in two *P. douglasiana* plantations (Corralitos and Coloradas management units). These were the first-ever reported *Ips* outbreaks in Mexican pine plantations. Both outbreaks occurred in seven- to eight-year-old plantations that were thinned and pruned during March and April, 2004. Red trees were first noticed in mid-July and early August, 2004. The Corralitos outbreak affected approximately 150 trees scattered over a 20-hectare area, while the outbreak in Coloradas affected an estimated 130 trees covering 7 hectares. Slash in Corralitos was primarily *Pinus douglasiana*, and in Coloradas, predominantly *P. oocarpa*. *Ips cribricollis* was the only beetle species collected from the Corralitos outbreak (live beetles collected from stems of dead and standing green infested trees shortly after discovery of the outbreak). At the Coloradas outbreak site, we found dead *I. lecontei* and *I. calligraphus* beetles and their galleries in remnant dead standing trees and slash one year post-outbreak. At both sites in 2004, C.I. Antiqueque personnel promptly treated the outbreaks by removing and burning as many infested trees as they could find.

Figure 9. Collecting beetles from a small spot infestation of Ips.

In addition to these larger outbreaks, small spot infestations of two to five trees occur occasionally in the plantations (Fig. 9). In February, 2006, we collected *Ips lecontei* and *I. calligraphus* from fading and recently killed trees in two of these spot infestations.

The diameters (dbh) of *Ips*-killed plantation trees that we observed during our visits ranged from 2.5cm to 8.1cm.

In 2006, *Ips lecontei* began causing significant mortality of all ages of pine trees throughout the general vicinity of Ciudad Guzman and the C.I. Atenquique plantations. According to Jamie Villa-Castillo, director of CONAFOR, this activity appears closely linked with droughty conditions in southern Jalisco that began in 2005.

Figure 10. Mature pine mortality caused by *Ips lecontei* in southern Jalisco.

Species aggressiveness: Of the six *Ips* species found in our field and trap collections (*Pseudips (Ips) mexicanus, I. bonansae, I. integer, I. cribricollis, I. lecontei, and I. calligraphus*), only three, *I. cribricollis, I. lecontei, and I. calligraphus*, were associated with dead and dying trees in plantation outbreak areas. The other three species were found solely in slash or pheromone traps. Based on our field collections from known outbreak sites and trapping data, published literature, and local field observations by Mexican professionals, we feel that the species of greatest concern to future plantation management is likely *I.lecontei*, followed by *I.cribricollis* and possibly *I.calligraphus*.

Time to complete one generation: In recent laboratory studies conducted at Colegio de Postgraduados in Texcoco, D.F, *Ips lecontei* completed its life cycle in 23 days (A. Hernández, unpublished data).

Flight periods: Our trap data show that there is no period when *Ips/Pseudips* in general and *Ips lecontei* specifically is not present (Table 2). However, seasonal abundance data does suggest that there may be fewer beetles flying during the spring dry season (Fig. 6). Whether this lower level indicates a period when slash is less likely to be colonized remains to be tested. Since the spring dry season is also the period when second-entry thinning and pruning management activities are conducted in the plantations, this lower trap catch level may actually reflect a higher *Ips* attraction to nearby fresh slash than to pheromone lures.

Management: Recommendations

The pattern of Ips activity observed in C.I. Atenquique plantations is very similar to that found in other North American intensively managed pine plantations, where forest management practices that create large amounts of slash and weaken residual trees can trigger *Ips* outbreaks. In general, preventative measures are preferable to suppressive actions because they are more practical and cost effective. Prevention of outbreaks is best achieved by integrating into normal management activities forest practices that minimize *Ips* habitat and attraction and promote residual tree resistance to beetle attack.

Manage slash to minimize habitat and attraction

Ips beetles are highly attracted to fresh, untreated slash, which provides optimal habitat for brood development. Large amounts of slash created within a relatively brief window of time when beetles are active provide conditions favoring population buildup and is conducive to outbreaks in standing residual trees. Slash management, therefore, is key to preventing *Ips* outbreaks. Slash management methods used successfully in other North American regions include timing slash creation to coincide with periods when the beetles are not active, progressive continuous slash creation ("green chaining"), specifications for timely

Figure 11. Recently pruned and thinned plantation and slash.

removal of host material down to a specified diameter that is too small to support significant beetle reproduction, moving slash away from close contact with residual trees, using pheromone traps pull beetles into "trap" slash piles which are then destroyed before the new brood emerges, and treating slash to render it unsuitable as habitat by removing bark, lopping and scattering, chipping, burning, or burying.

Promote tree resistance to bark beetle attack

The ability of thinning to prevent bark beetle infestations in coniferous stands is well documented (Fettig et al. 2006). The long-term positive effects on tree growth, vigor and resistance to bark beetle attack more than offset any beetle-induced losses resulting from the treatment itself when slash management methods are employed. Healthy, vigorous trees grow faster, are less attractive to bark beetles, and are better able to fend off bark beetle attacks. On the other hand, trees stressed from competition, wounding, drought, disease, soil compaction, etc., are usually more susceptible to bark beetle attack. Improper tree species selection when regenerating with nursery stock can also result in future stands that are stressed by unfavorable growing conditions and susceptible to *Ips* attack. Therefore, to promote tree resistance, tree species should be carefully matched to the site, appropriate spacing should be maintained throughout the life of the rotation, and management activities that damage or stress trees should be avoided or minimized whenever possible.

Suggested Management Strategy

The *Ips* species we have identified in our collections on C.I. Atenquique lands are all native bark beetle that are a natural part of the forest ecosystems in southern Jalisco. These beetles will always be present and active at some level. Occasional scattered small-scale mortality is likely to continue in plantations as a normal course of events, particularly during droughty periods. Managers should, however, try to prevent large-scale mortality from occurring as a direct result of plantation management activities. This may be best accomplished through a management strategy focused on prevention methods that manage slash and promote tree vigor. The following practices were selected as "best fits" for incorporating preventive measures into C.I. Atenquique's current management regime, following discussions with managers and field personnel regarding their management activity procedures, logistics, and operational facts. These practices should be implemented for all activities that create large amounts of pine slash greater than 6 cm on the small end:

1) **Discontinue pruning** activities in pulpwood plantations. The primary benefit provided by pruning is to reduce knot size and thus increase clear wood production on the lower bole of a tree. It normally is employed to enhance the value of trees grown for sawtimber or veneer production. Pruning as a silvicultural practice is expensive and provides little to no benefit for pulpwood production. Pruning causes wounding that induces tree stress and produces volatiles that are attractive to *Ips* beetles. It temporarily reduces the volume and thus the photosynthetic capacity of the tree crown, which also may contribute to a temporary reduction in the ability of a tree to resist bark beetles and other damaging agents.

2) **Continue thinning, but avoid thinning during the hot, dry season** (February through mid-June) when trees are experiencing high levels of moisture stress and are likely to have reduced resistance to beetle attack. Conduct thinning operations during October

through January, just after the rainy season has ended and when temperatures are cooler.

3) **Move pine slash away from close contact with residual trees**. Pine slash produces volatiles that are attractive to *Ips* beetles. Avoid piling fresh or currently infested slash up against live trees. Pulling loose slash away from the base of residual trees may help reduce *Ips* attacks on standing trees.

4) **Treat all pine slash within 3 weeks of cutting** so as to render it unsuitable for *Ips* colonization or development. Recommended slash treatments (derived from our local observations of the smallest size material infested in plantations and outbreak areas, and slash management guidelines used successfully to prevent *Ips* outbreaks in other parts of North America) are to:
   a. **Remove from the site** all pine material down to a diameter of 6cm, **OR**
   b. **Peel the bark** from pine slash pieces down to a diameter of 6cm.

4) **Continue to promptly cut and destroy *Ips*-infested trees** while the beetles or their brood are still in the trees. Infested trees will have crowns that are fading green, yellow, orange, or bright red, or may have green, healthy-looking crowns and boring dust present on the tree bole. Prompt sanitation reduces the numbers of beetles present in the stand.

Management: Further Studies

Implementing the above recommendations should provide a sound basis for managing to prevent large outbreaks of *Ips* from occurring as a direct result of management activities. However, further refinement of *Ips* and slash management techniques could be achieved by conducting additional investigative studies. We suggest the following as priorities:

1) Slash studies to ascertain the length of time following cutting that slash remains suitable habitat for *Ips* (i.e., how quickly do *Ips* colonize slash during various times of the year?), and to investigate piece size limits (would it be just as effective to treat slash down to a diameter larger than 6cm?)
2) Pheromone studies to further refine lure components for *I. lecontei*.
3) Tree density studies to discover, for pulpwood production in southern Jalisco, optimal spacing regimes on various site qualities.

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Sincerely,

/s/ Brytten Steed	/s/ Beth Willhite
Brytten Steed	Beth Willhite
Forest Entomologist	Forest Entomologist
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ADDENDUM

Overall Project Comments (from report to International Programs)

Key Results of this Project

1) *Ips* species identification in Mexico (and perhaps US and Canada) will likely be updated with additional new information available on biology of several little-known species;
2) improved forestry management guidelines to minimize Ips outbreaks will become practice at the plantation and may possible become the new national guidelines; and
3) tree/fiber losses due to Ips-caused mortality should be minimized.

Key Project Observations and Recommendations

1) additional efforts are needed to clarify *Ips* species in Mexico;
2) the practice of pruning plantation trees is likely making plantation trees more susceptible to *Ips* attack;
3) slash down to 6 cm diameter should be removed or debarked;
4) removal or debarking of slash should occur within three weeks of cutting based on data showing a 23 day life cycle for the most aggressive of the six *Ips* species found (*Ips lecontei*; per unpublished date from Angel Hernandez);
5) slash management in areas surrounding the plantation will also be important in minimizing *Ips* population. However, this requires regulations over the larger landscape;
6) planting site-appropriate trees and refining the thinning regime will augment tree vigor and resistance to bark beetles; and
7) additional work may be useful in creating additional management options (e.g. testing life cycle duration in the field at different seasons and specifpheromone reponse by the three most aggressive *Ips* species found).

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Personal and Professional Development

1) increased proficiency and understanding of *Ips* spp. identification;
2) met the challenge of developing management guidelines to meet the specific problems and needs of management over a large and various landscape;
3) developed a better understanding of plantation forestry and goals of fiber production (paper mill);
4) learned about Mexican forestry practices;
5) strengthed the working relationship of the Forest Health program in the US with the forest health program in Mexico;
6) visited with several students and discussed specific projects with three of them;,
7) increased our Spanish language ability and added many technical terms;
8) made many new professional contacts and reconnected with other previous contacts; and
9) deepened our understanding of Mexican culture and values.