

Forest Pest Management

USDA Forest Service

• Technology & Development Program •

3400 Forest Pest Management



Harold Thistle, Project Leader

Washington Office Forest Pest Management (FPM) and the Missoula Technology and Development Center (MTDC) have a five-year plan that defines nine specific areas of work and two areas of general support to ensure state-of-the-art techniques for Forest Service spray operations. The specific areas include aircraft guidance in Forest Pest Management programs, pesticide spray drift studies, single tree spray equipment, planning and simulation of spray operations, and thermal (non-insecticide) insect control. The two areas of general support will include physical support of field operations and dissemination of information such as articles or presentations of interest to the FPM community. In addition, the Forest Service-Cramer-Barry-Grimm (FSCBG) and Agricultural Dispersion (AGDISP) computer models, which are used to determine spray drift patterns, will continue to be upgraded and extended.

The Forest Pest Management Program is accomplished in conjunction with Washington Office Pest Management, coordinated by Jack Barry. The projects are directed by Dr. Harold Thistle.

Technical Transfer of Computer Models (Computer Modeling of Pesticide Spray Drift)

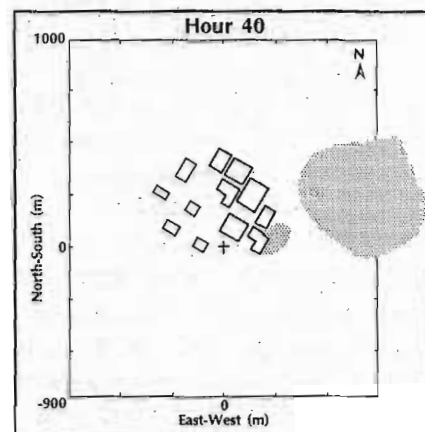
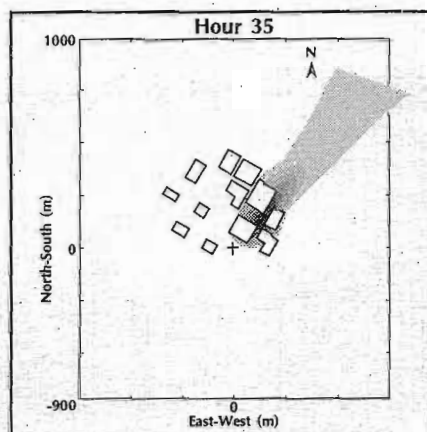
5E52P29

Harold Thistle, Project Leader

The pesticide spray droplet evaporation study was completed in FY 93. The results for water were tested against the FSCBG model and the agreement was very good. Results for *Bacillus thuringiensis* (BT) were used to upgrade the FSCBG model. The complex terrain dispersion modeling work is continuing. The Valley Drift (VALDRIFT) model for simulating pesticide flow in mountain valleys was developed by Battelle-Pacific Northwest Laboratories under

USDA Forest Service contract and sponsorship. The model has been written, and is currently being tested against existing data gathered in the Intermountain Region (4). Other model development tasks have been requested by various FPM steering committees. These projects are based on users' concerns, or are due to model performance questions raised by validation tests. Several of these projects are being considered for investigation. Among them is a full evaluation of the in-canopy drift algorithm in the model and a full evaluation of the source algorithm.

Dr. Harold Thistle of MTDC attended the Second International Symposium on Pesticide Application Techniques in Strasbourg, France in September



Concentration field of an atmospheric tracer in downtown Minneapolis, Minnesota. The left figure is a higher windspeed case with a thermally mixed atmosphere. The right figure is a low windspeed case with colder air on the surface (inversion or stable atmosphere).

1993, where he presented a paper, ***Development and Validation of the FSCBG Model for the Simulation of Spray Drift***, which covered the history and current developments in the field of computer modeling of off-target drift of pesticide spray. The USDA Forest Service models of off-target drift are among the most advanced and comprehensive tools available. A report was published and is available on request.

Participation in the Strasbourg Symposium afforded the USDA Forest Service, MTDC, and FPM international recognition for their accomplishments. The Strasbourg meeting also allowed extensive discussion between MTDC and Silsoe Research Institute of the United Kingdom. Silsoe has developed an algorithm for simulation of ground spray operations.

Dr. Thistle participated in a workshop in Rotorua, New Zealand, with the goal of exchanging information with New Zealand users of Forest Service spray dispersion models.

MTDC received the VALDRIFT model from Battelle-Pacific Northwest Laboratories. This model will be incorporated into the FSCBG system of models and allows a more realistic simulation of atmospheric dispersion and deposition in complex terrain. A substantial effort will be made in the coming year to interface this model into FSCBG. Other model development efforts involve introduction of a ground sprayer model in the system, as well as adding an edge model that could handle

dispersion near windbreaks, woodlots, and forest edges. A further focus is to develop a simplified drift model that could be used in conjunction with a GPS positioning system as an on-board alarm to notify a spray pilot that off-target drift may be exceeding a threshold limit.

GPS-Based Aircraft Navigation Guidance

3E12P73

Harold Thistle, Project Leader

In aerial spraying it is important to apply the product as accurately as possible. A reduction in the amount of spray material that misses the target translates directly into lowered costs and fewer unintended impacts.

A precise guidance system is needed to assist the pilot in initially finding the spray block and in determining the subsequent spray swath locations.

A permanent record-keeping system, accurately logging the aircraft's flight path, is needed

for post operation analysis, possible input into GIS, and potential use in future litigation.

In the past, LORAN-C and other navigation systems have been examined as potential guidance equipment for aerial spray operations. For a number of reasons (such as coverage, line-of-sight transmission problems, update speed, and overall accuracy), these systems have been unsatisfactory. The Department of Defense's Global Positioning System (GPS), however, shows high promise in this application.

GPS, when used in conjunction with a differential station, is capable of 5-meter accuracy. In an aerial spray application, GPS can be linked to a system that gives the pilot real-time location information. This information can precisely guide the pilot in swath placement and in accurate turn on and turn off at the target boundaries. GPS can be linked to a recording system that provides an accurate and permanent record of the aircraft's flight path. Harold Thistle and Tony Jasumback participated in an

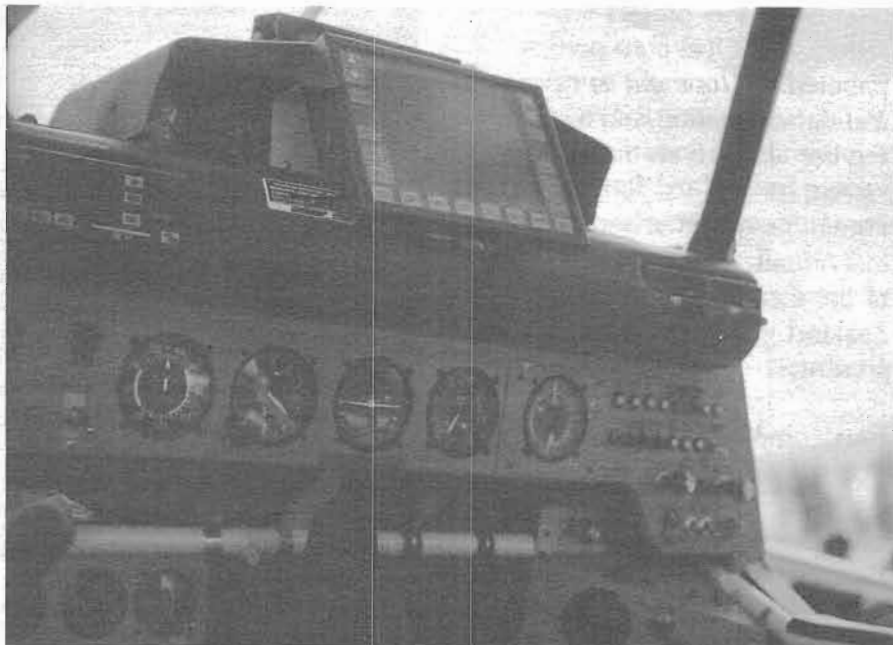


GPS is being evaluated as a tool for finding spray blocks and determining spray line locations.

evaluation of GPS equipment configured for aerial application work in Las Cruces, New Mexico (sponsored by Pennsylvania State University), in February 1993. The APHIS pilots who flew the evaluation flights were able to duplicate flight paths within 2 meters with differentially corrected GPS guidance. Numerous contacts have also been made with GPS users and members of the navigation industry this year.

In FY 94 MTDC staff attended four demonstrations of GPS navigation and guidance systems at Puyallup, Washington; Marana, Arizona; Mio, Michigan; and Phoenix, Arizona. Bill Kilroy, of MTDC, conducted a phone survey of Forest Service personnel and others involved in the actual use of GPS systems in aerial application operations during the spring of 1994. A report based on this survey has been published. A survey of spray block marking methods has also been produced by MTDC and is available for distribution.

A demonstration and test of differential GPS aircraft guidance operations in complex terrain was conducted by MTDC on the Ninemile Ranger District near Missoula, Montana, during the second week of October, 1994. These tests were done with the cooperation of the Northern Region (1) engineering and aviation personnel.



AgNav GPS guidance system installed in Cessna AG Truck.



GPS demonstrations on the Ninemile Ranger District attracted observers from resource agencies throughout the world.

Interest in this project was significant. Over fifty people traveled to Missoula to observe this demonstration and test. They represented private firms and various Federal and State agencies. The U.S. Air Force sent four individuals, and representatives of the Canadian and New Zealand governments were also present.

Two companies (SatLoc and AgNav) participated in these evaluations. Three days of round table discussions and seminars allowed interaction among contractors, equipment operators, industry, and government. Two reports have been published.

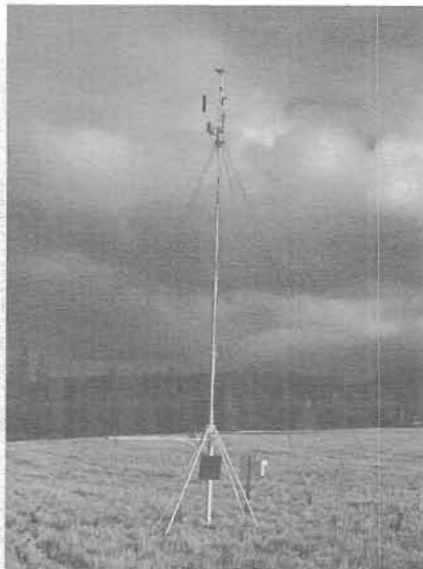
(Field Comments - Spray Block Marking; FPM DGPS Navigation Systems for Agricultural Aircraft in Forestry: Test Plan; and Testing of DGPS Aircraft Guidance and Recording Systems for Use in Forestry in Complex Terrain - Preliminary Report). A final report will be published in 1995.

Technical Services - FPM

TE02P18

Harold Thistle, Project Leader

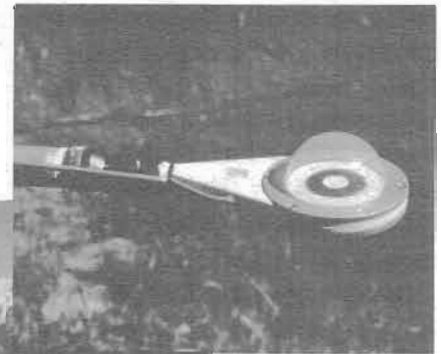
During the period 1991-1993, MTDC provided meteorological monitoring support for the Gypsy Moth Eradication Program along the Wasatch Front east of Salt Lake City, Utah. This program involved aerial spraying of *Bacillus thuringiensis* (BT). BT is a bacteria that is lethal to gypsy moths when ingested. This has been a successful program designed to eradicate the gypsy



MTDC collected meteorological data to validate the FSCBG computer model and to predict spray dispersion in complex terrain.

moth, which has destroyed thousands of acres of valuable timber in the last decade. A report, ***Meteorological Data Collection for the 1992 Utah Gypsy Moth Eradication Program***, documented results of the project in 1992.

MTDC's role in this operation has been to collect meteorological data that can be used in validating the FSCBG computer model and predicting spray dispersion in complex terrain. This model is a



Net radiometer.



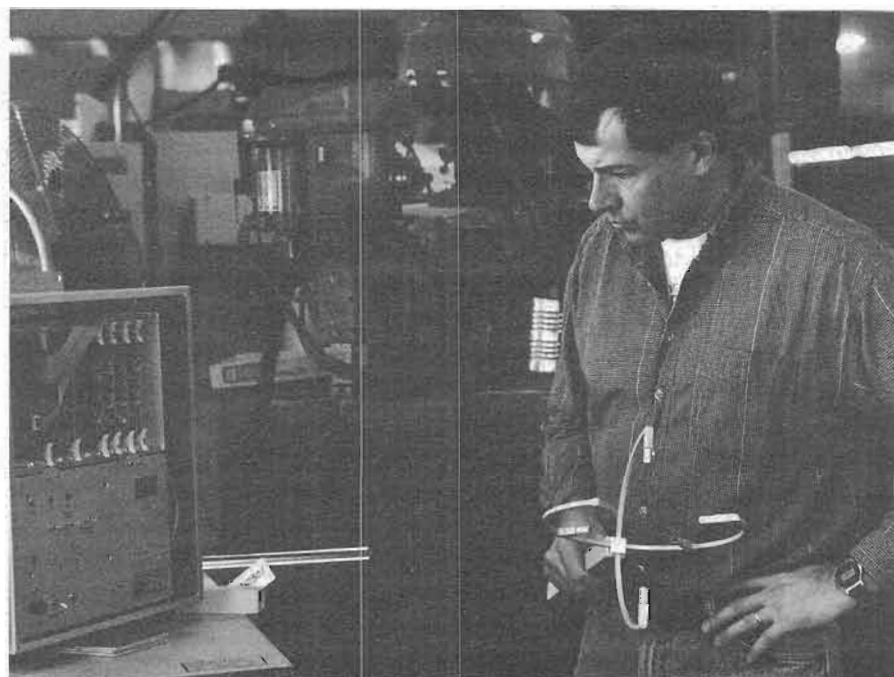
Gypsy moth spray project support.

tool that allows foresters and entomologists to simulate aerial spray operations with confidence. Also in the 1993 program, atmospheric acoustic sounding (SODAR) technology was evaluated as a tool in spray operations.

MTDC regularly attends meetings of the National Steering Committee for Seed, Cone and Regeneration Insects; Western Defoliators; Gypsy Moth and Eastern Defoliators; and the Spray Model and Application Technology Steering Committee. The MTDC FPM Program routinely works with personnel from all Forest Service Regions and the northern area.

The Center, along with its sponsors and partners, attends workshops, presents papers, and prepares manuscripts for professional journals. In 1993, Harold Thistle gave presentations to the Air and Waste Management Association/American Meteorological Society in Scottsdale, Arizona; the American Society of Agricultural Engineers in Spokane, Washington; the Second International Symposium on Pesticide Application Techniques in Strasbourg, France, and the Society of Environmental Toxicology and Chemistry in Houston, Texas.

In 1994 he spoke on the role of meteorology in spray dispersion to the Pacific Northwest section of the National Agricultural Aviation Association. He presented a workshop on Spray Drift Management and The Validation of Computer Models in Rotorua, New Zealand. Dr. Thistle presented technical papers to the American Society of Agricultural Engineers in Kansas



Turbulence monitoring instrumentation.

City, the National Agricultural Aviation Association in Las Vegas, and the Annual Gypsy Moth Review in Portland, Oregon.

MTDC has worked with the Forest Service personnel in Utah, California, Idaho, Connecticut, West Virginia, Oregon, Montana, Wisconsin, Michigan, Arkansas, North Carolina, South Carolina, and elsewhere. MTDC has also established substantive contacts with USDA-APHIS, and USDA-ARS.

In April 1994, MTDC assisted in conducting a comprehensive two-week course in insecticide and herbicide application and management in Marana, Arizona.



SODAR measurement of the wind at height.

Harold Thistle taught courses on spray physics and meteorology and spray modeling; Diane Herzberg conducted a class on pheromone application, and Tony Jasumback, Keith Windell, and Bill Kilroy discussed and demonstrated spray equipment.

In FY 94, the Center provided meteorological support to the Integrated Pest Management Peach Twig Borer Study, in Chico, California. This study involved transferring Forest Service

aerial application technology to agriculture by using a biological insecticide and applying the FSCBG model. MTDC provided meteorological support to the Intermountain Region background gypsy moth monitoring work, and the Gypsy Moth Larvae Survival Study run by the state of Utah and the Intermountain Region.

The revised FPM/MTDC 5-Year Plan—Supporting Forest Health is being distributed. The following projects are included in the revised plan:

1. *Technical Services.*
2. *Technical Transfer of Computer Models.*
3. *Ground and Aerial Pheromone Applications.*
4. *Characterizing Spray from Ground Sprayers.*
5. *Single Tree Sprayer.*
6. *GPS-Based Aircraft Navigation Guidance.*
7. *Non-Insecticide Insect Control.*
8. *Meteorological Factors in Pesticide Drift.*
9. *Pesticide Drift in Complex Terrain.*
10. *Vegetative Canopy Barriers and Pesticide Drift.*
11. *Non-Chemical Orchard Cone Sanitation.*
12. *Computer Assisted Sketch Mapping.*

Of these twelve projects, six are ongoing from the previous plan (1 thru 4, 6, and 7). Three were assigned under other projects in the previous plan (8, 9, and 10).

Two are direct requests from the field (5, and 12), and one (11), is a development effort that emerged from an existing project (7). These projects all have their origins in steering committee recommendations or come from Forest Service personnel in the field.

The plan allows FPM and MTDC personnel to focus priorities and resources to meet engineering and physical science needs of Forest Service FPM.

The Relationship Between In-Canopy Micrometeorology and Droplet Deposition report was published in 1993. In addition, two articles, ***Atmospheric Tracer Concentrations from an Elevated***

Source in an Urban Core, and Observed Downwash Concentrations Compared to ISCST Predictions in an Urban Core, appeared in the Journal of Environmental Engineering.

Other recently published reports in this project include: ***Computing Total Accountancy of Aerially Released Material; Penetration of Aerially Released Spray Material into Forest Canopies; A Review of Early Work; Environmental Fate and Accountancy; Aerial Spray Drift Modeling; Statistical Analysis of the Performance of Five Simulation Models for Heavier-than-Air Releases; and Performance Evaluation of Dense Gas Dispersion Models.***



Single tree sprayer.

Single Tree Sprayer

5E52P64

Harold Thistle, Project Leader

Washington Office Forest Pest Management has asked the Center to design and demonstrate a single tree spray system to protect rust-resistant sugar pine cones in wild stands.

In 1993, MTDC, working with Jack Barry, Washington Office FPM, Nancy Rappaport, Pacific Southwest Region (5), and Tom Catchpole, Sierra National Forest, developed a single tree sprayer system and performed a preliminary field evaluation of the unit in Central California. In this test, one of the three systems failed; two remained operational. Nancy Rappaport is preparing a publication on results.

MTDC also worked with FPM and the Coeur d'Alene Nursery, Coeur d'Alene, Idaho, to design a study to compare the single tree sprayer system with the hydraulic sprayer system currently used by the nursery for pesticide application. Ten single tree systems were installed in the tree improvement orchard. One application was conducted in June.

Single tree sprayer systems were also installed in seven trees in the Lookout Pass area on the Montana-Idaho border to determine the durability of systems exposed to the elements.

Testing of these systems will continue in FY 95. Systems will be installed in Forest Service seed orchards in Wisconsin and North Carolina.

Thermal Insect Control

3E32P11

Keith Windell, Project Leader

This effort is a pest management project dealing with control of detrimental insects inside fallen cones and in the duff layer of an orchard floor. In the past, control fires have been used to kill cone beetle larvae before they emerge in seed orchards. Optimum burn conditions, however, do not always occur before beetles have emerged. The goal of this project is to evaluate equipment and procedures that will be more effective in dealing with cone pests.

In FY 94 MTDC contacted experts and manufacturers regarding their thermal insect control experiences and techniques. The Center also conducted a literature search.

MTDC attended and participated in two equipment evaluations conducted in FY 94. One evaluation involved testing a prototype field burner for killing Douglas-fir cone gall midges in the duff layer. This evaluation

was conducted at the Beaver Creek Seed Orchard in Oregon. Participants included FPM Pacific Northwest Region (6), Oregon State University, and orchard personnel. The other test involved the Oconto River Seed Orchard in Wisconsin. This was an evaluation of a commercial agricultural weed burner in killing white pine cone beetle larvae as they wintered in the cones. Cooperators in this test included FPM State and Private Forestry - St. Paul, Minnesota, and Eastern Region (9) orchard personnel.

Neither of the trials was completely successful, and alternative concepts are being developed. MTDC conducted a market search to determine the availability of suitable equipment. A progress report has been generated and submitted to the sponsor, and a Data General computer survey has been distributed to federal seed orchard personnel to determine what budget restraints and alternative concepts should be considered. This project has been re-named **Non-Insecticide Insect Control**.



Thermal (non-insecticide) insect control (prototype field burner).

Characterizing Spray from Ground Sprayers

3E22P80

Harold Thistle, Project Leader

The objective of this project is to allow prediction of ground spray behavior by characterizing the spray plume, spray deposition, and spray drift from ground sprayers used in seed orchards, nurseries, and plantations. This information will then be used to add a ground spray module to the FSCBG model.



Jack Barry, Washington Office Forest Pest Management sponsor, conducting field training session.

Ground and Aerial Pheromone Applicator Evaluation

3E22P82

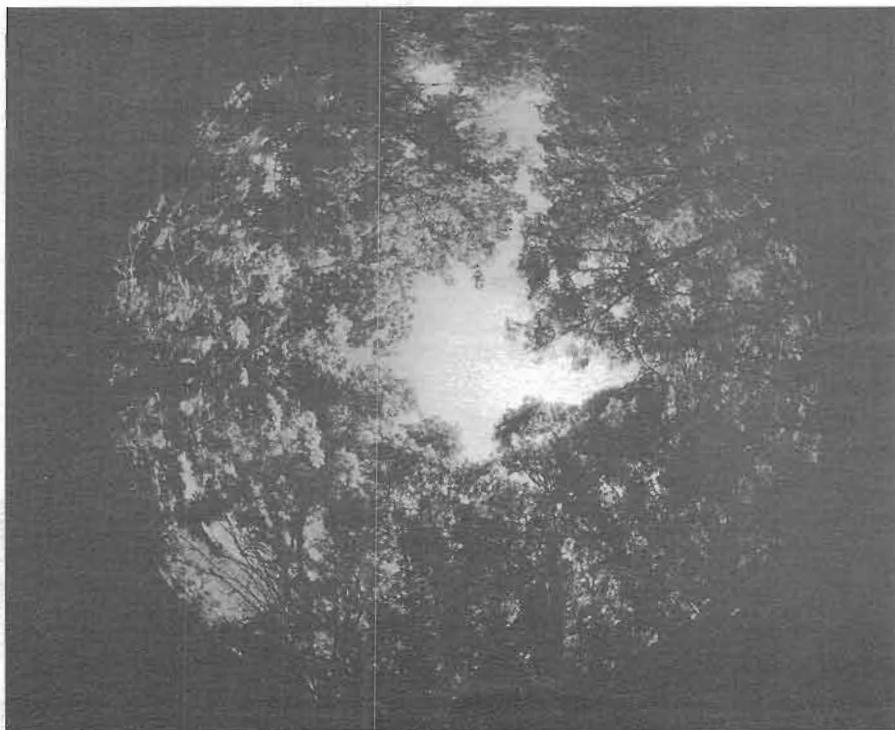
Diane Herzberg, Project Leader

Pheromones are chemical substances released by animals or insects. These chemicals serve as a means of communication between members of species. They may act to establish a territory, attract the opposite sex, or warn others away from an area. They can be used effectively, in place of insecticides, to deter reproduction.

Pheromones are gaseous in their natural state.

In their agricultural application, they are produced synthetically and packaged in various ways for slow release. This allows a controlled release of the pheromone that extends its effectiveness. The end product appears as small plastic granules or spaghetti-like tubes that must be broadcast over an area by aerial application or ground placement.

MTDC is working with Forest Service and Animal Plant Health Inspection Service (APHIS) personnel and with industry to improve pheromone application equipment and techniques. Both ground and aircraft systems are included in this program.



Fish eye view of the canopy from the forest floor.

Publications and Journal Articles

Meteorological Data Collection for the 1992 Utah Gypsy Moth Eradication Program, Thistle, May, 1993, Pub. No. 9334-2828-MTDC.

The Relationship Between In-Canopy Micrometeorology and Droplet Deposition, Thistle, Teske, and Barry, September, MTDC Pub. No. 9334-2842-MTDC and ASAE Paper No. 931058, Spokane, Washington, June, 1993.

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Atmospheric Tracer Concentrations from an Elevated Source in an Urban Core, Thistle, Murray, Ratte, and Carroll, Journal of Environmental Engineering, January, 1995, and MTDC Pub. No. 9434-2803-MTDC.

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Observed Downwash Concentrations Compared to ISCST Predictions in an Urban Core, Thistle, Murray, Ratte, and Carroll, Journal of Environmental Engineering, and MTDC Pub. No. 9334-2812-MTDC.

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Testing of DGPS Aircraft Guidance and Recording Systems for Use in Forestry in Complex Terrain - Preliminary Report, Thistle, Jasumback, Kilroy, and Barry, Pub. No. 9534-2812-MTDC.

Computing Total Accountancy of Aerially Released Material, Thistle, Barry, and Teske, Presentation at The Society of Environmental Toxicology and Chemistry, 14th Annual Meeting, Houston, Texas, November 14-18, 1993, and MTDC Pub No. 9434-2838-MTDC.

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Performance Evaluation of Dense Gas Dispersion Models, Touma, Cox, Thistle, and Zapert, Journal of Applied Meteorology, March, 1995 and MTDC Pub. No. 9534-2830-MTDC.

New Aerial Herbicide Application Technology, Barry, Teske, Thistle. Paper presented at 16th Annual Forest Vegetation Management Conference, Sacramento, California, January, 1995.

Interfaces in the FSCBG Pesticide Drift Modeling System, Thistle, Teske, Allwine and Barry. (Abstract) in Proceedings EOS Transactions, American Geophysical Union, San Francisco, California, December, 1994.

FSCBG Predictions Coupled to GPS/GIS Aircraft Tracking,

Teske, Barry, Thistle. Paper presented at the 15th Symposium on Pesticide Formulations and Application Systems, Phoenix, Arizona, October, 1994.

Testing and Demonstration of DGPS Aircraft Guidance and Recording Systems for Use in Forestry in Complex Terrain,

Preliminary Report, Thistle and Barry. Proceedings of the 1994 Annual Gypsy Moth Review, Portland, Oregon, p.48-57. February, 1995.

The Role of Atmospheric Stability in the Dispersion of Pesticide in the Atmosphere,

Thistle, AMCA, Portland, Oregon, March, 1995. MTDC Pub No. 9534-2829-MTDC.

Current MTDC Projects

Project Leaders

5E52P64	Single Tree Sprayer	Harold Thistle, (406)329-3981
5E52P29	Technical Transfer of Computer Models	Harold Thistle, (406)329-3981
3E22P80	Characterizing Spray from Ground Sprayers	Harold Thistle, (406)329-3981
3E32P11	Thermal Insect Control (Non-Insecticide Insect Control)	Keith Windell, (406)329-3956
3E21P81	Stationary Sprayer Project	Diane Herzberg, (406)329-3957
3E22P82	Ground and Aerial Pheromone Applicator Evaluation	Diane Herzberg, (406)329-3957
3E12P73	GPS-Based Aircraft Navigation Guidance	Harold Thistle, (406)329-3981
TE02P18	Technical Services-FPM: • Meteorological Factors in Pesticide Drift • Pesticide Drift in Complex Terrain • Vegetative Canopy Barriers and Pesticide Drift • Computer Assisted Sketch Mapping • Non-Chemical Orchard Cone Sanitation	Harold Thistle, (406)329-3981

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FOREST Pest LEAFLET

Mountain Pine Beetle

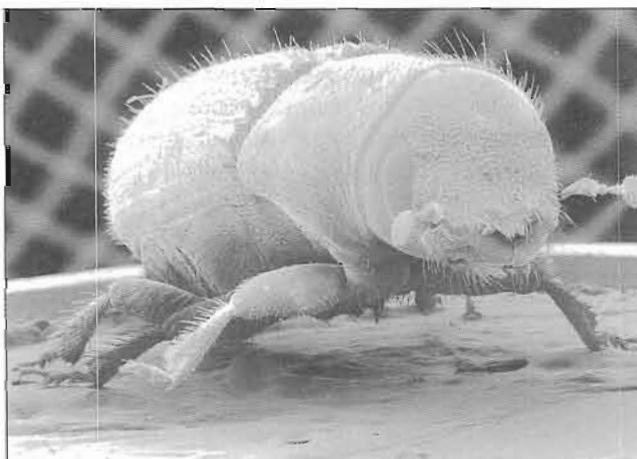
L. Unger

Introduction

The mountain pine beetle (*Dendroctonus ponderosa*), a native pest, is the most serious insect enemy of mature pines in western Canada. In British Columbia, major outbreaks occurred in all areas with a significant pine component, except for the northern quarter of the province. Since the first recorded infestations in 1913, in the Okanagan and Merritt areas, major infestations have occurred in Kootenay National Park and the Chilcotin Plateau in the 1930s, on Vancouver Island during the 1940-50s, near Takla and Babine lakes in the 1950s, and through much of the southern interior, Chilcotin Plateau and the Skeena and Nass river areas in the late 1970s and 1980s. Well over 500 million trees were killed by the mountain pine beetle during the past 80 years.

Outbreaks generally last 8-10 years and severely deplete the pine component of forest stands; trees with a diameter greater than 25 cm are

particularly susceptible. Extensive mountain pine beetle infestations hasten forest succession, change the age and diameter distribution of the pine components of the forest, and reduce aesthetic values. Infestations can also cause marketing and operational problems and environmental concerns



Adult beetle

when large volumes of dead pine are harvested either for control or salvage purposes.

Large reserves of mature pine forest are always at risk in areas climatically favorable for the beetle. Good access to susceptible forests is needed so that preventative measures

can be taken and so that infested stands can be quickly treated.

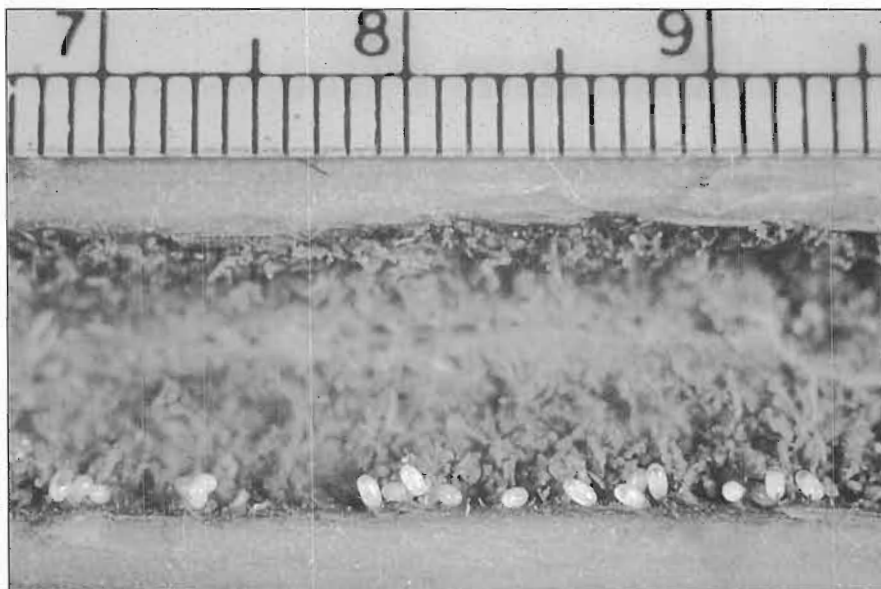
Hosts and distribution

The mountain pine beetle is distributed throughout British Columbia north to 56° latitude. Infestations have been recorded from sea level to the highest elevations where the host species grow. Native hosts include lodgepole pine (*Pinus contorta*), ponderosa pine (*Pinus ponderosae*), whitebark pine (*Pinus albicaulis*), and limber pine (*Pinus flexilis*). Some exotic pines may also be attacked. Occasionally non-host trees such as Engelmann spruce (*Picea engelmannii*) are attacked, but beetle populations do not persist in these occasional hosts.

Description and life history

Adults are cylindrical, 3.7 to 7.5 mm long; teneral adults are light creamy-tan in color, changing to black when mature.

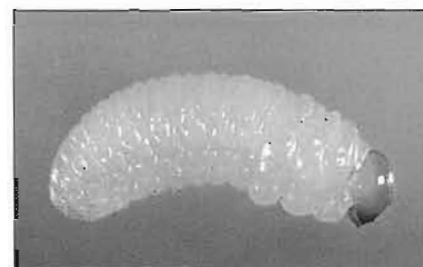
Eggs are pearly white, about 1 mm in size, and are laid singly in niches on both sides of the parent gallery.



Egg niches along parent gallery



Pupa



Mature larva

Larvae are white legless grubs with red-brown heads, about 5 mm long in the fourth (final) instar.

Pupae are white at first, changing to light brown, about 5 mm long, with the external characteristics of the adult beetle visible.

The life cycle of the mountain pine beetle varies considerably. The normal cycle takes one year to complete; however, during warmer than average summers, parent adults may re-emerge and establish a second

brood in the same year. Conversely, in cooler summers or at higher elevations, broods may require two years to mature. These variations in the life cycle may result in rapid increases in population levels, or conversely, sharp population decreases.

Beetle flights normally occur throughout July and into August, and generally peak in late July. Upon locating a suitable host, females bore through the bark to the phloem and cambium region, and start con-

struction of the egg gallery, usually on the lower 5 m of the bole. The first females that attack a tree emit an aggregating pheromone which attracts mainly males. The males in turn emit pheromones attracting additional females. This leads to a mass attack which overcomes the tree's resistance. The egg galleries are usually about 30 cm long but occasionally they may reach 90 cm. They extend upward parallel to the grain and usually score both bark

Mountain pine beetle life stages, symptoms, and control options

	Summer	Fall	Winter	Spring
Insect stage:	Flying adults, eggs	Parent adults, eggs, larvae	Larvae, parent adults	Pupae/adults
Detection/symptoms:	Boring dust, pitch tubes, galleries	Boring dust, pitch tubes, galleries	Pitch tubes, galleries, woodpecker feeding	Fading foliage, woodpecker feeding
Control:	Pheromones, pesticides	Brood tree removal	Brood tree removal	immediate utilization



Foliage discoloration (red tree crowns) is the most visible symptom of infestation in the year following attack

and sapwood. Eggs are laid in individual niches 0.5 cm apart along both sides of the gallery, and are tightly packed with frass. Eggs generally hatch in 10-14 days. Larvae feed on the phloem in individual mines extending, under uncrowded conditions, about 13 cm at right angles to the egg gallery. Broods overwinter mainly as larvae. Larval development is completed in early summer of the following year. When larvae mature, they excavate an oval chamber in which they turn into pupae. Following a short pupation period, pupae become adults. Newly formed adults, called teneral adults, spend a brief period feeding under the bark before the mature adults emerge by boring through the bark and fly to living trees to commence another cycle.

Fungi, yeasts, bacteria and other microorganisms associated with the

beetle are carried by them into the tree. Some of these microorganisms are pathogenic to the tree or the bark beetle, while others are beneficial to the beetle. Fungi, which are commonly introduced by the beetle and produce blue stain in the sapwood, commence growth in the phloem and xylem soon after the beetles start their galleries. As the fungi become established they interrupt the flow of water to the crown and reduce the tree's pitch flow, which is its main defense mechanism against beetle attack. Successfully established bluestain fungi will also retain moisture in the sapwood and prevent excessive dehydration of the phloem, which is essential for brood survival. The combined action of the beetle and fungi kills the tree. Teneral adults need to feed on fungal fruiting bodies to mature, and specialized mouth parts of the beetle ensure that

emerging beetles carry fungi to living trees.

Damage detection

Infested trees can be detected through crown and external symptoms, but the mountain pine beetle can only be positively identified (and the success of an attack can only be positively determined) by looking under the bark.

External evidence of beetle infestation on the bole usually consists of (i) pitch tubes on the stem where beetles have entered the tree, and (ii) boring dust at the base of the tree.

The color of the pitch tube often indicates the success or failure of the beetle attack. Scattered pitch tubes that are whitish in color indicate that the tree has repelled or killed the beetle by pitch exudation. In contrast, numerous reddish brown pitch tubes usually indicate that the attack has



Pitch tubes on a tree trunk: (left) unsuccessful attack; (right) successful attack



Reddish-brown boring dust around base of tree

succeeded. However, pitch tubes remain pliable for several years, so soft pitch tubes do not necessarily mean that a tree is currently under attack. Pitch exudation may not occur during periods of drought or when trees are stressed due to root rot or other reasons. However, trees that have been recently and suc-

cessfully infested will have dry boring dust in bark crevices and at the base of the tree. The boring dust is produced only during the initial stage of gallery construction and, depending on weather conditions, it may rapidly become inconspicuous. Woodpecker activity will often be greatly increased in infested areas,

and woodpeckers will leave numerous pecking holes and may remove sections of the bark.

Characteristic symptoms under the bark include a vertical parent gallery with a slight J-like hook at the bottom and evenly spaced larval galleries extending at right angles from the parent gallery. Galleries are tightly packed with sawdust. The phloem will be dried out and brownish, and the sapwood will usually be stained a bluish color due to the fungi associated with the beetle.

Tree foliage begins to dry out as soon as the conduction of water up the tree is interrupted. As a result, the color of the foliage on infested trees gradually changes from bright to dull green. This early symptom in the lower crown will often become visible 2-3 months after attack. However, more distinct color changes occur during the onset of the growing season the spring following attack. Most lodgepole pine change from yellowish green to an orangey red by July and rusty brown by late summer. At this time most of the beetles will have left the tree. Other tree species display varying color patterns: ponderosa pine seldom turns red but develops more of a straw color, while white pine tends to become bright red. With time, retained foliage color becomes more dull, and most of the foliage drops in 2-3 years; this will vary from species to species and with weather conditions. These rapid and distinct color changes are used to schedule aerial mapping of recently attacked trees.

Beetles associated with mountain pine beetle

A number of secondary beetles are associated with mountain pine beetle and at times these secondary beetles make diagnosis of the causal agent of tree mortality difficult. Secondary bark beetles generally do not successfully establish in healthy, vigorous trees.

Several engraver beetles (*Ips pini*, *I. latidens* and *I. mexicanus*) attack fresh windfelled trees, logging residue, and uninfested portions of the

boles of trees killed by mountain pine beetle, as well as trees of low vigor caused by root rots, stem diseases, defoliation, etc. Occasionally, however, they may become destructive in apparently healthy trees, but infestations are usually short. Since a portion of the population overwinters in the duff, extreme cold winter temperatures, which can devastate mountain pine beetle population, are much less destructive to the Ips beetles. As a result, these engraver beetles, which increased along with the mountain pine beetle population, may continue at epidemic numbers for 1 or 2 years.

Ambrosia beetles (*Trypodendron* spp. and *Gnathotrichus* sp.) are wood or pinhole borers that infest recently killed trees, fresh slash, and downed material. Infestation by these beetles can be recognized by the small piles of white boring dust surrounding the points of entry into the wood or around the lower portion of the stem.

The red turpentine beetle (*Dendroctonus valens*) bores under bark near the root crown and produces large reddish brown pitch tubes around the base of the bole. This is the largest of the *Dendroctonus* species: larvae are up to 12 mm long, and the reddish colored adults generally are between 5 and 9 mm.

The lodgepole pine beetle (*Dendroctonus murrayanae*) attacks the lower metre of the stem forming an irregular vertical gallery with eggs laid in groups of 20-50 along both sides of the gallery. Larvae feed gregariously. Larvae and the reddish brown adults are only slightly smaller than the same stages of the mountain pine beetle.

Sour sap bark beetles (*Hylurgops* and *Hylastes* spp.) usually attack the stem near and below duff level.



Beetle galleries in phloem (inner bark)

Adults are black or reddish, but tend to be shorter (3-6 mm) and more slender than mountain pine beetle.

Management

Prevention

The first step in prevention of mountain pine beetle outbreaks is to prioritize stands for preventive maintenance. To this end, risk and susceptibility rating systems have been developed combining the stand parameters associated with beetle infestations and the beetle pressure on a stand. Susceptibility increases in stands (i) with trees over 60 years of age (moderate susceptibility) and with trees over 80 years of age (high susceptibility), (ii) with trees over 25 cm in diameter, (iii) with a high pine component, (iv) with a density between 750 and 1500 trees/ha, and (v) at lower altitudes and latitudes. The risk of an infestation developing within a stand is based on

its distance to the nearest infestation and its level of current attack. For example, stands within 3 km of an active infestation and with more than 100 trees already attacked would be considered at risk. Risk factors can change dramatically within a year, while stand susceptibility changes gradually over a number of years.

Silvicultural treatments which help to reduce stand susceptibility include (i) reducing stand density to below 500 trees/ha, (ii) establishing an age and tree size mosaic within a stand or drainage, (iii) implementing a shorter rotation period, and (iv) establishing a species mix within a stand. The effectiveness of these measures may be reduced considerably in the presence of high beetle pressure, however.

Aerial surveillance, especially of moderate to high risk stands, will detect the initial phases of beetle invasion and allow for the

early implementation of effective control measures.

Ground surveys should be conducted when pockets of discolored trees first appear in a stand to verify the causal agent and the status of the brood.

Applied control

A variety of applied controls can be utilized, depending upon the extent of the beetle problem. In conjunction with controls, synthetic aggregating pheromones can be used effectively to concentrate beetle attack. This greatly improves the efficiency in locating newly attacked trees for follow-up treatment actions, or for containing most of an attack within a given harvesting area. Under specific conditions, mass trapping of beetles may prevent small local beetle populations from increasing or it may even reduce these populations to endemic levels. However, the effect of trapping becomes negli-

Control options at various infestation levels

Prevention	Small infestations	Intermediate infestations	Major infestations
hazard rating, reducing stand susceptibility, aerial monitoring	ground surveys, pheromones, fall & burn, pesticides	small patch log removal, pheromones	large clearcuts, salvage logging

ble when the beetle populations reach epidemic proportions.

During the initial phases of an infestation when only small infestation pockets are present, individual trees containing beetle brood can be treated by felling and burning, applying an appropriate silvicide to infested trees within 24 days of attack, application of a registered insecticide to the bole of infested trees just prior to beetle emergence, and the use of pheromone-baited, lethal (insecticide-treated) trap trees. Permits are required for such work in B.C. forests.

At intermediate infestation levels (up to about 100 trees per patch), small-patch logging can be used if good access is in place, and if beetle attack is concentrated naturally or through the use of pheromone baits.

Beyond the intermediate stage, and when infestations exceed 10 ha, control becomes increasingly more difficult. In larger infestations the rate and range of beetle dispersion increases and any effective control program will require very extensive ground surveys to locate the green, newly attacked trees. Consequently, the only practical control measure at this stage is clearcutting well beyond the areas having red trees in order to remove trees containing beetles.

Natural control

Resin flow and predation and parasitism are relatively ineffec-

tive in large infestations, but can be important in maintaining populations at endemic levels.

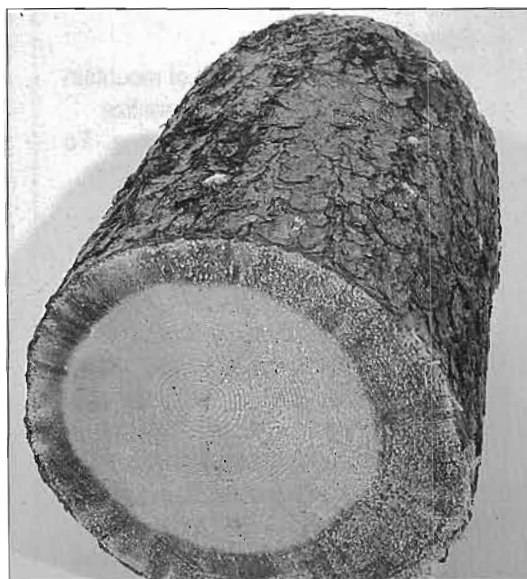
Resin flow is the tree's active defense mechanism against beetle invasion. It is effective in flushing out beetles (pitchout) or destroying eggs only when attack density is low, or when a high attack level is spread over a number of days. During periods of tree stress, such as drought, resin flow may be greatly reduced.

Predation and parasitism play a significant role in beetle population dynamics. Woodpeckers are the most conspicuous predators as they remove bark in search of beetle brood, in the process of bark removal they also reduce the survival rate of the remaining insects due to desicca-

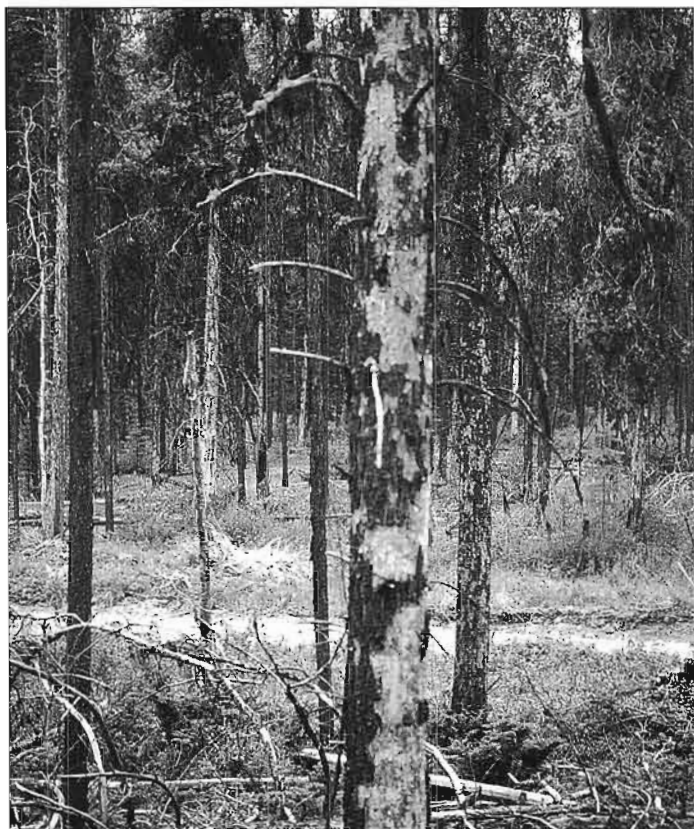
tion. Perching birds also consume large quantities of flying beetles. Some of the more commonly encountered insect predators include the clerid (checkered) beetles, and Diptera (various true fly species). Several species of wasps occasionally kill large numbers of mountain pine beetles.

Temperature can be an important factor in determining population levels during the course of an infestation. Optimum under-the-bark temperatures for brood development are between 20 and 26°C. Cool summers may delay beetle flight and subsequently slow brood development, which can affect overwintering brood survival. Early fall temperatures of -18° will kill brood, while even less severe temperatures will kill eggs and larvae in the first three larval instars. The most cold-hardy stage, late-instar larvae, when conditioned for cold temperatures, cannot withstand temperatures below -37°; temperatures of -27° persisting for several days will kill a large portion of the population. Once the maturing larvae have resumed feeding in the spring they again become very susceptible to freezing temperatures. Since the impact of low temperatures is moderated by tree size, bark thickness and snow insulation, the duration of the cold period and snow pack is a critical factor to beetle survival.

Intraspecific competition affects brood production. High attack densities result in a more



Blue stain in sapwood



Outer bark flaked off by woodpeckers feeding on beetles

rapid rate of phloem desiccation; consequently, fewer adults emerge per unit area of bark surface. The adults which do emerge will also have a reduced capacity for egg production. Optimum attack densities appear to be between 3 and 10 per 1000 cm² of lodgepole pine bark surface area, but it depends upon the thickness of phloem (food source).

Food supply (phloem) is a main factor in regulating beetle populations. Beetles initially select larger diameter trees with thick phloem, in which populations can increase rapidly. As an infestation progresses and the larger diameter trees have already been killed, smaller trees with thinner phloem are attacked resulting in smaller broods. These trees will also dry out faster, leading to increased brood mortality. In general, when beetles attack trees under 25 cm in diameter, the number of progeny emerging will progressively become less with decreasing diameter.

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Additional information

Additional copies of this and other leaflets in this Forest Pest Leaflets series, as well as additional scientific details and information about identification services, are available by writing to:

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