United States Department of Agriculture | Forest Service | RO

Reply to: 3400

Date: August 14, 1995

Subject: 1994 Bark Beetle Steering Committee Report

To: Bark Beetle Steering Committee

Enclosed is a copy of the 1994 Bark Beetle Steering Committee Report. The Appendix of the Report is an attempt to document the progess of our activities on the 5-Year Strategic Plan. This was developed based on input from some of the members and my interpretation of the project reports presented at the meeting. A few items have been added from the original 5-year plan, and these are highlighted. Please review this for accuracy. As part of our 1995 meeting, I would like to spend a little time reviewing and updating this list of items, as well as documenting progress.

The 1995 Bark Beetle Steering Committee meeting is scheduled for October 3-5. It will be held at the Lakeside Inn, Highway 50 at Kingsbury Grade, P.O. Box 5640, Lake Tahoe, Nevada/89449. The phone numbers for the motel are 1-800-624-7980 or 702-586-7748. Rooms are $53.10 plus tax. When making reservations, reference "U.S. Forest Service" and Account No. 298786. There is a shuttle from the Reno Airport to Lake Tahoe, the Tahoe Casino Express, that stops at the Horizon Casino, which is about one-half mile from the Lakeside. Cost is $15 one way; their number is 1-800-446-6128 or 702-785-2424.

The meeting is scheduled to run from 8 a.m. Tuesday, October 3, through 5 p.m. on October 4. A field trip is scheduled for Thursday, October 5. The agenda will be similar to previous meetings, starting with a report of the 1995 projects for each of the bark beetles. Please have the reports prepared in the format listing Project, Cooperator, Funding, Summary, and Recommended Future Actions. Also, include in parentheses after the project title the reference or tie to the 5-Year Strategic Plan; i.e., (MPB A3b). We will be identifying priorities for the TDP projects for 1996. Looking back, a number of the projects we prioritized for 1995 departed somewhat from those listed in the 5-Year Strategic Plan. We should discuss whether this is a direction we want to go in the future. As we evaluate our priorities for 1996, we may want to reference how these help the progress on the 5-Year Strategic Plan; we may also want to review the plan for those areas that should perhaps receive attention.

If you have any particular items or suggestion for the agenda and meeting, please let me know.

IRAL RAGENOVICH
Chair, National Bark Beetle
Steering Committee

*347

Airline Res --
2:30 pm Oct 2 (2141) 6:25 pm
7:35 am Oct 6 (5328) 2:00 pm

Reservations made
8/23

And a car -- dollar

Enclosure

REPORT OF THE 1994 BARK BEETLE STEERING COMMITTEE MEETING

October 4-6, 1995

Whitefish, Montana

REPORT OF THE 1994 BARK BEETLE STEERING COMMITTEE MEETING
October 4-6, 1994
Whitefish, Montana

The National Bark Beetle Steering Committee met in Whitefish with the following objectives:

1. Report on the results of all bark beetle related activities over the past year,
2. Identify and prioritize potential TDP projects,
3. Report accomplishments on the 5-Year Strategic Plan,
4. Visit examples of mountain pine beetle management related activities on the Swan Lake Ranger District and Glacier National Park.

Members reported on all activities in FY 1994. A summary of these projects and accomplishments are attached. Reports were provided fo 51 projects. Of these, 14, or 27%, were funded with TDP funds.

Peter Mika (University of Idaho) gave a presentation on the work being done by the Intermountain Forest Tree Nutrition Cooperative (IFTNC). The IFTNC is made up of a variety of Federal, State and private land mangers in Oregon, Idaho, and Montana. They have a series of nutrition plots throughout these states, that were established to determine the effects of applications of fertilizer to various forest types. Installation of the plots is over a period of several years as the money contributed by the various partners allows. Plots consist of four 2 1/2 acre treatments: Control, Nitrogen (N), Potassium (K), and Nitrogen + Potassium (N+K). Data collected on the plots included tree mortality; where possible the cause of mortality was determined. In some cases the mortality was determined to be the result of root disease (Armillaria in Douglas fir) or mountain pine beetle. In the case of mountain pine beetle, the plots on which it occurred seemed to indicate that treatments with N seemed to be particularly attractive to mountain pine beetle, while treatments of K seemed to reduce the potential for beetle attack. The previous year, Dave Bridgwater and Ken Gibson had visited some of the plots. Their concerns included: 1) there were actually very few plots that had any beetle attack at all, and 2) there was no way to determine what effect the treatments really had in regard to bark beetles unless the plots were subjected to beetle pressure. To ensure this, plots would need to be intentionally placed in the vicinity of significant bark beetle activity and baited with pheromone to ensure beetles would be coming to the area. As a result, the IFTNC was interested in exploring the opportunity to include this additional study into their plot network. The objective was to get feedback from the Bark Beetle Steering Committee, and explore opportunities for additional funding through the TDP. The initial intent was to just add pheromone to some of the existing and future fertilizer plots.

The Steering Committee had several concerns:

1. the existing information was not useful since the study had not been originally designed to take into consideration the presence of bark beetles;

2. needed changes could not be attached to the existing study; it would need to be designed to specifically address the relationship of bark beetles and fertilizer;

3. a study specifically designed to answer the question of bark beetles and fertilizer would involve a large amount of additional work; individual treatment plots would need to be a minimum of 4 acres to accommodate the action of the pheromone; this would almost double the amount of work and fertilizer over what is currently being used in the existing plots plus initial plot location would require additional work to ensure adjacent beetle populations.

4. the project would probably not qualify as a TDP; there is no pre-existing research that demonstrates that there is a relationship between bark beetles and fertilizer, so this project would actually be a research project.

During the Steering Committee meeting in Albuquerque, a number of members expressed concern about the western bark beetle model. As a result, two meetings were held with folks from MAG. The first meeting was to express the concerns of the Bark Beetle Steering Committee; then to review the process and development of the model, identify areas that may have contributed to the concerns, and identify ways to resolve the concerns. Actions included, efforts to involve the steering committee members more fully in the development and testing of the model. A second meeting was held with key steering committee members to review the development and explain and receive input from the members regarding the model.

Members identified future research and technology development needs. Those that were technology development needs were identified and priorities were developed for the WO Technical Review Committee. Generally, the needs can be categorized as: 1) semiochemicals for monitoring and managing bark beetle populations; 2) susceptibility and risk rating systems for bark beetles; 3) management tools for introduced species; and 4)defining the historic role of insects and diseases for ecosystem analysis and evaluation.

1995 Technology Development Priority Needs

WESTERN

1. Continued development and validation of plume model for determining the distribution of eluted semiochemicals in the stand atmosphere, and to sample pheromone plumes emitted from standing attacked trees to estimate atmospheric concentrations effective in repelling bark beetles.

2. Test the efficacy of lower doses of MCH bubble capsules for protecting Douglas-fir from Douglas-fir beetle attack.

3. Develop mountain pine beetle susceptibility/risk rating in southwestern ponderosa pine.

4. Develop techniques for determining historical disturbance regimes in fir, pine, and spruce forests on the Colorado Plateau.

5. Test different semiochemicals for their ability to prevent attacks by *Ips pini* in ponderosa pine slash.

6. Evaluate new technologies in multispectral analysis/remote sensing (such as the Xybion camera) for determining signatures of bark beetle stressed trees.

7. Test reduced verbenone dosage rates for roundheaded pine beetle.

8. Develop a preliminary hazard rating system for *Ips perturbatus* in managed and unmanaged stands of white spruce.

9. Test the efficacy of host chemicals to repel *Ips perturbatus* in damaged and stressed stands of white spruce.

10. Determine the effects of applications of fertilizer and lime to thinned and unthinned stands of spruce to enhance resistance to spruce beetle.

11. Determine the ecological role of *Ips pini* under presettlement conditions in old growth situations and as a bioindicator of forest health.

EASTERN

1. Operational use of methyl chavicol and verbenone for southern pine beetle disruption.

2. Use of bolts for trapping *Tomicus*:

   - determine bolt size and species in relation to attack density
   - determine effective trapping range of alpha-pinene and trap logs

3. Inhibitory effect of methyl chavicol and verbenone for *Tomicus*.

4. Biological control agents for *Tomicus*.

Members were asked to review the 5-Year Plan and update it regarding accomplishments over the past year, as well as any adjustments to the plan. Accomplishments are shown in Appendix A.

Steering Committee members were also requested to list the current and potential uses for semiochemicals, in order to provide an indication of how this management is being used and will be used. These uses include:

Anti-aggregating Pheromones

Use of MCH as an anti-aggregating pheromone for Douglas-fir beetle and spruce beetle. Currently uses are limited because of the status of the registration, however, that does not preclude the need:

-Protection of high-value stands during outbreaks. These high value stands would include maintaining the large tree character in recreation area, wildlife habitat, etc. Last year's MCH bubble cap study demonstrated that this could be done. Currently, in Oregon, the Oregon Trail Interpretive Center is very anxious to protect the large old Douglas-fir, some of which have wagon scars from the time of the settlers, from Douglas-fir beetle populations in the surrounding area during the current outbreak. Use of pheromones would be a short term until silvicultural management can be done.

-Preventing infestation (and subsequent population build up) in wind-thrown, fire-damaged, or defoliated stands.

-Preventing infestations of thinned trees that are left in the forest to meet ecosystem management objectives.

-Currently there are ongoing studies using exobrevicomin for dispersing and repelling western balsam bark beetles.

Aggregation pheromones:

Aggregating pheromones are currently being used in several ways - for drawing beetles into an area; in conjunction with trapping; and for monitoring insect slight and populations in order to determine management options. Some of these are:

-Mass trapping of spruce beetles from export log decks on Homer Spit.

-Mass trapping of spruce beetles from infested log decks in the Nililchick area of the Kenai Peninsula.

-Trap out of *Ips pini* around infested "abandoned" log decks in the Black Hills NF.

-Use of binary spruce beetle attractant to enhance trap trees in Moose Pass and Falls Creek areas of the Kenai Peninsula.

-Monitor spruce beetle populations in blow down on the Big Horn National Forest.

-Use of pheromones to monitor population trends for any of the bark beetles, for instance the Douglas-fir beetle.

-Use of pheromones to manipulate populations by concentrating DFB into specific areas during attack. Beetles could be drawn into areas that are scheduled for removal, or also they can be used to create snags or gaps for wildlife habitat.

The Committee also suggested once again stressing the need for doing tier one testing for semiochemicals, especially for methyl chavicol, to the WO.

John Wenz offered to host the next Committee meeting at Lake Tahoe, so we could have an opportunity to see some of the management being done in that area. The meeting will be held the first week in October.

Ed Holsten offered to host the meeting for 1996 on the Kenai Peninsula.

Summary of the 1994 Bark Beetle Projects

Douglas-fir Beetle

Project: Optimal dose of MCH bubble capsules for protecting Douglas-fir from attack by the Douglas-fir beetle

Cooperators: Darrell Ross, OSU; Ken Gibson, R1; Ralph Thier, R4; Steve Munson, R4; Iral Ragenovich, R6; Gary Daterman, PNW Station

Funding: TDP

Summary: Eight replications were installed in spring 1994 (three in northeastern Oregon, two in Montana, two in Idaho, and one in Utah). Each replication consisted of four treatments applied to one hectare circular plots. The treatments were 0, 50, 100, and 150 MCH bubble capsules per hectare. Each bubble capsule contained 400 mg of MCH. Three Lindgren funnel traps baited with frontalin and seudenol were at the center of each plot.

All plots have been surveyed and all trap samples have been processed. The data is currently being analyzed. Preliminary analyses indicate that all three MCH doses are equally effective. Mean percent infested host trees for the 0, 50, 100, and 150 capsule/ha treatments were 5.6, 1.2, 1.2, and 0.7%, respectively. All three MCH doses were significantly different from the check, but there were no differences between the three doses.

Future Actions/Recommendations: The analyses will be completed and a manuscript will be prepared for publication by the end of 1994.

Further testing should be conducted to determine the efficacy of doses below 50 capsules per hectare.

Project: Site and stand factors associated with the occurrence of Douglas-fir beetle in Douglas-fir

Cooperators: Bill Schaupp, R2; Ken Gibson, R1; Steve Munson and Ralph Thier, R4; Jose Negron, RM Station

Funding: TDP

Summary: The objectives of this project are to develop stand classification systems that will rate the relative probability of Douglas-fir beetle infestation (hazard) and the level of expected Douglas-fir mortality given a DFB infestation (risk). This will be based on analysis of standard USFS inventory data taken from infested and uninfested plots in the Rocky Mountains. By the end of the season, a total of 242 plots (half infested) were installed in Colorado, Idaho, Montana, and Utah. In addition, most of about

140 plots in Wyoming that were installed in 1992 and 1993 were rechecked and 14 new plots installed in that area.

Future Actions/Recommendations: Plot installation will continue through the 1995 field season. A product is expected by early 1996.

Project: Evaluating the course of a fire-induced DFB epidemic in the central Rocky Mountains

Cooperators: Bill Schaupp, Ken Lister (retired), and Judy Pasek, R2

Funding: FHM S&TA

Summary: The objective of this project is to document the course of a DFB epidemic that differs from those reported in the literature because it is (1) fire-induced and (2) taking place in the central Rocky Mountains, where little is known about DFB basic biology. Since 1989, data has been collected on overwintering DFB brood populations, timing of adult emergence from brood trees, and DFB-caused mortality in the Cathedral Cliffs area of the Shoshone NF.

Future Actions/Recommendations: Data collection will continue until the epidemic subsides. Results have been printed in Biological Evaluations by R2-Forest Health Management. It is expected that a summary article will be prepared for publication in a refereed journal.

Mountain Pine Beetle

Project: Use of pheromone baits to pull beetles into a designated stand of lodgepole pine in a strategy to manage mountain pine beetle populations.

Cooperators: Steve Munson, R$; Sherri Smith, R5; Lynn Rassmussen and Jim Vandygriff, INT Station; Jim Rineholt, SNRA.

Funding: TDP

Summary: The objective was to determine if MPB can be "pulled" into concentrated groups of trees within designated stands using attractant pheromone baits. Aggregative pheromone baits were placed in dwarf mistletoe infected stands of lodgepole pine on the Sawtooth National Recreation Area (SNRA). These stands are to be managed as fuelwood sales, harvesting infested trees before new beetle emergence (summer 1995). Previous push/pull tests conducted during summers of 1992 and 1993 demonstrated the effectiveness of MPB baits in grouping mountain pine beetle infested trees within a concentrated block. Baited blocks were located adjacent to verbenone and check blocks. Summary results for the 1992/1993 studies are as follows: The attractant treated blocks received 287 infested trees in 1992, and 166 in 1993, for an average of 36 and 17 new infestations per block, respectively. The verbenone treated blocks received 15 infested trees in 1992, and 2 in 1993, for averages of 2 and .2 new infestations per block. The control blocks had a total of 7 infestations in 1992 and 5 in 1993, for averages of 1 and .5 new infestations per block.

In 1994, 14 1-acre blocks were baited with 5-each MPB tree baits; there were 8 control blocks. Verbenone was not used in 1994. The treatment blocks were located in stands designated by the SNRA for dwarf mistletoe and fuelwood harvest management. Blocks were surveyed Sept. 13-14, 1994 and preliminary results show 116 mass attacked trees ranging from 0 to 23, with an average of 8.3 per block in the baited blocks. The control blocks had no mass attacked trees. These results show fewer mass attacked trees than in 1992 and 1993. Possible explanations for this are: (1) stands heavily infected with dwarf mistletoe are not as attractive to MPB; (2) MPB populations are declining in most of the treatment areas; and (3) much of the preferred host material has already been killed. This strategy has the potential to work well and the SNRA has expressed their desire to use it in the future.

Project: Risk rating system for southwestern ponderosa pine

Cooperators: Bernie Raimo, Ken Lister, Tom Eager, R2; Jesse Logan, Barbara Bentz, Lynn Rasmussen, INT; Jill Wilson, R3; Sheri Smith, R5; Steve Munson, R4

Funding: FIDR

Summary: Risk rating systems for mountain pine beetle currently in use were developed in the Black Hills. However, the condition of ponderosa pine stands found in the Southwest is so dissimilar that the behavior of the beetle is significantly different. Fine tuning of risk rating systems on a more regional basis is needed. Collection of current stand condition data will be integrated into a risk rating system that can be adjusted to local conditions as needed.

Future Actions/Recommendations: This work will require the continued cooperation of all participants. We plan to continue data collection of stand parameters in order to identify those stand characteristics which are most indicative of future mountain pine beetle outbreaks.

Roundheaded Pine Beetle

Project: Site and stand factors associated with the occurrence of roundheaded pine beetle outbreaks in ponderosa pine.

Cooperators: Dayle Bennett, R-3, Albuquerque
Jill Wilson, R-3, Flagstaff
Cloudcroft RD, Lincoln NF
Safford RD, Coronado NF
Jose Negron, RMFRES, Ft. Collins

Funding: TDP

Summary: A total of 102 permanent plots were established in the Cloudcroft RD during the summer of 1994. Plot establishment was stratified by six habitat types identified to contain the majority of the ponderosa pine component in the Lincoln NF. Stage II information forms the core of data collection but additional data fields are also collected. In 1995, sampling will continue at the Cloudcroft RD. Contact has been made with the Safford RD to conduct sampling in that district in 1995.

Project: Determination of the best combination and release rates of attractant compounds for roundheaded pine beetle (RPB).

Cooperators: Lincoln National Forest, Cloudcroft Ranger District; Coronado National Forest, Safford Ranger District; Pacific Southwest Experiment Station.

Funding: TDP, R3-93-01.

Summary: The 1993-94 technology development project was a repeat of the 1992-93 flight periodicity and verbenone test except the June flight was used to determine what concentration and combination of bait compounds (for the Sacramento Mtns., New Mexico and Pinelano Mtns., Arizona populations) was the best for maximizing the catch of RPB. We tested two different concentrations of exo-brevicomin and frontalin and three pine terpenes (myrcene, alpha-pinene, and beta-pinene) in eight different combinations with an empty trap as a control. These treatments were replicated five times in New Mexico and four times in Arizona. We found that the low release rates for both exo-brevicomin and frontalin at both locations caught as much or more RPB as any of the other seven treatments. The anti-attractant test with this bait was run only in New Mexico for 5 weeks in the fall. The bait only traps caught on the average of over 100 RPB per trap per week for three week from October 5th until November 9th. All of the verbenone treatments [the six enantiomeric combinations:(+)3,25,50,and 97% combined with (-)97,25,50,and 3%, respectively] except for the (+)97%,(-)3% treatment for the week ending on October 26th caught less than an average of 25 RPB per trap per week. Most treatments caught less than 10 RPB per trap per week. The highest catch for any of the verbenone treatments was an average of approximately 40 RPB per trap per week for the week ending October 26th, 1993 for the (+)97%,(-)3% verbenone treatment.

Project: Area application of verbenone to reduce the mortality of ponderosa pine by RPB in the Sacramento Mountains, southern New Mexico.

Cooperators: Lincoln National Forest, Cloudcroft Ranger District, Pacific Southwest Experiment Station.

Funding: TDP, R3-94-01.

Summary: In September, 1994 five five-acre areas were treated with 1) no pheromones, 2) low release rates of frontalin and exo-brevicomin as the attractant, 3) verbenone [(+)14%,(-)86%] at 50 bcaps per acre, and 4) the attractant and the verbenone bcaps (as described for both #2 and #3). These treatments were designed to determine the effectiveness of verbenone in preventing RPB attacks in areas where there were currently attacked trees.

After the October flight period the areas will be revisited to determine the number of newly attacked trees.

Spruce Beetle

Project: Stand protection with MCH bubble caps. (R10-94-01)

Cooperators: R10 FHM, PNW/INF, PSW, and Alaska Division of Forestry

Funding: TDP

Summary: The protection of stands of Lutz spruce using MCH and methyl chavicol (-4 allyanisole) bubble caps (formulated to release at 17 and 24°C) were tested at 32 and 50 bcaps per acre (16 and 25 bcaps per 1/2 acre). Each treatment plus control was replicated 5 times on 1/2 acre plots (150 x 150 feet) in a randomized block design. Plots were not baited since beetle pressure appeared to be adequate. Plots were spaced at 200 foot intervals along 5 transects spaced at 200 feet apart. Bubble caps were stapled to the south sides of trees at breast height in late May 1994. Previously infested and dead spruce trees were marked with orange spray paint. Treatments were evaluated in mid-August by counting trees with no attacks, new attacks and new pitch outs.

Results:
Treatment 1 - 16 MCH @ 17°C
Treatment 2 - 16 MCH @ 24°C
Treatment 3 - 25 MCH @ 17°C
Treatment 4 - 25 MCH @ 24°C
treatment 5 - 25 MC @ 17°C
Treatment 6 - 25 MC @ 24°C
Treatment 7 - 25 MCH/MC @ 17°C
Treatment 8 - 25 MCH/MC @ 24°C
Treatment 9 - CONTROL

Percentage of new attacks and new pitch outs for MCH and methyl chavicol bcap treatment of standing trees-1994.

	unatt	new att	new po	% new att	% po
16MCH @17	202	54	34	21	14
16MCH @24	209	43	34	17	14
25MCH @17	244	19	16	7	6
25MCH @24	174	20	22	10	11
25MC @17	236	53	39	18	14
25MC @24	186	83	31	31	14
25MCH/MC17	244	46	15	16	6
25MCH/MC24	216	23	13	10	6
control	157	67	28	30	15

Statistical analysis using Bonferonni's multiple comparison test showed no difference between treatment plots and control plots; however, the above percentages of unattacked trees shows possible positive effects for the following treatments: 25MCH @17, 25MCH @24, and 25MCH/MC24.

Future Actions/Recommendations: There appears to be some treatment effect, although it doesn't make much sense. However, the experiment will be done again in 1995 in an area with uniform beetle pressure.

Project: MCH bubblecaps for preventing spruce beetle attack in Utah.

Cooperators: Skeeter Werner, PNEW Station; Ed Holsten, R10; Pat Shea, PSW Station; Roger Burnside, Alaska Division of Forestry; Ralph Thier and Steve Munson, R4.

Funding: TDP

Summary: Six replicates consisting of a control, 50, and 75 bubblecaps per acre in 2.5 acre blocks were established on the Manti-LaSal national Forest in central Utah. Blocks were installed in September of 1993 and bubblecaps were placed the second week of June 1994. Field analysis was conducted the week of Set. 19th, 1994. When the bubble caps were placed in June, adult beetles had already begun to disperse. Two earlier attempts to place bubblecaps in the blocks using snowmobiles resulted in stranded snowmobiles due to mechanical problems. Data has been entered in D-base but not analyzed.

Future Actions/Recommendations: Results might be more meaningful if bubblecaps were placed before the adults began to disperse. Not sure what the significance of new infestations in treatment blocks had on dispersing beetles.

Project: Individual tree protection with MCH bubble caps. (R10-94-01)

Cooperators: R10 FHM, PNW/INF, PSW, and Alaska Division of Forestry

Funding: TDP

Summary: Single tree protection using MCH bubble caps (formulated to release at 17°C) at different heights on tree bole and different aspects of the tree bole. All trees, including checks, were baited with SB attractants. Attractants were placed 10 ft from treated and check trees. Five treatments, including checks, with 15 replications (single tree) per treatment: 1 = MCH@ 4, 8, 12 ft on north and south sides; 2 = MCH@ 4, 8, 12 ft on south side; 3 = MCH @ 6 ft on north and south sides; 4 = Check, and 5 = MCH @ 2 ft on north and south sides.

Results:

TREATMENT 1: 6 trees attacked = 40%
TREATMENT 2: 0 trees attacked = 0%
TREATMENT 3: 5 trees attacked = 33%
TREATMENT 4: 7 trees attacked = 46% (CHECK)
TREATMENT 5: 2 trees attacked = 13%

Future Actions/Recommendations: Appears there were no significant differences between treatments as check trees were too lightly (46%) attacked to demonstrate treatment effects. There were 5 transects of approximately 15 trees each. Very little spruce beetle activity occurred along transect 1 which contained five unattacked check trees. If transect 1 is excluded; results would be:

TREATMENT 1: 4 trees attacked = 36%, n=11
TREATMENT 2: 0 trees attacked = 0%, n=12
TREATMENT 3: 5 trees attacked = 33%, n=15
TREATMENT 4: 7 trees attacked = 70%, n=10 (CHECK)
TREATMENT 5: 2 trees attacked = 17%, n=12

There appears to be some treatment effect, although it doesn't make much sense. However, the experiment will be done again in 1995 in an area with uniform beetle pressure.

Project: Efficacy of pyrethrin and carbaryl insecticides to reduce mortality of Englemann spruce caused by the spruce beetle.

Cooperators: Mike Jenkins and Karen Johnson, Utah State University; Pat Shea, PSW Station; John Anhold and Steve Munson, R4.

Funding: TDP

Summary: Experiment consisted of six treatments and a control. The treatments were two concentrations each of esfenvalerate, cyfluthrin, and carbaryl applied to 32 trees. An unsprayed control of 100 trees was selected. Treatments were assigned at random to 192 trees. Spruce beetle aggregation pheromones were attached to each tree to enhance attack densities. Trees were treated in the fall of 1993 and baits were applied in April of 1994. Tree attack data was collected the week of Sept. 12th, 1994. Field evaluations indicate that the higher concentrations of esfenvalerate and cyfluthrin had some effect on attacking adults. No successful hits were recorded on trees treated with carbaryl. Data has not been analyzed.

Future Actions/Recommendations: All trees will be re-checked this winter to determine if they were successfully or unsuccessfully attacked. Trees unsuccessfully attacked will be baited again to determine efficacy of the treatments in 1995.

Project: Development of a hazard model for spruce beetle in sitka spruce.

Cooperators: Ed Holsten, FHM R10 and Keith Reynolds, PNW

Funding: FHM/FIDR

Summary: A hazard model for spruce beetle in sitka spruce, similar to the model for spruce beetle in white/lutz spruce was developed. The new model will be incorporated into version 2.0 of SBEXPERT which should be out within a year. The current SBEXPERT model can also be used for sitka spruce as well as lutz and white spruce as there was very little difference between hazard for the respective species.

Future Actions/Recommendations: Issue version 2.0 of SBEXPERT.

Project: Elution rates of MCH, verbenone and other semiochemicals from various controlled release devices such as bubble caps under various conditions.

Cooperators: R10 FHM, PNW/INF, PNW/CFSL, PSW, OSU

Funding: TDP

Summary: Elution rates for MCH, verbenone, and other materials appear to differ greatly under various field conditions and this affects results of field tests. A data base for elution rates of common bark beetle semiochemicals from controlled release systems currently being developed for use.

Elution rates and residual content of MCH and verbenone from bubble cap, bead, and possibly other controlled release materials were determined in the laboratory under diverse temperature and air speed conditions. This provided basic elution rates for these materials. In addition, performance of these materials under diverse field conditions were also evaluated. Releasors were evaluated through appropriate field seasons in diverse micro-climates in cold and warm soils in California, Oregon, and south-central Alaska.
Residual behavioral chemical and periodic elution rates were determined through the season. Some information already existed for some field conditions but there clearly are significant data gaps and need to be filled in a systematic manner. Existing data were incorporated into the project.

Materials were placed in the field in an "as used" manner in ponderosa pine, Douglas-fir, Lutz and Sitka spruce stands. Datapod temperature recorders were placed in the same locations to monitor the exact micro-climate the releasors are in. Samples of bubble caps and beads were collected at 2-week intervals for two months and their residual behavioral chemicals extracted and checked for quantity and quality via gas chromatography. In addition, rates of release of these collected materials were determined in the lab under standard temperature and air speed to correlate residual content with release characteristics of field seasoned material. Release rate is determined directly by trapping material from air passing over the releasors at defined temperature and air speeds. Methods for doing this have been described in the literature and also specifically developed for these materials. Residue and release rate measurements are labor intensive, tedious, and require careful attention to technique but the existing methods are also reliable and no technical development of methods is required. Similar determinations were made at several temperatures and air speeds at the Corvallis FSL (PNW) which is suitable equipped. A determination of quality of released material at several distances down wind from the release point in the field were also attempted. Methods have been develop in conjunction with another research project that should be adaptable for this purpose.

Results: Bubblecap and bead samples are being analyzed for parent materials. Date from datapods needs to be down-loaded to a PC and comparative analysis made between various study sites. The retirement of Lonne Sower has slowed the laboratory work as a technician is currently employed to do the analyses.

A contract with Warren Webb, Forest Science Department, Oregon State University was made to develop a model to predict MCH concentration in the atmosphere in both horizontal and vertical dimensions following its elution from bubble caps. The model thus far developed shows the horizontal distribution of MCH at the surface and downwind from a bubble cap placed at 2 meters above the surface. The horizontal distribution shows an area in which all atmospheric concentrations of MCH are above the minimum threshold, i.e., the beetles would be repelled within this zone.

Future Actions/Recommendations: The current model needs to be verified in field experiments using smoke plumes and video photography. Model also needs to be expanded to include many bubble caps within a stand. Crosswind effects on dispersal of the plume should also be determined. The amount of MCH produced by a single tree infested with the optimal number of beetles also needs to be measured before the model can be expanded to include entire stands treated with bubble caps.

Southern Pine Beetle

Project: Operational use of behavioral chemicals for suppression and manipulation of southern pine beetle (SPB).

Cooperators: R8 FPM; Texas Forest Service, University of Georgia; Virginia Polytechnic Institute.

Funding: TDP

Summary: Results in 1994 continued to be mixed. Treating infestations with only a verbenone buffer reduced infestation growth by 50% in the east and by 22% in Texas as compared to pre-treatment growth. Felling all infested trees and applying a verbenone buffer reduced growth by 82%. In Texas, felling only fresh attacks and egg stage trees with a verbenone buffer reduced growth 88%, while spot growth rate of the two spots treated in Alabama was not affected. Complete suppression of the infestation using any of the treatments is more likely when initial spot size is small (<50 trees).

Future Actions/Recommendations: Continue Region-wide testing of the verbenone treatments. Develop and initiate the technology transfer program.

Project: Environmental effects on pine tree carbon budgets and resistance to bark beetles.

Cooperators: Peter Lorio, SO; Matthew Ayers, Dartmouth College.

Funding: FIDR

Summary: This study was initiated in 1993 as part of the Southern Global Change Program and was to determine effects of thinning and fertilization on juvenile loblolly pines five years after treatment. Results to date indicate that diameter growth is no longer being affected by fertilization, but is still responding strongly to thinning. Fertilization reduced resin yield in intermediate trees in unthinned plots and in co-dominant trees in thinned plots, but not in co-dominants in unthinned plots. Photosynthesis was somewhat elevated by fertilization across crown classes and thinning treatments. Phloem specific mass of codominants greatly exceeded that in unthinned plots, especially in the spring. Preliminary C14 tests indicate levels of carbon assimilation in agreement with measured photosynthesis rates. To date, fertilization and thinning have not produced effects that would indicate increased resistance to bark beetle attack compared to untreated stands.

Project: Extended development in the clerid beetle, *Thanasimus dubius*.

Cooperators: John Reeve, SO

Funding: FIDR

Summary: This study was initiated to measure the development time of the clerid beetle *T. dubius* under field conditions. At four different times of the year, large emergence traps were attached to trees containing immature clerids, and the number of adult clerids that emerged recorded at weekly intervals. Preliminary results suggest that a significant fraction of clerids undergo a period of diapause during the summer months, suspending development until fall. Dissections of trees vacated by SPB also imply that clerid immatures may be present in those trees long after SPB emergence, in some cases nearly two years after attack by SPB.

Project: Predation by adult clerids on SPB during mass attack.

Cooperators: John Reeve, SO

Funding: FIDR

Summary: The objective of this study was to estimate the mortality inflicted by adult clerid beetles on SPB during mass-attack of the host-tree. Large cylindrical traps were used to determine density of adult clerids on the bark of trees undergoing mass-attack by SPB, and this information used to calibrate laboratory experiments in pine bolts, where SPB were exposed to a range of clerids densities. At densities commonly observed in the field, adult clerids caused high mortality of SPB, and substantially reduced the umber of successful attacks. These results suggest that predation by adult clerids may be a significant source of SPB mortality in nature.

Project: Defensive response of pines to bark beetles: role of pinewood nematode, a plot study.

Cooperators: Donald Kinn, SO

Funding: FIDR

Summary: The goal of this study is to determine whether the reduction of oleoresin flow that occurs in pines inoculated with pinewood nematode, Bursaphelenchus xylophilus (Steiner and Buhrer) Nickle, is localized at the inoculation site or is global throughout the bole of infested trees. Oleoresin flow in inoculated trees will be measured at three heights on the bole at monthly intervals. Wood samples will be taken each month and examined for the persistence of nematodes in inoculated trees. Results from this study will be significant in planning additional studies to determine if trees infested with the pinewood nematode are predisposed to attack by SPB, or are successfully colonized by beetles at lower attack densities.

Project: Relationship of flight activity in response to pheromone in the SPB.

Cooperators: Donald Kinn, SO

Funding: FIDR

Summary: Modification of a method used in clinical chemistry for determining cholesterol levels in mammalian blood sera was used to determine total lipid content of individual southern pine beetles. Triglycerides, the fuel used for dispersal, account for 81 - 85% of the total lipid content of this insect. The percentage of lipid based upon dry weight of individual beetles is slightly, but significantly, greater in females than males. In laboratory flight mill tests flight duration and distances are significantly greater for females than males. Female flights average about 26 minutes longer than those of males and females fly an average of 665 meters farther than male beetles. Based on the percentage lipid content of unflown beetles (sexes pooled), the lipid content of beetles with accumulated flight times of less than 3 hours is reduced from 18 to 12%, that of beetles flown 3 to 5 hours is reduced 10%, and that of beetles flown 5 hours or more is reduced to 7%. Based on flight mill studies, the average flight velocity of the southern pine beetle is 19 meters/minute and average distance flown is 3,000 meters. Although in field studies by Drs. P. Turchin and Wm. Thoeny 50% of marked beetles were recaptured within 500 meters of release, these results suggest beetles are capable of wider distribution.

Project: Evaluation of the area-wide efficacy of direct control tactics for SPB.

Cooperators: Peter Turchin and Jane Hayes, SO

Funding: FIDR

Summary: The summer of 1993 was the first field season for this 3-year study. Two SPB infestations on the Homochitto NF were studied experimentally. One infestation was manipulated by the method of cut-and-leave and the other was treated with the inhibitory pheromone verbenone. Movement of marked SPB out of experimental infestations was measured with a standardized array of trap trees and pheromone-baited traps. In addition, beetle fluxes within infestations were monitored using sticky screens. These data are currently being processed. There was also progress in developing the model of SPB population redistribution stimulated by a workshop on modeling bark beetle movement. It is being developed into a computer program.

Project: Long-term dynamics of SPB and their natural enemies.

Cooperators: Peter Turchin and John Reeve, SO

Funding: FIDR

Summary: There are still many unknowns in SPB ecology and population dynamics, such as what factors cause area-wide SPB out breaks and collapses, or how to stop area-wide epidemics. This study ahd three related objectives: 1)measure SPB fecundity and within-tree brood survival in relation to SPB outbreak cycle; 2) collect long-term data on SPB-associated natural enemies, fungi, and on the "quality" of individual beetles and relate these data to phases in the SPB outbreak cycle; and 3) measure mortality rate inflicted by SPB natural-enemy complex on SPB brood, and relate the mortality rate to SPB outbreak cycle.

Project: Predicting SPB population trends in using pheromone trap catch data.

Cooperators: Peter Turchin and John Reeve, SO

Funding: FIDR

Summary: The goal of this study is to improve the accuracy of the forecasting system for SPB infestation trends, and to increase the system's utility to forest managers. The first objective is to develop a statistical model that will accurately predict SPB trap catches in relation to such weather variables as temperature, moisture surplus, and moisture deficit. Because the weather conditions may have a delayed effect on the SPB flight activity, the trap catch data will have to be analyzed using time-series techniques. Thus, the second objective of this study is the development of statistical methods for separating the direct and time-lagged effects of weather variables on SPB and clerid trap-catches. Once we understand the effect of weather on the flight activity of SPB and clerids, we will be able to use the trap catch data to estimate the population pools of SPB and their clerid predators in the area where the pheromone traps are situated. The third objective is to relate the population numbers of SPB and clerids in the area to the future time course of SPB population trend. We will develop a model that will predict the severity of SPB infestation based on the knowledge of SPB abundance, clerid numbers, and such weather variables that prove to be relevant. The final objective is to use this model, should it prove an effective predictive tool in answering general questions about SPB population dynamics.

Project: Repellent properties of the host compound 4-allylanisole to the SPB.

Cooperators: Jane Hayes and Brian Strom, SO

Funding: FIDR

Summary: The phenylpropanoid, 4-allylanisole (CAS. #140-67-0), is a compound produced by many conifers, including loblolly pine. Gas chromatography/mass spectrometry analysis of resin collected before and after injection of loblolly pines with a fungicide mixture known to make pines more "attractive" to SPB resulted in the identification of 4-allylanisole as a likely candidate of repellent effects. The repellency of 4-allylanisole to SPB was demonstrated in laboratory behavioral assays and in natural populations comparing its effects with those of the beetle-produced inhibitory pheromone, verbenone. The response in the field of SPB to its attractant pheromone in funnel traps was significantly reduced by simultaneous release of either 4-allylanisole or verbenone, which did not differ from one another in repellency. Both compounds together did not significantly reduce trap catch. The response of SPB to selected chemical analogues of 4-allylanisole in the laboratory were tested. In preliminary field tests with 4-allylanisole, lightening-struck pines were protected from SPB attack. The response of the major predator to SPB, _T. dubius_, to the attractant pheromone of SPB did not differ with the simultaneous release of either compound. The response of natural populations of MPB in Oregon, WPB in California, and _Ips pini_ in Wisconsin to 4-allylanisole was tested. Traps containing attractant and 4-allylanisole or verbenone caught significantly fewer MPB than those traps baited with attractant alone, but verbenone and 4-allylanisole did not differ from each other. Results with WPB were inconclusive. Fewer _I. pini_ were caught in traps containing attractant and 4-allylanisole than in traps containing attractant alone. The response of common predators to baited funnel traps in each system (eg., clerids, trogostids, histerids) was not apparently affected.

Project Protection for red-cockheaded woodpecker from bark beetle infestation using novel host compounds.

Cooperators: Jane Hayes and Brian Strom, SO

Funding: FIDR

Summary: During 1992, it was determined that a coumpound found in loblolly pine and other pine consistently repelled SPB throughout all seasons of the year, but did not repel clerid beetles, which are common bark beetle predators. Responses to this compound were compared with the SPB's anti-aggregation pheromone, verbenone. In all cases, repellency was at least equivalent.

In 1993, two areas were established on the Kisatchie National Forest, Vernon Ranger District, to evaluate the novel host compound. In one area, a series of red-cockheaded woodpecker cavity trees were selected as controls and treatments, with preliminary results indicating protection of treated trees. In the other area, several small stands along a recreational trail were protected using the novel host compound. During the summer of 1994, several areas will be selected in Mississippi and Texas to continue evaluation of the novel host compound.

Ips perturbatus

Project: Field test ipsenol and methyl butenol in bubble caps and bead formulations to prevent infestations of Ips perturbatus populations in white spruce stands in interior Alaska.

Cooperators: R10 FHM, PNW/INF, and Alaska Division of Forestry

Funding: TDP

Project Objective: To evaluate the efficacy of stand treatment with slow-release bubblecap formulations of ipsenol and methyl butenol to protect stands of white spruce in interior Alaska from infestation by Ips perturbatus.

Research Basis: In 1992, the efficacy of ipsenol, verbenone, methyl butenol, exo-brevicomin, and MCH were tested as possible antiaggregants of I. perturbatus and only ipsenol and methyl butenol provided positive results. This research was done using funnel traps baited with the pheromones in a randomized block design with replications.

In 1993, a field test using ipsenol and methyl butenol bubblecaps at 25 and 50 bcaps per acre provided adequate protection to white spruce stands. Methyl butenol plots with 50 bcaps/acre provided the best protection of white spruce stands with only 13% new attacks compared to 19% for 32 bcaps/acre and 32% for untreated control plots. Ipsenol plots with 50 bcaps/acre had 21% infestation compared to 26% for plots with 32 bcaps/acre and 32% for untreated controls. Methyl butenol at 50 bcaps/acre, therefore, provided the best protection of spruce stands in this study.

The study was repeated in 1994 using ipsenol, methyl butenol, verbenone, and trans verbenol at 25 bcaps per acre. Four 1/2 acre treatment plots and one untreated control plot were replicated on two different sites. Each plot was baited with six ipsdienol bcaps to attract Ips beetles.

Summary: Protection of white spruce stands using the four behavioral chemicals was not successful because of inadequate beetle pressure in treated and untreated control plots. It was concluded that the ipsdienol bcaps did not attract beetles as other trap out applications by the Alaska Division of Forestry using the same batch of ipsdienol bcaps also did not attract beetles. The source of the bubble caps was Phero Tech. This was not the first time defective baits were purchased from Phero Tech.

Future Actions/Recommendations: There were no significant differences between treatments and check trees because beetle pressure was too light to demonstrate treatment effects. The study will be repeated in FY95 using ipsdienol dispersed in polyethylene vials as an attractive source for beetles. These will be prepared in the lab at Fairbanks.

Ips pini

Project: Preventing attack of pine slash by *I. pini* in northern Idaho and Montana.

Cooperators: Ken Gibson, R1; Ladd Livingston, Idaho Dept. of Lands

Funding: TDP

Summary: Our objective was to prevent overwintering populations of *I. pini* from infesting ponderosa pine slash by using ipsenol (50/50) and verbenone (86/14) bubble caps. The treatments consisted of 0,5,10, and 15 pairs of bubble caps, replicated four times in both Montana and Idaho. The treatments were applied in April and evaluated in June after monitoring had indicated that the flight of the population had ended. Results are as follows:

	Average number of attacks/sq. foot of bark	
Treatment	Montana	Idaho
Check	8.2	7.3
5 Pair	2.5	4.5
10 Pair	3.4	2.6
15 Pair	1.3	6.2

The Montana replicates show a general treatment effect, while the Idaho treatments do not, since the strongest treatment (15 pr.) shows no difference from the check.

Future Action/Recommendation: Test other enatiomeric ratios.

Project: Effects of overstory density on *Ips pini* brood production in ponderosa pine slash in northern Arizona

Cooperators: Jill Wilson, R3; and Mike Wagner and Jaime Villa-Castillo, Northern Arizona University

Funding: Northern Arizona University and FPM S&TA

Summary: The purpose of the project is to evaluate effect of overstory density on *Ips pini* population dynamics in ponderosa pine slash. The effects of four thinning intensities were examined. Measurements were taken on both physical and insect attributes: heat flux density, light intensity, log moisture (top and bottom), *Ips* attack and egg gallery density, Ips egg and larval gallery lengths, and *Ips* productivity (ratio of brood emergence and attacks). All the *Ips* variables were measured on both the top and bottom of the logs.

Overstory density had a dramatic impact on insect population attributes. Adult emergence to attack ratio indicates that slash exposed to overstory density of 60 sq. ft. of basal area (BA) would result in declining populations of *Ips pini*. Higher levels of overstory also reduced populations in the top of logs but not in the bottom. Slash in unthinned stands (BA = 130 sq. ft.

approximately) was equally attacked on the top and bottom of logs. Exposure of slash to direct sunlight with low or no overstory may be an effective strategy to reduce Ips pini populations following thinning.

Future Action/Recommendations: Study continuing.

Project: Effects of slash management practices on Ips spp. brood production in ponderosa pine

Cooperators: Jill Wilson, R3; and Mike Wagner and Victoria Wesley, Northern Arizona University

Funding: Northern Arizona University and FPM S&TA

Summary: This study is evaluating the effects of slash piece size, both diameter and length, on Ips pini and Ips lecontei population dynamics at two locations in southeastern Arizona. Log bolts of two different diameters (4 and 8 inches) were cut into three different lengths (2,4, and 8 feet) in order to test the hypothesis that slash piece size affects Ips brood production. Seasonal production of Ips is measured by the ratio of brood production (emergence) to attack rates.

The 1993 field site was located in an area with Ips pini populations but very low Ips lecontei consequently few data are currently available on Ips lecontei. A second study site established in 1994 supported much higher populations of Ips lecontei and these data should be available by late 1994.

Both log length and log diameter influence Ips pini population parameters. There is also a significant interaction term indicating that the effect of log diameter is dependent on length. Shorter log lengths reduce Ips pini populations. Improved slash treatment recommendations should arise from this study.

Future Actions/Recommendations: Study Continuing.

Ips paraconfusus

Project: The effect of dose on the efficacy of anti-aggregation pheromones for prevention of I. paraconfusus and I. pini colonization of piled ponderosa pine slash.

Cooperators: John Wenz and Sheri Smith, FPM, Stanislaus NF, and Pat Shea, PNW.

Funding: TDP and FIDR

Summary: The tests were conducted in ponderosa pine plantations located on the Groveland RD of the Stanislaus NF. Experimental plots consisting of piled and scattered ponderosa pine slash were created and evaluated before and after antiaggregation pheromone applications. The antiaggregation pheromones were formulated in the standard bubble caps. Lindgren funnel traps were used to monitor ips flight activity to assist in timing application. Treatments consisted of the following:

Piled Slash Experiment
- 0 bubble caps per slash pile
- 5 bubble caps per slash pile
- 10 bubble caps per slash pile

Scattered Slash Experiment
- 0 bubble caps per plot
- 12 bubble caps per plot
- 25 bubble caps per plot

Each treatment in both experiments were replicated 5 times for a total of 15 experimental units per experiment.

The average attacks per treatment for the piled slash experiment were:
- 5 bubble caps/pile - 0
- 10 bubble caps/pile - 0
- 0 bubble caps/pile - 578

The average attacks per treatment for the scattered slash experiment were:
- 12 bubble caps/plot - 0
- 25 bubble caps/plot - 0
- 0 bubble caps/plot - 378

Future Action/Recommendations: After two years of testing it appears that prevention of build-up of Ips paraconfusus in piled ponderosa pine slash is possible by treatment with a combination of verbenone (-86/+14) and racemic ipsdienol. Limited testing of this system will be continued, primarily to find the lowest treatment, i.e. 1-3 bubble caps per pile, at which the treatment fails. It is recommended that a larger scale (pilot test) demonstration of this strategy be conducted in 1995.

Western Balsam Bark Beetle

Project: Interaction of western balsam bark beetle and root diseases in Rocky Mountain landscapes

Cooperators: Bernie Raimo, Pete Angwin, Tom Eager, Dave Johnson, R2

Funding: FHM S&TA

Summary: Although the biology of the western balsam bark beetle is relatively unknown, the importance of this insect is rapidly becoming apparent. It is currently causing large amounts of mortality on a number of landscaped ski areas in Colorado. This project is assessing the impact of the beetle, its interactions with root disease and management techniques which could reduce the beetle's impact.

Future Actions/Recommendations: Basic biological information such as life cycle, semiochemical communication and interactions with natural enemies and other associates is needed.

Project: Western balsam bark beetle flight period study

Cooperators: Matt Hansen, Steve Munson, John Anhold, R4; Utah Department of Agriculture

Funding: S&TA

Summary: This project now has three years of data. Lindgren funnel traps baited with exo-brevicomin were deployed in Big Cottonwood Canyon, Utah at elevations ranging 2350 to 2840 meters. Trap contents were emptied twice weekly from May through October and insects were tallied by species. Flight commenced within a few days of snowmelt - usually early June - and continued into late September or early October depending on weather conditions. Western balsam bark beetles were trapped throughout the season whenever warm and dry conditions (>15 degrees C) were present. Two peaks of flight activity were typically observed though this apparently was influenced by the record weather extremes of each study year. The first and largest peak occurred within two weeks of flight commencement in June. A second peak occurred in August. The first peak was equally represented by males and females while the second peak was dominated by females.

Future Actions/Recommendations: A formal report on this project is in progress.

Project: Endo-brevicomin as a anti-aggregant for western balsam bark beetle.

Cooperators: Utah Department of Agriculture; Matt Hansen, Steve Munson, and John Anhold, R4.

Funding: S&TA

Summary: In 1993, captures from funnel traps baited with exo-brevicomin were compared to traps baited with exo-brevicomin and endo-brevicomin (Pherotech) at locations in Big Cottonwood Canyon, Utah. Overall, bait only traps caught 21,789 western balsam bark beetles while bait with endo-brevicomin traps captured 6,003. Canadian entomologists have found endo-brevicomin to be an effective anti-aggregant when applied at a rate of 100 bubble caps per hectare. FPM tested endo-brevicomin at 25 and 50 caps per hectare to find if lower cost treatments are effective. In May 1994, three replications were established on the Wasatch National Forest in areas currently infested with western balsam bark beetle. Each two hectare block - two treatments and control per replication - were evaluated for insect attack in late September. Preliminary results do not indicate any treatment effect.

Future Actions/Recommendations: Data needs to be statistically analyzed before a formal report can be written. Higher rates may need to be field tested to demonstrate an antiaggregant effect.

Tomicus piniperda

Project: Timing of *Tomicus piniperda* shoot departure in autumn to overwintering sites.

Cooperation: Bob Haack, NC; Rob Lawrence, NC

Funding: FIDR, FPM

Summary: Studies in the fall of 1992 and 1993 at a Scotch pine plantation in northeastern Indiana indicated that adults started departing from shoots in mid- to late October, apparently in response to the first few hard freezes. Practically all adults had vacated the shoots within 4-6 weeks (i.e., by late November to early December). Because this is an apparent response to temperature, beetle departure from shoots is expected to occur earlier at more northern sites, and later at more southern sites.

Future Action/Recommendations: Based on these results, APHIS is now changing the federal quarantine. At present, pine logs from infested areas can be cut and shipped without restrictions from 1 July to 31 October. This will likely be shortened to 1 July to 30 September. However, when *Tomicus* moves further north, 30 September may no longer be safe enough. *Tomicus* now occurs along a 300-mile-plus north-south transect. Future plans are to monitor shoot departure at various points along this transect in Michigan and Indiana.

Project: Overwintering behavior of *Tomicus piniperda*.

Cooperation: Bob Haack, NC; Rob Lawrence, NC

Funding: FIDR, FPM

Summary: In various studies during the winter months of 1992-93 and 1993-94, Scotch pine Christmas trees were cut and inspected for overwintering adults. Most beetles were found in short tunnels, in the thick outer bark, at the base of the trees, near groundline. Tunnels often made contact with the inner bark. A few beetles were found in overwintering sites as high as 8-12 inches above groundline. Apparently adults exit the shoots in autumn, walk back to the trunk along a branch, walk down the trunk until they contact soil or litter, and there seek overwintering sites.

Future Action/Recommendations: All work so far has been done on Christmas trees. During autumn 1994, we will determine where adults overwinter on mature red pine trees. This information may be used to set minimum stump heights for winter logging in infested areas, i.e., cut and ship the tree but leave the beetles behind in the stump.

Project: Timing and duration of *Tomicus piniperda* spring flight and its relation to native pine bark beetles.

Cooperation: Rob Lawrence, NC; Bob Haack, NC

Funding: FIDR, FPM

Summary: We monitored spring flight in all six infested states in 1993, but only in Michigan and Indiana in 1994; other cooperators monitored spring flight in Ohio and New York. In both years, Tomicus adults were first captured in alpha-pinene baited funnel traps in March. The threshold for flight is reported to be about 10-12C (50-54F). Also, in both years, the last parent adults were captured in funnel traps in June. Adults caught during late April to June are likely re-emerged parent adults. Native pine bark beetles and their natural enemies (clerids, histerids, and tenebrionids) were first collected in ipsdienol-baited traps about 4-6 weeks after the first Tomicus were collected. In the Great Lakes region, as in Europe, Tomicus is the first pine bark beetle to fly in spring. Tomicus has no known pheromone. Such early flight allows Tomicus to find suitable breeding material (recently cut pine logs, stumps, and branches) without competing with bark beetles that have well-developed pheromone systems (e.g., Dendroctonus and Ips).

Future Action/Recommendations: First flight and the duration of flight will be monitored along a north-south gradient in Michigan and Indiana. First flight will occur later as Tomicus spreads farther northward (e.g., April-June), and conversely it will occur earlier as Tomicus spreads southward (e.g., Dec-Feb).

Project: Tomicus piniperda within-tree attack patterns in red pine and Scotch pine.

Cooperation: Bob Haack, NC; Rob Lawrence, NC

Funding: FIDR, FPM

Summary: Pole-sized red pines and Scotch pines were felled at about monthly intervals during spring and early summer 1994 and allowed to undergo natural attack for 6-10 weeks prior to inspection. Analyses are not yet complete but early observations indicate that Tomicus attacked only the spring-felled trees. On both red pine and Scotch pine, Tomicus colonized the main trunk and the base of many major branches. Seasonal differences in Tomicus and Ips attack patterns were recorded.

Future Action/Recommendations: This study indicates that Tomicus will utilize practically all parts of red pine trees, down to branches that are about 1.5 to 2 inches in diameter. Chipping of larger slash would reduce the amount of breeding material available to Tomicus. The within-tree colonization pattern should be determined for jack pine and eastern white pine.

Project: Fate of Tomicus piniperda when infested Christmas trees are brought indoors.

Cooperation: Rob Lawrence, NC; Bob Haack, NC

Funding: FIDR, FPM

Summary: Tomicus adults overwinter at the base of pine trees. Therefore, infested trees can easily be moved indoors during the Christmas season. In this study, 12 infested Scotch pine trees were brought indoors in early December. Four trees were dissected immediately while the other 8 trees were placed in Christmas tree stands and watered regularly for one month. After one month, 4 of the trees were debarked and the other 4 were placed outdoors and then dissected several weeks later. Several overwintering beetles had constructed galleries and laid eggs while held indoors. Several egg galleries were initiated directly from the overwintering tunnels at the base of the trees. Eggs laid in these trees produced viable F1 adults. All adults, eggs, and larvae died in the trees that were returned to the outdoors. Temperatures in January-February 1994 were very cold; we feel that beetles would have easily survived under more mild conditions.

Future Action/Recommendations: This study indicates that adults do not require a lengthy cold period before becoming reproductively active and it shows that adults will reproduce in Christmas trees while they are held indoors. A needed companion study is to determine where adults overwinter when trees are cut prior to adults departing the shoots and then bound and stacked horizontally until shipping. Many trees are cut 4-6 weeks prior to shipping, being held in the meantime in large cold-storage facilities.

Project: Tomicus piniperda reproduction and shoot feeding in North American pines.

Cooperation: Rob Lawrence, NC; Bob Haack, NC

Funding: FIDR, FPM

Summary: In 1993, reproduction and shoot feeding was monitored in three eastern pines (eastern white, red, jack) and three western pines (limber, ponderosa, western white). Scotch pine, a native host of Tomicus, was used as a control. In 1994, shoot feeding was tested again in eastern white, jack, and red pine. Although variation occurred among species, Tomicus was able to reproduce and shoot feed in all species tested. In general, performance was better in the 2-3 needle hard pines compared with the 5-needle soft pines.

Future Action/Recommendations: Additional North American pine species could be tested. In other studies (see below), Tomicus has been able to reproduce in all species tested (loblolly, slash, longleaf, shortleaf, Virginia, and pitch pines). Tomicus may be able to utilize all North American pines.

Project: Tomicus piniperda reproduction and shoot feeding in North American non-pine conifers.

Cooperation: Rob Lawrence, NC; Bob Haack, NC

Funding: FIDR, FPM

Summary: In 1994, reproduction and shoot feeding was monitored in white spruce, Douglas-fir, balsam fir, and tamarack. Scotch pine was also used and served as a control. Final results are not yet available -- all rearing logs are being re-examined. Early results of the field studies, where Tomicus was able to freely attack logs of each species, showed that Tomicus reproduction was

successful in Scotch pine and white spruce. Attack density was much higher on Scotch pine. Tomicus constructed egg galleries on Douglas-fir, eggs hatched, but larvae eventually died. In no-choice shoot-feeding studies, using caged branches in the field, at least some adults were able to shoot feed and survive for 3-4 weeks on Scotch pine (27 of 100) and white spruce (2 of 100); all died on Douglas-fir, balsam fir, and tamarack. Mortality rates could have been higher than normal due to very warm temperatures experienced during this study (several days of >90F temperatures).

Future Action/Recommendations: This study could be repeated in 1995, using shorter periods of time (1-2 weeks). In Europe, conifers such as Norway spruce are occasionally used by Tomicus for reproduction and shoot feeding. Reproduction in spruce can occur when spruce and pine logs are piled together.

Project: Tomicus piniperda shoot feeding behavior in spring and summer.

Cooperation: Bob Haack, NC; Rob Lawrence, NC

Funding: FIDR, FPM

Summary: In 1994, we monitored 15 Scotch pine Christmas trees in a Michigan plantation for new shoot-feeding attacks. At 2-week intervals from March through November attacked shoots were removed from the trees. Live adults were found in shoots on all sampling dates examined so far (March-September). Adults in shoots during March-May represent parent adults that are shoot-feeding prior to reproduction or who are shoot-feeding after having produced brood galleries one or more times. Most adults encountered in shoots from June onward were probably F1 progeny adults.

Future Action/Recommendations: The fact that adults were found in shoots on all sampling dates during March-May indicates that there is no "beetle-free" period for shipping of pine nursery stock and ornamental pines. The nursery industry had hoped that a beetle-free period could be found so that pine stock could be shipped out of infested areas without any treatments. The fact that new attacks were found on all sampling periods indicates beetles are very active during spring and summer and that they have many opportunities to disperse.

Project: Dose response of Tomicus piniperda to alpha-pinene.

Cooperation: Rob Lawrence, NC; Bob Haack, NC

Funding: FIDR, FPM

Summary: A dose-response study was conducted at 4 sites in 1993 and 1994. Treatments of 0, 1, 2, and 3 (or 4 in 1994) alpha-pinene lures per funnel trap were replicated 4 times at each site. Tomicus adults were caught in all alpha-pinene baited traps. Final analyses are not yet complete but early results suggest that 2-lures/trap attracts significantly more beetles than traps baited with 1 lure. However, using 3 or 4 lures/trap may not result in a significant increase in trap catch over 2 lures/trap.

Future Action/Recommendations: Funnel traps baited with a single alpha-pinene lure are sufficient for survey purposes. If funds are available, two lures per trap would be better, especially in areas of low beetle density. A 3-component lure was used by APHIS in 1993 and 1994. Trap catches need to be compared to see if the added cost of the multi-component lure is justified.

Project: Effect of methyl chavicol on Tomicus piniperda response to alpha-pinene.

Cooperation: Bob Haack, NC; Rob Lawrence, NC

Funding: FIDR, FPM

Summary: A preliminary study was conducted in spring 1994 using funnel traps. Treatments were (1) no lures, (2) one alpha-pinene lure/trap, (3) one alpha-pinene lure and one methyl chavicol dispenser/trap, and (4) one alpha-pinene lure and two methyl chavicol dispensers/trap. These four treatments were replicated four times at each of two sites. Final results are not complete, but early results suggest that methyl chavicol did suppress the trap catch of Tomicus adults somewhat compared with traps baited with alpha pinene alone.

Future Action/Recommendations: This study will be conducted again in 1995. Traps baited with methyl chavicol alone should also be used. Dispensers with known release rates should be used.

Project: Influence of felling date and log exposure on colonization by Tomicus piniperda.

Cooperation: Bob Haack, NC; Rob Lawrence, NC

Funding: FIDR, FPM

Summary: Two studies were conducted to address this issue. First, in 1993, Scotch pine trees were felled at various times from February to July. Logs from these trees were exposed to bark beetle attack and later debarked. Tomicus attacked logs from trees cut from February through May. Highest attack densities occurred in the February-cut logs, which were felled prior to peak adult flight that occurred later in March. Second, at monthly intervals from October 1993 to January 1994, jack pine, red pine, white pine, and Scotch pine trees were felled at a site in Michigan. Logs from these trees were placed either in direct sunlight or in shade, and later debarked and inspected. Final analyses are not yet complete but Tomicus did attack logs from each felling date. Attack densities and brood densities were higher on the shaded logs.

Future Action/Recommendations: These studies indicated that Tomicus can be expected to colonize slash and stumps created during the previous fall and winter as well as slash and stumps created during the spring months. The current policy of APHIS to allow "unrestricted" shipping of pine logs felled after July 1 appears to be relatively safe. Slash created during thinning operations will probably produce more Tomicus adults than will slash after clearcuts.

Project: Genetic patterns among North American Tomicus piniperda populations.

Cooperation: Carol Carter, PNW; Lula Greene, PSW; Jane Hayes, SO; Jacqueline Robertson, PSW; Bob Haack, NC; Rob Lawrence, NC

Funding: FIDR, FPM

Summary: In 1993 and 1994, adults from several sites throughout the infested area were collected and shipped to Carol Carter and Lula Greene for testing. Carol is conducting DNA analyses of the beetles and Lula is doing isozyme analyses. Final results are not yet available but early DNA results suggest that there may have been two separate introductions, one that started in the Ohio area and another that started in the Illinois area. More collections are now being made in Illinois, Indiana, and Michigan to clarify this issue.

Future Action/Recommendations: The ultimate goal of this study is to determine the origin(s) of the beetles that have been introduced to North America. More beetles will be collected in 1994 and 1995 in both the United States and Canada. In addition, beetles are being solicited from several countries in Europe and Asia. DNA from the North American populations will be compared with European and Asian DNA profiles. Knowledge of the origin(s) of our beetles would be valuable in predicting its colonization potential, understanding its behavior, and selecting the proper country for possible importation of biological control agents.

Project: Tomicus piniperda reproduction and shoot-feeding in southern pines.

Cooperation: Wayne Berisford, U-GA; Tom Eager, U-GA/USFS; Dave Nielsen, Ohio State Univ.; Bob Haack, NC; Rob Lawrence, NC

Funding: FIDR, FPM

Summary: During 1993 and 1994, five southern pines were tested as potential hosts for Tomicus: loblolly, slash, longleaf, shortleaf, and Virginia pines. Final results are not yet complete from the 1994 studies. Early results suggest that all five southern pines can be used by Tomicus for reproduction. Similarly, Tomicus appears able to use the southern pines for shoot feeding but it did poorly in the highly resinous slash pine and longleaf pine.

Future Action/Recommendations: These results suggest that if Tomicus becomes established in the South, it should be able to utilize most southern pines. However, it is still unknown how Tomicus will interact with the southern pine bark beetle complex and the much warmer temperatures during winter.

Project: Nematodes associated with Tomicus piniperda.

Cooperation: Ho Yul Choo, UC-Davis (on sabbatical from Korea); Harry Kaya, UC-Davis; Leah Bauer, NC; Bob Haack, NC; Rob Lawrence, NC

Funding: No funds were transferred

Summary: Leah Bauer observed numerous nematodes inside the bodies of Tomicus adults that had been collected from various sites in the Great Lakes region in 1993. Several beetles were sent to the lab of Harry Kaya where they were identified by a visiting scientist from Korea, Dr. Ho Yul Choo, an expert in scolytid-associated nematodes. He identified them as all belonging to the genus Parasitaphelenchus. In a 4 February 1994 letter, Drs. Choo and Kaya said that these nematodes are at best "weak parasites" in bark beetles, and "do not cause much pathology to the beetles."

Future Action/Recommendations: Further studies should be done to record what additional nematodes become associated with Tomicus as it spreads throughout North America. Perhaps other nematode species will be more potent biocontrol agents.

Project: Bluestain fungi associated with Tomicus piniperda.

Cooperation: Gene Smalley, Univ. of Wisconsin-Madison; Bob Haack, NC; Rob Lawrence, NC

Funding: FIDR, FPM

Summary: In 1993, beetles from throughout the six infested states were examined for associated bluestain fungi. From newly emerged F1 adults collected in spring, Gene Smalley isolated Ophiostoma ips, Ophiostoma nigrocarpa, Ophiostoma piceae, Leptographium terebrantis, and Leptographium procerum. All of these fungi are native to North America and are common associates of Ips pini, Dendroctonus valens, and pine root weevils in the genus Hylobius. In a fall 1993 collection of adults from shoots, no Ophiostoma nor Leptographium species were isolated! The main fungus that was isolated from fall-collected was Aureobasidium pullulans. Results suggest that adults acquire their bluestain fungi when moving to overwintering sites near groundline, or when co-infesting logs with other bark beetles.

Future Action/Recommendations: No European fungi were isolated from the Tomicus collected in North America. Apparently, Tomicus has "picked up" the fungi that are commonly associated with midwestern pine bark beetles and weevils. Further isolations should be made as Tomicus spreads throughout North America. Hopefully, Tomicus will not become a vector of the pitch canker fungus.

Project: Chemical ecology of Tomicus piniperda.

Cooperation: Stephen Teale, SUNY-Syracuse; Bob Haack, NC

Funding: FIDR, FPM

Summary: European studies indicate that Tomicus responds most strongly to the terpenes alpha-pinene, delta-3-carene, and terpinolene. Using an electroantennogram technique, these and other host compounds are being tested at SUNY. Studies in Europe have thus far failed to find evidence of pheromones in Tomicus piniperda. Females attack first and therefore would be expected to be the pheromone-producing sex. In 1994, aeration studies were conducted on

Scotch pine logs with no beetles, on pine logs with females, and on pine logs with males. GC-MS analyses revealed peaks unique to females.

Future Action/Recommendations: Studies will continue to determine key host compounds that elicit strong EAG responses, and likewise, studies will continue to determine if there is a pheromone associated with Tomicus piniperda.

Project: Insecticidal control of Tomicus piniperda.

Cooperation: Deb McCullough, Michigan State Univ.; Bob Haack, NC

Funding: FIDR, FPM

Summary: The efficacy of various insecticides to kill shoot-feeding beetles was tested in 1994. Results are still being analyzed. Overall, although some products did provide good protection, none were 100% effective.

Future Action/Recommendations: Additional products will be tested in 1995. These results suggest that insecticides can be used as part of an IPM program but cannot be relied on alone for adequate control of this quarantined insect.

Project: Cultural control of Tomicus piniperda.

Cooperation: Cliff Sadof, Purdue Univ.; Bruce Cummings, IN-DNR; Bob Haack, NC

Funding: FIDR, FPM

Summary: The effectiveness of using trap logs in spring to "trap out" breeding populations of Tomicus was tested in 12 fields of Christmas trees in Indiana in 1994. Early results suggest that deployment of trap logs was very effective in reducing beetle populations in all test sites.

Future Action/Recommendations: Studies in 1995 will evaluate how varying the density of trap logs (logs/acre) affects beetle numbers later in the summer.

APPENDIX A

This appendix shows accomplishments in the 5-year bark beetle plans.

Year 1 represents activities conducted up to and including 1994.

Activities are designated as:

O = Ongoing or work currently in progress
C = Work has been completed
X = When activity was tentatively scheduled; or no work currently being conducted.
D = Project dropped or deferred

MOUNTAIN PINE BEETLE
5-Year Strategy

	YEAR SCHEDULED 1	2	3	4	5	5+
A. Short Term Basic Research:						
1. Aggregation pheromone components						
a. Define, make improvements	X	X	X			
b. Define geographic differences	X	X	X	X	X	
2. Anti-aggregation pheromones components						
a. Verbenone enantiomers	X	X	X			
b. Combinations of other pheromones		X	X	X		
3. Pheromone effects on assoc. species						
a. Competitive displacement		X	X	X		
b. Flight periodicities		X	X	X		
c. Effect on species diversity		X	X	X		
4. Dynamics of endemic populations						
a. Managed stands	X	X	X	X	X	
b. Unmanaged stands	X	X	X	X	X	
c. Epidemic "triggers"			X	X	X	X
5. Beetle dispersal						
a. How far do they fly?	X	X				
b. Distance of pheromone response		X	X	X		
6. Pheromone effects on natural enemies		X	X	X		
7. Attraction to fire-weakened trees			X	X	X	
B. Long Term Basic Research:						
1. Semio-chemical based population monitoring			X	X	X	X
2. Fate of semio-chemicals in environment			X	X	X	X
a. Effect of stand microclimate			X	X	X	
b. Effect of host condition			X	X	X	
3. Fate of semio-chemical adjuvants		X	X	X		
4. Effect of semio-chemicals on non-target organisms		X	X	X		

	1	2	3	4	5	5+
5. Primary host attraction behavior	X	X	X			
6. Population "fitness" (genetics)		X	X	X		
7. Host/beetle interaction relative to semio-chemical response		X	X	X		
8. Biological control				X	X	X
C. Short Term Applied Studies:						
1. Hazard rating systems for all hosts						
a. Managed stands	X	X	X	X	X	
b. Unmanaged stands	X	X	X	X	X	
c. Mature/second-growth stands	X	X	X	X	X	
d. In southwestern ponderosa pine	O					
2. Short-term modeling (expert system)			X	X	X	
3. Verbenone evaluations						
a. Aerial--Dose, formulation	X	X	X	X		
b. Bubble caps--Dose, formulation	X	X	X	X		
c. Individual tree protection		X	X	X	X	
d. Where do "dispersed" beetles go?			X	X	X	X
D. Long Term Applied Studies:						
1. Trap-out strategy--is it viable?			X	X	X	X
1a. Push-pull strategy	O					
2. Semiochemical-based population monitoring			X	X	X	X
3. Stand management based on stand micro-climate/beetle biology inter-actions				X	X	X
4. Silvicultural treatments						
a. Unevenaged management		X	X	X	X	
b. Ecosystem management		X	X	X	X	X
5. Model development and validation						
a. Western Pine Bark Beetle Model (ESSA)			X	X	X	X
b. PROGNOSIS variant			X	X	X	X
6. Operational "decision support system"				X	X	X

	1	2	3	4	5	5+
E. Operational Activities:						
1. "How To" publications		X	X	X		
2. Sanitation/Salvage effectiveness	X	X	X			
3. Individual tree protection alternatives		X	X	X	X	
4. Silvicultural treatment effectiveness						
a. Demonstration areas-thinning plots	O	X	X	X	X	
b. Effects in various hosts	X	X	X	X		
5. Bait and cut effectiveness	X	X	X			
6. Spray and bait effectiveness		X	X	X		
7. Evaluate hazard-rating systems	O	X	X	X		
8. Evaluate/refine loss prediction model(s) for all hosts	X	X	X	X		

WESTERN PINE BEETLE
5 Year Strategy

	YEAR SCHEDULED					
	1	2	3	4	5	5+
A. Short Term Basic Research:						
1. Beetle Dispersal						
a. How far do they fly	X	X				
b. How far is pheromone response effective	X	X				
2. Aggregation and Antiaggregation Pheromones						
a. Define pheromone spectra	X	X				
b. Determine dose responses to verbenone, ipsenol& ipsdienol		X	X	X		
c. Determine optimal release rates and temperatures			X	X	X	X
d. Determine nontarget effects particularly natural enemies	X	X	X	X	X	X
e. Determine geographical variation in response to pheromones		X	X	X		
3. Biology						
a. Determine host selection behavior		X	X	X		
b. Explore host/prey interactions			X	X	X	X
B. Long Term Basic Research:						
1. Aggregation and Antiaggregation Pheromones						
a. Host/insect interactions relative to semiochemical responses	X	X	X	X	X	X
2. Biology						
a. Natural controls						
1. importation, augmentation, conservation	X	X	X	X	X	X
b. Behavior						
1. primary attraction			X	X	X	X
3. Determine the impact of WPB caused tree mortality on threatened and endangered species	X	X	X	X	X	X

	1	2	3	4	5	5+
C. Short Term Applied Studies:						
1. Aggregation and Antiaggregation Pheromones						
a. Efficacy of verbenone treatments						
1. field bioassay of different enantiomers	X	X	X			
2. Field bioassay of verbenone plus aggregation pheromone of competative species		X	X	X		
3. Different release rates			X	X	X	
4. Individual tree protection						
a. efficacy		X	X	X		
b. develop operational release device			X	X	X	
5. Effects on nontargets such as natural enemies		X	X	X	X	
6. Area protection						
a. efficacy			X	X	X	X
b. develop operational release devices			X	X	X	X
b. Efficacy of combination of protective sprays and baits						
1. determine optimum density of treatment centers		X	X	X		
2. effects on nontargets such as natural enemies		X	X	X	X	X
c. Efficacy of combination of baits and infested tree removal						
1. use of baits to prevent dispersal of overwintering populations			X	X	X	X
2. determine optimum density of treatment centers				X	X	X
3. effects on nontargets such as natural enemies				X	X	X
4. quantify "spillover" around baited centers			X	X	X	X
2. Silviculture or Stand Conditions						
a. Treatments						
1. trap trees	X	X	X	X	X	
b. hazard rating	X	X	X	X	X	

	1	2	3	4	5	5+
D. Long Term Applied Studies:						
1. Aggregation Pheromones						
a. Beetle monitoring systems						
1. optimum trapping density and pattern	X	X	X	X	X	X
b. Trap out strategy for low level populations						
1. optimum trap/density pattern	X	X	X	X	X	X
2. effects on nontarget organisms such as natural enemies	X	X	X	X	X	X
2. Silviculture or Stand Conditions						
a. Efficacy of thinning	X	X	X	X	X	X
b. High risk tree removal	X	X	X	X	X	X
c. Efficacy of stand fertilization	X	X	X	X	X	X
d. Influence of pruning	X	X	X	X	X	X
3. Impacts						
a. Loss and impact predictions	X	X	X	X	X	X
b. Growth and yield models	X	X	X	X	X	X
4. Role of WPB caused mortality on creating and maintaining critical wildlife habitat	X	X	X	X	X	X
E. Operational Activities:						
1. "How to" series of publications		X	X	X	X	
2. Sanitation/Salvage efficacy	X	X	X	X	X	X
3. Protective sprays for individual trees - identify new materials			X	X	X	X
4. Use of Antiaggregants	X	X	X	X	X	X
5. Develop data visualization sequence	X	X	X	X	X	X

ROUNDHEADED PINE BEETLE
5 Year Strategy

	YEAR SCHEDULED					
	1	2	3	4	5	5+
A. Short Term Applied Studies:						
1. Aggregation Pheromone						
a. optimum blend	O	X				
b. optimum release rate	O	X				
c. geographic difference in response	O	X				
2. Antiaggregants						
a. optimum blend	O	X	X			
b. optimum release rates	O	X	X			
c. geographic difference in response	X	X	X			
3. Dispersal						
a. flight periodicity	X	X				
b. flight distance		X	X			
c. pheromone effective distance			X	X		
4. Develop Hazard and Risk Models			X	X	X	
5. Determine Outbreak Triggers		X	X			
-site/stand factors assoc. with occurance		O				
6. Model Integration						
a. loss and impact prediction				X	X	X
b. growth and yield model				X	X	X
7. Association with other insects and pathogens	X	X				
8. Effects of outbreak on:						
a. stand structure and composition	X	X				
b. MSO habitat	X	X				
c. biodiversity	X	X				
d. visual quality			X	X		

	1	2	3	4	5	5+
B. Long Term Applied Studies:						
1. Aggregation Pheromones						
a. population monitoring						
1) effective number of traps			X	X	X	X
2) trap placement			X	X	X	X
b. trap-out						
1) release rates			X	X	X	X
2) trap placement			X	X	X	X
c. bait and cut						
1) spot treatment			X	X	X	X
2) area-wide effects			X	X	X	X
2. Antiaggregants						
a. stand/area-wide protection				X	X	X
C. Operational Activities						
1. Silvicultural Treatments To Reduce Risk/Hazard						
a. unevenaged regeneration			X	X	X	X
b. evenaged regeneration			X	X	X	X
c. thinning			X	X	X	X

JEFFREY PINE BEETLE
5 Year Strategy

	YEAR SCHEDULED					
	1	2	3	4	5	5+
A. Short Term Basic Research:						
1. Determine flight periodicty		X	X	X		
2. Identify, isolate, and sythesize aggregation and antiaggregation phermones	O	X				
3. Field bioassay phermones		X	X	X		
4. Determine insect/pathogen interactions	O	X	X	X		
5. Determine geographical variation in response to pheromones		X	X	X		
6. Determine natural enemies	X	X	X			
B. Long Term Basic Research:						
1. Dispersal-- How far to beetles fly?	X	X	X	X	X	X
2. Host/insect/pathogen interaction	X	X	X	X	X	X
3. Role of associated species relative to semiochemical complex	X	X	X	X	X	X
4. Role of primary attraction in beetle behavior and host selection	X	X	X	X	X	X
5. Effects of JPB caused mortality on decreasing critical wildlife hab.	X	X	X	X	X	X
C. Short Term Applied Studies:						
1. Develope hazard rating system	X	X	X			
2. Test efficacy of 'bait and cut'		X	X	X		
3. Pilot test thinning and pruning (ie Toiyabe NF 1988)	X	X	X			
4. Test individual tree protection treatments (phermones/insecticides)	X	X	X			
5. Pilot test Sanitation/Salvage Treatments (ie LTBM campgrounds)	X	X	X			
6. Effects of hazard tree removal on area mortality	X	X	X	X		
7. Develope antiaggregation strategies for mortality reduction		X	X	X		
8. Effects of combining antiaggregation strategies with pheromones of competitors			X	X	X	
9. Test efficacy of fertilization	X	X	X			
10. Test efficacy of trapout strategy		X	X	X		
11. Removal of currently infested trees	O					

	1	2	3	4	5	5+
D. Long Term Applied Studies:						
1. Develop silvicultural strategies	X	X	X	X	X	X
2. Develop long term pheromone based monitoring system	X	X	X	X	X	X
3. Role of pathogens in beetle attack/ host selection behavior	X	X	X	X	X	X
4. Role of natural enemies in the population dynamics of JPB	X	X	X	X	X	X
5. Develop population dynamics model coupled to growth and yield	X	X	X	X	X	X
6. Role of JPB in creating and maintaining unique wildlife hab. (snags, down woody material etc)	X	X	X	X	X	X
7. Establish demostration sites for documenting changes in vegetative structure, pre to post JPB events	X	X	X	X	X	X
E. Operational Activities:						
1. How to's			X	X	X	X
2. Sanitation salvage	X	X	X	X	X	
3. Demonstrate hazard rating system			X	X	X	
4. Demonstrate area effects of hazard reduction		X	X	X	X	
5. Develop data visualization series			X	X	X	

SOUTHERN PINE BEETLE
5 Year Strategy

	YEAR SCHEDULED 1	2	3	4	5	5+
A. Short Term Basic Research:						
1. Host-tree/insect interactions						
a. determine responses important to resistance to SPB attack and brood development in plantation-grown loblolly pine across a range of stand and site conditions	C	X	X			
b. mechanisms of tree response to attack and fungal inoculation	O	X				
2. Determine the role of natural enemies in the population dynamics of SPB						
a. determine which natural enemies cause substantial mortality of SPB						
1. numerical and functional response from clerids	C	X	X			
2. clerid SPB/IPS switching	C	X				
b. identify and isolate parasitoid host-detection cues	O	X				
c. determine seasonal dynamics of natural enemies	O	X				
3. Identify beetle characteristics (environmental or gentically-based) that indicate SPB population fluctuations.						
a. develop a continuous (artificial) rearing technique	O	X	X	X		
4. Investigate the role of symbiotic associates of SPB/beetle quality in SPB population dynamics.						
a. lipid-fungal associates	D	X				
b. effect on beetle of nematodes	O	X	X			
c. valid annosum/SPB associate	C					

	1	2	3	4	5	5+
5. Develop and improve technology to predict changes in insect populations in space and time.						
a. Winter biology-seasonal dynamics	C					
b. Movement model						
1. dispersal pattern	C					
2. SPB movement model	C	X	X			
3. definition of SPB population concentration around mass-attacked pine trees	C	X				
4. influence of tree spacing and composition on movement	C	X	X	X		
6. Investigate new prevention & suppression strategies using natural enemies, selective chemicals, and pheromones.						
a. impact of semiochemicals on SPB natural enemies	C					
B. Long Term Basic Research:						
1. Host-tree/insect interactions						
a. environmental conditions	O	X	X	X	X	X
2. Determine the role of natural enemies in the population dynamics of SPB						
a. determine which natural enemies cause substantial mortality of SPB - survey of natural enemy occurrence	O	X	X	X	X	
b. determine if natural enemies are responsible for the initiation or termination of SPB outbreaks	O	X	X	X	X	X
3. Identify beetle characteristics (environmental or gentically-based) that indicate SPB population fluctuations.						
a. identify & determine heritability of characteristic attributes of endemic and epidemic populations	O	X	X	X	X	
b. determine the potential critical relationship of these attributes relative to SPB population dynamics	O	X	X	X	X	
4. Investigate the role of symbiotic associates of SPB/beetle quality in SPB population dynamics.						
a. explore bacterial/viral control	O	X	X	X	X	

	1	2	3	4	5	5+
5. Develop and improve technology to predict changes in insect populations in space and time.						
a. general bark beetle movement model	O	X	X	X	X	X
b. landscape level models	X	X	X	X	X	X
6. Investigate new prevention & suppression strategies using natural enemies, selective chemicals, and pheromones.						
a. identify and evaluate possible SPB biological control agents, include microbial agents and insect natural enemies	O	X	X	X	X	X
C. Short Term Applied Studies:						
1. Develop and improve technology to predict changes in insect populations in space and time.						
a. modification of spot growth model	O	X				
b. clerid/SPB trap prediction scheme	O					
2. Validations						
a. control tactics	O	X	X			
b. prediction models	X	X	X			
3. Management tool						
a. ISPBEX II	C	X				
b. INFORMS	O	X				
c. CLEMBEETLE	O	X				
d. Pine Plantation Hazard Rating	C	X				
4. Investigate new prevention & suppression strategies using natural enemies, selective chemicals, and pheromones.						
a. use of host-based compounds for individual tree protection	C	X				
b. use of semiochemical-based tactics in remedial control						
1. antiaggregation chemicals for SPB	O					
2. SPB and behavioral chemicals	O					
3. push-pull spot strategy	O					

	1	2	3	4	5	5+
5. Use of selective chemicals for remedial control.						
a. evaluation of systemic chemicals for SPB control	X					
6. Influence of RCW habitat management strategies on SPB populations	O	X	X			
D. Long Term Applied Studies:						
1. Validation						
a. SPB Demonstration Area Project	C	X	X	X	X	X

SPRUCE BEETLE
5 Year Strategy

	YEAR SCHEDULED					
	1	2	3	4	5	5+
A. Short Term Basic Research:						
1. Spruce Beetle Dispersal:						
a. How far do they fly?	C	X				
b. How far is pheromone response effective?		X	X			
2. Anti & Aggregation Pheromones:						
a. Determine optimal release rates and temps.		X	X			
b. Geographic differences among spruce beetles		X	X	X		
B. Long Term Basic Research:						
1. Population dynamics & attack behavior of spruce beetle in Sitka spruce.		X	X	X	X	X
2. Effect of semiochemicals on non-target organisms		X	X	X		
3. Effect of semiochemicals on species diversity			X	X	X	X
C. Short Term Applied Studies:						
1. Develop Hazard & Risk Models for Sitka spruce	C	X				
2. MCH Evaluations:						
a. Aerial--dose, formulation	C	X	X			
b. Bubble caps--dose, formulation	C	X	X			
c. Individual tree protection	C	X	X	X		
3. Competitor species pheromone						
a. Use with & without MCH	C	X				
b. Aerial/ground--dose, form.			X	X	X	

	1	2	3	4	5	5+
D. Long Term Applied Studies:						
1. Aggregation pheromones:						
a. Population monitoring--# of traps, trap placement	C	X	X	X		
b. Trapout--release rates, trap placement	C	X	X	X		
2. Silvicultural treatments:						
a. Uneven-aged management			X	X	X	X
b. Thinning and pruning	C	X	X	X	X	X
c. Fertilization	X	X	X	X	X	X
3. Modeling integration:						
a. Loss & Impact Predictions	X	X	X	X	X	X
b. Obtain rec. & aesthetic impact info	C	X	X	X	X	X
c. Wildlife habitat impact info	C	X	X	X	X	X
d. Growth & Yield Models	X	X	X	X	X	X
E. Operational Activities:						
1. Demonstration areas:						
a. Thinning	X	X	X	X	X	X
b. Bait & Cut		X	X	X		
2. "How to" series of pubs.		X	X	X		
3. "Best Management Practices" Guidelines		X	X	X	X	X

DOUGLAS-FIR BEETLE
5 Year Strategy

	YEAR SCHEDULED 1	2	3	4	5	5+
A. Short Term Basic Research:						
1. Dispersal of MCH and related material						
a. Dispersal and fate in air	O	X				
b. Release characteristics of dispensors	O	X				
2. Dispersal Patterns of DF beetle	O	X	X			
B. Long Term Basic Research						
1. Population dynamics						
a. Factors predisposing trees to attack	O	X	X	X	X	
b. Fungi associated with beetle damage	O	X	X	X	X	
c. Natural enemies of DFB	O	X	X			
C. Short Term Applied Studies						
1. Test MCH						
a. Test beads for green tree protection	D	X				
b. Test MCH bubble caps for standing green trees	O	X	X			
c. Develop improved formulation			X	X	X	
d. Effects of MCH on non-target animals		X	X	X		
2. Test mitigants such as MCH in coastal area			X	X	X	
3. Determine usefulness of new attractants	C	X				
4. Develop hazard/risk rating models.	O	X	X	X		
5. Test methods for individual tree protection	O					
6. Develop methods for population monitoring	O	X	X			

	1	2	3	4	5	5+
D. Long Term Applied Studies						
1. Silvicultureal Treatment for management of uneven aged stands		X	X	X	X	
E. Operational Activity						
1. Literature search		X				
2. Popular article		X				
3. Forest Insect Pest Leaflet up-date				X	X	
4. Up-date on DFB management "How To"						
5. Register MCH with EPA	O	X	X			

FIR ENGRAVER
5 Year Strategy

	YEAR SCHEDULED					
	1	2	3	4	5	5+
A. Short Term Basic Research:						
1. Isolate, identify, synthesize pheromone complex	X	X	X			
2. Field bioassay candidate compounds		X	X	X		
3. Determine geographic variation to pheromones		X	X	X		
B. Long Term Basic Research:						
1. Dispersal- How far do beetles fly?		X	X	X	X	X
2. Primary attraction behavior		X	X	X	X	X
3. Host/insect/pathogen interaction						
a. root diseases	X	X	X	X	X	X
b. localized defect due to beetle attack			X	X	X	X
4. Interaction of beetle attacks on triggering latent infections of Indian paint fungus	X	X	X	X	X	
5. Effects of semiochemicals on natural enemies			X	X	X	X
6. Effect of fir engraver caused tree mortality on threatened and endangered species habitat	X	X	X	X	X	X
7. Effect of fir engraver caused tree mortality on creating and maintaining critical and unique wildlife habitat	X	X	X	X	X	X
8. Use of synomones to prevent attack				X	X	X
C. Short Term Applied Studies:						
1. Develop hazard rating system for grand fir/Inland Empire	X	X	X			
D. Long Term Applied Studies:						
1. Develop various semiochemical based management strategies for population manipulation	X	X	X	X	X	X
2. Area management of fir engraver		X	X	X	X	
3. Test trap-out strategy			X	X	X	
4. Develop silvicultural treatments						
a. effect of timing of thinning		X	X	X	X	X
5. Develop pheromone based monitoring system	X	X	X	X	X	X

	1	2	3	4	5	5+
E. Operational Activities:						
1. Develop How to's						
a. Hazard rating systems for California, white & red fir		X	X			
b. Hazard and risk rating systems for Inland Empire.			X	X	X	
2. Silvicultural Treatments						
a. Hazard reduction	X	X	X	X	X	X
b. Sanitation/Salvage	X	X	X	X	X	X
c. Use of trap trees			X	X	X	X

ARIZONA FIVE SPINED IPS
5 Year Strategy

	YEAR SCHEDULED					
	1	2	3	4	5	5+
A. Short Term Basic Research:						
1. Identify bait	X					
2. Identify antiaggregant		X	X			
B. Short Term Applied Research:						
1. Determine optimum bait blend		X				
2. Determine optimum bait release rate			X			
3. Determine flight periodicity		X				
4. Determine optimum antiaggregant blend			X	X		
5. Determine optimum antiaggregant release rate			X	X		
C. Long Term Applied Studies:						
1. Determine outbreak triggers		X	X	X	X	X
2. Determine relationships with stand factors		X	X	X	X	X
3. Develop hazard rating system			X	X		
D. Operational Activities:						
1. Evaluate effectiveness of baited slash in trap-out strategy				X	X	X
2. Evaluate effectiveness of anti-aggregrant in protecting slash piles					X	X
3. Validate and modify slash disposal recommendations	O	X	X			

CALIFORNIA FIVESPINED IPS
5 Year Strategy

	YEAR SCHEDULED					
	1	2	3	4	5	5+
A. Short Term Basic Research:						
1. Determine geographic variation in response to established aggregation and antiaggregation pheromones		X	X	X		
2. Determine response of natural enemies to various pheromones of the CFIB	X	X	X			
B. Long Term Basic Research:						
1. Determine the effects of semiochemical based management strategies on the natural enemy complex		X	X	X	X	X
2. Dispersal- How far do beetles fly?	X	X	X	X	X	X
3. Interaction between CFIB and pine engraver via semiochemicals		X	X	X	X	X
C. Short Term Applied Studies:						
1. Test efficacy of semiochemical based management strategies on prevent CFIB build-up in slash	O	X	X			
2. Test efficacy of a combination of semiochemical based management strategies to prevent build-up of CFIB and pine engraver simultaneiously	O	X	X	X		
D. Long Term Applied Studies h:						
1. Develop pheromone based monitoring system		X	X	X	X	X
E. Operational Activities:						
1. Operation test of antiaggregation efficacy for preventing build-up of ips beetles in slash.				X	X	X

IPS PINI
5 Year Strategy

	YEAR SCHEDULED					
	1	2	3	4	5	5+
A. Short Term Basic Research:						
1. _I. pini_ dispersal:						
a. How far do they fly?		X	X			
b. How far is the pheromone response effective?		X	X			
c. Determine flight periodicity	X	X	X			
be used as a management tool?				X	X	
B. Long Term Basic Research:						
1. Aggregation pheromone blends:						
a. pheromone components	X	X	X	X	X	
b. geographic variation	X	X	X	X	X	
2. Antiaggregation pheromone blends of associated species:						
a. pheromones of different species	X	X	X	X	X	
b. enantiomers	O	X	X	X	X	X
c. geographic variation		X	X	X	X	X
3. Fate of applied semiochemicals in the environment.				X	X	X
4. Determine impact of feeding attacks.			X	X	X	X
5. Determine live host selection behavior			X	X	X	X
C. Short Term Applied Studies:						
1. Continue development of antiaggregants to prevent attack of slash by _I. pini_.						
a. Improve bead formulations	X	X	X			
b. Evaluate bubble caps	O	X				

	1	2	3	4	5	5+
D. Long Term Applied Studies						
1. Development /document silvicultural strategies.						
a. Timing of creation of slash	O		X	X	X	
b. Use of trap trees				X	X	
c. Use of prescribed fire on overwintering adult populations in the duff			X	X	X	
d. Effects of overstory density on brood production in slash	O					
2. Models:						
a. Loss and impact predictions				X	X	X
b. Insect phenology/population dynamics				X	X	X
3. Beneficial role of Ips populations in reducing stand basal area					X	X
E. Operational Activities:						
1. "How to" series publications			X	X	X	
2. "Best Management Practices" Guidelines, update			X	X	X	

IPS PERTURBATUS
5 Year Strategy

	YEAR SCHEDULED					
	1	2	3	4	5	5+
A. Short Term Basic Research:						
1. Ips beetle dispersal:						
a. How far do they fly?	C	X				
b. Do they fly across openings?	C	X	X			
2. Antiaggregation pheromones:						
a. Release rates of ipsenol and methyl butenol (beads & caps)	C	X				
3. Determine characteristics of overwintering sites	X	X				
B. Long Term Basic Research:						
1. Effects of semiochemicals on non-target organisms			X	X	X	
2. Effect of semiochemicals on species diversity			X	X	X	X
3. Interrelationship between spruce beetle and Ips			X	X	X	
4. Effect of budworm defoliation and Ips attack	C	X	X	X	X	
5. Effect of ice/snow breakage on Ips population buildup		X	X	X		
C. Short Term Applied Studies:						
1. Effect of ipsdienol on parasites & predators	X	X				
2. Evaluate efficacy of anitaggregants on Ips populations	C	X				
3. Develop hazard and risk models for white spruce			X	X		
4. Effects of prescribed fire on over-wintering populations in leaf litter of cutover areas				X	X	

	1	2	3	4	5	5+
D. Long Term Applied Studies:						
1. Silvicultural treatments:						
a. Even-aged/unevenaged management				X	X	X
b. Thinning	X	X	X	X	X	X
c. Fertilization			X	X	X	X
2. Models:						
a. Loss and impact predictions				X	X	X
b. Growth and yield models				X	X	X
3. Role of Ips beetle activity on white spruce ecosystem stability			X	X	X	X
4. Beneficial role of Ips populations in reducing stand basal area			X	X	X	X
E. Operational Activities:						
1. Demonstration areas:						
a. Thinning		X	X	X	X	X
b. Fertilization		X	X	X	X	X
2. "How to" series publications		C	X	X	X	
3. "Best Management Practices" Guidelines		X	X	X	X	

WESTERN BALSAM BARK BEETLE
5 Year Strategy

	YEAR SCHEDULED					
	1	2	3	4	5	5+
A. Short Term Basic Research:						
1. Biology						
a. Life history	X	X	X	X		
- Life cycles						
- Geographic & elevational influences on development						
- Attack densities & pattern						
- Brood sizes						
- Symbiotic fungal associations						
- # of generations						
- Re-emergence patterns						
- Hosts						
- Insect associations						
b. Adult flight	O	X	X	X		
- Periodicity						
- Distances						
- Dispersal						
- Orientation						
2. Pheromones						
a. Aggregants						
- How far is response effective	X	X	X	X	X	
b. Antiaggregants						
- Define	X	X	X			
B. Long Term Basic Research:						
1. Biology						
a. Predators & Parasites	X	X	X	X	X	X
- Define						
- Effect						

	1	2	3	4	5	5+
2. Host/WBBB Interactions						
a. Root disease associations	O	X	X	X	X	X
b. Habitat type associations	X	X	X	X	X	X
c. Climate/weather associations			X	X	X	X
d. Host response to attack	X	X	X	X	X	X
e. Susceptibility to attack	X	X	X	X	X	X
- tree size						
- tree age						
- stand density						
- stand damage						
C. Short Term Applied Studies:						
1. Treatments						
a. Increase stand vigor & susceptibility to attack through fertilization.	X	X	X	X		
b. Thinning	X	X	X	X	X	
c Pruning	X	X	X	X	X	
d. Insecticides		X	X	X	X	
- Identify						
- Develop application techniques						
2. Pheromones						
a. Mode of application -						
- Aggregants	X	X	X	X		
- Antiaggregants			X	X	X	
b. Strategies for population management.						
- Trap out			X	X	X	
- Lethal traps			X	X	X	
- Bait & cut			X	X	X	
c. Population monitoring			X	X	X	
3. Impacts						
a. Economic				X	X	
b. Changes in stand density			X	X	X	
c. Changes in species comp.			X	X	X	
d. Changes in snow retention				X	X	X
D. Long Term Applied Studies:						
1. Develop hazard rating scheme			X	X	X	X
2. Develop silvicultural techniques to reduce stand hazard				X	X	X
3. Model development					X	X
4. Expert system					X	X

E. Operational Activities:

	1	2	3	4	5	5+
1. "How to" series of publications			X	X	X	X
2. Sanitation/Salvage methodology			X	X	X	X
3. Trap trees		X	X	X	X	
4. Hazard tree removal			X	X	X	X
5. Insecticide treatment individual tree protection				X	X	X
6. Silvicultural treatments				X	X	X
7. Bait & cut strategies				X	X	X
8. Data Visualization Series			X	X	X	X

TOMICUS PINIPERDA
5 Year Strategy

	YEAR SCHEDULED					
	1	2	3	4	5	5+
A. Short Term Basic Research:						
1. Life History of T. piniperda in the United States						
a. Overwintering behavior	O	X	X			
b. Flight activity/periodicity	O	X	X			
c. Reproduction, brood development, and re-emergence	O	X	X			
d. Identify fungal associates	O	X				
e. Determine internal pathogens	O	X	X			
f. Determine predators & parasites	O	X	X			
g. Determine within-tree attack pattern.	O	X				
h. Determine survival in cut Christmas trees	O		X	X		
B. Long Term Basic Research:						
1. Life History of T. piniperda						
a. Determine host-selection behavior	X			X	X	X
b. Determine interactions with native bark beetles	O	X	X	X	X	X
c. Determine dispersal potential				X	X	X
d. Determine genetic similarity among different US sub-populations	O	X	X	X	X	
2. Evaluate Ability to Shoot-feed and Reproduce in Native Conifers						
a. Describe shoot-feeding behavior in Scotch pine and native conifers	O	X	X	X		
b. Describe reproduction in Scotch pine and native conifers	O	X	X	X		
c. Describe ability to attack and kill live North American conifers			X	X	X	

	1	2	3	4	5	5+
C. Short Term Applied Studies:						
1. Develop Survey/Trapping Methodologies						
a. Determine attraction to alpha-pinene	0	X				
b. Determine radius of attraction of alpha-pinene lures		X	X			
c Develop use of trap trees as a survey tool		X	X	X		
d. Develop methods to estimate population levels using shoot-feeding damage		X	X	X		
2. Develop Control Tactics						
a. Develop methods to prevent within and between-stand spread	0	X	X	X		
b. Determine effectiveness of insecticides for control	0	X	X			
c. Determine effectiveness chipping and tarping for control	X	X	X			
d. Determine effectiveness of verbenone		X	X	X		
e. Evaluate shoot feeding behavior for timing nursery stock shipment	0					
f. Determine effect of methyl chavicol	0					
D. Long Term Applied Studies:						
1. Develop Impact Studies		X	X	X	X	X
2. Develop Silvicultural Strategies						
a. Timing of logging operation		0	X	X	X	
b. Slash treatment		0	X	X	X	
c. Use of trap trees		0	X	X	X	
d. Handling methods for infested logs			X	X	X	X
E. Operational Activities:						
1. Develop Best Management Practices			X	X	X	
2. Develop "How To" publications			X	X	X	
3. Produce slide/tape series			X	X	X	
4. Develop a compliance program		0				