



**USDA FOREST SERVICE**  
**STATUS REPORT**  
**ON**  
**WESTERN BARK BEETLE R&D PROGRAM**  
**December 1995**

*Pacific Southwest Research Station, Albany, CA*  
*Pacific Northwest Research Station, Portland, OR*  
*Intermountain Research Station, Logan, UT*



# **FY'92 - FY'94 SUMMARIZED ACCOMPLISHMENTS**



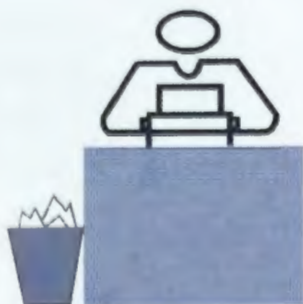
***Pacific Southwest Research Station, Albany, CA***

***Pacific Northwest Research Station, Portland, OR***

***Intermountain Research Station, Logan, UT***

**December 1995**

**Prepared by: Patrick J. Shea, PhD.  
Principal Research Entomologist  
USDA Forest Service  
Pacific Southwest Research Station  
2121C Second Street  
Davis, CA 95616**



## TABLE OF CONTENTS

|                                                                       |     |
|-----------------------------------------------------------------------|-----|
| Executive Summary .....                                               | 3   |
| Background .....                                                      | 4   |
| Accomplishments .....                                                 | 5   |
| Publications .....                                                    | 8   |
| Appendix A Western Bark Beetle RD&A Program .....                     | A-1 |
| Appendix B Pacific Southwest Research Station<br>Summary Report ..... | B-1 |
| Appendix C Pacific Northwest Research Station<br>Summary Report ..... | C-1 |
| Appendix D Intermountain Research Station<br>Summary Report .....     | D-1 |



## EXECUTIVE SUMMARY

USDA Forest Service research scientists have recently accelerated research on the development of bark beetle management systems. This accelerated program was developed in response to the strong public reaction to widespread tree mortality and other forest health problems in several western states. To meet the public's concerns, Congress appropriated funds<sup>1</sup> to initiate a Western Bark Beetle Research and Development program. The program was carried out by research scientists and cooperators in three USDA Forest Service Research Stations – Pacific Southwest, Pacific Northwest, and Intermountain Research Stations.

The research focused on pheromone-based bark beetle management systems. These natural chemicals produced by insects themselves and nontoxic to other organisms, can influence the behavior of targeted species of bark beetles. These beetles are significant pest of forest in the western United States. Forest Service researchers have conducted over 55 studies and experiments involving 8 species<sup>2</sup> of bark beetles and their associated natural enemies. Specifically, their research has concentrated on: (1) understanding the behavior of bark beetle populations and their chemical ecology; (2) isolating, identifying, and synthesizing new aggregation pheromones; (3) field-testing new formulations and delivery systems of pheromones for pest management purposes; (4) and advancing our knowledge of the functional role and impact of bark beetles in forest ecosystems.

Research scientists have conducted rigorous experiments that have successfully demonstrated that antiaggregation pheromones of two species of *Ips* beetles can be used to prevent population build-up of these insects in ponderosa pine debris resulting from forests management and/or storm damage and thus greatly reduced the threat of mortality to the residual forest. In a unique R & D operational demonstration project aggregation (attractive) and

---

<sup>1</sup> Congress added \$1,000,000 to the Forest Service Research budget in fiscal year 1992 for the R and D program; in fiscal year 1993 Congress appropriated \$500,000 for the program. Since then funding for the bark beetle pheromone research has been included in the base Forest Service Research budge.

<sup>2</sup> Douglas-fir beetle - *Dendroctonus pseudotsugae*; Jeffrey pine beetle - *Dendroctonus jeffreyi*; Mountain pine beetle - *Dendroctonus ponderosae*; Western pine beetle - *Dendroctonus brevicornis*; Roundhead pine beetle - *Dendroctonus adjunctus*; Spruce beetle - *Dendroctonus rufipennis*; Pine engraver - *Ips pini*; California fivespined ips - *Ips pararconfusus*.



antiaggregation (repellent) pheromones of the California fivespined *Ips* were effectively used to halt the ongoing and unacceptable losses of the rare and endangered Torrey pine in Torrey Pine State Reserve, San Diego, CA.

Research has successfully demonstrated that the antiaggregation pheromone (MCH) of Douglas-fir beetle (DFB) and spruce beetle (SB) can be used to: (1) reduce build-up of damaging populations of DFB in storm damaged Douglas-fir; (2) reduce mortality caused by DFB in standing Douglas-fir; (3) reduce mortality caused by SB in standing white spruce in Alaska. The only segment missing for a fully functional pheromone-based management system for DFB is the pesticide registration required by the Environmental Protection Agency. Finally, it has been demonstrated that aggregation pheromones can be used to attract mountain pine beetles into areas scheduled for fuelwood harvesting. Possible additional benefits from this strategy were that adjacent riparian areas were protected from attack by MPB and the residual stands from which the fuelwood was harvested was sanitized of heavy infections of dwarf mistletoe.

### BACKGROUND

The health of forest ecosystems throughout the western United States, including Alaska, have been greatly affected by human activities during the past 200 years. Fire suppression during the previous 90+ years has profoundly increased the threat of catastrophic wildfire and insect outbreaks, by changing the species composition of forest stands and increasing the susceptibility of trees to stress. As a consequence, the severe drought that has affected much of the western United States, Canada, and Mexico—especially California—since 1988 has resulted in unprecedented levels of tree mortality. The detrimental effects of bark beetles have not only further degraded forest health conditions throughout vast areas of western North America but also have greatly exacerbated the threat of catastrophic fire by significantly increasing the fuel load.

Most of this tree mortality has resulted from infestations by various species of bark beetles. For example, in California, in overstocked stands and in stands where past harvesting practices have encouraged growth of off-site species, the fir engraver beetle has killed more than 80% of the standing volume of timber. In addition, in 1993, on lands administered by the USDA Forest Service in California, the volume of timber killed by bark beetles - ponderosa pine killed by the western pine beetle and white fir killed by bark beetles- exceeded 1.5



billion board feet. The spruce beetle, the primary tree-killing insect in Alaska, is in outbreak status in several areas south of the Alaska Range and has covered about 600,000 acres throughout the state. About half of this acreage (280,000 acres) is in white spruce stands on the Kenai Peninsula, including significant portion of the Chugach National Forest.

Many insects including bark beetles, use chemical messages as a means of communication between individuals of the same or different species. Collectively these unique and biologically powerful compounds are called "semiochemicals". The compounds specifically used by individuals of the same species are defined as "pheromones". Some compounds attract members of the same species ("aggregation pheromones") and some compounds block the aggregation pheromone ("antiaggregation pheromones"). The existence and functional role of some bark beetle semiochemical systems have been known to science for over 25 years. However, only recently has research been conducted to develop the use of these unique compounds for forest pest management purposes. In the western United States this research and development program has operated at an accelerated rate since 1992.

Coordination of this research and development effort has been accomplished via the National Bark Beetle Steering Committee whose members comprised personnel from Forest Service Research, forest pest management specialist from all West (including Alaska), and several State forest entomologists. The research summarized in this report was carried out by scientists from the Pacific Southwest Research Station, Albany, CA; the Pacific Northwest Research Station, Portland, OR; and the Intermountain Research Station, Ogden, UT. Funds were obtained through FIDR (appropriated Research funds) and the Technology Development Program (appropriated FPM funds) from FY92 to FY94. Station FIDR personnel formed partnerships with each other in accomplishing certain tasks in addition to forming partnerships with FPM personnel from Regions 1,2,3,4,5,6, and 10; University of California, Riverside and Davis; Oregon State University, and Universidad Autuonoma Nuevo Leon, Linares, N.L., Mexico.

## ACCOMPLISHMENTS FOR THE WESTERN BARK BEETLE R&D

### WESTERN PINE BEETLE

\*Advanced the knowledge of the flight periodicity of WPB/MPB/Ips throughout California. This knowledge is necessary in order to develop pheromone-based strategies.



\*Determined the most effective formulations (enantiomeric blend) of verbenone (antiaggregation pheromone) for interrupting aggregation behavior. Extended knowledge of the effect of ipsdienol for enhancing the effect of verbenone.

\*Completed efficacy testing of verbenone/ipsdienol treatments for protecting high-value ponderosa pine sites from attack by WPB. Such sites include campgrounds, isolated small old-growth stands or other special use habitats.

\*Determine attractiveness of WPB, MPB, Ips pheromones (alone and in combination with each other) on insect predator complex. (Through Cooperative Agreement with University of California, Davis)

\*Advanced knowledge of the distribution, impact, and year-to-year variation in WPB/MPB/Jeffrey pine beetle mortality in the eastside pine ecoregion.

\*Advanced knowledge of the role of WPB in creating suitable habitat for birds that utilize snags for nesting, foraging, and defense of territory.

#### MOUNTAIN PINE BEETLE (MPB)

\*Determined the most effective enantiomeric blend of verbenone to interrupt the aggregation behavior of MPB. Determined the effect of ipsenol on enhancing efficacy of verbenone.

\*Advanced the knowledge of response of mountain pine beetles in old and new infestations to antiaggregation pheromones. Demonstrated that mountain pine beetles will respond negatively to the host volatile, methyl chavicol.

\*Demonstrated that the antiaggregation pheromone, verbenone, could be used to reduce lodgepole pine mortality caused mountain pine beetle in fire-injured stands.

\*Used a combination of aggregation and antiaggregation pheromones to reduce mountain pine beetle infestations in unwanted areas of the Sawtooth National Recreation Area.



\*Used aggregation pheromones to concentrate mountain pine beetle infestations in dwarf mistletoe infested stands. Two management goals were achieved by this action; (1) Fuelwood harvest was focused on stands that were readily accessible by existing roads; (2) mistletoe stands were sanitized by concentrating beetle mortality in heavily infected trees.

#### DOUGLAS-FIR BEETLE (DFB)

\*Developed MCH treatment methods that successfully protect high-risk, high value resources such as recreation sites, old-growth stands, special habitat areas, from Douglas-fir beetle attacks to the Douglas-fir component of these stands, and particularly the larger diameter trees. Methods are effective in either low or high density beetle populations.

\*Developed use of aggregation pheromones in trapping systems to reduce beetle numbers and maneuver flying beetle populations into stands of lower value, scheduled for removal, or that are designated for other purposes consistent with multi-resource, ecosystem-based management.

\*Advanced knowledge of dispenser placement, release rates, and dosage considerations of antiaggregation and aggregation pheromones of Douglas-fir beetle and spruce beetle.

#### SPRUCE BEETLE (SB)

\*Developed use of pheromones of associated bark beetle species to preempt spruce beetles in host logs, thus reducing the probability of population increase by spruce beetle and the potential of this more aggressive species to cause tree mortality.

\*Advanced the knowledge of using MCH in various release devices (both ground and aerial) for reducing white spruce mortality caused by spruce beetle infestations in south-central Alaska.

\*Advanced knowledge of the dispersal behavior and capabilities of both spruce and Douglas-fir beetles.

\*Advanced the knowledge of the response of natural enemies and associated insects to the pheromones (aggregation and antiaggregation) of spruce beetle, Douglas-fir beetle, and Ips perturbatus.



#### JEFFREY PINE BEETLE (JPB)

\*Isolated and identified major components of the JPB aggregation pheromone. (Cooperative Agreement with University of California, Riverside)

#### ROUNDHEADED PINE BEETLE (RHPB)

\*Determined the flight periodicity of RHPB in New Mexico and Jalisco State, Mexico. Field bioassay response of RHPB to various enantiomers of verbenone in New Mexico and Jalisco State, Mexico.

\*Advanced knowledge of the geographic variation in chemotaxonomy, and response to aggregation pheromones by RHPB from New Mexico and Jalisco State, Mexico.

#### IPS Beetles (Pine Engraver and California Fivespined Ips)

\*Developed the use of various blends of antiaggregation pheromones to prevent build-up of ips population in pine slash. These tactics will be used to prevent top killing or whole tree mortality to leave trees.

\*Developed a trap-out strategy that deployed both aggregation and antiaggregation pheromones to eliminate tree mortality caused by California fivespined ips that threatened the last remaining natural stand of Torrey pine at Torrey Pine State Reserve, San Diego, CA.

### PUBLICATIONS

Amman, G.D. 1994. Potential of verbenone for reducing lodgepole and ponderosa pine mortality caused by mountain pine beetle in high-value situations. pp33-37. IN P.J. Shea (Tech. Coord) Proceedings of a symposium on management of western bark beetles with pheromones: research and development. Gen. Tech. Rep. PSW-GTR-150, USDA Forest Service, Pacific Southwest Research Station, Albany, CA. 53pp.

Amman, G.D. and K.C. Ryan. 1994. Using pheromones to protect heat-injured lodgepole pine from mountain pine beetle infestation. Res. Note INT-419. USDA Forest Service, Intermountain Research Station, Ogden, UT. 8pp.

Amman, G.D. and S.B. Lindgren. 1995. Semiochemicals for management of mountain pine beetle: status and research and application. In Salom,



S.M. and K.R. Hobson (eds) Proceedings of an informal conference, Ann. Meeting of the Entomological Society of America, 1993. Gen. Tech. Rep. INT-GTR-318. USDA Forest Service, Intermountain Research Station, Ogden, UT. 54pp.

Borden, J. H., L.J. Chong, R.A. Werner, E.H. Holsten, and G. H. Gries. 1996. Regionally specific bioactivity of two new pheromones for *Dendroctonus rufipennis* (Kirby) (Coleoptera:Scolytidae) J. Applied Entomology. (IN PRESS).

Daterman, G.E. 1994. Protecting unique habitats and riparian areas from insect attack. IN: Everett, R.L. Compiler, Eastside Forest Ecosystem Health Assessment, Vol. IV. Restoration of Stressed Sites and Processes. USDA Forest Service, Pacific Northwest Research Station, Portland, OR. PNW-GTR-330, pp43-46.

Hobson. K. R. 1995. Host compounds as semiochemicals for bark beetles. pp.48-51. IN Salom, S.M. and K. R. Hobson (eds) Proceedings of an informal conference, Ann. Meeting of the Entomological Society of America, 1993. Gen. Tech. Rep. INT-GTR-318. USDA Forest Service, Intermountain Research Station, Ogden, UT. 54pp.

Holsten, E.H. 1994. The role of spruce beetle pheromones as management strategies in Alaska. pp11-14. IN: P. Shea (Tech. Coord.) Proceedings of the Symposium on Management of western bark beetles with pheromones: recent research and development. Gen. Tech. Rep. PSW-GTR-150. USDA Forest Service, Pacific Southwest Research Station, Albany, CA. 53pp.

Page, M., J. Richmond, J. Flores Lara, and P.J. Shea. 1993. Analisis preliminares de los escarabajos descortezadores de Mexico. IN: Proc. VII Simposio Nacional Sobre Parasitologia Forestal. ABSTRACT. p.22.

Paine, T., C. Hanlon, J. Millar, and S. Huang. 1996. Attractant pheromones of the Jeffrey pine beetle. J. of Chem. Ecology. (IN PRESS).

Ross, D.W. and G.E. Daterman. 1995. Reduction of Douglas-fir beetle infestation of high risk stands by antiaggregation and aggregation pheromones. Can. J. For. Res. 24:00-000. (IN PRESS).



- Ross, D.W. and G.E. Daterman. 1995. Response of Dendroctonus pseudotsugae (Coleoptera:Scolytidae) and Thanasimus undatulus (Coleoptera:Cleridae) in traps with different semiochemicals. J. Econ. Ent. 88:0000. (IN PRESS)
- Ross, D. W. and G.E. Daterman. 1995. Confirmation of the efficacy of an anti-aggregation pheromone for reducing Douglas-fir beetle, Dendroctonus pseudotsugae Hopkins (Coleoptera:Scolytidae), infestations of high risk stands. Canad. Entomol. 127:00000 (IN PRESS).
- Salom, S.M. and K.R. Hobson. 1995. The now and future of applications of semiochemicals for management of bark beetle infestations. pp1-2. IN Salom, S.M. and K.R. Hobson (eds.) Proceedings of an informal conference, Ann. Meeting of the Entomological Society of America, 1993. Gen. Tech. Rept. INT-GTR-318. USDA Forest Service, Intermountain Research Station, Ogden, UT. 54pp.
- Seybold, S. D.L. Wood, P.J. Shea, S.R. Mori, K. Mori. 1993. Estudios de campo sobre el comportamiento de agregación de Ips lecontei Swaine e insectos forestales asociados en la parte central-sur Arizona. In Proc. de VII Simposio Nacional Sobre Parasitología Forestal. ABSTRACT p19.
- Shea, P.J. 1993. Technical Coordinator. Proceedings of the Symposium on Management of western bark beetles with pheromones: Research and development. USDA Forest Service, Gen. Tech. Rept. PSW-GTR-150, Pacific Southwest Research Station, Albany, CA. 54pp.
- Shea, P.J. 1993. Management of western bark beetles with pheromones: Introduction. p1-3. IN: P.J. Shea (Tech. Coord) Proceedings of the Symposium on Management of western bark beetles with pheromones: Research and development. USDA Forest Service, Gen. Tech. Rept. PSW-GTR-150, Pacific Southwest Research Station, Albany, CA 54pp.
- Shea, P.J. and J.M. Wenz. 1993. Bark beetle research in California. p46-53. IN: P.J. Shea. (Tech. Coord) Proceedings of the Symposium on Management of western bark beetles with pheromones: Research and development. USDA Forest Service, Gen. Tech. Rept. PSW-GTR-150, pp54.



- Shea, P.J. and M. Neustein. 1995. Protection of a rare stand of Torrey pine from Ips paraconfusus with aggregation pheromones. p49-53. In: Salom, S. and K. Hobson (eds) Proceedings of an Informal Conference on application of semiochemicals for the management of bark beetle infestations. Ann. Meeting of Entomological Society of America. USDA Forest Service, Gen. Tech. Rept. INT-GTR-318. Intermountain Research Station, Ogden, UT. pp54.
- Shea, P.J. 1995. Use of insect pheromones to manage forest insects - present and future. p272-283. IN: F. Hall and J. Barry (Tech. Coord) Proceedings of a Symposium on Biorational Pest Control: Formulation and Delivery. American Chemical Society Symposium Series 595. pp306.
- Shea, P.J. 1994. Native conifers with limited distributions: Ips paraconfusus in Torrey pine. IN Proceedings of the 43rd Annual Meeting California Forest Pest Council, USDA Forest Service, Region Five, Forest Pest Management. ABSTRACT pp16.(LIST PUBS. BY STATION
- Werner, R.A. 1993. Response of the engraver beetle, Ips perturbatus, to semiochemicals in white spruce stands of interior Alaska. USDA Forest Service, PNW-RP-465. Pacific Northwest Research Station, Portland, OR. pp23.
- Werner, R.A. 1994. Research on the use of semiochemicals to manage spruce beetles in Alaska. p 15-21. IN: P.J. Shea (Tech. Coord.) Proceedings of a Symposium of Management of western bark beetles with pheromones: Research and development. USDA Forest Service, PSW-GTR-150. Pacific Southwest Research Station, Albany, CA. 54pp.
- Werner, R.A. and E. H. Holsten. 1995. Current status of research with spruce beetle. p23-29. IN: Salom, S. and K. Hobson (eds) Proceedings of Informal Conference, Ann. Meeting of Entomological Society of America. USDA Forest Service, INT-GTR-318. Intermountain Research Station, Ogden, UT. 54pp.



## APPENDIX A

### WESTERN BARK BEETLE RD&A PROGRAM

#### FY1992 Research Implementation Plan

November 14, 1991

The appropriations bill for FY1992 includes \$1,000,000 to initiate some of the research described in the Western Bark Beetle RD&A Plan. The RD&A Plan outlines a 5-year, \$5.72 million program to reduce short- and long-term bark-beetle caused tree mortality in the West. This implementation plan described research that will be funded with the appropriated money in FY1992.

The research described below is a subset of what was proposed in the RD&A Plan and will focus on using behavioral chemicals (pheromones) as tools to reduce mortality from bark beetles in the West. Several criteria were used to evaluate and prioritize research studies to be funded in FY92. The research concentrates on testing behavioral chemicals that are already available. Short-term research and studies with a relatively high probability for success were given priority, because there is no guarantee that funding in subsequent years will be appropriated. Priority was also given to test research involving bark beetle species currently having high populations. The idea is to test behavioral chemical strategies with the available money while bark beetle populations exist to permit rigorous testing.

The research covers most of the important bark beetles species in the West. Emphasis of this research will be on the most aggressive species--western pine beetle (WPB), mountain pine beetle (MPB), Douglas-fir beetle (DFB), and spruce beetle (SP). The following Table summarizes the studies that will be initiated in FY92. In the accompanying table the Station(s) responsible for each study is listed in parentheses. As shown in the Table, most of the money will be used to test suppression strategies using behavioral chemicals.



| Study Description                                                                                       | Amount (in \$1000) |     |
|---------------------------------------------------------------------------------------------------------|--------------------|-----|
| -----                                                                                                   |                    |     |
| IDENTIFICATION AND SYNTHESIS OF PHEROMONES                                                              |                    |     |
| Jeffrey pine beetle pheromone identification (PSW)                                                      | 100                | 100 |
| FIELD BIOASSAYS                                                                                         |                    |     |
| Assays to determine when bark beetles fly                                                               |                    |     |
| WPB, Ips, MPB (PSW)                                                                                     | 95                 |     |
| SB (PNW)                                                                                                | 25                 |     |
| Assay attractiveness of pheromone lures for MPB in white bark pine. (INT)                               | 17                 |     |
| Use of pheromone traps for predicting MPB population trends (INT)                                       | 35                 |     |
| Air sampling technology--Develop procedures to measure concentration of pheromones being released (PNW) | 100                | 272 |

#### BEHAVIORAL CHEMICAL-BASED MANAGEMENT STRATEGIES

|                                                                                                              |     |  |
|--------------------------------------------------------------------------------------------------------------|-----|--|
| Push/Pull--Use of attractants in combination with repellents to protect high values tree                     |     |  |
| MPB (INT)                                                                                                    | 71  |  |
| DFB (PNW)                                                                                                    | 70  |  |
| Single Tree Protection--Use of antiaggregants to protect individual high value trees from WPB (PSW)          | 85  |  |
| Bait and Spray--Use of pheromones to attract WPB to lethal trap trees for area-wide population control (PSW) | 165 |  |
| Trap out--Suppress area-wide bark beetle populations by trapping beetles.                                    |     |  |
| SB (PNW)                                                                                                     | 50  |  |
| DFB (PNW)                                                                                                    | 75  |  |



62

628

1000

## APPENDIX B

### WESTERN BARK BEETLE RD & A SUMMARY REPORT

FY'92 - FY'94 Summarized Accomplishment Report

for

Pacific Southwest Research Station, Albany, CA

#### EXECUTIVE SUMMARY

Since 1992 when funding was received to conduct research on the development of pheromone-based bark beetle management systems, personnel at PSW have initiated, conducted or participated in 22 studies (13 completed and 9 ongoing) involving six bark beetle species and their associated predators. These target species range geographically from Mexico to Alaska. Research has concentrated on gathering relevant data on bark beetle behavior; identification, characterization, and synthesis of new aggregation pheromones; field testing new enantiomeric blends, formulations, and delivery devices; and studying the functional role of bark beetles in forest ecosystems. Among other results studies show that antiaggregation pheromones can effectively inhibit colonization of slash by *Ips* beetles and reduce tree mortality in infested pine stands by both mountain and western pine beetles. The aggregation pheromones of *Ips paraconfusus* were effectively deployed in an R & D operational demonstration project that halted the ongoing and unacceptable losses of the rare Torrey pine in Torrey Pine State Reserve, San Diego, CA. Research is continuing to develop pheromone-based management systems and investigate the beneficial role and function of bark beetles in sustainable forest ecosystems.

#### BACKGROUND

Forest health in the western United States is of great concern to the public at large and to both public and private land managers. Forest ecosystems in California have been greatly affected by human activities during the past 200



years. The effect of fire suppression during the previous 90+ years has been especially profound in increasing the threat of catastrophic wildfire and insect outbreaks mediated by weather-induced stresses.

Since 1988 much of western United States, Canada, and Mexico, but especially California, has been suffering from a very severe drought. As a consequence of these droughty conditions unprecedented tree mortality, caused by several species of bark beetles, has occurred. In some overstocked stands, and in stands where past harvesting practices have encouraged growth of off-site species, mortality has exceeded 80% of the standing volume. In 1993 tree mortality (primarily ponderosa pine and white fir), on lands administered by USDA Forest Service, exceeded 1.5 billion board feet. These bark beetle outbreaks have not only further degraded forest health, but greatly exacerbated the threat of catastrophic fire by significantly increasing the fuel load.

Many insects, including bark beetles, use chemical messages as a means of communication between individuals of the same or different species. These unique and biologically powerful compounds are called semiochemicals. The existence and functional role of some bark beetle semiochemical systems have been known to science for over 25 years. However, only recently has research been conducted to develop the use of these unique compounds for forest pest management purposes. In the western United States this research and development program has operated at an accelerated rate since 1992. Coordination of this research and development has been accomplished via the National Bark Beetle Steering Committee (formerly the Western Bark Beetle Pheromone Working Group).

This report summarizes research and development activities on western bark beetles organized, directed, conducted, or participated in by personnel of the Pacific Southwest Research Station, Davis, CA. Funds were obtained through FIDR and Technology Development (FPM) sources appropriated in FY's 1992-1994. PSW personnel have worked with scientists from Pacific Northwest Station, Intermountain Forest and Range Experiment Station, Forest Pest Management personnel in R-1, R-3, R-5, R-10, University of California, Riverside and Davis, and Universidad Autonoma Nuevo Leon, Linares, N.L., Mexico.

#### RESEARCH AND DEVELOPMENT ACTIVITIES

Western bark beetle research and development projects, involving personnel from PSW-4502, have concentrated in four areas: (1) testing



semiochemical-based bark beetle management strategies; (2) gathering critical biological data concerning bark beetle behavior i.e. flight periodicity and response of several natural enemies to prey aggregation pheromones; (3) census of bark beetle mortality at Blacks Mountain Experiment Forest and interaction between and functional role of several Dendroctonus spp. in an eastside pine type; and (4) basic isolation, identification, and synthesis of the Jeffrey pine beetle pheromone complex.

DENDROCTONUS BREVICOMIS (Western pine beetle - WPB): Development of semiochemical based WPB management systems; field bioassay of verbenone and other semiochemical for inhibition of WPB to baited funnel traps; impact and role of WPB in California forest ecosystems; flight periodicity of WPB throughout California.

Rationale: Over the past 6 to 7 years of drought in California WPB has been the primary agent of ponderosa pine mortality. Since 1989 in excess of 800 mmbf of ponderosa pine have been killed in the four major forest provinces. The semiochemical ecology of WPB is well documented, but only recently has research been directed toward developing semiochemical-based pest management systems. In addition, it is becoming increasingly clear that individual WPB-killed ponderosa pine trees are important to maintenance of biological diversity via creation of unique wildlife habitat units.

Status of R & D:

1. The flight periodicity of western pine beetle, mountain pine beetle, Ips paraconfusus, and Ips pini in California, 1991-1994. The primary objective of this study was to determine the flight periodicity of the major scolytid bark beetles on both a north to south transect and along two elevational transects in the Sierra Nevada. In addition to the target species, this study also monitored the flight periodicity of the predators associated with each bark beetle (prey) species. As a result of this study we now know the flight behavior of these species throughout their entire range in California. In addition, we now have a clear understanding of the effect of elevation on flight behavior and the distribution of each species. This study is important because in order to develop a semiochemical based management system for these bark beetles it must be determined when the adults are in flight. This study has been



completed and management guidelines are being prepared, as are various manuscripts for publication. (Cooperative study with R-5, FPM, funded by FIDR and FPM)

2. The response of western pine beetle to various enantiomers of verbenone alone and in combination with ipsdienol, 1992. The objective of this study was to test the inhibitory effect of various enantiomers of verbenone in combination with a pheromone (ipsdienol) of a potential competitor species, *Ips paraconfusus*. In summary the combinations of verbenone and ipsdienol clearly enhance the inhibition of WPB to baited funnel traps compared to verbenone alone. This theory, i.e. enhancement of the inhibitory effect of a species' specific antiaggregation pheromone with the addition of an aggregation pheromone of a potential competitor, has been demonstrated in other bark beetle systems. This study has been completed and results indicate that the inhibitory effect of (-)97%/ (+)3% verbenone on WPB is significantly enhanced in the presence of racemic ipsdienol. A manuscript reporting these results is in preparation and will be distributed for review. (Cooperative study with R-5, FPM, funded primarily by FIDR)

3. Use of antiaggregation pheromones to reduce mortality of ponderosa pine by western pine beetle. 1992-1993. Building on the data generated by the field bioassays summarized above, a field experiment was conducted to test the efficacy of verbenone combined with ipsdienol for reducing mortality in infested ponderosa pine stands. Both pheromones were formulated in controlled-release mechanisms (bubble caps) and distributed on a gird system throughout the experimental plots. Results generated from the 1992 and 1993 experiments were strongly suggestive of efficacy, but because of insufficient mortality in the untreated controls, statistical conclusions concerning efficacy were not possible. This study is ongoing and a study plan for the 1995 experiment is being prepared. (Cooperative study with R-5, FPM, funded jointly by FIDR and FPM)

4. The attractiveness and selection by insect predators to various pheromones of the major California bark beetles, 1992-1993. This study was conducted under a cooperative agreement with the University of California, Davis. The objective of this study was to assay whether various species of bark beetle predators exhibit a preference for a specific host pheromone when presented simultaneously. In addition, the



individual components of the pheromones of major bark beetles was also field assayed. This study has been completed and is being compiled as a Master's Thesis for Ms. Terry Cuneo. The major finding of this study is that several bark beetle predators show a clear preference for pheromone components that contain some form of verbenol. (Funded by FIDR)

5. Efficacy of novel combinations of bark beetle aggregation pheromones for protection of individual ponderosa pine from attack by western pine beetle in California, 1992-1994. There is a tremendous need for finding alternatives to chemical insecticides for protection of individual ponderosa pine from lethal attack by WPB. This is especially true in the wildland/urban interface along the Sierra Nevada front, in the Lake Tahoe Basin, and in Southern California where WPB has been especially devastating. A series of experiments was conducted to test the efficacy of verbenone and ipsdienol in various combination of dosages, formulations, release mechanisms, and treatment timings. Phero Tech Inc. has conducted extensive in-house formulation development in support of this field research. To date none of the formulations (dosage, release device etc.) tested has been shown to be effective. This study has been ongoing, but is dependent on development of sprayable, slow-release formulations by Phero Tech Inc. (Funded by FIDR)

6. The distribution, impact, and year-to-year variation of bark beetle-caused tree mortality in Blacks Mountain Experimental Forest, 1992-1994. This research is an integral part of the larger Blacks Mountain Ecosystem Study. The primary objective of this study is to ascertain the response of the complex of bark beetle species to the vegetation manipulations imposed in the Blacks Mountain experiment. The spatial distribution and impact on tree mortality caused by western pine beetle, mountain pine beetle, Jeffrey pine beetle, and the fir engraver has been censused on ten-200+ acres plots in Blacks Mountain Experimental Forest. A stem map illustrating percent mortality by tree species, insect species, diameter distribution by tree/insect species, mortality group size, and insect species composition within mortality groups has been generated. Surprisingly, we found that MPB is the primary ponderosa pine mortality agent instead of WPB. Further, this mortality is ranging between 15% and 5% of the entire stand and is concentrated in those trees 6"-18" dbh. Initially, data from this census will be used in an attempt to generate risk rating systems for individual



bark beetle species, as well as for multiple species. These data are being transferred to an established GIS data base (both temporal and spatial references) so that other researchers in the Blacks Mountain experiment can have access, i.e. wildlife research (snag creation and dynamics), soils research (nutrient cycling, carbon cycle model), wood destroying insects (termite, carpenter ants, coarse woody debris dynamics). In addition, researchers from other research stations can have access to data for population behavior modelling, gap dynamics, disturbance ecology, i.e. Intermountain Research Station, Pacific Northwest Research Station. This study is ongoing. (Funded by FIDR)

7. Process and dynamics of snag creation by activity of western pine beetle for forest ecosystem management, 1992-1999. This study investigates the processes and dynamics of snag formation in naturally killed trees (WPB) and in trees killed by "pseudo-natural" methods (girdled). The goal of this study is to develop methods of snag formation that are both technically and biologically optimal. A series of randomized complete block sites were established with the following treatments randomly assigned: (1)girdled and WPB killed; (2) Large (>25" dbh) and small (<20" dbh); Spring and Fall. The invasion sequence of insects and fungi in subject trees will be evaluated, as well as bird visitation and utilization. This study is ongoing. (Funded by FIDR)

DENDROCTONUS PONDEROSAE (Mountain pine beetle - MPB): Development of semiochemical-based MPB management systems; field bioassay of verbenone and other semiochemicals for inhibition of MPB to baited funnel traps; impact and role of MPB in eastside pine type; flight periodicity of MPB throughout California, including northeastern California.

Rationale: Until recently the mountain pine beetle had been in outbreak status in the lodgepole pine ecosystem of the northern Rocky Mountains for over 20+ years. Presently, in western Montana and Idaho there are still isolated infestations of MPB occurring in lodgepole pine stands that, because of stocking or other within stand conditions, are conducive to population expansion. The destructive effect of MPB on a landscape scale defines this beetle as an important ecosystem change agent. Recent and current research in western Canada and the United States focuses on the potential of semiochemicals of MPB for pest management purposes.



In California MPB is a serious pest of both ponderosa pine (primarily in northeastern California) and sugar pine (western Sierra Nevada). The management and functional role of MPB in the eastside pine is critical to critical to ecosystem management goals in this province. In addition, the threat of blister rust to sugar pine throughout the Sierras makes the development of individual tree protection systems critical so that this technology can be applied to protect genetically resistant sugar pines.

Status of R & D:

1. Response of mountain pine beetle to an array of enantiomeric combinations and release rates of verbenone and ipsdienol in both western white pine and lodgepole pine stands. The objective of this study was to assess the inhibition of mountain pine beetle to traps baited with various enantiomers and release rates of verbenone and ipsdienol. The results of this study determined the most efficient and effective antiaggregation pheromone which was then tested for reducing MPB caused tree mortality in Montana. This study has been completed and a manuscript has been prepared. (Cooperative study with R-1, FPM, funded primarily by FPM)

2. Multiple aerial applications of verbenone to reduce tree mortality by mountain pine beetle in Montana. The objective of this experiment was to test the efficacy of multiple aerial applications of antiaggregation pheromones for reduction of lodgepole pine mortality caused by MPB. Results indicated that mortality was not reduced by treatments primarily due to rapid elution of the pheromone from slow release formulation while significant beetle flight was still occurring. This study has been completed. (Cooperative study with R-1, FPM, funded primarily by FPM)

3. Flight periodicity of western pine beetle, mountain pine beetle, Ips paraconfusus, and Ips pini in California, 1991-1994. (See WPB section for discussion)

4. Distribution, impact, and year-to-year variation of bark beetle caused mortality in Blacks Mountain Experimental Forest, 1993-1996. (See WPB section for discussion)



DENROCTONUS JEFFREYI (Jeffrey pine beetle - JPB): Isolation and identification of semiochemical attractants and inhibitors.

Rationale: The present droughty conditions throughout California have induced a serious outbreak of Jeffrey pine beetle over the entire range of Jeffrey pine, but especially in the Lake Tahoe Basin. A minimal amount of research has been directed toward characterizing the chemical communication system of this beetle. Lack of knowledge concerning the aggregation and antiaggregation pheromones limits potential management options including detection, inhibition, or trapping, that are currently being tested for other bark beetles species. In addition there is a paucity of reliable information on the flight behavior, life history characteristics, and impact of this beetle on the Jeffrey pine ecosystem.

Status of R & D: Cooperators at the University of California, Riverside (Drs. Tim Paine and Jocelyn Millar) have successfully isolated and identified the aggregation pheromone of Jeffrey pine beetle. Current emphasis is to delineate dosage rates and optimal ratios of 1-heptenol and heptane. Walking bioassays and limited field bioassays are being conducted to test additional compounds that may be important in the aggregation process. Phero Tech Inc. has been contacted about manufacture and supply of the various pheromone components in controlled release devices. They are currently conducting the necessary in-house development in order to meet our needs. This study is close to completion and a preliminary report has been completed. To date no antiaggregation compound(s) have been identified. (Funded entirely by FIDR)

Anticipated Future R & D: In FY'95 PSW and R-5 FPM will begin a series of field bioassays to test the efficacy of the aggregation compounds along a north to south transect on the eastside of the Sierras. These locations will also be used to initiate studies on the flight periodicity of this bark beetle. In addition, at several localities a range of release rates will be tested in an effort to optimize the attractiveness of the aggregation pheromone.

DENDROCTONUS RUFIPENNIS (Spruce Beetle - SP): Development of semiochemical-based SP management systems; develop slow-release delivery systems for pheromones.

Rationale: Spruce beetle has been in outbreak status in Alaska for over 10+ years. The semiochemical ecology of this insect is well-documented, but only



recently has research been directed toward developing semiochemical-based pest management systems. Many of the slow-release devices (bubble caps and polyethylene plastic beads) used in this SP research may be applicable to other bark beetles in other parts of the western United States. Conversely, the experimental designs and statistical analyses developed and used in the WPB, MPB, and Ips research are being adapted to SP research.

#### Status of R & D:

1. Aerial and ground application of methylcyclohexenone (MCH) to reduce tree mortality by spruce beetle in south-central Alaska, 1992. The antiaggregation pheromone, MCH, was tested for reducing white spruce mortality caused by SP. A granular (polyethylene plastic bead) controlled release formulation was applied both aerially and by ground equipment at several rates. There was no significant difference in tree mortality between treatment and control plots. The primary problem encountered in this experiment was low endemic SP populations. This study has been completed and a FPM technology development report has been prepared. (This was a cooperative study between R-10, FPM, PNW, PSW, funded primarily by FPM)

2. Evaluation of MCH and methyl chavicol (4-allylonisole) bubble caps to protect spruce trees from infestations by spruce beetle, 1994. The objective of this study was to evaluate the effect of MCH and methyl chavicol, both alone and in combination with each other, in reducing white spruce mortality caused by SP. Methyl chavicol has been implicated as a compound with inhibitory effects on multiple species of bark beetles. Results indicate no significant effects of methyl chavicol on SP activity. This study has been completed and the results have been reported in an FPM technology development report. (This was a cooperative study between R-10, FPM, PNW, and PSW, funded primarily by FPM)

3. Evaluation of the elution rates of MCH, verbenone, and other semiochemicals from various controlled release devices, such as bubble caps and polyethylene beads, under various climatic conditions, 1994. The objective of this study was to evaluate the elution characteristics of various semiochemicals under actual field conditions in Alaska, Oregon, Idaho, and California. This study has been completed and the data are being summarized for analysis. (This was cooperative study between



R-10, FPM, PNW, PSW, Oregon State University, funded by FPM and FIDR)

DENDROCTONUS ADJUNCTUS (Roundheaded pine beetle, RHPB): Development of semiochemicals based RHPB management systems in United States and Mexico; flight periodicity of RHPB in New Mexico and Jalisco, Mexico; bioassay of antiaggregation compounds; field evaluation.

Rationale: Recently, in both New Mexico and Jalisco State, Mexico, RHPB has been in outbreak status and is causing considerable mortality. Little is known about the semiochemical ecology of this bark beetle and this research is the first attempt to develop basic pheromonal response behavior.

Status of R & D:

1. Flight periodicity and response to antiaggregation compounds of RHPB in the Sacramento mountains of southern New Mexico, 1992. The objective of this study was to collect data on flight periodicity of this insect and establish its response to various enantiomers of verbenone. Results of this experiment revealed new knowledge concerning flight periodicity and delineated a clear response of RHPB to a specific enantiomeric composition of verbenone. This study has been completed and a FPM technology development report has been filed. (Cooperative study between R-3, FPM and PSW, funded by FPM).
2. A field test of the efficacy of verbenone for reduction of ponderosa pine mortality in roundheaded pine beetle infested stands in New Mexico, 1994. The objective of this study was to the efficacy of verbenone for reducing ponderosa pine mortality caused by RHPB. This study is ongoing. (Cooperative study between R-3, FPM and PSW, funded by FPM)
3. Response of the bark beetle, Dendroctonus adjunctus, to an array of aggregation and antiaggregation pheromones, 1992-1993. This research is being conducted in Mexico through a cooperative agreement with Dr. Jaime Flores, Professor of Entomology, Universidad Autonoma de Neuvo Leon, Linares, Mexico. The objectives are: (1) field bioassay various combinations and release rates of pheromones for attractiveness to RHPB; (2) field bioassay an array of enantiomers and release rates of verbenone for inhibiting the response of RHPB to (1) above. This study



has been completed, data analysis has been completed, and a manuscript is in preparation. (Funded by FIDR)

4. Geographic variation in the genetic structure, chemotaxonomy, and pheromone response of several species of Dendroctonus found in Mexico and the United States, 1994-1996. This research is being conducted through a cooperative agreement with Dr. Jaime Flores (see above for affiliation). Initial results indicate a clear variation in cuticular hydrocarbon profiles between populations of RHPB found Mexico and United States. Future studies will examine variation in genetic structure, cuticular hydrocarbon profiles, and response to pheromones of RHPB and other species found in both Mexico and United States. This study is ongoing. (These studies are a cooperative effort involving PSW, U.A.N.L., Southern Station, funding currently from FIDR, additional extramural funding being sought)

IPS PARACONFUSUS AND IPS PINI (California fivespined ips & pine engraver):

Development of semiochemical based ips management systems; field bioassay of ipsdienol, ipsenol, and verbenone; flight periodicity of ips species throughout California.

Rationale: As with the Dendroctonus species, both species of Ips have responded to the recent droughty conditions in California. Increased levels of top-killed ponderosa pine have occurred throughout California, with particularly high levels of activity occurring in low elevation ponderosa pine plantations. Under the ecosystem management philosophy, new standards and guidelines governing stand manipulation activities will prescribe increased levels of coarse-woody-debris (CWD) being left on the forest floor. The objective of this increase in CWD is to provide adequate nutrients to be returned to the soil, maintain wildlife habitat (rodents, reptiles, amphibians), and reduce soil compaction all of which are important to sustaining healthy, functioning forest ecosystems. The entomological concern is that this CWD may provide habitat for the unwanted build-up in populations of ips beetles. These increased levels of ips populations could, in turn, present a threat to the residual stands.



#### Status of R & D:

1. The flight periodicity of western pine beetle, mountain pine beetle, Ips paraconfusus, and Ips pini in California, 1991-1994. (See discussion in WPB section).
2. The efficacy of antiaggregation pheromones formulated in slow-release devices to prevent colonization and population build-up of Ips paraconfusus and Ips pini, 1992-1994. The objective of this series of field experiments was the development of semiochemical-based management systems to prevent colonization and build-up of ips beetles in ponderosa pine slash. The slash was presented in two configurations that represented current standards and guides; (1) dispersed i.e. where slash is lopped and scattered; (2) piled i.e. where slash is piled for later burning and subsequent reduction of fuel load." The results from these experiments indicate that a combination of verbenone and ipsdienol, formulated in bubble caps, can effectively inhibit colonization of ponderosa pine slash by I. paraconfusus. Similar results were obtained for I. pini when ponderosa pine slash was treated with combination of verbenone, ipsenol, and cis-verbenone. However, these strategies are not without problems. On occasion we found that inhibiting colonization of slash by one species allowed the other species to attack and inhabit the slash. Research is continuing to find combinations of antiaggregation pheromones that will effectively inhibit both species of Ips simultaneously. A recommendation has been made to FPM personnel in R-5 that these strategies should be pilot tested. Major portions of this research has been completed and specific, limited research to develop combination treatments will be pursued. Manuscripts of this research are in preparation. (These were cooperative studies involving R-5, FPM and PSW, funded jointly by FPM and FIDR).
3. Aggregation pheromones of Ips paraconfusus were deployed in a trap-out strategy to reduce mortality of Torrey pine. Torrey pine is the rarest pine on the North American continent and occurs as an intact natural stand of about 90 acres only at Torrey Pine State Reserve, San Diego, CA. Between 1990 and 1992 over 800 Torrey pine were killed in the Reserve by an outbreak I. paraconfusus. The trap-out strategy was deployed between the years 1991-1993 and essentially eliminated the bark beetle caused tree mortality by 1993. This R & D operational demonstration is completed and a manuscript is in press. In addition,



operational guidelines, monitoring protocols, and stand management prescriptions have been prepared for Reserve personnel. (This cooperative operational demonstration was jointly conducted by PSW and California Department of Parks and Recreation, funded jointly by FIDR and CDPR).

File # 100

Date: March 13, 1975

Project: Status of Western Bark Beetle RDB's

To: Deputy Chief, Research

The purpose of this report is to provide a summary of the status of the Western Bark Beetle RDB's which are currently being developed. The RDB's are being developed to provide a means of monitoring the status of the bark beetle population and to provide a means of monitoring the status of the bark beetle population and to provide a means of monitoring the status of the bark beetle population.

The RDB's are being developed to provide a means of monitoring the status of the bark beetle population and to provide a means of monitoring the status of the bark beetle population. The RDB's are being developed to provide a means of monitoring the status of the bark beetle population and to provide a means of monitoring the status of the bark beetle population.

We appreciate the opportunity to share these findings from the RDB's project in FY75. However, the RDB's are being developed to provide a means of monitoring the status of the bark beetle population and to provide a means of monitoring the status of the bark beetle population.



## APPENDIX C

United States  
Department of  
Agriculture

Forest  
Service

PNW

---

File Code: 4500  
Date: March 13, 1995

Subject: Status of Western Bark Beetle RD&A

To: Deputy Chief, Research

This memorandum responds to your December 1994 letter on the status of the Western Bark Beetle RD&A which was initially funded in FY92 to accelerate pheromone technology development, and transfer technology for silvicultural methods of beetle management. The enclosed list of accomplishments and recommendations for additional work will provide a good measure of PNW Station's activities and future plans for this area of work.

The intent of Congress was to accelerate development of promising pheromone approaches for managing the major western bark beetle species. At the PNW Station, development of an antiaggregant pheromone, methylcyclohexenone (MCH), has progressed to the point of being operational for management applications. The only segment missing for a fully complete package is the pesticide registration required by the Environmental Protection Agency (EPA). Other aspects of R&D for both Douglas-fir beetle and the spruce beetle will continue in FY's 95 and 96.

We appreciate the opportunity to shift funds from this RD&A project in FY95, however, the Station plans to continue priority work on pheromones of both spruce beetle and Douglas-fir beetle. We are also concerned with the urgent need to obtain EPA registration for MCH, and other bark beetle pheromones. We believe congressional intent for this project included



pheromone registration so that new technology will become available for operational use.

With reference to the last paragraph of your memorandum, we have attached a list of accomplishments, plans, and recommendations for further work. We expect this information will be useful for the agency report being coordinated by Bob Bridges of the WO-FIDR staff. If further PNW information is needed, please contact Gary Daterman at the Corvallis FSL. In regard to the second action request in your letter (plans to redirect the RD&A funds), we do not plan to redirect these funds at this time. We are using these and other funds to continue bark beetle pheromone work, with emphasis on developing technologies and approaches supportive of ecosystem management objectives.

/s/ Fred A. Stormer (for)

EXECUTIVE TEAM  
PNW Research Station

Enclosure

cc:

J.Stewart, FIDR, WO

A.Bartuska, WO

G.Daterman, Corvallis

R.Bridges, FIDR, WO

#### PUBLICATIONS

#### Douglas-fir beetle

Daterman, G.L. 1994. Predicting current behavior and dispersal of Douglas-fir beetle from forest attack. Ph.D. Thesis, R.L. Campbell, Canada Forest Ecosystem Health Assessment, Vol. IV. Mitigation of Current and Future USDA Forest Service, PNW-477. PNW Forested, OR, pp. 43-45.



## PNW STATION ACCOMPLISHMENTS FOR THE WESTERN BARK BEETLE RD&A

1. MCH treatment methods that successfully protect high-risk, high-value resources such as recreation sites, old-growth stands, special habitat areas, etc. from Douglas-fir beetle attacks to the Douglas-fir component of these stands, and particularly the larger diameter trees. Methods are effective in either low or high-density beetle populations.
2. Use of aggregation pheromones in trapping systems to reduce beetle numbers and maneuver flying beetle populations into stands of lower value, scheduled for removal, or that are designated for other purposes consistent with multi-resource, ecosystem-based management.
3. Advanced knowledge of dispenser placement, release rates, and dosage considerations of antiaggregation and aggregation pheromones of Douglas-fir beetle and spruce beetles.
4. Use of pheromones of associated bark beetle species to preempt spruce beetles in host logs, thus reducing population increase by the spruce beetle and the potential of this more aggressive species to cause tree mortality.
5. Advanced knowledge of the dispersal behavior and capabilities of both spruce and Douglas-fir beetles.
6. Advanced knowledge of associated species of bark beetles in Alaska, particularly *Ips perturbatus*, and of pheromone responses of natural predators of the Douglas-fir beetle in eastern Oregon.

## PUBLICATIONS

### Douglas-fir beetle:

Datorman, G.E. 1994. Protecting unique habitats and riparian areas from insect attack. IN: Everett, R.L., Compiler, Eastside Forest Ecosystem Health Assessment, Vol. IV. Restoration of Stressed Sites and Processes. USDA-Forest Service, PNW-GTR-330, Portland, OR, pp 43-46.



Ross, D.W. and G.E. Daterman. (in press). Reduction of Douglas-fir beetle infestation of high risk stands by antiaggregation and aggregation pheromones. Can. J. For. Research 24:000-000.

Ross, D.W. and G.E. Daterman. (in press). Response of *Dendroctonus pseudotsugae* (Coleoptera: Scolytidae) and *Thanosimus undatulus* (Coleoptera: Cleridae) to traps with different semiochemicals. J. Econ. Ent. 88:000-000.

Ross, D.W. and G.E. Daterman. (in press). Pheromone-based strategies for managing the Douglas-fir beetle on a landscape scale. IN: Payne, T.L. and F.P. Hain, editors; IUFRO Symposium Proceedings, Insect Behavior and Population Dynamics, Maui, Hawaii, Feb. 1994.

Ross, D. W. and G. E. Daterman. (in press). Confirmation of the efficacy of an antiaggregation pheromone for reducing Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopkins (Coleoptera: Scolytidae), infestation of high risk stands. Canadian Entomol. 127:000-000.

#### The Spruce Beetle:

Borden, J.H., Chong, L.J., Werner, R.A., et.al. (in press). Regionally specific bioactivity of two new pheromones for *Dendroctonus rufipennis* (Kirby) (Coleoptera:Scolytidae). J. Applied Entom.

Holsten, E.H. 1994. The role of spruce beetle pheromones as management strategies in Alaska. IN: P. Shea, Ed., Proc. of the Symposium on Management of Western Bark Beetles with Pheromones: recent research and development. Kailua-Kona, HI, 1992. Gen. Tech. Report. PSW-GTR-150. Albany, CA, USDA-Forest Service, pp. 11-14.

Werner, R.A. 1994. Research on the use of semiochemicals to manage spruce beetles in Alaska. IN: P. Shea, Ed., Proc. of a Symposium of Management of western bark beetles with pheromones: recent research and development. Kailua-Kona, HI, 1992. Gen. Tech. Report. PSW-GTR-150. Albany, CA, USDA-Forest Service, pp. 15-21.

Werner, R.A. and E.H. Holsten. (in press). Current status of research with the spruce beetle. IN: Salom, S. and K. Hobson, Eds., Application of semiochemicals for



management of bark beetle infestations. Symposium Proc., Indianapolis, IN, 1993, Gen. Tech. Report INT-000. USDA-Forest Service, INT Res. Sta., Logan, UT.

Werner, R.A. and E.H. Holsten. (in press). Use of semiochemicals to increase interspecific competition between spruce beetles and other bark beetles in Alaska. Environ. Ent.

Werner, R.A. and E. H. Holsten. (in press). Dispersal of *Dendroctonus rufipennis* and *Ips perturbatus* in Alaska. Environ. Ent.

Werner, R. A. 1993. Response of the engraver beetle, *Ips perturbatus*, to semiochemicals in white spruce stands of interior Alaska. PNW-RP-465. Portland, OR, USDA-Forest Serv., PNW Research Sta. 23 p.

#### PLANS FOR ADDITIONAL RESEARCH:

1. Dispersal behaviors and capabilities of spruce beetle and Douglas-fir beetle as it relates to pheromone treatment efficacies.
2. Refinements to pheromone dosages and dispensing technologies to enhance treatment effects with synthetic pheromone formulations and dispensing methods.
3. Development of strategies to manipulate Douglas-fir beetle populations and attack behaviors on a landscape scale and in the context of ecosystem management objectives.
4. Advance development of using interspecific pheromone responses to preempt spruce beetle attacks, or reduce intensity of attacks, in Alaska.
5. Advance knowledge of the effectiveness of MCH on spruce beetle in Alaska, and determine if its efficacy is sufficient for operational management objectives.

#### OTHER RECOMMENDATIONS:

At the National level, coordinate with Forest Pest Management for a concerted effort to obtain registration of MCH and other pheromones such as verbenone, with the Environmental Protection Agency. Registration of pheromones should be given high priority. Without EPA registration, the



new technologies for effective management of western bark beetles cannot be put into practice.

Additionally, once registration has been secured for particular pheromone formulations and their applications, handbooks of methods and guidelines should be written for users.

#### 1992 - FY 94 Interim Accomplishment Report

##### Intermountain Research Station, Logan, UT

### EXECUTIVE SUMMARY

The Mountain Pine Beetle (MPB) Project was born in 1982, and in the Intermountain Research Station was the early 1980's. Since its inception, the underlying theme of the project has been to develop management strategies through an improved understanding of bark beetle population dynamics and biology. The thrust of our pheromone work has been to use it as a tool to study behavioral changes in response to various stimuli and to study on chemical ecology. This report describes three major objectives: (1) to develop a model of bark beetle population growth that can be used during the course of an outbreak; (2) to investigate chemical cues that influence population of the beetle; and (3) to develop a model of bark beetle attack and use of resources that leads to beetle mortality or other density-dependent factors. We have also conducted research that will allow us to develop a model of bark beetle attack and use of resources that leads to beetle mortality or other density-dependent factors. We have also conducted research that will allow us to develop a model of bark beetle attack and use of resources that leads to beetle mortality or other density-dependent factors.

### RESEARCH AND DEVELOPMENT ACTIVITIES

Continued research on the biology of bark beetles, including the MPB, has been ongoing. Although more research has been completed on MPB than any other single bark beetle species in the western United States, a number of important questions remain unanswered. Many factors have been implicated in both the spread of the outbreak and its control, including weather, host, beetle characteristics, and population dynamics. A number of studies are underway to investigate



## APPENDIX D

### **WESTERN BARK BEETLE RD & A SUMMARY REPORT**

**FY'92 - FY'94 Summarized Accomplishment Report  
for  
Intermountain Research Station, Logan. UT**

#### EXECUTIVE SUMMARY

The Mountain Pine Beetle (MPB) Project has been an identified research unit in the Intermountain Research Station since the early 1960's. Since its inception, the underlying theme of this project has been to develop management strategies through an improved understanding of basic bark beetle population dynamics and ecology. The thrust of our pheromone work has, therefore, been to use these powerful behavioral chemicals in ecological investigations rather than research on chemical ecology per se. This report describes three areas of research: (1) studies designed to elucidate shifts in population quality that may occur during the course of an outbreak, (2) management oriented strategies that included protection of fire damaged trees from bark beetle attack and use of mountain pine beetle mortality to more effectively manage fuelwood harvesting, and (3) modeling spatial dynamics of semiochemical mediated dispersion and attack. We anticipate continued research that will utilize semiochemicals for sampling in ecological studies, further refinement development of management strategies, and to manipulate populations for spatial dynamics studies.

#### RESEARCH AND DEVELOPMENT ACTIVITIES

##### Contrasts Between Old and New Outbreak Populations.

Introduction. Although more research effort has been expended on MPB than any other single bark beetle species in the western United States, a generally accepted explanation of events that either precipitate an outbreak or lead to its collapse is lacking. Many factors have been implicated in both the phases of the outbreak cycle, including weather events, habitat characteristics, anthropogenic influences, and shifts in population structure and quality. A series of studies was initiated to investigate



potential differences in population quality that might occur during different phases of the outbreak cycle. Contrasts were made between population attributes in a new, building population and an old collapsing population. Comparisons were also made between early and late emerging beetles within outbreak phases.

Rationale. Relatively little information exists on the shifts in physiology and semiochemical behavior of bark beetles that occurs during the course of an outbreak. Such shifts may have important consequences on pheromone based management strategies and interpretation of results from pheromone trials.

1. Lipid content of adult beetles from old v.s. new infestations. Lipid content of emerging beetles is an important measure of population quality because it is directly related to both the ability and propensity for flight. Beetles in new infestations were significantly larger, heavier, and leaner than beetles collected from old infestations. Beetles that emerged early in the flight season were lighter and leaner than beetles that emerged later. Male and female beetles did not differ significantly in their mean percent lipid. This study was conducted in collaboration with Jane Hayes and Brian Storm, USDA-FS, Pineville, LA., who provided the lipid analysis.

2. Pheromone tests were conducted during summers of 1992 and 1993 in 4 separate locations, two of which were in new infestations and two were in old infestations. In each area, 12 treatments were compared with respect to attractiveness to MPB populations. In the 1993 trial, beetles in new epidemic populations were repelled more strongly by anti-aggregation pheromones (verbenone and ipsdienol) than beetles in old infestations. In 1992, there was no significant difference in the anti-aggregation effect of verbenone between old and new populations; but ipsdienol had a stronger anti-aggregation effect in the new epidemic populations. Combining ipsdienol with



verbenone did not reduce trap catch below verbenone alone when these treatments were combined with MPB lure.

Beetle response to a host volatile, methyl chavicol (tested in 1993 only) was the reverse of the response to pheromones. Beetles in old infestations avoided methyl chavicol more strongly than in new infestations.

3. Beetle size. Beetles in new populations were larger (mm length) than beetles in old populations. The observation was independent of beetle sex. There was also an inverse relationship between beetle size and trap attractiveness, i.e. large beetles were less likely to be repelled by verbenone than were smaller beetles. Larger beetles of both sexes flew during the first week of the flight period. Smaller beetles of both sexes flew during the third week of flight. Hence, early emerging beetles were less likely to be repelled by verbenone than were later emerging beetles.

4. Beetle sex ratios. Overall, traps in both old and new infestations caught more females than males, although there was a higher proportion of females in the old infestation than the new. In both years, treatments that included verbenone caught more males than females in new populations but more females than males in old populations. This trend was observed in all 7 treatments that contained verbenone. In new infestations, all verbenone treatments caught more males than females despite the overall bias in favor of females.

Taken together these results indicate significant differences between new and old MPB infestations. Collection and analysis of data has been completed, several publications are in preparation.

#### Protecting Fire Injured Lodgepole Pine.

Introduction. Mountain Pine Beetles (MPB) have been observed infesting fire-injured pines. It has further been hypothesized that fire injured trees could serve as the focal



point for subsequent bark beetle outbreaks. Bark beetle anti-aggregative pheromones offer promise for protecting fire-injured trees from infestation. Fire injury was simulated by placing peat moss around 70% of the basal circumference of lodgepole pines. When the peat moss was ignited, it simulated the smoldering of natural duff, generating temperatures that killed the cambium. Combinations of verbenone and ipsdienol were tested for effectiveness in protecting fire injured trees from beetle attack.

Rationale. Drought conditions in the Intermountain West resulted in numerous and large wildfires in 1988 and following years. Several studies had been conducted to determine the feasibility of using bark beetle anti-aggregative pheromones to protect trees from infestation. In the case of the MPB these studies centered around the use of verbenone. The bark beetle anti-aggregative pheromones, verbenone and ipsdienol, were tested in protecting heat-injured lodgepole pine.

Results. Check treatments (lure alone) contained more unattacked and mass-attacked trees, whereas pheromone treatments contained more unsuccessfully attacked trees. Ipsdienol did not increase verbenone's efficacy in protecting trees. This study has been completed and results published in: Amman, G. D. and Ryan, K. C. 1994. Using Pheromones to Protect Heat-Injured Lodgepole Pine from Mountain Pine Beetle Infestation. Res. Note INT-419 Ogden UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 7 p.

Monitoring Low-Level Mountain Pine Beetle Populations.  
Introduction. Although populations of MPB occasionally build to spectacular population levels during epidemics, most of the time populations remain at low endemic levels. During these endemic phases, population densities are low enough that effective sampling procedures are lacking. Studies were designed to test the potential of pheromone traps for monitoring populations during endemic phases.



Rationale. Currently, population trends are monitored by locating and counting trees that were infested the previous year (red tops). A monitoring system based on pheromone traps would provide a more direct measure of beetle population levels, and could also detect populations that were not high enough to successfully mass attack trees. Pheromone traps could, therefore, result in earlier detection of building populations leading to improved risk assessment.

Results. Data gathered during the 1992 flight season has not yet been analyzed or reported.

Use of Pheromones in a "Push/Pull" Strategy to manage Mountain Pine Beetle populations in Lodgepole Pine Forests.

Introduction. The anti-aggregative effects of verbenone and the attractiveness of the MPB lure are well known. Studies were designed to test these two types of pheromones could be used in a management setting to protect (push) beetles from some stands, and to attract (pull) beetle populations into other stands.

Rationale. Large populations of MPB are present in the Sawtooth National Recreation Area (SNRA) in central Idaho. The SNRA resource managers are interested in evaluating a push/pull strategy in a beetle management program that focuses attacks on stands that are to be harvested, and to protect stands in sensitive riparian areas.

Results. Two years of trials indicate that the pull strategy is effective, beetles can be preferentially attracted to specific areas and thereby concentrating tree mortality in the desired stands. Effectiveness of the push strategy has not been demonstrated. These results are discussed in a manuscript in preparation by L. A. Rasmussen and J. C. Vandygriff.



Baiting Dwarf Mistletoe Infected Stands with Mountain Pine Beetle attractant Tree Baits in a Dwarf Mistletoe/Fuelwood Harvest Program.

Introduction. An ongoing MPB outbreak in the SNRA has resulted in a large quantity of personal-use and commercial fuelwood becoming suddenly available. Managing this fuelwood supply became a problem because a large number of permit holders were building unauthorized roads, and crossing streams in a sensitive salmon fisheries area. Past experience (see previous study) indicated that we could attract MPB into baited stands. Dwarf mistletoe infected stands near existing roads were baited with MPB lure.

Rationale. Significant resource damage was being caused by the large number of people harvesting fuelwood. Not only were unauthorized roads being pioneered but also streams were being damaged in this important salmon fishery. The SNRA management team expressed an interest in using MPB pheromones for managing their fuelwood harvest to minimize resource damage.

Results. By concentrating tree mortality in mistletoe stands that were easily assessable by existing roads, two management goals were achieved. First, the fuelwood harvest was focused on stands that were accessible by existing roads; and second, mistletoe stands were sanitized by concentrating beetle mortality on heavily infected trees. These results are discussed a manuscript in preparation by L. A. Rasmussen and J. C. Vandygriff .

Modeling the pheromone mediated spatial/temporal dynamics of mountain pine beetle attacks.

Introduction. The adverse economic and ecological impact of mountain pine beetle outbreaks has long been recognized. However, it is becoming increasingly recognized that natural disturbance events, like MPB outbreaks and fire, play important roles in the evolution of



structure and function of healthy forest ecosystems. Interpretation of MPB in this dual role as a serious economic competitor and as a co-evolved component of the ecosystem presents an interesting challenge. One important approach we are using to help address this challenge is development and analysis of quantitative models.

Rationale. Spatial dynamics play a central role in the ecology of highly mobile insects. For MPB populations, the spatial dynamics associated with host location and mass attack are essential for survival. Chemical signals (both pheromones and host compounds) form the basis of MPB spatial redistribution, attack, and the resultant pattern of tree mortality. A more complete understanding of spatial phenomena, and how semiochemicals mediate these dynamics, is essential for both the interpretation of field results and the development of effective management strategies.

Results. A partial differential equation model of the system has been formulated that is a reasonable compromise between ecological credibility and mathematical tractability. Our current model involves 7 state variables and approximately 20 parameters. Numerical simulation has resulted in the uncovering of a rich dynamical behavior that results from the structure of the system itself. Previously, partial patterns of killed trees has primarily been attributed to external factors (individual tree susceptibility). In contrast, this work demonstrates that spatial complexity may also arise from the intrinsic nature of the chemical ecology itself. Simulation results are also providing ecological insights into the sensitivity of spatial patterns to various attributes of chemical interactions. This research may result in insights to development of management actions that serve to maximize anti-aggregation or minimize attractiveness. Spatial complexity largely results from nonlinearity in the self-focusing aspects of chemical ecology. These nonlinearities result in a system that is extremely stiff, and therefore presents significant numerical challenges. Numerical investigations are leading



to promising new approaches to modeling both beetle dynamics and stand attributes. This work is an on-going research effort which will continue to be actively pursued for the foreseeable future. Publications to date are: (a) Powell, J. A., J. A. Logan, & B. J. Bentz. Local projections for a global model of mountain pine beetle attacks. J. Theor. Biol. (in press). (b) White, P., J. A. Powell. Dynamics of mass attack and spatial invasion of pine beetles into lodgepole forests: a numerical study. SIAM J. Numerical Analysis (in preparation).



