

Reply to: 3400

Date: June 5, 1996

Subject: Bark Beetle Steering Committee Report

To: Bark Beetle Steering Committee

Enclosed is the report for the Bark Beetle Steering Committee meeting held in Stateline, NV last fall. The report is in three sections. The first six pages contain a summary of the meeting and accomplishments. The middle section contains the summaries of many of the individual projects; (my apologies to Barb - I goofed on the MPB section so only the first project summary made it through the printing; the complete summary of MPB projects is included as an insert). The third section is an update of the accomplishments and activities in the 5 year strategies for each of the beetles.

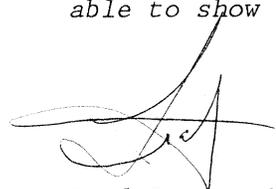
-and includes
IPSP in
section

Activity was reported in at least some area for all of the bark beetle strategic plans and included work in population dynamics, development of models and risk rating systems, short term management strategies for protecting high value stands or individual trees, and adapting the roles of bark beetles to achieved desired conditions. Almost all projects involved one or more cooperators, including Forest Service Research, FHP, National Forest System, State Agencies, universities, and private industries. Funding, or services in kind, also came from a variety of sources (see graph on page 4).

One suggestion during the meeting was to include a summary of publications and reports that have resulted. For the next meeting, plan to provide a list of publications and reports from 1994 on, and those will be included.

The next meeting of the Bark Beetle Steering Committee is currently scheduled for the week of September 23, 1996, in Kenei, AK. If you have not already received some of the preliminary information that Ed has provided, please contact him at (907) 586-2573, or you can contact me at (503) 326-6680.

Thank you all for the work that you have done. Your efforts and commitment to working together have made this Steering Committee a success, and we have been able to show very important accomplishments.



Iral Ragenovich
Chair, Bark Beetle Steering Committee

**REPORT OF THE 1995 BARK BEETLE
STEERING COMMITTEE
MEETING**

October 24-26, 1995

Stateline, NV

CONTENTS

Report of the 1995 Bark Beetle Steering Committee Meeting	1
Summaries of the 1995 Bark Beetle Projects	7
Mountain Pine Beetle	7
Western Pine Beetle	8
Southern Pine Beetle	9
Jeffrey Pine Beetle	17
Roundheaded Pine Beetle	18
Ips pini	20
Western Balsam Bark Beetle	21
Douglas-fir Beetle	22
Spruce Beetle	27
Tomicus piniperda	33
Other	37
Appendix - Accomplishment of 5 Year Strategies	1A
Mountain Pine Beetle	2A
Western Pine Beetle	5A
Roundheaded Pine Beetle	8A
Jeffrey Pine Beetle	10A
Southern Pine Beetle	12A
Spruce Beetle	16A
Douglas-fir Beetle	18A
Fir Engraver	20A
Arizona Five Spined Ips	22A
California Five Spined Ips	23A
Ips pini	24A
Ips perterbatus	26A
Western Balsam Bark Beetle	28A
Tomicus piniperda	31A

REPORT OF THE 1995 BARK BEETLE STEERING COMMITTEE MEETING

October 24-26, 1995
Stateline, NV

The 1995 National Bark Beetle Steering Committee meeting was held October 24-26, in Stateline, NV. Attending were: Iral Ragenovich, Chair; Dave Bridgwater, R6; Ralph Thier, R4; Tom Eager, R2; Steve Clarke, R8; Warren Webb, OSU; Ken Gibson, R1; Ladd Livingston, IDL; Josep Riba, PSW; Patrick Shea, PSW; Mark Schultz, R3; Robert Borys, PSW; Skeeter Werner, PNW; Gary Daterman, PNW; Barbara Bentz, INT; Darrell Ross, OSU; Dave Thomas, WO; Jill Wilson, R3; and John Wenz, R5.

Status of MCH Registration: Dave Thomas, WO, reported on the status of MCH registration. In 1992, following his attendance at the meeting in Salt Lake, Dave had been optimistic about working with EPA to get MCH registered. Lonnie Sower, PNW, provided assistance in preparing the MCH registration package. EPA has been non-responsive, often going over a year before responding and requesting additional information that was already included in the original registration package that was submitted. All of the information and studies that EPA requested have been provided. Both technical and formulated registrations are being pursued together. Technical and formulated registration differs. A product can have a technical registration, but it must also have be registered in a formulated form (dilution and device) before it can be used. The Forest Service will grant its technical registration, and allow a "Me too" registration to anyone who is interested in submitting a MCH formulation. Pherotech has a "Me too" registration submitted with our technical MCH package. There has been a reorganization in EPA and with the increased emphasis on biopesticides; Dave was optimistic that registration may now move forward. It is possible MCH will be registered within 9 months.

Registration of Other Biopesticides: Nancy Rappaport, PSW, will be on a year detail to EPA to work in the area of biopesticides. This will be a significant benefit to us as she is a very competent person and will be a good contact within the office. WO-FPM conducted a biopesticides seminar for EPA in order to increase our visibility since we are one of the major biopesticide users.

The question has been asked regarding whether the Forest Service should be in the registration business. Currently, the FS holds the patent on MCH, but there is only one year left on the patent. The FS also holds the EUP and is pursuing the technical registration of MCH. The FS holds registrations on other biopesticides, such as Gypcheck and TM- Biocontrol-1, as well. We need to register 4aa. The EUP for verbenone is through Pherotech and includes uses for mountain pine beetle, southern pine beetle, and western pine beetle in various formulations. The proposed registration strategy for the Forest Service is that we would continue to register or reregister a pesticide only if no one else is interested. We do not anticipate revising the FS 2150 manual, but will put the FS policy in writing.

Worker protection standards are a very political issue. Many of the worker protection standards, such as re-entry waiting periods, were developed for chemical pesticides and do not necessarily pertain to pheromones.

Funding for conducting supporting research for biopesticides is bleak, and we need to look for opportunities for cooperation in funding. Other sources of funding include IR4, which supports research for obtaining registration of minor use pesticides, NAPIAP, and IPM.

Meeting of the Steering Committee Chairs: Iral reported on a meeting of the Steering Committee chairs. The objective of this meeting was to review the various strategic plans and methods of operation for each steering committee ; identify ways that the committees could operate more efficiently and effectively; and increase communication among the committees. Also, the committees can serve as sources of technical expertise for the WO.

Such aspects as location, scheduling of meetings, membership and voting would be left to the discretion of the committee; but there was opportunity to standardize such aspects as the scope of the committees, evaluation and establishment of project priorities, and a consistent practice of providing service for technical review.

Recommendations from the chairs included:

- Annual coordination of chairs to discuss overlap and share information and reports of committees;
- Promote visibility and outcomes of the Technology Development Program;
- Committee Chairs conduct the review of the TDP;
- Formally present suggestions to the WO for changes to be implemented ;
- Offer to provide services for the technical review of the TDP project proposals;
- Assist in the design and production of an annual report of the TDP;
- Establish a TDP award to be sponsored by the Chairpersons;
- Look at other programs for opportunities for coordination and cooperation.

MESSAGE DISPLAY FOR KEN GIBSON

To beetle work group
CC ross

From: Iral R. Ragenovich:R6/PNW Host: R06C
Postmark: Jun 14,96 4:40 PM Delivered: Jun 14,96 5:35 PM

Subject: Forwarded: Report

Comments:

From: Iral R. Ragenovich:R6/PNW
Date: Jun 14,96 4:40 PM
attached is a correction to the bark beetle report i just sent out.
thanks ~iral~

Message:

From: Dave Thomas:WO
Date: Jun 14,96 2:11 PM
Iral - I received a copy of the BB Steering Committee Report. In my section I would have preferred to say something like " EPA has been nonresponsive in the past, but under the new Biopesticides and Pollution Prevention Division, they have become very responsive." Could you send this note to your members please. Thanks!

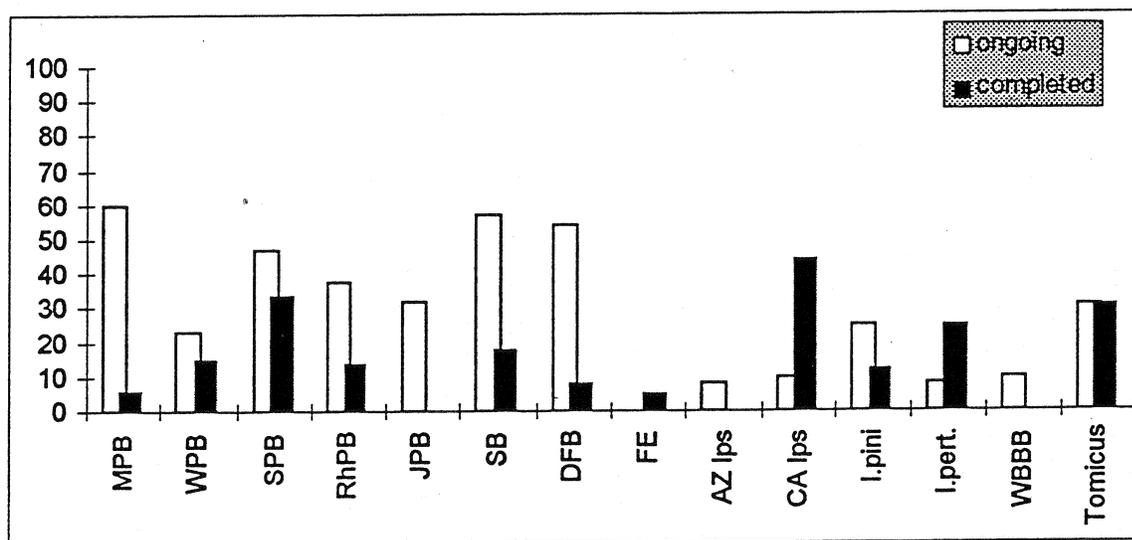
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- Formally report research needs to the Deputy Chief of Research and management leadership teams.

Project Reports: Members reported on the status and progress of bark beetle projects for the last year. Project summaries that were provided, are included. Activity was reported in at least some area for all of the bark beetle strategic plans (see Appendix). Accomplishments have been reported in:

- *** Understanding beetle population dynamics, including pheromone identification and response, which will be useful in developing monitoring techniques and management strategies;
- *** Developing computer models and risk-rating systems to aid in analysis and decision-making;
- *** Developing short term management strategies for protecting stands or individual trees, through beetle population manipulation;
- *** Continuing to refine long-term silvicultural management techniques.
- *** Developing ways to adapt the roles of bark beetles to achieve desired conditions, such as creating wildlife habitat.
- *** Demonstrating our ability to work together in response to urgent situations, such as the introduction of exotic bark beetles, where little information is available

Percentage of accomplishment of items within the 5 year strategies are shown in the following graph



The 5 Year Strategic Plans were developed by members of the Committee. These Plans identified areas of needed research and studies based on existing knowledge, existing strategies and anticipated needs. Completion of these studies is dependent on the availability of insect populations and funding levels. Funding through the Western Bark Beetle RD&A Program, the FHP Technology Development Program; Forest Insect and Disease Research Operating budget, and Forest Health Protection survey and technical assistance has made much of the accomplishment possible.

Funding for projects came from a variety of sources, which demonstrates the cooperative nature of the Bark Beetle Steering Committee's Five Year Strategic Plan. Of the projects included in this report:

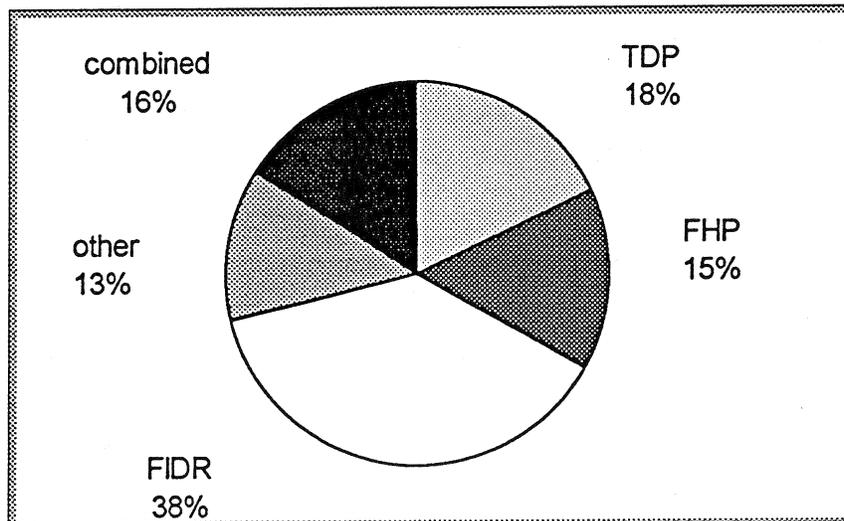
18% were funded by Technology Development

15% were funded by FHP funds

38% were funded by FIDR operating funds

13% were funded by other sources such as university, NSF grant, Southern Global Change grant, etc.

16% were funded by a combination of funds such as TDP, FIDR, FHP, State, APHIS, etc. See chart below.



Over 50% of the projects were funded through FIDR and TDP funding. Concern was expressed and a discussion followed on the continued decrease in Forest Service Research Funding, and TDP funds. Only continuing projects would be funded through TDP for FY96. Most of the short and long term basic research, identified in the bark beetle strategies would be conducted by Forest Insect and Disease Research scientists. This basic research provides the building blocks for the applied and operational aspects of the strategies. Many of the advances over the last 4-5 years in bark beetle technology and information are the result of the Western Bark Beetle Research and Development Program. Achievements in the Western Bark

Beetle RD&D were carried further because they were supplemented by TDP and other funding. Without the FIDR and TDP funding, basic information and the ability to continue accomplishment of the five year strategies would be severely crippled at a point in time when we are near to realizing some very useful management strategies.

Continuing Technology Development Projects: TDP funding would only be available for continuing TDP projects. There were five bark beetle TDP projects that were continuing for FY96. These were:

R1-95-01 - Testing the effectiveness of semiochemicals in preventing attacks by Ips pini in ponderosa pine slash.

R3-95-01 - Mountain pine beetle susceptibility/risk rating in southwest ponderosa pine.

R8-94-01 - Operational use of behavioral chemical for suppression and manipulation of southern pine beetle.

R8-95-01 - Operational use of 4-AA and verbenone for southern pine beetle suppression.

R10-95-01 - Develop and validate a plume model to determine horizontal, vertical, and crosswind movement of eluted semiochemicals in a stand atmosphere; and measure pheromone plumes emitted from standing attacked trees to estimate atmospheric concentrations effective in repelling bark beetles.

The Committee felt that all projects were of value and should continue to move forward in 1996. Due to limitations on available funding, sponsors were encouraged to review projects for any opportunity for reducing costs.

The Committee did not establish priorities for new TDP projects, but agreed to continue working towards accomplishment of the five year strategies where opportunities existed.

Items of Interest: During the discussions of projects, several items of interest were mentioned that do not occur within the project summaries, but bear mentioning.

— During the Douglas-fir beetle/MCH topic there was extensive discussion of deployment of the bubble caps and protecting areas larger than the 2.5 acre, or even the Oregon Trail 20 acre, areas. It was felt that we needed to pilot test going from 2.5 to 200 acres. In order to keep from losing effective concentration in the center of a larger area, lines of bubble caps about 50 meters apart would need to be spaced throughout. MCH does not keep the beetles out of a plot, it just keeps them from

initiating an attack. The beetles are still flying through the area, but do not attack unless a tree is already attacked.

— MCH appears to have no effect on clerids. Darrell is doing a study to determine how best to trap without trapping clerids, using different trapping techniques, composition of lure, and screens. Another study looked at which commercial baits clerids were attracted to. Most were caught with seudenol. There is also a Master's student at Davis that is looking at different bait components and predator catch. In pine, clerids seem to prefer the Ips pheromone. Enoclerus is more attracted to Ipsdienol.

— Work is also being done in using pheromones to create snags by initiating beetle attacks to kill trees. On the trees that were baited, there were an additional 3.5 trees attacked. When baits plus MCH were used, there was only an average of 0.5 additional trees attacked. Woodpeckers were using the trees and it will be interesting to see what wildlife will utilize these tree. Many of the land managers are more interested in the artificial inoculation study that creates living cavity trees. Both approaches are useful, because there are different needs. In the past methods such as dynamiting the tops out of trees, or girdling trees, were used to create snags. Neither of these approaches creates a particularly useful snag. Inducing bark beetles to kill the trees "naturally" allows for the full utilization of the tree by wildlife, and is much less expensive and considerably safer. We need to market these techniques for the various uses of pheromones.

— Pat mentioned that gas chromatograph analysis is expensive, but PSW now has a service contract with Larry Cool of the Forest Products Lab at UC Berkeley. They are able to offer us the service at a very good rate because they have extra equipment.

Members divided into groups and updated the accomplishments in the 5 year strategies for the various bark beetles, and then reported on the status of bark beetles in the various Regions/States. In Alaska, spruce beetle increased in Sitka spruce. Idaho and Montana have Scolytus monticolae killing the tops of Douglas-fir and in the following year DFB is filling in the lower bole. Oregon and Washington have seen an increase in Ips in lodgepole pine. Jeffrey pine beetle is big around the Tahoe Basin area in California, but Scolytus in white fir may be decreasing south of Lake Tahoe. Mountain pine beetle has picked up on the front range of Colorado, but may be decreasing on the north Kiabab in Arizona. Roundheaded pine beetle in the Sacramentos appears to be decreasing in some areas. Southern pine beetle is of low incidence except in Arkansas and north Florida where there is increased activity.

1996 Meeting Site: The 1996 meeting is currently scheduled to be held in Alaska in order to tie in with some of the spruce beetle activities being conducted on the Kenai peninsula. Budgets may affect this and a decision will be made closer to the meeting.

Summary of 1995 Bark Beetle Projects

MOUNTAIN PINE BEETLE

1. PROJECT: Mountain Pine Beetle Susceptibility/Risk Rating in Southwest Ponderosa Pine.

COOPERATORS: Jill Wilson, Borys Tkacz, Region 3; Tom Eagar, Roy Mask, Region 2; John Anhold, Steve Munson, Region 4; Barbara Bentz, John David, Matt Hansen, Jesse Logan, Lynn Rasmussen, Intermountain Station; Ken Lister (Retired Region 2), Gene Amman (retired Intermountain station volunteer), John Schmid (retired Rocky Mountain Station volunteer)

FUNDING: TDP, INT FIDR, FHP

SUMMARY: Project activities this year were focused on three activities: (1) Field sampling designed to detect the spatial structure (degree of clumpiness) of stand attributes, and the way in which this spatial structure effects the probability of successful beetle attack and subsequent tree mortality. (2) Evaluation of weather related events on mountain pine beetle population dynamics and the probability of an outbreak occurring. (3) Development of computer aided systems that integrate diverse information to result in landscape level prediction of susceptibility and risk. Accomplishments for each area (1,2, and 3) are summarized below.

(1) Sampling sites were selected by FPM collaborators in the 3 participating regions. Areas were located in Utah, Arizona and Colorado. Plots were established in 21 areas, 10 in Utah, 6 in Arizona, and 5 in Colorado. A variation on the quadrant-variance approach was used as a sampling method. A variety of site and stand variables and beetle related variables were identified by all the collaborators in April, and were measured on the plots established this field season. A database program, Paradox was selected to store information collected from the field.

(2) A historical database on outbreak events has been set up. This database is intended to eventually include every written historical account of significant mountain pine beetle activity. To date information on over 200 events have been entered. Letters have been sent to many forest entomologists (primarily retired) requesting information, particularly references to obscure or unpublished information. A source for a weather data base (temperature and moisture) has been identified and purchased.

(3) A public domain forest pest Decision Support System, bioSIM, from Dr. Jacques Reginiere, Canadian Forest Service, was obtained. The model MPBmod, developed by INT, has been modified to fit within the BioSIM environment.

FUTURE ACTIONS/RECOMMENDATIONS:

(1) Data collected during 95 will be analyzed for indications of tree/stand attributes associated with tree mortality, and for spatial patterns in distribution of stand attributes that are associated with high risk. Additional sampling sites will be selected for sampling during summer 1996. Photo interpretation of selected sampled sites will be evaluated to determine the potential for remotely sensed spatial analysis of stand attributes.

(2) Important historical events in the regions of interest will be identified. Empirical and model generated data bases will be used to build relevant time series. Analyses of time series generated from data bases will be performed to look for signature patterns that have predictive power for outbreaks.

(3) BioSIM will be used to generate a time series of critical population indices. The model generated data will be analyzed in conjunction with historical weather and outbreak data to look for signature patterns that have predictive power for outbreaks. Additionally the potential for BioSIM to provide the basis for a landscape level risk evaluation tool will be evaluated.

WESTERN PINE BEETLE

1. PROJECT: The effect of dose on the efficacy of a combination of antiaggregation pheromones in reducing mortality of ponderosa pine caused by western pine beetle.

COOPERATORS: Patrick J. Shea, Pacific Southwest Research Station, W. Branham, Silviculturalist, McCloud RD, Shasta-Trinity NF.

FUNDING: FIDR

SUMMARY: This experiment was conducted on the McCloud RD of the Shasta-Trinity NF in an area located about 25 miles east of the city of Mt. Shasta, northern California. It is locally known as the McCloud Flats area and is characterized as mostly pure ponderosa pine lying on the southern easterly slopes of Mt. Shasta. The study involved five replications of six treatments (30 plots): (1) control with no bubble caps(bc) and no baits; (2) control with no bc and baited; (3) 50 bc/acre/no bait; (4) 50

**Mountain Pine Beetle
FY 95
Summary of Projects**

Project: Mountain Pine Beetle Susceptibility/Risk Rating in Southwest Ponderosa Pine.

Cooperators: Jill Wilson, Borys Tkacz, Region 3; Tom Eagar, Roy Mask, Region 2; John Anhold, Steve Munson, Region 4; Barbara Bentz, John David, Matt Hansen, Jesse Logan, Lynn Rasmussen, Intermountain Station; Ken Lister (Retired Region 2 volunteer), Gene Amman (retired Intermountain station volunteer), John Schmid (retired Rocky Mountain Station volunteer)

Funding: TDP, INT 4501, FPM S&TA

Summary: Project activities this year were focused on three activities: (1) Field sampling designed to detect the spatial structure (degree of clumpiness) of stand attributes, and the way in which this spatial structure effects the probability of successful beetle attack and subsequent tree mortality. (2) Evaluation of weather related events on mountain pine beetle population dynamics and the probability of an outbreak occurring. (3) Development of computer aided systems that integrate diverse information to result in landscape level prediction of susceptibility and risk. Accomplishments for each area (1,2, and 3) are summarized below.

(1) Sampling sites were selected by FPM collaborators in the 3 participating regions. Areas were located in Utah, Arizona and Colorado. Plots were established in 21 areas, 10 in Utah, 6 in Arizona, and 5 in Colorado. A variation on the quadrat-variance approach was used as a sampling method. A variety of site and stand variables and beetle related variables were identified by all the collaborators in April, and were measured on the plots established this field season. A database program, Paradox was selected to archive and manage information collected from the field.

(2) A historical database on outbreak events is being developed. This database is intended to eventually include every written historical account of significant mountain pine beetle activity. To date, information on over 200 outbreak events have been entered. A source for a weather data base and management has been identified and purchased.

(3) A generalized forest pest Decision Support System, BioSIM, has been obtained from Dr. Jacques Regier, Canadian Forest Service. The mountain pine beetle life system model MPBmod, developed by INT, has been modified to fit within the BioSIM environment

Future Actions/Recommendations:

(1) Data collected during 95 will be analyzed for indications of tree/stand attributes associated with tree mortality, and for spatial patterns in distribution of stand attributes that are associated

with high risk. Additional sampling sites will be selected for sampling during summer 1996. Photo interpretation of selected sampled sites will be evaluated to determine the potential for remote sensed spatial analysis of stand attributes.

(2) Important historical events in the regions of interest will be identified. Empirical and model generated data bases will be used to build relevant time series. Analyses of time series generated from data bases will be performed to look for signature patterns that have predictive power for outbreaks.

(3) BioSIM will be used to generate a time series of critical population indices. The model generated data will be analyzed in conjunction with historical weather and outbreak data to look for signature patterns that have predictive power for outbreaks. Additionally, the potential for BioSIM to provide the basis for a landscape level risk evaluation tool will be evaluated.

Project: Historical reconstruction of mountain pine beetle infestations in lodgepole pine on the south slope of the Uinta Mountains.

Cooperators: Barbara Bentz, INT; Ashley National Forest, SO, Vernal Utah.

Funding: FIDR

Summary: A field study to describe the long-term role of bark beetle outbreaks on lodgepole pine forests was initiated in August 1995. Preliminary data, in the form of tree cores and wedges, were collected in areas of known bark beetle outbreaks. This data is being used in the development of techniques for describing historical outbreak patterns. Dates of disturbance events can be estimated from tree rings and scars (both beetle and fire), and through cross-dating with an established chronology from the local area to remove climatic signals. Although the data has not yet been statistically analyzed with appropriate dendrochronology software, several patterns have qualitatively been observed. We were able to detect releases in rings from live trees that coincided with known outbreak events. This information provides support for the use of these techniques to describe historical patterns of bark beetle disturbance events in lodgepole pine forests and the interaction of these events with fire. Results from this endeavor will provide personnel on the Ashley National Forest with a reference condition for understanding when and if current bark beetle populations are behaving within the range of historical variability for this disturbance agent.

Future Actions/Recommendations: Continue development of techniques by collecting data for pines, spruce, and fir on additional National Forests. Once techniques are fully developed, intensive transects and data collection should be conducted across the Colorado Plateau in order to understand, at the landscape scale, the ecological role of bark beetles in forest ecosystems.

Project: Life-history strategies of MPB in response to micro-habitat temperature

Cooperators: Barbara Bentz, Jesse Logan, INT; Paul Bolstad, University of Minnesota

Funding: FIDR

Summary: Mountain pine beetle development and associated phloem temperatures were intensively monitored in several geographic regions for 3 generations (3 years). Work associated with this project falls into three categories: (a) **Overwinter survival and cold adaptation.** The largest proportion of individuals observed in the middle of winter were in the 3rd and 4th larval instars, although all instars were present at that time, as well as during the spring and fall. There were no significant differences in supercooling points among the 4 instars, or between north and south aspects of the bole. Supercooling points and associated phloem temperatures suggest that the fall and spring are periods when increased cold-temperature mortality occurs, not during the winter as previously hypothesized. MPB population response to local weather patterns during the 3 years reveal that this non-diapausing insect has enormous capacity for flexibility and adjustment during times of adverse weather conditions. This information is helpful in understanding triggers that cause populations to move from the endemic to epidemic phase. (b) **Field validation of the MPB life-systems model MPBmod.** A preliminary evaluation of the model using field-collected phloem temperatures indicated that the model does a good job of predicting development in all but the 3rd instar. Lab experiments have been conducted to re-parameterize equations for this instar. The MPB life-systems model is being used for ascertaining the importance of weather on historical MPB outbreaks and landscape scale representations/predictions of MPB populations. We were also able to detect a pupal developmental threshold from these data that is between 17°C & 18.5°C. (c) **Analysis of temperature patterns of MPB infested trees.** Phloem temperatures on the north and south aspect of infested and green trees were monitored. This data was used to develop and validate a model for predicting hourly phloem temperatures in infested trees at any point on a complex landscape using daily maximum and minimum from a regional NOAA weather station data. This model provides information necessary to analyze MPB population growth and movement at the larger landscape scale. Analysis of phloem temperature patterns and effects of stand structure on temperatures is in progress.

Future Actions/Recommendations: Continued sampling and monitoring at a reduced frequency in 2 geographic regions (central Idaho, southern Utah), and an additional site in California has been added for the 95-96 generation. Perform lab experiments to more fully understand the complex patterns of MPB response to cold temperatures. Design and conduct experiments to provide a more accurate representation of low temperature mortality based on cold-hardening capabilities. These results will be used for refinement of mortality predictions in the MPBmod life systems model

Project: PC-INDIDS

Cooperators: Barbara Bentz, INT; Dawn Hansen, FPM R4; Dayle Bennet FPM R4

Funding: FPM R3, R4; FIDR

Summary: The Insect and Disease Survey System (INDIDS) is a computer program residing on the Forest Service Data General computer system. The system was developed in the early 1980's to provide NFS Ranger District and FPM personnel a means to summarize insect and disease stand survey information. The person who originally developed the program has retired, and without a manager the program has become outdated. Additionally, because USFS personnel are beginning to use PCs for computing needs, and many state and private personnel who do not have access to the DG would like to use the program, a PC version of the program was developed. A DOS version is available for limited dispersal and testing, and a Windows version is in preparation.

Future Actions/Recommendations: Finalize system and write users manual. Incorporate additional requests for modifications to current PC program.

Project: Mountain Pine Beetle Modeling Activities.

Cooperators: Jesse Logan, Barbara Bentz, Jim Powell (Utah State University), Peter White (Utah State University), Jacques Réginère (Forestry Canada), Paul Bolstad (University of Minnesota)

Funding: FIDR

Summary: Modeling activities are central to many of the research activities of the Mountain Pine Beetle Project. In addition, some of these models may in themselves become end products of technology transfer. Modeling efforts involve 4 major efforts:

(a) *MPBmod* is a phenologically based life systems model for the mountain pine beetle. It was developed as a research tool for evaluating the role of weather related events on the population performance of MPB and to assist in the prediction of outbreak risk. The model explicitly includes the temperature driven developmental rates for each life stage, temperature driven recruitment, and winter related cold mortality. Model output includes population density distributions for all life stages and for designated number of years.

(b) **Weather landscape model.** We have developed a regionally specific model that is capable of projecting temperature profiles for any digitally described landscape. The temperature projection model is based on elevation, slope and aspect. Geographically specific regional parameters for the model can be estimated from historical data. The model is fully described in Bolstad, et al. (submitted). Landscape coverage is accomplished by interfacing the model with available DEM's (Digital Elevation Model, available from USGS) through a GIS. The GIS

provides (1) automated input of driving variables for the model, and (2) an automated map of output temperature coverage. In turn, weather model output provides driving variable input for *MPBmod* through *BioSIM* protocols (see below). Initial model validation was accomplished using temperature data from our long-term phenology sites.

(c) *BioSIM* is a generalized Decision Support System (DSS) specifically designed to address the non-trivial problems projecting insect model predictions across complex landscapes. Through *BioSIM*, we are able to produce map coverages of critical MPB population indices for designated landscapes. These capabilities are allowing us to: (1) Use the system to generate long-term time series of key population performance indices for subsequent time series analysis.

(d) **Models of spatial dynamics.** The spatial dynamics of bark beetle movement are particularly interesting because of the complex chemical ecology that in large part determines the patterns of attack and tree mortality. The classical approach to modeling spatial dynamics of highly mobile organisms is through reaction/diffusion equations. We, in conjunction with collaborators in the Departments of Mathematics and Forestry at Utah State University, have formulated a system of Partial Differential Equations (PDEs) that attempts to capture the essential components of the spatial dynamics and semiochemistry ecology of mountain pine beetle. Unfortunately, in mathematical terms, this model is relatively complex and poses significant computational difficulties. As a result, we have successfully projected the global PDE model to a local ordinary differential equation model with finite dimension. This advance is important for three reasons: (1) The local model is computationally simple enough to allow solutions on a mid range PC. Pine beetle ecologists are, therefore, able to game with the model without prohibitive investment in computer equipment. (2) Most field observations are made on a tree, not forest, level. The local projection model, therefore, substantially enhances use of published literature for parameter estimation. (3) The projection method generalizes to more than one tree (Powell, work in progress), which may allow us to include both spatial complexity and spatial dynamics in future models. Preliminary simulations with the simplified model have resulted in potentially important insights into MPB ecology with unambiguous management implications. For example, one **model** result is that thinning to some stocking levels actually increases risk. Intensive field experiments during beetle flight in August 1995 were conducted to gather data for validation and parameterization of the model.

Future Actions/Recommendations:

(a) *MPBmod*. (1) Refinement of the cold mortality section based on analysis of cold hardening experiments. (2) Continued validation of phenology/seasonality based on analysis of field sampled data of life stage distributions.

(b) **Weather landscape model.** Validation of predictions from: (a) data from phenology field studies; (b) high resolution weather stations on Railroad Ridge.

(c) *BioSIM*. (1) Use capabilities of *BioSIM* to generate time series of population performance indicators. These model generated data, for relevant locations and time periods, will be used in conjunction with historical information of weather and MPB outbreaks for time series analysis of weather related events and outbreak potential. (2) Evaluation of *BioSIM* capabilities for producing landscape coverages of susceptibility and risk rating.

(d) **Models of spatial dynamics.** (1) Continued development of efficient numerical techniques

to solve high dimension, stiff partial differential equation models. (2) Continued research on the mathematics of linking "individual tree" models with spatially distributed resource models.

Project: Pine Beetle Disturbance Ecology of High Elevation Whitebark Pine.

Cooperators: Jesse Logan, Dana Perkins.

Funding: FIDR

Summary: Intensive sampling of whitebark pine demographic attributes was conducted at a high elevation site (Railroad Ridge) in the Whitecloud mountains in central Idaho. The sampled stands are in an area that experienced a severe outbreak of mountain pine beetle in the late 1920's to early 1930's. The occurrence of significant beetle mortality at these elevations pose significant questions with regards to the conventional wisdom of how mountain pine beetle interacts with both its physical and biological environment. Interesting research questions are also centered on the population level response of the host to MPB disturbance. A high-resolution system of four meteorological stations have been established to monitor current conditions and to provide validation data for landscape level modeling efforts.

Future Actions/Recommendations: (1) Continued field sampling of whitebark pine demographic attributes. (2) dendrochronological analysis of long-term weather patterns. (3) Model gaming using historical weather data to help test hypotheses regarding mountain pine beetle outbreaks at high elevation sites.

Project: Mountain Pine Beetle Related Historical Data Bases.

Cooperators: Jesse Logan, John David, Lynn Rasmussen, Bridget Kobe.

Funding: FIDR

Summary: One reason for disappointing performance of many current risk rating schemes is the failure to include beetle population dynamics in the risk rating. Even in highly susceptible stands if beetles are not present, or if environmental conditions are not conducive for population buildup, then the risk is low. Weather related events have consistently been implicated in both the initiation of outbreaks and their collapse. Weather effects are expressed both directly as a determinant of beetle population performance, and indirectly through drought stress on host trees. We are applying time series analysis procedures to address these weather related effects. Progress to date involves the initial work required to develop the required data sets. Three related data bases are currently under development. All data bases are used in other MPB studies, but a more complete description is provided in case they are of interest to other researchers. Any data base will be provided to interested parties in an appropriate PC format.

(1) **Historical data base of outbreak events.** The objective of this data base is to include every written historical account of significant mountain pine beetle activity. This includes informal accounts and/or anecdotal references (e.g. letters), informal reports, insect surveys, and published accounts in the scientific literature. For each event, the data base includes: (1) bark beetle species involved; (2) host species involved; (3) year of record; (4) state; (5) Forest; (6) Ranger District; (7) prominent landmark for location of the site; (8) latitude; (9) longitude; (10) map with outbreak and/or trees delineated (if it exists); (11) number of acres affected; (12) number of trees; (13) population status; (14) control action taken; (15) general comments and notes; (16) citation. All entries are cross listed with an archived hard copy of the record. The information is managed as a PARADOX[®] data base. To date, information on over 200 outbreak events have been entered.

(2) **Weather data base.** The weather data of primary interest are temperature and moisture. We need to have high resolution access capabilities to weather records for large geographic regions over long time periods. This requirement poses substantial data base management problems. Fortunately, due to the universal importance of weather and climate, a great deal of resources have been invested in both the recording and management of weather data. We have identified a local company that provides the data bases and management systems required to generate the time series we need, and have purchased their DBM system.

(3) **Population dynamics data base.** Weather influences are often subtle, and further confounding the issue is the fact that very different weather patterns can result in similar impacts on population performance. What is needed is some means to integrate the annual weather cycle into a metric of population performance. We have developed such a tool in the mountain pine beetle life systems model, *MPBmod* (Logan et al. 1995). This model is a traditional temperature driven phenology/population dynamics model that was specifically developed to represent the impacts of weather on population performance. Through the use of this model we can predict key indicators of population performance for any given annual temperature regime. Therefore, by combining *MPBmod* with the capabilities provided by the *BioSIM* modeling system (Réginière 1995) we can generate long term time series of modeled populations for any weather record at any geographic location. The key variables we are predicting for time series analysis are (1) net population growth rate; (2) synchrony of emergence as measured by the difference between the Julian date of last emergence (95 percentile) and the Julian date of first emergence (5 percentile); (3) percent of maximum potential recruitment that is actually achieved. These model generated population indices will then be used as independent (predictor) variables in time series analysis of observed outbreak events.

Future Actions/Recommendations:

To date we have developed the capabilities to access and manipulate relevant data for time series analysis. Effort in FY96 will be directed toward performing the actual analyses. (1) Identify important historical events in the regions of interest. (2) Use empirical and model generated data bases to build relevant time series. (3) Perform the analysis of time series generated in (2) to look for signature patterns that have predictive power for outbreaks.

bc/acre/baited; (5) 25bc/acre/no baited; 25bc/acre/baited. Bubble caps contained (-)85%/(+)14% verbenone and (+97%)/(-)3% ipsdienol. Each plot was 5 acres in size and was initially baited with western pine beetle tree bait to create an infested center. Plot boundaries (5 acre square plot) were established around these infested centers on each plot. Treatments were randomly assigned to each plot. Brood development was monitored in a subsample of each infested center on half of the plots. When flight of brood from infested centers was estimated to take place over the next two weeks treatments were made. On those treatments that required baited centers, 1 western pine beetle tree bait was attached to a ten foot pole which was placed in the middle of the plot. Preliminary results indicate a clear trend of lowered infestation rates in the treated plots, regardless of whether they were baited or not, compared to the controls.

FUTURE ACTIONS/RECOMMENDATIONS: Continue to test dosages and rate placement of antiaggregation compounds i.e. grided vs circular placement.

SOUTHERN PINE BEETLE

1. PROJECT: Environmental Effects On Pine Tree Carbon Budgets and Resistance to Bark Beetles.

COOPERATORS: Peter L. Lorio, Jr., SO, Richard T. Wilkens, SO/Dartmouth College, Matthew P. Ayres, Dept. Biol. Sci., Dartmouth College.

FUNDING: Southern Global Climate Change Program

SUMMARY: Responses in 1994 to fertilization and thinning treatments applied in 1989 continued to indicate positive effects of thinning on both diameter and height growth of juvenile loblolly pines. Diameter growth is no longer being affected by fertilization, but height growth of codominant trees is responding positively to fertilization in both thinned and unthinned plots. Fertilization reduced resin yield in intermediate trees in unthinned plots and in codominant trees in thinned plots, but not in codominants in unthinned plots. Photosynthesis was apparently unaffected by treatments in 1994. Analyses of ^{14}C tests in September of 1993 (hot and dry) and May of 1994 (warm and moist) indicate a strong shift in carbon partitioning to secondary (e.g., resin) rather than primary metabolites when growth is limited by water deficits (1993). The opposite was indicated under warm and moist conditions in the spring of 1994. Treatment effects were not apparent. Treatments were repeated in the winter of 1995, and measurements will continue to assess short-term effects.

2. PROJECT: Extended Development in the Clerid Beetle Thanasimus dubius.

COOPERATORS: John D. Reeve, SO

FUNDING: FIDR

SUMMARY: A study was initiated to measure the development time of the clerid beetle Thanasimus 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 or even the next year. Dissections of trees vacated by SPB also imply that clerid immatures may be present in these trees long after SPB emergence, in some cases nearly two years after attack by SPB. Current control methods for SPB could be improved by taking this long life-cycle into account. The most commonly recommended technique, "cut-and-remove," in practice often destroys trees vacated by SPB that still contain immature clerids.

3. PROJECT: Predation by Adult Clerids on SPB During Mass Attack.

COOPERATORS: John D. 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 the density of adults clerids on the bark of trees undergoing mass-attack by SPB, and this information was used to calibrate laboratory experiments on pine bolts, where SPB were exposed to a range of clerid densities. At densities commonly observed in the field, adult clerids caused high mortality of SPB, and substantially reduced the number of successful attacks. These results suggest that predation by adult clerids may be a significant source of SPB mortality in nature. In addition, a long-term survey of clerid and SPB numbers shows a strong numerical response by clerid to increases in SPB density, implying this predator may help suppress SPB outbreaks.

4. PROJECT: Long-Distance Dispersal by the Clerid Beetle Thanasimus dubius.

COOPERATORS: John D. Reeve, SO

FUNDING: National Science Foundation grant

SUMMARY: Mark-recapture methodology was used to measure the long-distance dispersal of the clerid beetle Thanasimus dubius, an important natural enemy of SPB. Funnel traps baited with the SPB attractant frontalin were laid out in a 4 km-wide trapping grid in forested habitat, and marked clerids released at the center of the grid and recaptured over a period of several weeks. A passive-diffusion model was then fitted to the data and used to calculate the median dispersal distance of the marked clerids. The results of this experiment indicate that this predator is capable of longer-range dispersal than SPB during its life-span. This finding may have implications for the spatial patterning of SPB infestations.

5. PROJECT: Seasonal Changes in Southern Pine Beetle Flight Potential and Energy Reserves.

COOPERATORS: Jane L. Hayes, Project Leader (for Don Kinn, Retired), and Bernie Parresol, SO

FUNDING: FIDR

SUMMARY: This study examined weight, lipid content, and flight potential of southern pine beetles from natural populations in east Texas and central Louisiana from April 1991 through April 1994. Beetles were paired by gender, one member was flown to exhaustion on a flight mill, and distance and duration were recorded; the control member was weighed and analyzed for total lipid content. To test for seasonality, the control data were aggregated into 4 three-month groupings, based on average temperature trends for central Louisiana, as follows: Nov - Jan, Feb - Apr, May - July, Aug - Oct. Based on analysis of variance (ANOVA) and post-NOVA contrasts, dry weights of beetles differed by monthly groupings and exhibited a cubic trend in both females and males. Total lipid also differed by "season" and exhibited a quadratic and weaker cubic trend in both females and males. Female beetles flew longer and farther than males. The mean flight duration was 3 h, 27 min for females and 2 h, 51 min for males. In general females flew 3.9 km whereas males flew a mean distance of 3.0 km. Correlation analysis revealed that both flight distance and duration were positively correlated with beetle weight and lipid content. The cyclic nature of flight capacity and beetle quality (as defined by weight and lipid reserves) has important implications in beetle dispersal, reproductive efficiency, and survival capacity.

6. PROJECT: Energy Reserves and Olfactory Behavior of the Southern Pine Beetle

COOPERATORS: Jane L. Hayes for (Don Kinn, Retired), SO

FUNDING: FIDR

SUMMARY: Total lipid content of southern pine beetles responding to turpentine/frontalin mixture was compared to that of non-responding beetles. Because the presence of endoparasitic nematodes could reduce available lipid to the beetle, the incidence of Controtylenchus brevicomi (Massey) Ruhm also was noted in responding and non-responding beetles. In walking olfactometer trials, male beetles responded in significantly greater numbers than female beetles. Lipid content did not vary significantly between responding and non-responding beetles and the presence of C. brevicomi did not appear to affect their walking response to the attractant.

7. PROJECT: Defensive Response of Pines to Bark Beetles: Role of Pinewood Nematode.

COOPERATORS: Jane L. Hayes (for Don Kinn, Retired), SO and Marc J. Linit, Dept. of Entomol., Univ. of Missouri.

FUNDING: FIDR

SUMMARY: This study was designed to determine the spatial extend of the impact of pinewood nematode inoculation on oleoresin flow along the bole of shortleaf pine. The objective was to compare oleoresin flow at three heights (1.5, 4, and 7 m) from inoculated and control trees, and to compare the flow from different heights on individual trees. The study was initiated in 1993 and terminated in 1994. Nematodes were recovered from nematode-inoculated trees three months after inoculation in both years of the study. A reduction in oleoresin flow at each height was observed in inoculated trees compared to control trees. Oleoresin flow tended to be highest at the 7 m height and lowest at the 1.5 m sampling height. Mean reduction in oleoresin flow from all heights in nematode inoculated trees ranged from 6.15 to 54.3% of the flow of the corresponding control trees in 1993. The reduction ranged from 5.56 to 73.33% in 1994. With reduced oleoresin flow along the entire bole the tree would be vulnerable to colonization by bark beetles at lower densities than if the primary defense system was intact.

8. PROJECT: Evaluation of the Area-Wide Efficacy of Direct Control Tactics for SPB.

COOPERATORS: James T. Cronin, Univ. of Georgia/SO, Peter B. Turchin, Dept. of Ecol. & Evol. Biol., Univ. of Connecticut, and Jane L. Hayes, SO

FUNDING: USDA Competitive Grant

SUMMARY: The objective of this study is to examine how cut-and-leave treatment affects the dispersal of SPB from treated infestations, and whether these beetles contribute to incipient infestations in the area. The procedure consists of selecting a set of SPB infestations and randomly assigning each of them to be either treated with cut-and-leave, or left untreated as an experimental control. Beetles in the experimental infestations are self-marked with fluorescent dust that is applied to the bark of trees from which beetles are emerging. Dispersal is assessed with a standardized spatial grid of "trap trees" (trees on which attack is induced by baiting them with the attractive pheromone frontalin) that extend in four directions to a distance of 500m. Each trap tree has a set of sticky panels on which marked beetles are recaptured. To date, beetle dispersal has been measured from 6 infestations (3 cut-and-leave, and 3 untreated). We determined that the proportion of marked beetles recaptured at all the trap trees was higher in cut-and-leave infestations (27%) compared to untreated infestations (11%). As predicted from earlier dispersal work, the proportion of recaptured beetles decreased with distance between the source infestation and the trap tree, indicating that each active infestation is surrounded by a gradually attenuating "halo" of dispersing beetles. In other words, a tree closer to the source of infestation had a much higher chance of being killed by beetles than a tree farther away. Finally, the proportion of trap trees successfully attacked and killed by beetles tended to be higher in the cut-and-leave treatment compared to untreated infestations (58% vs. 46%, respectively). These preliminary results do not support the hypothesis that treating an SPB infestation with cut-and-leave will decrease the occurrence of infestations in the vicinity.

9. PROJECT: Protecting valuable pines from bark beetle infestation with the host compound 4-allylanisole.

COOPERATORS: Jane L. Hayes, SO and James Meeker, Florida Dept. of Agric.

FUNDING: FIDR

SUMMARY: In a recent historical review, SPB damage to pine forests over the last 30 yrs has been estimated at 900 million dollars. Not included in this impressive figure are losses suffered by homeowners, by communities with tree-lined streets and parks, or in campgrounds, recreational or wildlife areas. Protection of these highly prized

trees, particularly at the urban/forest interface is of great importance. Tactics used for suppression of infestations have not proven effective at area-wide control nor are they suitable for the control of infestations in high-value stands (such as homesites or wildlife habitat areas), or for protecting uninfested pines of urban forests. During 1994, an unprecedented and intense SPB outbreak occurred throughout a 60 sq. mi. area of greater Gainesville, FL killing over 18,000 pines, and impacting more than 350 public and private landowners. The community, under the direction of the Florida Division of Forestry and with federal assistance, combatted this "freak" outbreak aggressively, attempting to remove all infested trees and in many cases treating uninfested trees with registered materials for protection (lindane and chlorpyrifos). On a small-scale voluntary basis, five homeowners allowed us to treat their trees (73 trees) with 4-allylanisole (4-AA), a host-produced compound found to have repellent effects on bark beetles. Virtually all untreated trees in the vicinity of active SPB infestations were attacked. However, all three materials, lindane, chlorpyrifos, and 4-AA, provided good protection (90%) from attack by SPB. In these tests, 4-AA provided homeowners with an environmentally-neutral alternative to chemical pesticide application for protection of high risk pines to attack by the SPB. A patent for use of 4-AA as repellent for conifer bark beetles (scolytids) has been issued jointly to the Forest Service and Forest Products Lab-Mississippi State University. Environmental Protection Agency (EPA) has granted a waiver from Environmental Use Permit (EUP) requirements allowing large-scale (up to 250 acres) testing of 4-AA. Development of improved dispensers and licensing agreements negotiations are underway.

10. PROJECT: The role of 4-allylanisole and selected monoterpenes in the host selection and colonization behaviors of the southern pine beetle

COOPERATORS: Brian Strom & Jane L. Hayes, SO/Dept. of Entomol., LSU, Rich Goyer, Dept. of Entomol., LSU, Lary Roton, SO.

FUNDING: FIDR

SUMMARY: 4-Allylanisole, a phenylpropanoid, occurs naturally at low levels in stem tissues and resins of southern pines. 4-Allylanisole inhibits/disrupts southern pine beetle (SPB) response to attractant pheromones and it inhibits growth of fungi associated with SPB. However, the role of naturally occurring 4-allylanisole in the host selection process and subsequent colonization behaviors of SPB and its associated organisms is unknown. It is also not known whether absolute concentrations of 4-allylanisole or interactions of this compound with other host volatiles are important, and thus monoterpenes will also be included in the study. This study will begin by quantification of the levels of naturally occurring 4-allylanisole and monoterpenes in potential hosts of SPB, (including so-called infestation "escapes") and determination of factors important in its variation. Additionally, levels

of these host compounds, both constitutive and induced, will be related to host selection by SPB using field and laboratory assays.

11. PROJECT: Development of Operational Techniques for using 4-Allylanisole Alone or in Conjunction with Verbenone for Southern Pine Beetle Infestation Disruption.

COOPERATORS: Jane L. Hayes, SO, and Steve Clarke, S&PF, R-8,

FUNDING: TDP

SUMMARY: The Forest Service (S&PF, R-8), in cooperation with State and University colleagues, has studied anti-aggregating pheromones of the southern pine beetle for use in IPM strategies. One identified pheromone, verbenone, has received an Experimental Use Permit from EPA. The permittee is Phero Tech, Inc., a cooperating firm interested in pheromone research, development and registration. Forest Service researchers (RWU-SO-4501) are now coordinating verbenone technology development with studies of 4-allylanisole (4-AA), a tree-produced semiochemical which has shown repellent or deterrent activity to southern pine beetles and other bark beetles (e.g., mountain pine beetle, western pine beetle, Ips pini). The Forest Service has petitioned EPA to include 4-AA in the "250 acre exemption rule" wherein qualifying pheromones are not required to obtain an Experimental Use Permit as long as the test area does not exceed 250 acres. 4-aa has shown significant promise for use in protecting both small stands and individual high value trees such as red cockaded woodpecker colony trees, and trees in recreation areas and urban environments. The primary objective of the project is the operational evaluation of using 4-aa and verbenone together to disrupt SPB infestation growth. To increase efficacy, determine whether, due to differences in behavioral response, applying verbenone and 4-aa together significantly improves efficacy (as measured by reduced buffer strip tree loss and/or variability of control success) when compared to using verbenone alone. Additionally, to decrease cost, determine whether, due to substantially lower cost of 4-aa than verbenone needed is reduced, provides protection for buffer strip trees equal to verbenone alone.

12. PROJECT: Novel Host Compounds as Repellents for Bark Beetles: Protection of Red Cockaded woodpecker Cavity Trees from Southern Pine Beetle.

COOPERATORS: Jane L. Hayes and Brian L. Strom, SO

FUNDING: FIDR

SUMMARY: The objective of this project is to determine the efficacy of 4-allylanisole (4-aa) for protection of high value stands or individual trees from death due to bark beetle infestation, with particular emphasis on red cockaded woodpecker (RCW) cavity trees (RCW is a federally listed endangered species). 4-aa is a host-produced compound shown to have repellent effects on a number of scolytids of economic and ecological significance in N. American pine forests, including southern pine beetle (SPB) which poses a serious threat to the southern pines in RCW habit. From Oct-Feb in FY 93-95, three treatments [all clan (active and inactive) trees were treated with 4-aa, half of the clan trees were treated, or no trees were treated] were randomly assigned to 30 clans in predominately longleaf pine habitat on the Vernon RD, KNF. Additionally in FY95, 19 clans in predominantly loblolly/shortleaf pine habitat were treated [all clan trees (n=10) or no clan trees (n=9)] on the Homochitto, RD, Miss NF. Relatively little SPB activity has been reported on the Vernon RD, and within the experimental clans no cavity trees on the Vernon RD were infested by SPB. Over the same period, SPB activity on the Homochitto RD has grown to outbreak conditions in FY95, and there has been significant RCW cavity tree mortality caused by SPB. In the experimental clans, SPB did not attack any trees that had been treated with 4-aa, while a total of 8 untreated cavity trees were killed during the period of the study, one each of longleaf and shortleaf and six loblolly. This study will be repeated one more season, with an increased emphasis of cavity trees protection on the Homochitto RD and other high SPB activity sites.

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

COOPERATORS: Region 8 Forest Health, Texas Forest Service, University of Georgia, Virginia Polytechnic Institute.

FUNDING: TDP

SUMMARY: Developed and tested standardized application rates for verbenone only and verbenone plus felling treatments. Verbenone only treatment reduced spot growth an average of 68.2%, with 13 of 19 spots totally suppressed. Verbenone plus felling all active, infested trees reduced spot growth by 89.1%, with 15 of 18 spots totally suppressed. Treatment failures occurred early in the summer when spot activity was the most intense. Technology transfer survey of potential users was completed and results are being analyzed. Instructional materials for treatment application are in development.

FUTURE ACTIONS AND RECOMMENDATIONS: Study long-term effects of treatments on infestations not initially suppressed, and complete benefit/cost analyses of the treatments. Conduct technology transfer workshops to train users. Refine

treatment techniques based on feedback from users. Push for EPA registration of verbenone and the development of commercially available delivery devices.

JEFFREY PINE BEETLE

1. PROJECT: A preliminary study of the flight periodicity and within tree distribution of Jeffrey pine beetle on the Tahoe NF.

COOPERATORS: Patrick J. Shea and Josep M. Riba, Pacific Southwest Research Station; Sheri Smith, Zone Entomologist, Lassen NF, Karen Jones, District Ranger, Tahoe National Forest; John Wenz, Zone Entomologist, Mammoth RD, Inyo National Forest.

FUNDING: FIDR

SUMMARY: The objectives of these studies were to measure the response of JPB adults to Lindgren funnel traps baited with experimental aggregation pheromones; assess the vertical distribution of JPB and their insect associates along the infested portion of the tree bole. In reference to the first objective 15 funnel traps to set up in both the Tahoe and Inyo National Forests and baited with 2 different ratios of 1 heptinol to heptane. Each treatment was replicated 5 times and there were 5 unbaited traps in each test location. Treatments were assigned randomly to each traps. Traps were visited weekly and all insects were removed, identified, and counted. Traps were established the second week of June and visited weekly until the late September on the Inyo NF and until mid to late October on the Tahoe NF. New pheromone baits were replaced weekly. With regard to the second study three currently infested Jeffrey pine trees were felled and 1 meter sections, starting the base, were removed for later dissection, identification of insects, and counted. These data are still be summarized.

FUTURE ACTIONS/RECOMMENDATIONS: In 1996 we will continue our studies on JPB and extend our knowledge of semiochemical ecology of this important bark beetles. Contract research in progress at the University of Nevada, Reno, will provide insight to the testing of new semiochemical compounds.

ROUNDHEADED PINE BEETLE

1. PROJECT: Area Application of Verbenone to Reduce the Mortality of Ponderosa Pine by Roundheaded Pine Beetle in the Sacramento Mountains, Southern New Mexico

COOPERATORS: Mark Schultz, Region 3; Pat Shea, Pacific Southwest Experiment Research Station, advisor to the project, Lincoln National Forest, and BIA Foresters, Mescalero Apache Indian Reservation.

FUNDING: TDP, FHP

SUMMARY: In September, 1994, 20 study areas each 5 acres were established to determine the effect of verbenone, an antiaggregant, on Roundheaded Pine Beetle (RPB). The study involved five replications of four treatments: 1. control, 2. RPB bait (low release rates of both exo-brevicomin and frontalin, as determined by Lindgren trap studies), 3. verbenone [enantiomer blend (-)86%/(+)14%], 4. RPB bait plus verbenone. The bait was placed near the center of the baited treatments atop 10 foot poles. There were 50 verbenone bcaps (PHERO TECH INC., B.C., Canada) per acre distributed evenly throughout each of the verbenone and bait plus verbenone treatments. They were stapled to the base of a tree or to stakes. Baited Lindgren traps were used to determine the timing of the fall RPB flight. The diameter breast height (DBH) and height of each ponderosa pine attacked by RPB and Western Pine Beetles previous to the fall, 1994 RPB flight were recorded for each area. In February, 1995, areas were visited to determine the number, DBH, and attack type of fall, 1994 bark beetle attacked ponderosa pine. The average number of percent successfully attacked trees in 1993 for the control treatments was the same as in 1994. There was a 80% increase, 40% decrease, and a 9% decrease in the percent successfully attacked trees for the bait, verbenone, and bait plus verbenone treatment areas, respectively. Though these treatment averages are not statistically significant they do show a trend. The release of verbenone results in fewer attacked trees even when the area is boosted with additional bait pheromones. Also, there were two to three times more unsuccessfully attacked trees (pitch outs) in the verbenone treatments than in any of the other treatments.

FUTURE ACTIONS/RECOMMENDATIONS: Repeat but include a design based on the pheromone plume work now being done and try the new compound 4 aa as part of the test.

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

COOPERATORS: Terry Rogers, R-3, Albuquerque; Jill Wilson, R-3, Flagstaff; Cloudcroft RD, Lincoln NF; Safford RD, Coronado NF; Jose Negron, RMFRES, Ft. Collins.

FUNDING: TDP

SUMMARY: An additional 102 permanent plots were established in the Cloudcroft RD during the summer of 1995 bringing the 2-year total to 204 plots. This was the target established at the beginning of the project base on power calculations. Plot establishment was stratified by habitat types identified to contain the majority of the ponderosa pine component in the Lincoln NF. Modified stage II information forms the core of data collection but additional data fields are also collected. In 1995, sampling was also initiated at the Safford RD of the Coronado National Forest. Target was to establish 100 plots. We have completed 50% of the field work at Safford. Based on the data collected from 1995 a preliminary model was built using a classification tree approach that estimates probability of infestation by the RPB. The model correctly classifies at the rate of 74%.

FUTURE ACTIONS/RECOMMENDATIONS: Field work at the Safford RD was stopped because of the uncertainty of carryover funds. We had planned to continue field work into October and possibly November. Unspent funds are available to complete the work assuming we can carry the funds into FY96. Upon completion of the work at Safford there will still be additional funds available. The RMS would like to use those funds for additional field work in 1996 to collect data relating beetle population pressure in the study areas.

3. PROJECT: Roundheaded Pine Beetle, Dendroctonus adjunctus, Flight Periodicity on the Dixie National Forest

COOPERATORS: Jesse Logan, Lynn Rasmussen; Mountain Pine Beetle Population Dynamics Project; Pat Shea, Chemical Ecology of Forest Insects Project; Mike Van Dyck, Brian Ferguson, Dixie National Forest; John Anhold, Forest Pest Management, Ogden Field Office

FUNDING: FHP

SUMMARY: This study was initiated to determine flight periodicity of D. adjunctus on the Pine Valley Ranger District, Dixie National Forest in southern Utah. There were some questions raised by Forest staff regarding early spring and fall flight. Some thought the early spring flight might be heavier than fall dispersal. Ten funnel traps

baited with attractant pheromones were placed June 19, 1995 throughout the ponderosa pine type on a 1/4 mile grid. Beginning in July, traps were checked every Thursday continuing until mid-November 1995. A temperature recorder has been installed to assist with beetle phenology and dispersal. Additional studies were also conducted to determine the effectiveness of a baiting strategy. Baits were deployed in some sites in an attempt to concentrate and trap out local populations of the insect. Fall flight began September 27, 1995 with heavy flight occurring the week of October 16th.

FUTURE ACTIONS/RECOMMENDATIONS: The study will be continued in 1996 to determine spring and fall adult dispersal. Data analysis will be conducted in 95-96 to document flight periodicity of this insect in southern Utah. Cooperators will also analyze the effectiveness of baiting strategies used to concentrate and trap out low level populations of roundheaded bark beetles.

IPS PINI

1. PROJECT: The effect of dose on the efficacy of antiaggregation pheromones to prevent colonization of scattered ponderosa pine slash by Ips pini.

COOPERATORS: Patrick J. Shea, Pacific Southwest Research Station, Sheri Smith, Region 5, Zone Entomologist, Lassen N.F., William Merrihew, Modoc N.F.

FUNDING: FIDR, FHP (completion of a previously funded TDP)

SUMMARY: This experiment was conducted on the Big Valley R.D. of the Modoc National Forest, located in northeastern California. The study involved 3 treatments (5 replications of each treatment): (1) 12 bubble caps/plot; (2) 25 bubble caps/plot; and (3) control (no treatment). The experiment required 15 plots which consisted of 5-7, 15-20 ft. felled ponderosa pines scattered on 1 chain square plot. Treatments consisted of a combination of 2 bubble caps evenly dispersed (by grid) over each plot. 1 bubble cap contained (-)86%/(+)14% verbenone and the other bubble cap contained racemic ipsdienol. Treatments were made on 5/24/95 and plots were evaluated on 7/18/95. Baited Lindgren funnels placed in the local vicinity of the experiments indicated a beetle flight had occurred over the duration of the experiment. Preliminary summary results are as follows and stated in average number of attacks/tree/plot: (1) 12 bubble caps/plot, 1.8; (2) 25 bubble caps/plot 0.0; (3) control, 182.6.

FUTURE ACTIONS/RECOMMENDATIONS: As with are past recommendations regarding the status of the use of antiaggregation compounds with Ips paraconfusus we recommend advancing to a pilot test project to evaluate the efficacy on these

Insert in Ips pini section

Project: Effectiveness of a Combination of Bark Beetle Semiochemicals in Preventing Attacks by Ips pini in Ponderosa Pine.

Cooperators: Ken Gibson, R-1; Ladd Livingston, IDL

Funding: FPM, TDP

Summary: In 1993 and 1994, Ipsenol (+50/-50) and Verbenone (+86/-14) were tested for effectiveness in preventing attacks by pine engravers in ponderosa pine slash. Research by Drs. Steve Seybold and Pat Shea (PSW) suggest that varying combinations of the attractant pheromones of a common competitor species, some of which are antiattractants of the pine engraver, might provide more effective protection from attacks by the engraver beetle than the antiattractant pheromone(s), alone. This two year study is to investigate the ability of a combination of semiochemicals which constitute the attractant pheromone blend of California five-spined Ips (Ips paraconfusus Lanier) in preventing I. pini attacks in ponderosa pine slash. These were: Ipsenol, cis-Verbenol, and +Ipsdienol. In 1995, combinations of these semiochemicals were used in Lindgren funnel traps in an effort to mask the attractiveness of the aggregating pheromone (Ipsdienol and Lanierone) of the pine engraver. These included the most promising one that we had previously tested, Ipsenol and Verbenone. In addition, we tested the effectiveness of 4-allylanisole (4-aa) as an antiattractant. In 1996, the most effective combinations of pheromones will be tested for preventing attack to ponderosa pine slash.

Sites were located in both western Montana and northern Idaho in areas with high beetle populations. There were eight treatments; each consisting of a Lindgren funnel trap baited with the pine engraver attractant (-Ipsdienol and Lanierone) and another semiochemical combination. Treatments were replicated five times at each site. Treatments were:

1. Pini attractant, Ipsenol, verbenone;
2. Pini attractant, Paraconfusus attractant;
3. Pini attractant, Ipsenol, cis-Verbenol;
4. Pini attractant, +Ipsdienol, cis-Verbenol;
5. Pini attractant, 4-allylanisole (methyl chavicol) (SFES formulation);
6. Pini attractant alone;
7. Pini attractant, Ipsenol, verbenone, 4-allylanisole (SFES formulation);
8. Pini attractant, 4-allylanisole (PheroTech gel formulation).

Ips pini attractant = Ipsdienol (+50/-50), Lanierone

Ips paraconfusus attractant = Ipsenol (+50/-50), cis-verbenol, +Ipsdienol (+97/-03)

The study was installed prior to beetle flight (April 4, in MT), and concluded at the end of the beetle's initial flight (June 22, in MT). Weekly trap collections were used to measure beetle flight and the masking effect of the antiaggregant combinations.

Results are as follows:

<u>Western Montana</u>			
<u>TMT</u>	<u>#F</u>	<u>#M</u>	<u>Total</u>
1	0	2	2
2	1	1	2
3	1	1	2
4	185	125	310
5	15	26	41
6	1	6	7
7	0	2	2
*8	17	30	47

<u>Northern Idaho</u>			
<u>TMT</u>	<u>#F</u>	<u>#M</u>	<u>Total</u>
1	9	11	20
2	42	14	56
3	17	18	35
4	42	86	128
5	24	99	123
6	97	468	565
7	10	26	36
*8	85	288	373

*Treatment 8 for MT with 1 dispenser; ID with 2 dispensers per trap

Analysis of Idaho results:

Fisher's LSD Comparison Report (Treatments\Totals) Summary Results $\alpha=.05$

<u>Treatment</u>	<u>Mean</u>	<u>Level Codes</u> <u>ABCDEFGH</u>
A(1)	4.0S
B(3)	7.0S
C(7)	7.2S
D(2)	11.2S
E(5)	24.6S
F(4)	25.6S
G(8)	74.6
H(6)	113	SSSSSS..

Future Actions/Recommendations: Further efforts will be to test bubble caps or plastic bead formulations simulating operational conditions. Slash could be created specifically for the test or slash from a logging or thinning operation could be used. Since both of these tests have been done once before with limited results, we need to discuss what to do that might be different from prior efforts.

strategies at larger spatial scale. We will continue to test lower doses of the treatments on both species of lps.

WESTERN BALSAM BARK BEETLE

1. PROJECT: Subalpine Fir Field Assessment

COOPERATORS: Ladd Livingston and Dave Beckman - Idaho Department of Lands; Dave Grierson - Utah Sovereign Lands & Forestry; Steve Munson, Leon LaMadeleine and John Guyon - USFS Forest Pest Management, R-4

FUNDING: FHP

SUMMARY: During the week of September 11th, 1995 we visited various field sites on the Wasatch-Cache NF - Logan & Ogden Ranger Districts, Unita NF - Spanish Fork Ranger District and Dixie NF - Cedar City Ranger District to assess insect & disease activity thought to be responsible for subalpine fir mortality. Various numbers of fading trees were dropped at each site which allowed whole tree examination.

Depending on location, tree fading and mortality could be attributed to a number of insect and disease agents. In northern Utah near the Idaho border, no Dryocetes confusus was found on any of the trees sampled. On branches we found Scolytus opacus, Pityokeines minutus, Pityophthorus spp., Crypturgus borealis and Cystospora abietis. On the bole: Pissodes spp., Buprestidae, Crypturgus borealis and Pityophthorus spp. As we moved southward we began to find Dryocetes confusus, in Salt Lake much of the mortality in subalpine is due to this insect. However, south of Provo, Utah, Dryocete's populations began to drop and we found many of the other secondary's listed above. In southern Utah we once again found Dryocetes in larger numbers and subalpine mortality caused by Scolytus ventralis, armillaria and annosus. In addition to the secondary's listed previously, in central and southern Utah, Trypodendron lineatum and Pityophthorus opaculus were also found.

It's obvious following our field assessment, that subalpine mortality in Utah is caused by a variety of organisms. Drought may be the principle factor in many sites stressing the trees allowing successful attacks and subsequent mortality by secondary organisms. Dryocetes does play an important role, particularly along the Wasatch Front between Ogden and Provo. The field evaluation indicates that Dryocetes confusus populations are only a part of the complex that is responsible for the abundant subalpine fir mortality in Utah.

FUTURE ACTIONS/RECOMMENDATIONS: Insect specimens were taken to Dr. Steven Wood at BYU, unfortunately because of their size, many will have to dry

mounted to ensure accurate identification. A Utah State grad student will prepare the specimens for Dr. Wood who has agreed to identify all those collected during our field evaluation.

DOUGLAS FIR BEETLE

1. PROJECT: Site and Stand Factors Associated with the Occurrence of Douglas-fir Beetle in Douglas-fir.

COOPERATORS: Jose Negrón, Rocky Mountain Forest and Range Experiment Station; Ken Gibson, Forest Health Protection, R-1; Bill Schaupp, Forest Health Protection, R-2; Ralph Thier and Steve Munson, Forest Pest Management, R-4.

FUNDING: TDP

SUMMARY: Project objective is to evaluate characteristics of Douglas-fir beetle spot infestations in Douglas-fir to develop a hazard-rating system. Forty-two study plots were installed by Ogden Field Office (FPM) staff in the second year of data collection. Field sites were concentrated on the Wasatch-Cache, Manti-LaSal, and Bridger-Teton National Forests. On the Wasatch-Cache National Forest in northeastern Utah, 16 study plots were installed on the Logan Ranger District. On the Manti-LaSal National Forest in central Utah, 16 study plots were installed on the Ferron Ranger District. On the Bridger-Teton National Forest in southwestern Wyoming, 10 study plots were installed on the Greys River Ranger District. Copies of the field data were forwarded to Jose Negrón at the Rocky Mountain Research Station for data entry and analysis.

FUTURE ACTIONS/RECOMMENDATIONS: A report will be submitted suitable for Journal publication by Bill Schaupp and Jose Negrón.

2. PROJECT: Optimal dose of MCH bubble capsules for protecting Douglas-fir from attack by the Douglas-fir beetle: Part I.

COOPERATORS: Ken Gibson (R1), Ralph Thier (R4), Steve Munson (R4), Iral Ragenovich (R6), Gary Daterman (PNW Station), and Darrell Ross (Oregon State University).

FUNDING: TDP

SUMMARY: Eight replications were installed during spring 1994 (three in northeastern Oregon, two in Montana, two in Idaho, and one in Utah) in a randomized

complete block design. 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 multiple-funnel traps baited with frontalin and seudenol were at the center of each plot to provide a standard source of attraction on all plots and to monitor beetle response to the treatments.

All three doses of MCH resulted in similar and significant reductions in the number of Douglas-fir beetles collected in baited funnel traps. In contrast, the numbers of predators caught in the traps were unaffected by any of the MCH doses. The differences in response of the bark beetles and predators suggest that beetles attacking trees within an MCH treated area will be subjected to higher levels of predation than would occur in the absence of MCH. This could lead to unsuccessful attacks or lower brood production from successfully attacked trees.

There were no significant differences among treatments in basal area, percentage of total stand basal area, tree density, or dbh for Douglas-fir trees > 20 cm dbh. However, the percentage of these trees that were mass attacked by the Douglas-fir beetle was significantly lower on the MCH treated plots compared with the control plots. All three doses of MCH were equally effective at preventing mass attacks.

FUTURE ACTIONS/RECOMMENDATIONS: These results demonstrate that MCH applied at rates as low as 20 g/ha (=50 bubble capsules/ha) is effective in protecting mature Douglas-fir from infestation by the Douglas-fir beetle. Further tests are needed to determine if even lower doses of MCH will be effective. We are currently testing rates of 15, 30, and 50 bubble capsules per hectare in a similar study.

3. PROJECT: Optimal dose of MCH bubble capsules for protecting Douglas-fir from attack by the Douglas-fir beetle: Part II.

COOPERATORS: Ken Gibson (R1), Ralph Thier (R4), Steve Munson (R4), Iral Ragenovich (R6), Gary Daterman (PNW Station), and Darrell Ross (Oregon State University).

FUNDING: TDP

SUMMARY: This study followed the same protocol used in 1994, but tested lower doses of MCH. Eight replications were installed during spring 1995 (three in northeastern Oregon, two in Montana, one in Idaho, and two in Utah) in a randomized complete block design. The treatments were 0, 15, 30, and 50 MCH bubble capsules per hectare.

Traps were monitored throughout the beetle flight period on all plots. Over half of the trap samples have been processed and the remainder should be completed by the end of November 1995.

All of the plots have been surveyed. Preliminary analyses of these data indicate that there are no significant differences in tree density, dbh, or percentage of trees mass attacked among the four treatments. However, the mean percentage of trees mass attacked on the plots receiving the highest dose of MCH was less than half of that on plots receiving any other treatment. Furthermore, the mean numbers of mass attacked trees demonstrate a clear dosage effect (i.e., declining numbers with increasing dosage). Overall, combined with the results of the 1994 project, the data suggest that 50 MCH bubble capsules/ha is near the lower threshold of efficacy for protecting live trees from infestation.

FUTURE ACTIONS/RECOMMENDATIONS: The results of the 1994 and 1995 dosage studies will be combined in a manuscript to be submitted to the Journal of Economic Entomology by the end of December 1995.

4. PROJECT: Oregon Trail Interpretive Park operational test of MCH bubble capsules.

COOPERATORS: Deb Barrett and Jim Barrett (La Grande R.D., Wallowa-Whitman N.F.), Don Scott and Craig Schmitt (Blue Mountains Pest Management Zone), Dave Bridgwater (R6), and Darrell Ross (Oregon State University).

FUNDING: FHP

SUMMARY: Four pairs of plots were established in the spring of 1995 on the La Grande R.D., Wallowa-Whitman N.F. Plots were approximately 20 acres in size. One plot in each pair was treated with MCH bubble capsules (40/acre = 100/ha) and the other was left untreated. In July, all Douglas-fir > 20 cm dbh on each plot were surveyed to determine Douglas-fir beetle infestation rates. The data are currently being analyzed.

FUTURE ACTIONS/RECOMMENDATIONS: Data will be analyzed and summarized this winter. Possibly publish the results in a referred journal such as the Western Journal of Applied Forestry.

5. PROJECT: Testing a new formulation of MCH

COOPERATORS: Philipp Kirsch (IPM Technologies) and Darrell Ross (Oregon State University).

FUNDING: None

SUMMARY: This study was designed to compare a new formulation of MCH to the currently available bubble capsule formulation (Phero Tech, Inc.). The study included five replications of three treatments. The experimental units were multiple-funnel traps baited with frontalin and seudenol in PVC formulations. Within each replication, one trap contained an MCH bubble capsule (Phero Tech, Inc.), one contained an MCH pouch (IPM Technologies), and one contained nothing other than the aggregation lure. Traps were placed in the field on August 2nd and emptied on August 10 and 23. Mean total catches for the first collection period were: Control, 222 beetles; MCH bubble capsules, 14 beetles; and MCH pouch, 2 beetles.

FUTURE ACTIONS/RECOMMENDATIONS: The data will be completely summarized and subjected to statistical analyses. The preliminary indications are that the new formulation is as effective as the currently available formulation, at least during the short-term. Further tests will be necessary to determine if the new formulation will remain effective throughout the beetle flight period.

6. PROJECT: Improving trapping efficiency for the Douglas-fir beetle.

COOPERATORS: Gary Daterman (PNW) and Darrell Ross (Oregon State University).

FUNDING: FIDR

SUMMARY: This project includes a number of independent studies designed to improve the efficiency of trapping for the Douglas-fir beetle. Studies began in 1994 and will continue through 1996. Studies are addressing Douglas-fir beetle dispersal, trap lure composition and strength, trap design, attraction range of baited traps, and seasonal phenology of the Douglas-fir beetle and associated predators.

FUTURE ACTIONS/RECOMMENDATIONS: Data from the 1994 and 1995 field seasons are currently being analyzed and summarized.

7. PROJECT: Role of Thanasimus undatulus in the population dynamics of the Douglas-fir beetle.

COOPERATORS: Chris Niwa (PNW), Jianlin Zhou and Darrell Ross (Oregon State University).

FUNDING: FIDR

SUMMARY: This project includes a number of studies that are being conducted by Jianlin Zhou, a Ph.D. candidate at OSU. Three studies were conducted in 1995. First, a cross-attraction study compared the response of predators to multiple-funnel traps baited with commercial lures for several major western bark beetle species. The results indicate that T. undatulus responds more strongly to seudenol, a component of the Douglas-fir beetle lure, than to any other pheromone component tested. Second, trees were baited with different components of the Douglas-fir beetle aggregation pheromone to establish infestations with different levels of predation. The baited trees have been monitored with sticky traps and by taking bark samples. Sampling of these trees will continue through the spring of 1996. Third, bolts were infested with three different densities of Douglas-fir beetles and placed in separate cages. Three different densities of T. undatulus were introduced into the cages in a replicated, factorial design. The bolts will be sampled periodically to determine the impact of the predator on beetle reproduction.

FUTURE ACTIONS/RECOMMENDATIONS: Available data are currently being analyzed and summarized. These studies will continue in 1996.

8. PROJECT: Using Douglas-fir beetle pheromones to produce snags for wildlife habitat.

COOPERATORS: Chris Niwa (PNW) and Darrell Ross (Oregon State University).

FUNDING: FIDR

SUMMARY: A study was installed in 1994 to compare snag production using aggregation pheromones alone and in combination with antiaggregation pheromones. The purpose of the combination treatment was to try to regulate the number of trees that became mass-attacked around the baited trees. Both treatments involved baiting three adjacent trees at the center of a half-hectare circular plot. Additionally, MCH bubble capsules were applied at a rate of 100/ha around the perimeter of the plots receiving the combination treatment. All of the baited trees were attacked on all plots. However, a significantly greater number of unbaited trees were mass-attacked on the plots without MCH compared to those with MCH. One year after treatment, a

significantly greater number of the baited trees were dead on the plots without MCH compared to those with MCH.

FUTURE ACTIONS/RECOMMENDATIONS: The results indicate that it is possible to regulate the number of mass-attacked trees around baited trees by the simultaneous application of MCH. A draft manuscript has been prepared and will be submitted to the Western Journal of Applied Forestry by the end of December 1995.

9. PROJECT: Pathogenicity of Douglas-fir beetle associated blue-stain fungi to Douglas-fir and western larch.

COOPERATORS: Halvor Solheim (Norwegian Forest Research Institute) and Darrell Ross (Oregon State University).

FUNDING: None

SUMMARY: This project includes several studies that began in 1994 to assess the pathogenicity of Douglas-fir beetle associated fungi. The first study involved mass inoculations of Douglas-fir with two fungi, Ophiostoma pseudotsugae and Leptographium abietinum at three densities. The results indicated that both fungi are moderately pathogenic to Douglas-fir. O. pseudotsugae appeared to be slightly more aggressive than L. abietinum. A similar study was installed in the spring of 1995 that involved inoculations of western larch.

FUTURE ACTIONS/RECOMMENDATIONS: Results of the first study have been summarized in a manuscript that is currently in review. Trees inoculated in the second study will be harvested and processed in November 1995. The data will be analyzed and summarized during the winter of 1995-96. Further studies are planned for spring 1996.

SPRUCE BEETLE

1. PROJECT: Effectiveness of Carbaryl and Pyrethroid Insecticides for Protection of Englemann Spruce From Attack by Spruce Beetle

COOPERATORS: Utah State University: Michael Jenkins Ph.D., Karen Johnson; USDA Forest Service: John Anhold, Steve Munson

FUNDING: FHP

SUMMARY: A field experiment tested the effectiveness of carbaryl and two pyrethrin insecticides, cyfluthrin and esfenvalerate, in protecting high-value Englemann spruce

trees from attack by Dendroctonus rufipennis Kirby. The following formulations were used: a carbaryl suspension at the 2% registered rate and a reduced rate of 1%, cyfluthrin at .025%, and esfenvalerate at .025% and .05%. Most of the treatments effectively protected Englemann spruce trees from attack by D. rufipennis through one spring/summer of adult flight. Only cyfluthrin at the lowest rate, .008% was judged ineffective in providing single tree protection. Treated and control trees were baited and exposed to heavy populations of spruce beetle. Eighty-two percent of the untreated check trees were killed by spruce beetle.

Data collection to evaluate insecticide effectiveness following baiting and a second year of adult flight was concluded in September 1995. This assessment will be used to determine insecticide efficacy over a 24 month period. The data collected in September has not been analyzed.

FUTURE ACTIONS/RECOMMENDATIONS: Karen Johnson is currently conducting the data analysis for the information collected in September which will be added to her thesis. Karen's thesis defense is scheduled for December 1995. A paper suitable for Journal publication will be submitted in early 1996. A report has been submitted to Forest Pest Management, Ogden Field Office summarizing first year insecticide efficacy. A copy of this report is available through either John Anhold or Steve Munson, (801) 476-9720.

2. PROJECT: Single Tree Protection of Spruce in a Developed Recreation Site using MCH - Dixie National Forest, Cedar City Ranger District

COOPERATORS: Steve Munson, Forest Pest Management;- Mike VanDyke, Dixie National Forest

FUNDING: FHP

SUMMARY: Cedar Canyon campground is comprised of overstory Englemann spruce averaging 18.42 inches dbh. A perennial stream runs through the center of the campground with campsites distributed on each side of the stream. A spruce beetle epidemic is currently in progress adjacent to the camping area. The stream is part of the Cedar City watershed and contributes to the cities drinking water. Although carbaryl is an effective preventative treatment for spruce beetle, the close proximity of high risk spruce to the cities municipal drinking water prevented insecticide use within the campground. As an experimental alternative, an MCH capsule was stapled to every spruce greater than 12 inches dbh in the campground. In 1995, 464 Englemann spruce were treated with MCH caps. An adjacent site consisting of 440 Englemann spruce averaging 18.32 inches dbh was used as a control. Beetle pressure near the treated and untreated sites was similar. In 1994, two trees were attacked in the campground and three trees were attacked in the control. In 1995, no attacked trees were found in the campground, however, seven infested trees were

recorded in the control block. The intent of this study is to determine if MCH can be used operationally to prevent spruce beetle attacks.

FUTURE ACTIONS/RECOMMENDATIONS: Annual MCH treatments will continue unless the treatment proves ineffective or until spruce beetle populations collapse. A Regional Office-FPM publication will be used to summarize results when the test is terminated.

3. PROJECT: Evaluation of Host Chemicals as Attractants and Repellents for Spruce Beetles in Interior and South-central Alaska

COOPERATORS: Richard A. Werner, Institute of Northern Forestry, Pacific Northwest Research Station, Fairbanks, AK; and Edward H. Holsten, Forest Health Management, State and Private Forestry, Region 10, Anchorage, AK

SUMMARY: Spruce beetle, Dendroctonus rufipennis (Kirby), infestations have occurred continuously in south-central Alaska with over 1 to 2 million acres infested since 1974. The most promising tools for reducing bark beetle losses in the short-term involve the use of behavioral chemicals such as semiochemicals.

The purpose of this study was to develop operational strategies for monitoring and manipulating spruce beetle populations using semiochemicals in traps and on baited trees in interior and south central Alaska.

Objectives were: 1994 - to evaluate the repellent activity of host compounds to low and medium level populations of SB to frontalin baited funnel traps. 1995 - to evaluate the repellent activity of host compounds to low and medium level populations of SB to frontalin + alpha pinene baited funnel traps.

This field test was conducted in the Bonanza Creek Experimental Forest in interior Alaska where low populations of SB exists, and at Summit Lake on the Chugach National Forest in south-central Alaska where populations of SB are at medium levels.

In 1994, the field test utilized a 9 x 9 randomized block design with 9 treatments replicated 2 times per site in a complete randomized design. The 1995 field test utilized a 7 X 3 randomized block design with 7 treatments replicated 3 times in each of 3 study plots and at 2 geographical sites. In both years there were 3 sites in two geographic locations. One area will contain a low population and one a medium population of beetles. Baits were dispersed from 12-unit Lindgren funnel traps spaced at 50-foot intervals. Traps were hung from a rope suspended between two trees at a height of 6 feet with the collection container of each trap 1-foot from ground level. Traps were checked weekly and beetles collected, placed in plastic zip-lock

bags and stored in a freezer at 20°F. The response variable was the total number of beetles caught per treatment.

The 1994 experiment utilized combinations of frontalin and other aggregation pheromones identified from spruce beetles and several host compounds.

- frontalin, 0.1 mg/day, flex-lure
- (R)-(+)-limonene, 0.5 mg/day, eppendorf
- (S)-(-)-limonene, 0.5 mg/day, eppendorf
- alpha pinene, 0.7 mg/day, eppendorf
- myrcene, 0.5 mg/day, eppendorf
- 4-allylanisole, 0.5 mg/day, eppendorf
- ethyl butyrate, 0.5 mg/day, eppendorf
- (1R)-(-)-myrtenol, 0.5 mg/day, eppendorf
- Unbaited control

The 1995 experiment utilized combinations of frontalin + alpha pinene and several host compounds.

- Frontalin + alpha pinene
- Frontalin + alpha pinene + (R)-(+)-limonene
- Frontalin + alpha pinene + (L)-(-)-limonene
- Frontalin + alpha pinene + 4-allylanisole
- Frontalin + alpha pinene + (R)-(+)-limonene + (L)-(-)-limonene
- Frontalin + alpha pinene + (R)-(+)-limonene + (L)-(-)-limonene + 4-allylanisole
- unbaited control

Data will be tested for homogeneity. If non-homogenous, data will be transformed using a parametric test because of zero counts, which can be expected in control treatments. Total number of spruce beetles caught for each of the treatments will be subjected to an ANOVA (Dunn 1987). Differences between means will be tested using Tukey's Studentized Range (HSD) test (Tukey 1953).

In 1994, the most spruce beetles from low level populations were caught in funnel traps baited with frontalin + alpha pinene > frontalin + myrtenol > frontalin + ethyl butyrate = frontalin alone. In medium level populations, frontalin + myrtenol > frontalin + alpha pinene > frontalin + ethyl butyrate > frontalin alone. The host compound 4-allylanisole repelled 200 percent more low level population spruce beetles than other host compounds when added to frontalin. The most spruce beetles in a medium level population were repelled by a combination of frontalin + (L)-limonene (150 percent more).

In 1995, the combination of frontalin + alpha pinene + (R)- and (L)-limonene caught 24 percent more spruce beetles than frontalin + alpha pinene in low level populations.

The addition of (R)-limonene to frontalin + alpha pinene reduced the number of beetles caught by 671 percent > a combination of (R)-limonene + (L)-limonene + 4-allylanisole > (L)-limonene = 4-allylanisole.

In 1995 medium level populations, frontalin + (R)-limonene and frontalin + (R)-limonene + (L)-limonene caught 62 and 59 percent more beetles, respectfully, than frontalin + alpha pinene. The addition of 4-allylanisole to frontalin + alpha pinene reduced the number of beetles caught by 148 percent compared to the addition of (R)-limonene + (L)-limonene + 4-allylanisole, which reduced trap catch by 82 percent.

It is apparent from the 1994 and 1995 field tests that 4-allylanisole repels spruce beetles in both low- and medium-level populations. The repellency of both (R)-limonene and (L)-limonene is still questionable.

4. PROJECT: MCH Bubble Caps for Preventing Spruce Beetle Attacks.

COOPERATORS: Edward H. Holsten, Region 10; Richard A. Werner, PNW; Patrick J. Shea, PSW; Roger Burnside, Alaska Division of Forestry; Kenai Borough; University of Alaska; Cook Inlet Native Corporation; and Ninilchik Native Corporation; Ralph Thier and Steve Munson, FPM R4.

FUNDING: TDP, PNW-FIDR, PSW-FIDR, FHP-R10, FHP-R4, State of Alaska

SUMMARY: Objectives were: 1) Evaluate the operational use of MCH bubble caps to protect stands of Lutz, Englemann and Sitka spruce from attack by spruce beetles, and 2) evaluate the use of MCH bubble caps to protect single trees from spruce beetle attack. Field tests done by PNW in 1992-93 demonstrated successful protection of 1/2 acre stands of Lutz spruce in stands of Lutz spruce on the Kenai Peninsula in south-central Alaska using MCH bubble caps at 32 and 50 bubble caps per acre; however, treatment with MCH beads did not work. Bubble caps were first formulated to release at 24°C; however, field trial results were variable from year to year in spruce stands in Alaska. In 1994, bubble caps were formulated to release at 17°C, three degrees above the threshold temperature required for beetle flight.

Stand Protection-1994. The protection of stands of Lutz spruce in south-central Alaska using MCH and methyl chavical (MC) (=4 allylanisole) bubble caps (formulated to release at 17 and 24°C) were tested at 32 and 50 bubble caps per acre. There were 5 replicates of 1/2 acre each in a randomized block design. Statistical analysis using Bonferonni's multiple comparison test showed no difference between treatment plots and control plots; however, the above percentages of attacked vs unattacked trees showed positive effects for the 25MCH @17°C treatment. Treatments were evaluated in mid-August by counting trees with no attacks, new attacks and new pitch

outs. Attack densities were estimated on the lower 6 feet of the bole as light (<10 attacks), medium (11-25 attacks), and high (>25 attacks).

Statistical analysis using Bonferonni's comparison test showed no difference between treatment plots and control plots; however, percentages of attacked trees vs unattacked trees showed positive effects for 25MCH @17 degrees C. treatment.

In Utah, the 1994 field trials with MCH bubble caps utilized two treatments of 50 and 75 bubble caps per acre with untreated stands as controls. Eighteen 2.5 acre rectangular plots were treated with each treatment replicated six times. Bubble caps were stapled 5 to 6 feet above ground on the north side of the tree bole. 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. Attack densities were estimated on the lower 6 feet of the bole as light (<10 attacks), medium (11-25 attacks), and high (>25 attacks).

In comparing the proportion of total trees with new attacks, a Tukey's comparison (using mean proportions of the total number of trees) showed significant differences between the proportion of trees that had high attack densities. Both treatment groups were found to be different from the untreated control. There were no differences between low and medium attack densities between treatment and control plots. When all attack densities were combined into one variable, there was a significant difference between the 50 bubble cap treatment and the control but not the 75 bubble cap treatment and control.

Stand Protection-1995. In 1995, field tests were only done in south-central Alaska. Plots were treated in May 1995 with MCH bubble caps that released MCH at 17°C. The percentages of attacked trees of control plots compared to MCH treated plots show positive effects for the application of MCH bubble caps to both round and square plots of Lutz spruce.

Single Tree Protection-1994. 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 spruce beetle pheromone to increase beetle pressure in the study area. There were no significant differences between treatments as check trees were too lightly (46%) attacked to demonstrate treatment effects.

Single Tree Protection-1995. Sixty Lutz spruce were randomly treated in May 1995 with MCH bubble caps that released MCH at 17°C on the Chugach NF. Evaluations of the treatments was done in August 1995 following beetle attack. Statistical analysis of the data show no significant difference between treated and untreated trees. Apparently, application of a single MCH bubble cap to an individual tree does not protect the tree from attack by spruce beetles.

FUTURE ACTIONS/RECOMMENDATIONS: The data suggest that MCH acts as a repellent for dispersing spruce beetles in both Englemann spruce stands in Utah and Lutz spruce stands in south-central Alaska. In field trials in Utah and Alaska, 50 MCH bubble caps per acre protected trees from attack by spruce beetles. Results from 1994 and 1995 field trials in stands of Lutz spruce showed the bubble caps with a release rate at 17°C protected stands of spruce significantly more compared to stands treated with bubble caps that eluted at 24°C.

MCH bubble caps did not protect individual Lutz spruce when 2-6 bubble caps were used on 2 to 12 feet of the tree bole. The elution rate of MCH from beads is currently inadequate at cold climates characteristic of boreal forests to provide protection of uninfested stands. Additional field tests need to be done on individual tree protection using bubble caps and on the development of a bead that elutes MCH at lower temperatures.

TOMICUS PINIPERDA

1. **PROJECT:** Tomicus piniperda attack density on pine logs that vary in species, length, diameter, and pile size.

COOPERATION: Robert Haack, NC; Robert Lawrence, NC

FUNDING: TDP

SUMMARY: This study was aimed at elucidating how pine species (Scotch vs. red), log length (1 ft vs. 2 ft.), log diameter (2 inch, 4 inch vs 6 inch), and log pile size (1, 2, or 3 logs per pile) affected Tomicus attack density. Three sites were used; 144 trap logs per site. In general, Tomicus attack density was (a) higher on Scotch pine, (b) higher on 2-foot long logs, and (c) higher on 4-6 inch diameter logs. Log pile size did not alter Tomicus attack significantly. Attack densities appeared to be linked to bark roughness, with higher densities on rougher logs.

FUTURE ACTIONS/RECOMMENDATIONS: These results suggest that the most effective trap logs will be cut from Scotch pine trees and be a minimum of 2-ft long, and 4-inches in diameter. Logs can be placed out singly in the field, especially if using Scotch pine. If Scotch pine is not available, red pine is adequate, but logs with rougher bark should be used. These results can be put into practice by managers and regulators for survey, detection, and control purposes.

2. PROJECT: Tomicus piniperda attack density on pine logs placed at various distances from the edge of infested pine plantations.

COOPERATION: Robert Haack, NC; Robert Lawrence, NC

FUNDING: TDP

SUMMARY: This study evaluated Tomicus attack densities on standard-sized Scotch pine logs (ca. 5-6 inches in diameter; 20 inches long) when placed at 25, 50, and 100 meters from the borders of isolated Tomicus-infested pine stands. All of the sample logs used in this study were attacked by Tomicus, no matter their distance nor direction from the plantation. In general, attack density decreased with increasing distance from the stand edge. Overall, mean attack density (galleries/square-meter of bark) was 201 for logs at 25 m, 166 at 50 m, and 114 at 100 m.

FUTURE ACTION/RECOMMENDATIONS: These results demonstrate that Tomicus adults are very active during the spring flight season, moving out from isolated plantations in all directions. The fact that trap logs placed at 100 m from a stand edge were detected by Tomicus adults, indicates that trap logs do not have to be placed within the center of a plantation to be attacked. However, since attack densities were highest at locations nearest the stand edge, we recommend that trap logs be placed close to the stand edge whenever practical.

3. PROJECT: Timing of Tomicus piniperda shoot departure in autumn.

COOPERATION: Robert Haack, NC; Robert Lawrence, NC

FUNDING: FIDR

SUMMARY: As in 1992 and 1993, studies on Tomicus shoot departure were again conducted in 1994 at the same Scotch pine plantation in northeastern Indiana. A similar pattern was observed in 1994 as was recorded in the previous two years. Overall, for the years 1992-94, adults initiated shoot departure in mid- to late October, and finished during the subsequent 4-6 weeks (i.e., by late November to early December). A similar study was conducted in 1994, further north in lower Michigan, where beetle departure ran 1-2 weeks ahead of the Indiana site, apparently in response to cooler temperatures in Michigan.

FUTURE ACTION/RECOMMENDATIONS: In the next version of the federal quarantine, APHIS will tentatively allow free movement of newly cut pine logs to occur 1 July to 30 September. These dates are relatively safe for the currently known area of infestation, however, as Tomicus moves further north, 30 September may no longer

be sufficiently safe. Further refinements in the federal quarantine will likely need to be made as Tomicus moves further north and south.

4. PROJECT: Overwintering sites of Tomicus piniperda along trunks of Scotch pine and red pine.

COOPERATION: Robert Haack, NC; Robert Lawrence, NC

FUNDING: FIDR

SUMMARY: During the 1994-95 winter, four Scotch pine trees and four red pine trees were felled within a single stand that was very heavily infested with Tomicus. The lower 2 meters of trunk were debarked and inspected for overwintering adult Tomicus. We found 681 overwintering beetles on the four Scotch pines, and 103 beetles on the four red pines. In one of the Scotch pine trees over 400 beetles were found, with one beetle as high as 2-m. On Scotch pine, 64% of the beetles were at or below 8 inches, and 78% were at or below 12 inches. Similarly, on red pine, 71% and 91% of the beetles were at or below 8 and 12 inches, respectively. On trees with fewer than 25 beetles, nearly 100% were encountered below the 8-inch mark.

FUTURE ACTION/RECOMMENDATIONS: APHIS is considering further changes in the Tomicus federal quarantine, including one where logs from newly felled pine trees could be shipped out of infested areas in fall or winter if, among other things, an 8-inch stump is left. The above results suggest that this new rule will be relatively safe except possibly in heavily infested stands.

5. PROJECT: Tomicus piniperda reproduction and shoot feeding in North American conifers.

COOPERATION: Robert Lawrence, NC; Robert Haack, NC

FUNDING: FIDR

SUMMARY: During 1993-1995, ten species of North American conifers have been evaluated for suitability for Tomicus reproduction and shoot feeding, including three eastern pines (eastern white, red, jack), three western pines (limber, ponderosa, western white) and four non-pines (white spruce, Douglas-fir, balsam fir, tamarack). Scotch pine, a native host of Tomicus, was used as a control in all tests. In 1995, reproduction was tested for a 2nd year in non-pines, and shoot feeding was tested for a 2nd year in non-pines and a 3rd year in eastern pines. Tomicus has been able to reproduce and shoot feed in all species of pines tested, although performance was generally better in the 2-3 needle hard pines compared with the 5-needle soft pines.

White spruce was the only non-pine in which Tomicus successfully reproduced. Attack density in spruce was much lower than in the native host, Scotch pine. In 1994, Tomicus attacked Douglas-fir logs in the field and constructed egg galleries, the eggs hatched, but all larvae eventually died. In 1995, only aborted egg galleries were observed on Douglas-fir logs in the field. In no-choice shoot-feeding studies, using caged branches in the field, at least some adults were able to shoot feed and survive for 2-4 weeks on white spruce (2% in 1994, 4% in 1995) and Douglas-fir (none in 1994, 12% in 1995), although at levels lower than on Scotch pine (27% in 1994, 20% in 1995). No adults survived on balsam fir or tamarack in either year. Mortality rates in shoot feeding tests may have been higher than normal due to very warm temperatures (several days of >90F temperatures) that occurred during both 1994 and 1995.

FUTURE ACTION/RECOMMENDATIONS: Additional North American pine and spruce species could be tested. In other studies (W. Berisford, T. Eager, M. Dalusky, D. Nielsen), Tomicus has been able to reproduce in all southern pine species tested (loblolly, slash, longleaf, shortleaf and Virginia pines). Tomicus may be able to utilize all North American pines. In Europe, conifers such as Norway spruce are occasionally used by Tomicus for reproduction and shoot feeding. Reproduction in spruce has frequently occurred in Europe when spruce and pine logs are piled together.

6. PROJECT: Comparison of Tomicus piniperda to Lindgren funnel traps vs. Theysohn traps.

COOPERATORS: Robert Lawrence, NC; Robert Haack, NC

FUNDING: FIDR

SUMMARY: The efficiency at which 12-unit funnel traps captured Tomicus adults was contrasted with standard Theysohn traps. All traps were similarly baited with alpha-pinene lures; 20 traps of each type were used in the study. Overall, 2-times more Tomicus were captured in funnel traps than in Theysohn traps. Later in 1995, when these same traps were baited with ipsdienol lures, significantly more clerids (Thanasimus dubius) were captured in funnel traps than in Theysohn traps. However, significantly more Ips pini were captured by Theysohn traps than by funnel traps.

FUTURE ACTION/RECOMMENDATIONS: Based on these initial results, funnel traps appear to be superior to Theysohn traps in capturing Tomicus and clerid adults, but Theysohn traps are superior for catching Ips. Theysohn traps appear to have less of a negative impact on natural enemies.

7. PROJECT: Studies on the exotic predator, Thanasimus formicarius (Cleridae), for possible release in the United States against Tomicus

COOPERATION: Robert Haack, NC; Robert Lawrence, NC; USDA ARS-France; USDA ARS-Delaware; USDA APHIS-Niles, MI.

FUNDING: FIDR, APHIS, ARS

SUMMARY: A few hundred Thanasimus formicarius adults were collected in 1995 in France by Richard Dysardt of USDA-ARS. Adults were shipped to Larry Ertle of the USDA ARS Quarantine facility in Delaware. Eggs from these adults have been shipped to the USDA APHIS Biological Control lab in Niles, MI where they are being reared on scolytids and various other insect hosts. Soon, some of the clerid larvae will be shipped to us (Haack & Lawrence) in East Lansing, MI, where we will rear them on Ips and Tomicus.

FUTURE ACTIONS/RECOMMENDATIONS: We will conduct several tests in East Lansing to examine the interactions of the exotic Thanasimus formicarius, the native Thanasimus dubius, the exotic Tomicus, and the native Ips pini. Our results will be used by APHIS in their Environmental Assessment for the possible field release of Thanasimus formicarius in 1997 in perhaps Michigan and Indiana.

OTHER

1. PROJECT: Lake Tahoe Large Scale Aerial Photography

COOPERATORS: John Wenz, USFS - Forest Health Protection R-5, Steve Munson, USFS - Forest Pest Management R-4, Lake Tahoe Basin Management Unit

FUNDING: FHP

SUMMARY: In August 1995, aerial photography was obtained over the Tahoe Basin Land Management Unit to assess insect impacts. The photography is large scale, 1:8,000 true color imagery. Imagery will be used to determine the location and amount of insect caused mortality, fire risk, previous & current management activities on all ownership's within the Basin and stand susceptibility of the residual green component. Photo indexing was completed in mid-October and copies of the aerial photography are available through the Aerial Photo Field Office located in Salt Lake City, Utah.

FUTURE ACTIONS/RECOMMENDATIONS: Photo interpretation will begin in November/December 1995, GIS will be used to document the variables stated above. A final report documenting the impacts of a large bark beetle epidemic in the Tahoe Basin should be available in December of 1996.

2. PROJECT: Westwide Pine Beetle Model

COOPERATORS: Dawn Hansen, Region 4, Ogden Field Office; Eric Smith, Forest Health Technology Enterprise Team, Ft. Collins.

FUNDING: TDP

SUMMARY: Model has been coded and working versions have been installed on the DG and on PCs.

We have abandoned efforts to create display outputs with S+, we are developing Arcview II routines to take full advantage of 615 capabilities.

We are exploring techniques for using data from sample stands to infer conditions across a landscape through the FVS Most Similar Neighbor approach.

We have digitized Black's Mt. Exp. Forest data from original pine methods of cutting studies, and are working on a translator to create FVS tree lists.

We have requested recent data from PSW researchers to use to validate the model through the present and to project ecosystem management prescriptions into the future.

3. PROJECT: Develop and validate a plume model to determine horizontal, vertical, and crosswind movement of eluted semiochemicals in a stand atmosphere; and measure pheromone plumes emitted from standing attacked trees to estimate atmospheric concentrations effective in repelling bark beetles.

COOPERATORS: Edward H. Holsten was the FHM (R10) coordinator. Richard A. Werner, Supervisory Research Entomologist, PNW Fairbanks, and Patrick J. Shea, Research Entomologist, PSW, Davis CA were responsible for collecting and analyzing MCH eluted from spruce beetle infested logs. Analysis of beetle-produced volatiles were be done under contract with the Forest Products Laboratory, University of California. Warren Webb, Professor, Oregon State University conducted the tracer and video image capture experiments.

FUNDING: TDP, PNW - FIDR, PSW - FIDR, FHP - R10

SUMMARY: Project objectives were: 1) determine the effect of crosswind distribution downwind from bubble caps on the absolute atmospheric concentration of MCH in stands of Lutz spruce in south-central Alaska, and 2) determine the optimum amounts

of MCH that elutes from beetle-infested trees that is needed to repel further beetle attack. The minimum atmospheric concentration of MCH that repels beetles can then be computed for stands of Lutz spruce.

Accomplishments and Results: Elution rates and residual content of MCH and verbenone from bubble caps and beads were determined in a FY94 Technological Development project (R10-94-02). Performance of these materials under diverse field conditions were also evaluated in other Technology Development Projects (R10-94-01 and R6-94-). MCH bubble caps were formulated to release at 17°C and 25°C for field tests in south-central Alaska and at 25°C for field tests in Oregon on both north and south aspect sites.

MCH Production by Female Beetles. The amount of MCH that is produced by beetle-infested Lutz spruce logs was measured in logs artificially infested with low population density of beetles (10 and 60 pairs/m² of bark surface). Infested spruce logs were placed in 30 gal plastic drums and Porapak filters connected to through the drums to collect the MCH that was eluted from the female beetles. The volatiles were collected in Porapak Q (50-80 mesh) for 3, 6, and 20 days following infestation with both females and males. Volatiles were also collected from an empty drum, a drum with an uninfested log, and a drum with an MCH bubble cap. The Porapak adsorbent was extracted and cleaned-up by removing the hydrocarbons, which were estimated at 98% of the total volatiles in the Porapak. Even with this cleanup procedure, some of the remaining 2% (polar compounds) partially overlapped the MCH peak on gas chromatography with flame ionization detection. It was, therefore decided to use GC-mass spectrometry to "filter out" interfering substances by looking only for a mass ion unique to MCH. There was a significant difference in the amount of MCH produced bolts infested with low and high density populations of beetles. Days of infestation were non-significant except for bolts infested with a high density of beetles for 20 days. The experiment should be repeated using bolts infested with medium and high density populations for 10, 20, and 30-day periods.

Development of Plume Model. Research focused on the validation portion of the model during the 1995 field season. Colored smoke plumes released from single point sources were videotaped simultaneously using three video cameras. Images of each tape, which provided three views of the smoke plume, were computer captured and the digitized images used to construct a digitized 3-dimensional representation of the plume. The temporal dynamics of the plume volume then provided a means to validate the MCH plume. This is a new technique which gives a better integrate view of plume turbulence than does more expensive anemometers which are point source only. Smoke plume distribution has been studies in two areas of old-growth Douglas-fir at the Wind River Canopy Crane site in Washington.

An extended data set was obtained from the military who had done experiments where fluorescent particles were released at point sources in forest stands and the particles

retrieved in a sampling grid. This data provides estimates of atmospheric concentration. The data set also has supporting meteorological data such as air temperature, wind speed, etc. Some of these data were transferred to the OSU computer system and are being analyzed for model validation.

Visual analysis of the colored smoke plumes clearly shows that the steady state Gaussian Plume models will not adequately describe plume dynamics. Emphasis will be shifted to a "puff" model representation, which allows for more rapid wind shifts; the Gaussian model does not accommodate rapid wind shifts. The puff model is an "off-the-shelf" model so time spent adapting the model to MCH plumes should be relatively short.

FUTURE ACTIONS/RECOMMENDATIONS: The current model needs to be verified in field experiments in uniform stands and stands with gaps in the canopy 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 time of day when spruce beetle flight occurs should be determined as ground and canopy wind direction and speed vary with time of day. This could effect the response of flying beetles to optimum release time and temperature of MCH from bubble caps.

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
- CO= Initial project completed; additional work ongoing

MOUNTAIN PINE BEETLE
5-Year Strategy

	YEAR SCHEDULED					
	(94) 1	(95) 2	(96) 3	(97) 4	(98) 5	(98+) 5+
A. Short Term Basic Research:						
1. Aggregation pheromone components	X	X	X	X	X	
a. Define, make improvements	X	0	X	X	X	
b. Define geographic differences						
2. Anti-aggregation pheromones components						
a. Verbenone enantiomers	X	C				
b. Combinations of other pheromones		C				
3. Pheromone effects on assoc. species						
a. Competitive displacement		0	X	X	X	
b. Flight periodicities		0	X	X	X	
c. Effect on species diversity		X	X	X		
4. Dynamics of endemic populations						
a. Managed stands	0	0	X	X	X	
b. Unmanaged stands	0	0	X	X	X	
c. Epidemic "triggers"		0	X	X	X	X
5. Beetle dispersal						
a. How far do they fly?	X	0	X	X	X	
b. Distance of pheromone response		0	X	X		
6. Pheromone effects on natural enemies		0	X	X	X	
7. Attraction to fire-weakened trees		C				
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	X
b. Effect of host condition			X	X	X	X
3. Fate of semio-chemical adjuvants		X	X	X	X	
4. Effect of semio-chemicals on non-target organisms		X	X	X	X	

	(94)	(95)	(96)	(97)	(98)	(98+)
	1	2	3	4	5	5+
5. Primary host attraction behavior	X	0	X	X	X	
6. Population "fitness" (genetics)		0	X	X	X	
7. Host/beetle interaction relative to semio-chemical response		0	X	X	X	
8. Biological control				X	X	X
9. Weather effects on populations	0	0	X	X	X	
10. Historic disturbance patterns	0	0	X	X		
C. Short Term Applied Studies:						
1. Hazard/risk rating systems for all hosts						
a. Managed stands	0	0	X	X	X	
b. Unmanaged stands	0	0	X	X	X	
c. In southwestern ponderosa pine	0	0				
2. Short-term modeling (expert system)			X	X	X	
3. Verbenone evaluations						
a. Aerial--Dose, formulation	X	X	X	X	X	
b. Bubble caps--Dose, formulation	X	0	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?		0	X	X	X	
a. Push-pull strategy			X	X	X	
2. Stand management based on stand micro-climate/beetle biology interactions	0	0	X	X	X	
3. Silvicultural treatments						
a. Unevenaged management	0	0	X	X	X	
b. Ecosystem management	0	0	X	X	X	
4. Model development and validation						
a. Western Pine Bark Beetle Model(ESSA)	0	0	X	X		
b. PROGNOSIS variant	X	X	X	X		
c. MPB life system model		0	X	X		
d. Dispersal		0	X	X		

	(94) 1	(95) 2	(96) 3	(97) 4	(98) 5	(98+) 5+
5. Operational "decision support system"		0	X	X		
6. Permanent plot monitoring	0	0	X	X		
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	0	0	X	X		
b. Effects in various hosts	X	X	X	X		
5. Bait and cut effectiveness	0	0	X	X		
6. Spray and bait effectiveness		X	X	X		
7. Evaluate hazard/risk-rating systems	0	0	X	X	X	
8. Evaluate/refine loss prediction model(s) for all hosts	X	0	X	X	X	

WESTERN PINE BEETLE
5 Year Strategy

	YEAR SCHEDULED					
	(94)	(95)	(96)	(97)	(98)	(98+)
	1	2	3	4	5	5+
A. Short Term Basic Research:						
1. Beetle Dispersal						
a. How far do they fly	X	X	X			
b. How far is pheromone response effective	X	X				
2. Aggregation and Antiaggregation Pheromones						
a. Define pheromone spectra	X	C				
b. Determine dose responses to verbenone, ipsenol & ipsdienol			C			
c. Determine release rates and temperatures			C			
d. Determine nontarget effects particularly natural enemies	X	C				
e. Determine geographical variation in response to pheromones		O	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

(94)	(95)	(96)	(97)	(98)	(98+)
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	C			
2. Field bioassay of verbenone plus aggregation pheromone of competitive species		C			
3. Different release rates			X	X	X
4. Individual tree protection					
a. efficacy		O	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		O	X	X	X
b. develop operational release devices		O	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

c. Efficacy of combination of baits and infested tree removal

1. use of baits to prevent dispersal of overwintering populations		O	X	X	X
2. determine optimum density of treatment centers				X	X
3. effects on nontargets such as natural enemies				X	X
4. quantify "spillover" around baited centers			X	X	X

2. Silviculture or Stand Conditions

a. Treatments

1. trap trees	X	D			
b. hazard rating	X	O	X	X	X

(94)	(95)	(96)	(97)	(98)	(98+)
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	D				
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	O	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	D				
3. Impacts						
a. Loss and impact predictions	X	O	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	O	X	X	X	X

E. Operational Activities:

1. "How to" series of publications		X	X	X	X	
2. Sanitation/Salvage efficacy	X	O	X	X	X	X
3. Protective sprays for individual trees - identify new materials		C				
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					
	(94)	(95)	(96)	(97)	(98)	(98+)
	1	2	3	4	5	5+
A. Short Term Applied Studies:						
1. Aggregation Pheromone						
a. optimum blend	C	CO	X			
b. optimum release rate	C	CO	X			
c. geographic difference in response	O	O	X			
2. Antiaggregants						
a. optimum blend	C	X	X	X		
b. optimum release rates	C	X	X			
c. geographic difference in response			X	X	X	
3. Dispersal						
a. flight periodicity	O	O	X			
b. flight distance		O	X			
c. pheromone effective distance			X	X		
4. Develop Hazard and Risk Models			X	X	X	
5. Determine Outbreak Triggers	O	O	X			
-site/stand factors assoc. with occurrence		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		

(94)	(95)	(96)	(97)	(98)	(98+)
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

2) trap placement

X X X

c. bait and cut

1) spot treatment

X X X

2) area-wide effects

X X X

2. Antiaggregants

a. stand/area-wide protection

0 X X X

C. Operational Activities

1. Silvicultural Treatments To Reduce Risk/Hazard

a. unevenaged regeneration

0 X X X X

b. evenaged regeneration

0 X X X X

c. thinning

0 X X X X

JEFFREY PINE BEETLE
5 Year Strategy

	YEAR SCHEDULED					
	(94) 1	(95) 2	(96) 3	(97) 4	(98) 5	(98+) 5+
A. Short Term Basic Research:						
1. Determine flight periodicity		0	X	X		
2. Identify, isolate, and synthesize aggregation and antiaggregation phermones	0	0	X	X		
3. Field bioassay phermones		0	X	X		
4. Determine insect/pathogen interactions	0	0	X	X		
5. Determine geographical variation in response to pheromones		X	X	X		
6. Determine natural enemies	X	0	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 critical wildlife habitat	X	0	X	X	X	X
C. Short Term Applied Studies:						
1. Develop 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	0	X			
4. Test individual tree protection treatments (phermones/insecticides)	X	0	X			
5. Pilot test Sanitation/Salvage Treatments (ie LTBM campgrounds)	X	X	X	X		
6. Effects of hazard tree removal on area mortality	X	X	X	X		
7. Develop antiaggregation strategies for mortality reduction			X	X		
8. Effects of combining antiaggregation strategies with phermones of competitors				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	0	0	X	X	X	

	(94) 1	(95) 2	(96) 3	(97) 4	(98) 5	(98+) 5+
D. Long Term Applied Studies:						
1. Develop silvicultural strategies	X	X	X	X	X	X
2. Develop long term pheromone based monitoring system		O	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	O	X	X	X	X
7. Establish demonstration 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					
		(94)	(95)	(96)	(97)	(98)	(98+)
		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	0	0	X			
	b. mechanisms of tree response to attack and fungal inoculation	0	C				
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	0	0				
	c. determine seasonal dynamics of natural enemies	0	C				
3.	Identify beetle characteristics (environmental or genetically-based) that indicate SPB population fluctuations.						
	a. develop a continuous (artificial) rearing technique	0	0	X	X		
4.	Investigate the role of symbiotic associates of SPB/beetle quality in SPB population dynamics.						
	a. lipid-fungal associates	D	D				
	b. effect on beetle of nematodes	0	C	X			
	c. valid annosum/SPB associate	C					

	(94)	(95)	(96)	(97)	(98)	(98+)
	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	0	0	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	0	0	X	X	X	
b. determine if natural enemies are responsible for the initiation or termination of SPB outbreaks	0	0	X	X	X	X
c. clerid dispersal		0				
3. Identify beetle characteristics (environmental or genetically-based) that indicate SPB population fluctuations.						
a. identify & determine heritability of characteristic attributes of endemic and epidemic populations	0	0	X	X	X	
b. determine the potential critical relationship of these attributes relative to SPB population dynamics	0	0	X	X	X	
4. Investigate the role of symbiotic associates of SPB/beetle quality in SPB population dynamics.						
a. explore bacterial/viral control	0	0	X	X	X	

	(94)	(95)	(96)	(97)	(98)	(98+)
	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	0	0	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	0	X	X	X	X	X
7. Evaluation of area-wide efficacy of direct control strategies		0	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	0	X				
b. clerid/SPB trap prediction scheme	0	C				
2. Validations						
a. control tactics	0	0	X			
b. prediction models	X	0	X			
3. Management tool						
a. ISPBEX II	C	X				
b. INFORMS	0	0				
c. CLEMBEETLE	0	0				
d. Pine Plantation Hazard Rating	C	C				
4. Investigate new prevention & suppression strategies using natural enemies, selective chemicals, and pheromones.						
a. use of host-based compounds for individual tree protection	0	0				
b. use of semiochemical-based tactics in remedial control						
1. antiaggregation chemicals for SPB	0	0	X			
2. SPB and behavioral chemicals	0	0				
3. push-pull spot strategy	0	C				
c. augmented feeding for parasitoids		0	X	X		

	(94) 1	(95) 2	(96) 3	(97) 4	(98) 5	(98+) 5+
5. Use of selective chemicals for remedial control.						
a. evaluation of systemic chemicals for SPB control	X					
b. evaluation of synthetic pyrethroids for remedial control			X	X	X	X
6. Influence of RCW habitat management strategies on SPB populations	0	0	X			
D. Long Term Applied Studies:						
1. Validation						
a. SPB Demonstration Area Project	0	0	X	X	X	X
E. Operational Activities						
1. "How To" for semiochemical for suppression			X	X		
2. Use of aerial vieography to evaluate SPB in special management areas		0	X	X	X	
3. Management recommendtaions and guides based on results of SPB demonstration area.				X	X	X

SPRUCE BEETLE
5 Year Strategy

	YEAR SCHEDULED					
	(94) 1	(95) 2	(96) 3	(97) 4	(98) 5	(98+) 5+
A. Short Term Basic Research:						
1. Spruce Beetle Dispersal:						
a. How far do they fly?	CO	C				
b. How far is pheromone response effective?		X	X			
2. Anti & Aggregation Pheromones:						
a. Determine optimal release rates and temps.		O	X			
b. Geographic differences among spruce beetles	O	O	X	X		
c. Develop plume model	O	O				
B. Long Term Basic Research:						
1. Population dynamics & attack behavior of spruce beetle in Sitka spruce.		O	X	X	X	X
2. Effect of semiochemicals on non-target organisms		O	X	X		
3. Effect of semiochemicals on species diversity			X	X	X	X
4. Host resistance	O	O	X			
C. Short Term Applied Studies:						
1. Develop Hazard & Risk Models for Sitka spruce	CO	C				
2. MCH Evaluations:						
a. Aerial--dose, formulation	C	X	X			
b. Bubble caps--dose, formulation	O	O	X			
c. Individual tree protection	O	O	X	X		
3. Competitor species pheromone						
a. Use with & without MCH	O	O				
b. Aerial/ground--dose, form.			X	X	X	

(94)	(95)	(96)	(97)	(98)	(98+)
1	2	3	4	5	5+

D. Long Term Applied Studies:

1. Aggregation pheromones:					
a. Population monitoring--# of traps, trap placement	C				
b. Trapout--release rates, trap placement	C				
2. Silvicultural treatments:					
a. Uneven-aged management			X	X	X
b. Thinning and pruning	O	O	X	X	X
c. Fertilization	C	CO	X	X	X
3. Modeling integration:					
a. Loss & Impact Predictions	C	CO	X	X	X
b. Obtain rec. & aesthetic impact info	C	X	X	X	X
c. Wildlife habitat impact info	O	O	X	X	X
d. Growth & Yield Models	X	X	X	X	X

E. Operational Activities:

1. Demonstration areas:					
a. Thinning	C	CO	X	X	X
b. Bait & Cut		X	X	X	
2. "How to" series of pubs.		O	X	X	
3. "Best Management Practices" Guidelines		O	X	X	X

DOUGLAS-FIR BEETLE
5 Year Strategy

	YEAR SCHEDULED					
	(94)	(95)	(96)	(97)	(98)	(98+)
	1	2	3	4	5	5+
A. Short Term Basic Research:						
1. Dispersal of MCH and related material						
a. Dispersal and fate in air	0	0				
b. Release characteristics of dispensers	0	0				
2. Dispersal Patterns of DF beetle	0	0	X			
B. Long Term Basic Research						
1. Population dynamics						
a. Factors predisposing trees to attack	0	0	X	X	X	
b. Fungi associated with beetle damage	0	0	X	X	X	
c. Natural enemies of DFB	0	0	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 - eastside	0	0	X			
down trees - westside			X	X		
standing green trees - westside			X	X	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	0				
4. Develop hazard/risk rating models.	0	0	X	X		
5. Test methods for individual tree protection	0	0				
6. Develop methods for population monitoring	0	0	X			

	(94)	(95)	(96)	(97)	(98)	(98+)
	1	2	3	4	5	5+

D. Long Term Applied Studies

1. Silvicultureal Treatment for management of uneven aged stands		X	X	X	X	
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E. Operational Activity

1. Literature search		X	X			
2. Popular article			X	X		
3. Forest Insect Pest Leaflet up-date				X	X	
4. Up-date on DFB management "How To"			X	X	X	
5. Register MCH with EPA	0	0	X			
6. Establish demonstration areas to demonstrate management using MCH		0	X	X	X	

FIR ENGRAVER
5 Year Strategy

	YEAR SCHEDULED					
	(94) 1	(95) 2	(96) 3	(97) 4	(98) 5	(98+) 5+
A. Short Term Basic Research:						
1. Isolate, identify, synthesize pheromone complex	X					D*
2. Field bioassay candidate compounds						D*
3. Determine geographic variation to pheromones						D*
B. Long Term Basic Research:						
1. Dispersal- How far do beetles fly?			X	X	X	X
2. Primary attraction behavior			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
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						D*
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						D*
2. Area management of fir engraver			X	X		
3. Test trap-out strategy						D*
4. Develop silvicultural treatments						
a. effect of timing of thinning			X	X	X	X
5. Develop pheromone based monitoring system						D*

	(94)	(95)	(96)	(97)	(98)	(98+)
	1	2	3	4	5	5+

E. Operational Activities:

1. Develop How to's

- a. Hazard rating systems for California, white & red fir
- b. Hazard and risk rating systems for Inland Empire.

2. Silvicultural Treatments

- a. Hazard reduction
- b. Sanitation/Salvage
- c. Use of trap trees

		X	X			
			X	X	X	
X	X	X	X	X	X	X
X	X	X	X	X	X	X
		X	X	X	X	X

Research has determined there is no identifiable attractant pheromone for fir engraver so all activities relating to testing or using the pheromone have been dropped.

ARIZONA FIVE SPINED IPS
5 Year Strategy

	YEAR SCHEDULED					
	(94)	(95)	(96)	(97)	(98)	(98+)
	1	2	3	4	5	5+
A. Short Term Basic Research:						
1. Identify bait	X	X	X	X		
2. Identify antiaggregant	X	X				
B. Short Term Applied Research:						
1. Determine optimum bait blend		X	X			
2. Determine optimum bait release rate			X			
3. Determine flight periodicity				X	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-aggregant in protecting slash piles					X	X
3. Validate and modify slash disposal recommendations	0	0	X			

CALIFORNIA FIVESPINED IPS
5 Year Strategy

	YEAR SCHEDULED					
	(94) 1	(95) 2	(96) 3	(97) 4	(98) 5	(98+) 5+
A. Short Term Basic Research:						
1. Determine geographic variation in response to established aggregation and antiaggregation pheromones		C				
2. Determine response of natural enemies to various pheromones of the CFIB	X	C				
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		C				
C. Short Term Applied Studies:						
1. Test efficacy of semiochemical based management strategies on prevent CFIB build-up in slash	O	C	X	X	X	
2. Test efficacy of a combination of semiochemical based management strategies to prevent build-up of CFIB and pine engraver simultaneously	O	O	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					
	(94)	(95)	(96)	(97)	(98)	(98+)
	1	2	3	4	5	5+
A. Short Term Basic Research:						
1. <u>I. pini</u> dispersal:						
a. How far do they fly?			X	X		
b. How far is the pheromone response effective?			X	X		
c. Determine flight periodicity	0	0	X	X		
B. Long Term Basic Research:						
1. Aggregation pheromone blends:						
a. pheromone components	X	C	X	X	X	
b. geographic variation	X	0	X	X	X	
2. Antiaggregation pheromone blends of associated species:						
a. pheromones of different species	X	C	X	X	X	
b. enantiomers	0	0	X	X	X	X
c. geographic variation		0	X	X	X	X
3. Fate of applied semiochemicals in the environment.						
			D			
4. Determine impact of feeding attacks.						
			X	X	X	X
5. Determine live host selection behavior						
			X	X	X	X
6. Effect of drought on live tree susceptibility						
			X	X	X	X
C. Short Term Applied Studies:						
1. Continue development of antiaggregants to prevent attack of slash by <u>I. pini</u> .						
a. Improve bead formulations			X	X	X	X
b. Evaluate bubble caps	0	0	X	X		

	(94)	(95)	(96)	(97)	(98)	(98+)
	1	2	3	4	5	5+

D. Long Term Applied Studies

1. Development /document silvicultural strategies.

a. Timing of creation of slash	0	0	X	X	X	
b. Use of trap trees/slash(green chain)				X	X	
c. Use of prescribed fire on overwintering adult populations			X	X	X	
d. Effects of overstory density on brood production in slash (Arizona)	0	0				
e. Development of a Hazard/Risk rating system			X	X	X	X

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
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E. Operational Activities:

1. "How to"(Public use) series publications Work for Az and NM completed			X	X	X	X
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2. "Best Management Practices" Guidelines, update			X	X		
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IPS PERTURBATUS
5 Year Strategy

	YEAR SCHEDULED					
	(94) 1	(95) 2	(96) 3	(97) 4	(98) 5	(98+) 5+
A. Short Term Basic Research:						
1. Ips beetle dispersal:						
a. How far do they fly?	C					
b. Do they fly across openings?	C					
2. Antiaggregation pheromones:						
a. Release rates of ipsenol and methyl butenol (beads & caps)	O	C				
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	O	C	X	X	X	
5. Effect of ice/snow breakage on Ips population buildup		O	X	X		
C. Short Term Applied Studies:						
1. Effect of ipsdienol on parasites & predators	O	O	D-to be dropped in 96			
2. Evaluate efficacy of anitaggregants on Ips populations	O	C				
3. Develop hazard and risk models for white spruce			X	X		

	(94)	(95)	(96)	(97)	(98)	(98+)
	1	2	3	4	5	5+

4. Effects of prescribed fire on over-wintering populations in leaf litter of cutover areas

X X

D. Long Term Applied Studies:

1. Silvicultural treatments:

- a. Even-aged/unevenaged management
- b. Thinning
- c. Fertilization

				X	X	X
X	X	X	X	X	X	X
		X	X	X	X	X

2. Models:

- a. Loss and impact predictions
- b. Growth and yield models

			X	X	X
			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
- b. Fertilization

	X	X	X	X	X
	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

(94) (95) (96) (97) (98) (98+)
1 2 3 4 5 5+

A. Short Term Basic Research:

1. Biology

a. Life history

- Life cycles
- Geographic & elevational influences on development
- Attack densities & pattern
- Brood sizes
- Symbiotic fungal associations
- # of generations
- Re-emergence patterns
- Hosts
- Insect associations

0 X X X X

b. Adult flight

- Periodicity
- Distances
- Dispersal
- Orientation

0 0 X X

2. Pheromones

a. Aggregants

- How far is response effective

X X X

b. Antiaggregants

- Define

X X

B. Long Term Basic Research:

1. Biology

a. Predators & Parasites

- Define
- Effect

X X X X

	(94)	(95)	(96)	(97)	(98)	(98+)
	1	2	3	4	5	5+
2. Host/WBBB Interactions						
a. Root disease associations	0	0	X	X	X	X
b. Habitat type associations			X	X	X	X
c. Climate/weather associations			X	X	X	X
d. Host response to attack			X	X	X	X
e. Susceptibility to attack			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	
b. Thinning	X	X	X	X	X	
c. Pruning		0	X	X	X	
d. Insecticides			X	X	X	
- Identify						
- Develop application techniques						
2. Pheromones						
a. Mode of application -						
- Aggregants			X	X	X	
- Antiaggregants					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		D				
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
2. Develop silvicultural techniques to reduce stand hazard				X	X	X
3. Model development					X	X
4. Expert system					X	X

(94)	(95)	(96)	(97)	(98)	(98+)
1	2	3	4	5	5+

E. Operational Activities:

1. "How to" series of publications			X	X	X	X
2. Sanitation/Salvage methodology			X	X	X	X
3. Trap trees			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	X

TOMICUS PINIPERDA
5 Year Strategy

	YEAR SCHEDULED					
	(94)	(95)	(96)	(97)	(98)	(98+)
	1	2	3	4	5	5+
A. Short Term Basic Research:						
1. Life History of <u>T. piniperda</u> in the United States						
a. Overwintering behavior	0	CO	X			
b. Flight activity/periodicity	0	CO	X			
c. Reproduction, brood development, and re-emergence	0	CO	X			
d. Identify fungal associates	0	CO				
e. Determine internal pathogens	0	D	X			
f. Determine predators & parasites	0	0	X			
g. Determine within-tree attack pattern.	0	CO				
h. Determine survival in cut Christmas trees	0	CO	X			
2. Life history of the exotic clerid <u>Thanasimus formicarius</u> in the United States						
a. Import clerid from Europe		0	X			
b. Develop lab rearing techniques		0	X	X		
c. Determine impact on non-target native scolytids			X	X	X	
d. Determine impact on non-target native natural enemies			X	X	X	
e. Potentially field release and monitor				X	X	
B. Long Term Basic Research:						
1. Life History of <u>T. piniperda</u>						
a. Determine host-selection behavior	0	CO	X	X	X	X
b. Determine interactions with native bark beetles	0	CO	X	X	X	X
c. Determine dispersal potential		CO		X	X	X
d. Determine genetic similarity among different US sub-populations	0	CO	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	0	CO	X	X		
b. Describe reproduction in Scotch pine and native conifers	0	CO	X	X		
c. Describe ability to attack and kill live North American conifers			X	X	X	

	(94)	(95)	(96)	(97)	(98)	(98+)
	1	2	3	4	5	5+

C. Short Term Applied Studies:

1. Develop Survey/Trapping Methodologies						
a. Determine attraction to alpha-pinene	0	D				
b. Determine radius of attraction of alpha-pinene lures		D	X			
c. Develop use of trap trees as a survey tool		0	X	X		
d. Develop methods to estimate population levels using shoot-feeding damage		D	X	X		
2. Develop Control Tactics						
a. Develop methods to prevent within and between-stand spread	0	0	X	X		
b. Determine effectiveness of insecticides for control	0	0	X			
c. Determine effectiveness of chipping and tarping for control	0	D	X			
d. Determine effectiveness of verbenone	0	D	X	X		
e. Evaluate shoot feeding behavior for timing nursery stock shipment	0	D				
f. Determine effect of methyl chavicol	0	D				

D. Long Term Applied Studies:

1. Develop Impact Studies	0	0	X	X	X	
2. Develop Silvicultural Strategies						
a. Timing of logging operation	0	0	X	X	X	
b. Slash treatment	0	0	X	X	X	
c. Use of trap trees	0	0	X	X	X	
d. Handling methods for infested logs		D	X	X	X	

E. Operational Activities:

1. Develop Best Management Practices		0	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	X	X		