J. W. Gottstein Memorial Trust Fund

The National Educational Trust of the Australian Forest Products Industries

GOTTSTEIN TRUST

THE USE OF STATIC TRAPS FOR THE DETECTION AND MONITORING OF EXOTIC FOREST INSECTS

RICHARD BASHFORD

2003 Gottstein Fellowship Report

JOSEPH WILLIAM GOTTSTEIN MEMORIAL TRUST FUND

The Joseph William Gottstein Memorial Trust Fund was established in 1971 as a national educational Trust for the benefit of Australia's forest products industries. The purpose of the fund is *"to create opportunities for selected persons to acquire knowledge which will promote the interests of Australian industries which use forest products for the production of sawn timber, plywood, composite wood, pulp and paper and similar derived products."*

Bill Gottstein was an outstanding forest products research scientist working with the Division of Forest Products of the Commonwealth Scientific Industrial Research Organization (CSIRO) when tragically he was killed in 1971 photographing a tree-felling operation in New Guinea. He was held in such high esteem by the industry that he had assisted for many years that substantial financial support to establish an Educational Trust Fund to perpetuate his name was promptly forthcoming.

The Trust's major forms of activity are,

1. Fellowships and Awards - each year applications are invited from eligible candidates to submit a study programme in an area considered of benefit to the Australian forestry and forest industries. Study tours undertaken by Fellows have usually been to overseas countries but several have been within Australia. Fellows are obliged to submit reports on completion of their programme. These are then distributed to industry if appropriate. Skill Advancement Awards recognise the potential of persons working in the industry to improve their work skills and so advance their career prospects. It takes the form of a monetary grant.

2. Seminars - the information gained by Fellows is often best disseminated by seminars as well as through the written reports.

3. Wood Science Courses - at approximately two yearly intervals the Trust organises a week-long intensive course in wood science for executives and consultants in the Australian forest industries.

4. Study Tours - industry group study tours are arranged periodically and have been well supported.

Further information may be obtained by writing to,

The Secretary,
J.W. Gottstein Memorial Trust Fund,
Private Bag 10,
Clayton South, VIC 3169, Australia

The information contained in this report is published for the general information of industry. Although all reasonable endeavour has been made to verify the accuracy of the material, no liability is accepted by the Author for any inaccuracy therein, nor by the Trustees of the Gottstein Memorial Trust Fund. The opinions expressed are those of the author and do not necessarily represent the opinions of the Trustees.

Dick Bashford is a Senior Silvicultural Technician within the Biology and Conservation Branch of the Division of Forest Research and Development for Forestry Tasmania, where he has been employed since 1979. Prior to that time he was a Senior Technical Officer with CSIRO Division of Entomology, serving in the UK and in Hobart for a total of 15 years. His current responsibilities include maintaining the technical standards of all disciplines with the Branch, supervision of the research laboratories and staff, and development of quality standards and OH&S guidelines. He is a specialist technician in forest entomology and invertebrate research, and manager of various projects and of the Tasmanian Forest Insect Collection. He has been the State Representative on Research Working Group 8 (Forest Health) since 1990, and on the Council of Heads of Australian Entomological Collections since 1996.

Executive Summary

Quarantine touches every member of the Australian community either directly or indirectly. The forest industry, as a member of that community, is also affected in a number of ways. Quarantine is a vital element in the protection of the forest estate in its broadest sense. This report looks at the use of pheromone traps for forest protection through improved methods of detection, monitoring and control of exotic insect pest incursions.

In February 1999, the President of the United States issued Executive Order 13112 on Invasive Species, establishing the National Invasive Species Council. The council provides, for the first time, a coordinated effort of 10 member Government Departments. In October 2001, the council completed a management plan, *Meeting the Invasive Species Challenge*, to address the Executive Order. The plan is designed to raise public awareness and control the introduction and spread of non-native invasive pests. According to the plan, the economic cost of invasive species is estimated at $us137 billion every year. The forestry component administered by the USDA Forest Service is $US97 million in 2002/2003.

It is the experience in many countries with high levels of cargo trade entering the country that there are well-defined pathways for the introduction of insect pests. If we look at forest insect pests then we need to look at trees in the context of urban street trees, home gardens, nurseries, rural shelterbelts, agro-farm planting's commercial tree plantations, commercial native forests and finally protected native forest. The entry pathway of an exotic forestry insect is usually through a port of entry, which may be a seaport or airport, initial establishment within a five kilometre radius of that port, then expansion over time to suitable areas and other host tree species.

During the past three years Forestry Tasmania has been conducting a number of trials at several sea and airports in cooperation with quarantine and port authorities to develop such detection and monitoring systems. A number of commercial traps and lure/attractants have been tested for suitability in Australian conditions. The additional information obtained during the study tour, the contacts made, and the networking of similar programs should enable us to expand the pilot program to cover all ports of entry. Over a period of time this model should be taken up nationally as international trade volumes increase and the rate of forest insect incursions increase.

The study tour aimed to provide information on the methodology and static trapping techniques used in the United States, Canada and UK for the early detection of exotic forest insect, methods of containment and eradication, and community involvement in those programs.

Table of Contents

Types of commercial static trap systems examined in the study tour.

Lindgren Funnel Trap.

The Lindgren funnel trap is the most widely used beetle trap in North America and Canada. Semiochemicals are chemicals that mediate interactions between organisms. Semiochemicals in controlled release devices are centrally placed in the trap funnels. Traps are available in 4, 8, 12 and 16 funnel combinations. The funnels collapse into each other for easy storage and transportation. Collection jars fitted to the base of the funnels are available for both dry and wet collection. Highly recommended for trapping scolytid and platypodid beetles both for detection and mass collection.

Figure 1: Lindgren 12-funnel trap uses for scolytids and platypodid beetles.

Intercept Panel Trap.

A universal trap for bark beetles, ambrosia beetles, longhorn beetles and other woodborers. Its unique design was developed by IPM-Tech in cooperation with Oregon State University and USDA. The silhouette simulates a tree of large diameter and provides a large surface area to maximise trapping. Constructed of treated weather proofed plastic which is lightweight easily assembled and can be folded to store flat. Panel traps can be joined to form longer traps of greater surface area. Rain slip surfaces greatly improve catch. Baby wipes soaked in car windscreen cleaner provides ‘wipes’ which can be used to prepare the panel surfaces when servicing the trap. This trap design has been shown to be more effective in trapping larger woodborer species than funnel traps.

Figure 2: Intercept panel trap used for larger woodborers..

Delta or wing traps.

Heavy gauge poly-coated paper traps with a sticky interior or removable sticky panel. Pheromone patches or wicks are inserted which provide species specific monitoring. Ideal for monitoring low populations of lepidopterous pest species. A large number of designs and sizes. Used in Australia for Asian Gypsy Moth monitoring.

Figure 3: Delta trap use for Asian Gypsy Moth.

UNI-Trap.

A bucket/funnel combination trap used for mass trapping of lepidopterous pest species and some coleoptera such as scarabs. Pheromone release units are placed in the trap for specific species trapping. Insects lured inside are knocked down by use of a toxicant strip. Available in yellow/white, all white or green.

Figure 4: UNI-trap with light trap both used to capture Lepidoptera.

Dome trap.

An effective trap for fruitflies and vespulid wasps when used in conjunction with a pheromone based liquid bait. Moulded in plastic with a yellow base and clear upper section. The trap is used for *Vespula* spp. distribution studies in Tasmania.

Numerous other trap designs are commercially available mainly for use in monitoring agricultural pest species. Some such as sticky plates or bands have been used on trees for the detection of forest tree pests. They are not necessarily pest specific.

Figure 5: Dome trap used for vespid wasp capture.

Maintenance of traps and pheromone/semiochemical lures.

Traps. Keeping traps in good condition ensures that they function as efficiently as possible. Keeping them clean enables insects to enter the traps easier and where coloured keeps the trap attractive to target species. Clean before storage after use. Under forestry conditions set up traps in shaded flight paths canopy. Set outside of tree canopy drip line and at standard height (one metre above ground) using trap poles. Allow semiochemical plumes to be pristine as regards competition from attractive host trees. As a general rule of thumb pheromone traps should be spaced at two traps, or set of traps, per hectare, or four traps or sets per ten hectares. If monitoring for more than one species of insect, pheromone traps for each species should be placed at least 10 metres apart.

Pheromone/semiochemical lures. Extreme caution must be exercised when handling lures to prevent contamination. Wear washable cotton or disposable gloves to prevent the skin being impregnated by the chemicals. Do not use different lures in the same trap as the combined odours may react to repel the target insect. Field life varies from two weeks to thirty weeks dependent on release rates. All lures should be stored in a refrigerator, which will give them several years shelf life, but it is better to obtain fresh lures each season. Pheromone lures can be frozen at minus 25^{o}C to minus 40^{o}C. Never leave lures in a car at high temperatures, as this will rapidly exhaust the lure. Transport in insulated cooler box until ready for use.

Case Studies

Procedures for Control and Monitoring of established exotic insects.

1) **A new exotic with well defined distribution within urban areas.** Eradication is still an option but requires ongoing control to achieve that end.

Asian Longhorned Beetle. (ALB)

Figure 6: Asian longhorned beetle adult.

This destructive insect was discovered in New York City in 1996. Since then some 5,800 trees have been removed and replaced from streets in Queens, Manhattan, Bayside and Islip, Brooklyn, Long Island and Hudson. In 2003 many potential host trees were injected with a systemic insecticide in an attempt to protect them from attack. It seems unlikely that eradication can be achieved but substitution of tree species by replanting over many years will contain and limit the spread of this insect.

In Chicago with only 19 additional infested trees found in 2002 and 2 trees in 2003 there is a real hope of eradication.

Potential Impact.

With maple as a preferred host ALB is a major threat to street trees in the cities of USA and Canada.

Figure 7: Street tree removal in central Chicago.

Has already had a huge impact in the cities of Chicago and New York. The attempted eradication and tree replacement scheme has cost $US90 million.

Figure 8: Damage to Maple trunk following attack by Asian longhorned beetle.

Use of static traps.

Panel traps are used in China to determine population levels of ALB in Poplar stands. Traps have not been used in the United States for two reasons. Firstly a pheromone or attractant has not yet been made commercially available although some host attractant semiochemicals have been isolated. It is likely that these will be available in the 2004 season. Secondly the use of traps in dense urban area such as Brooklyn or Queens would prove very difficult due to vandalism and theft of the traps.

2) A new exotic incursion. Has potential for rapid spread with eradication no longer an option.

Emerald Ash borer (EAB).

Figure 9: Emerald ash borer adult.

The Emerald Ash Borer, *Agrilus planipennis* (Buprestidae), has been established in Michigan for at least five years. It is thought that the beetle arrived in infested solid wood crating or pallets from Asia. Formal identification was made in July 2002 following evidence of considerable *Fraxinus* spp. (Ash) tree decline and death occurring. Larvae feed in the phloem and outer sapwood, producing galleries that eventually girdle and kill branches and entire trees over several years. Eradication is now no longer an option and control in both forested and urban areas necessary for economic and aesthetic reasons. Over 6 million ash trees have been killed in the Detroit area. Action to date has been limited to determination of distribution and the establishment of quarantine zones. Quarantine zones prohibit the movement of ash trees and ash wood products to limit human-assisted spread of this pest. Meetings in July 2003 to determine action and funding were not conclusive pending further research results. The rate of spread has been rapid with current quarantine areas exceeded. The beetle has now been found in Ontario, Ohio, and Maryland.

Potential Impact. Ash occurs extensively in the natural and urban forests of the Eastern United States. In 2001, ash accounted for more than 149 million cubic feet of timber products in nationwide worth $US236 million. There are more than a billion ash trees in the United States and is extensively planted as a shade tree in urban situations in many major cities. In many midwestern and Canadian towns and cities ash species comprise 5-20% of all street trees. In both Chicago and New York many thousands of elm and maple street trees have been replaced by ash species following tree infestation by Dutch elm disease and Asian longhorn beetle. If EAB reaches these cities yet another replacement cycle will occur costing many millions of dollars. Removal and replacement of killed ash trees in six county region of southeastern Michigan could cost up to $US9 billion according to a Michigan State University estimate.

Use of static traps. A monitoring system needs to be set in place to provide early detection of EAB into these cities so control can be initiated. Identification of a host attractant semiochemical would allow a static trap system to perform this function. Currently panel traps are being tested for their use to detect the presence of EAB in urban areas in the absence of commercial production of a pheromone. A trapping system, combined with a routine check of tree health in 'at risk' sites should provide sufficient lead-in time for control options to be implemented. An advisory committee of scientists has recommended that the federal government pay for the removal and destruction of infested trees. In heavily infested areas all ash trees would be removed to eliminate borers and reduce the rate of spread.

3) **A well-established exotic.** Able to be limited in its distribution and held at sub-economic population levels.

European Gypsy Moth.

Figure 10 : Female Gypsy Moth laying egg batch.

Established in North America since 1869 when larvae being evaluated for silk production were blown from a window in Medford, Massachusetts. Gypsy moth caterpillars have defoliated millions of acres of trees and shrubs in the northeastern United States since first establishment. Natural spread over short distances occurs as newly hatched larvae spin short lengths of silken thread which allows them to be blown by the wind. Movement of larvae and eggs has moved over longer distances on vehicles, firewood, and household goods.

Potential Impact.

European Gypsy Moth is one of the most damaging pests of hardwood forests and urban landscapes, defoliating a million or more forested acres annually. Defoliated forests are susceptible to disease, fire, and erosion and may provide a poor habitat for other forms of plant and animal life. Gypsy moth larvae feed on over 500 different plant species. Population numbers fluctuate from year to year. Populations can rapidly build to large infestations causing widespread defoliation, weakening or killing trees.

Use of static traps.

Once established in an area, gypsy moth populations vary widely from year to year. Monitoring these fluctuations in population size dictates the need for control measures and the type of control needed. A national program of sticky delta trap monitoring is conducted in most States throughout the United States and Canada. Almost half a million delta traps were positioned in 2002/2003. The detection of male moths captured in pheromone traps, baited with disparlure, brings into action control measures. At low population levels a 'slow the spread' technique utilising mating disruption by the aerial application of synthetic pheromone flakes. This aerial application 'floods' the area with attraction pheromone scent, which prevents male moths finding females to mate. Pheromone flakes remain active for 12-16 weeks but take 10-15 years to biodegrade. At high population level aerial application of the biotic agent *Bacillus thuringensis ssp kerstaki* (Btk) is applied to reduce feeding and kill the larvae.

4) **Established but new incursion.** Can be eradicated and populations held at low levels.

Asian Gypsy Moth.

The Asian strain of *Lymantria dispa*r (AGM) has recently become established in Germany and other European countries where it hybridises with European Gypsy Moth. AGM have arrived in the US on bulk cargo ships, ship containers and on the ships themselves.

Potential Impact.

Female AGM can fly unlike the European strain. There is thus greater potential for rapid spread. The larvae also develop more quickly and feed on a greater range of host plants. These factors make AGM a significant exotic economic pest.

Use of static traps.

The national trapping program for the detection of European gypsy moth using the pheromone lure disparlure, also detects AGM. Each detection is treated as a new incursion with eradication the aim. Areas are sprayed with Btk to kill the larvae and post monitoring conducted to ensure areas are clear of AGM.

Discussion

In Australia, quarantine biosecurity is confined to within port of entry site with container and cargo inspections. Overseas experience is that initial establishment is usually in urban port surround areas followed by distribution expansion into native forests, plantations and commercial forest areas. In Australia there is no system of routine monitoring for the detection of exotic forest insect incursions between the port gate and commercial forest areas except for the Asian Gypsy Moth trapping program. The development of a static trapping system in a five-kilometre radius of port and airport sites would provide a system of early detection. Early detection is vital if eradication or containment is to be an option. The principal aims of the Fellowship application was to have the opportunity to see developments in trapping technology, to establish links with workers in similar fields of research, and to see how containment and eradication procedures were conducted in urban situations. The information gathered will enable early implementation of management methods when an exotic forest insect is detected.

There is an increasing trend towards the use of static trap technology to detect and monitor populations of exotic insects in both urban and commercial forest areas. In New Zealand there are well established monitoring and detection practices in place using traps for exotic forestry insect detection and an acceptance at both government and industry levels that protection does not stop at the port gate. In the United States and Canada a number of states and provenances have accepted the model of detection country wide not just port gate. Systems in these countries are not yet national or standardised. Never the less as more monitoring is done the results will flow into standardisation, as funding becomes more readily available. In the United States the take over of port inspection funding by Homeland Security has enabled some States to finance urban, agricultural and forestry monitoring systems in an integrated manner. The commercial companies have increased research into semiochemicals and sex pheromone in anticipation of developing monitoring systems being established.

The attempts at eradication and containment of exotic forest insects such as Asian Longhorn beetle and Emerald Ash borer has provides three important pieces of information. Firstly the value of urban trees, especially in large cities, are very valued by those communities affected. The involvement in the community in understanding why trees had to be removed and the subsequent selection of tree species for replacement is considerable Some streets have evolved a residents roster for watering the replacement trees as well as checking the trees for signs of insect attack. Secondly the costs involved in protecting urban trees is well documented. With both these issues it is vital that communities are involved in all the processes. This also means that the costs can be divided between the different levels of government and business organisations. A prime example is in a small park in Queens where local shops, businesses, schools, home owners as well as local government and federal government have pooled resources in a cooperative, to perform monitoring and control functions as a community to protect ‘their’ park trees. The spin off has been a safer environment for children as well as improvements to the play equipment and increased planting’s in the park as the community value of the park increased. The third point is the level of cooperation and fund sharing achieved within the cities. An example was the need for eight cherry pickers for the survey teams in Chicago. These machines were all donated for part time use by private companies and borough councils with APHIS funding the running costs and USDA-Forest Service the driver costs. The underlying factor to achieve this level of cooperation was the strong media campaign in the press; television and information leaflet distribution to all households in the areas affected as well as the personal contact between the survey teams and the public. Everyone knew what was happening, why, and when. It is of great credit to those cities that they achieved such a high level of community unity against a problem affecting their city. Clearly there is a blueprint here to follow if an exotic forest insect were to establish in urban Australia that threatened to destroy the character of a city. We have one example of this happening in Melbourne when the elm leaf beetle threatened to impact on the mature street elms. A group of concerned citizens formed a protection society that published literature and helped raise funds for control of the beetle. The society provided a forum for the dissemination of information and acted as a lobby group to State and federal politicians to provide funding. The result has been an active research program and an aggressive control regime.

Acknowledgments

I would sincerely like to acknowledge the assistance given by the Gottstein Memorial Trust Fund and its directors, the current secretary Dr Adrian Wallis, and Dr Glen Kile who acted as mentor. My thanks to all the people I visited for their hospitality, time, and friendship.

Appendix 1.

Gottstein Travel Report

Facilities and people visited

Vancouver, British Columbia, Canada.

June 13th 2003 to June 21st 2003.

Simon Fraser University, Burnaby Campus.

Global Forest Insect Facility.

The GFIF was established in 2001 with the aim of providing quarantine facilities enabling the containment of forest insect pest species from any part of the world. Live insects are required for the extraction and testing of chemical sex pheromones. The long-term aim is to determine and stockpile synthetic pheromones necessary for use in traps to detect incursions of exotic Lepidopera. In particular the *Lymantria* group (Lepidoptera:Lymantriidae) contains a number of Asian species, which would be very damaging if established in Australia. The identification of semiochemicals released by insects of economic importance is vital in the development of integrated pest management programs and early detection monitoring. Current research is targeting the painted apple moth, an Australian species recently found in New Zealand. In a second major project in cooperation with USDA Agricultural Research Service (ARS) scientists at Newark, Delaware, the development of lures that can be used in the detection of Asian *Lymantria* species closely related to the gypsy moth. Several of these pheromones are now available for survey and detection of these potentially invasive non-indigenous species.

The laboratory is set up to isolate, identify and test by antennal response techniques. the use of coupled gas chromatographic-chromatography, micro-analytical chemistry, coupled GC-mass spectrometry, windtunnel and field bioassays provides the data to justify the production of synthetic pheromones on a commercial basis. The cost to determine a pheromone blend for a species is $US7000-$US12000 dependant on student help availability, over a one year time frame.

Gerhard Gries, Associate Professor, Biological Sciences

Regine Gries. Biological Sciences.

Department of Biological Sciences.

The Department facilities include an insectary, an analytical laboratory, photography darkroom walk-in cold rooms, a media preparation room, a greenhouse and a pest management library.

A major relevant project conducted by the Department is the Large WoodBorer Trapping project. The development of trapping techniques to monitor woodborer populations at sawmills and log depots in the interior of British Columbia has required cooperation between researchers and commercial interests. In some areas up to 40% of logs stored at depots prior to sawing, are damaged by timber insects. Monitor trap systems for bark beetles and allies are well developed but larger beetles still cause a considerable degrade of stored and fresh sawn lumber.

Work on testing new semiochemical blends for mountain pine beetle control in the interior of British Columbia is ongoing.

John H. Borden, Professor, Biological Sciences.

Technicians: Kathy Simmonds and Leslie Chong.

PheroTech. Inc.

This company provides a commercial outlet for much of the insect biotechnology products development work at Simon Fraser University. The company's forest semiochemical products have been an industry standard for over two decades across North America. A core product is the Lindgren Funnel Trap. This trap is a standard used world wide for the monitoring of bark beetles especially in conifer forests. An annual purchasing budget by the American Plant Health Inspection Service (APHIS) of $US0.5 million for these traps and appropriate lures for use in stored grain and import timber storage areas at port entry sites in North America indicates the value of trapping programs within port areas. Contracts with private timber companies in western Canada indicate the importance in reducing timber degrade. Some of the private trapping programs involve over 100 multiple funnel traps and the catches are often in the millions of insects per year at single sites.

The company provides services and consultation to manage damaging wood boring insects in log processing sites throughout western Canada and United States. In uncontrolled situations about one third of all logs in a timber company's operations are attacked by some species of wood-boring insect. The timber degrade is costly; an average mill will experience a 30% reduction in high-value wood products. The trapping programs provide clients with information on the incidence, hazard and risk of woodborer activity.

Specialising in *Lymantria* spp. pheromones with pheromones isolated from all pest species. *L. monarcha* should have only polyurethane dispensers not rubber based for volatile release at 200 ug blend compared to *L. dispar* at volatile release 500 ug disparlure. It may be possible to use a double delta trap baited separately with the pheromone mix for *L. dispar* and *L. monarcha* as a monitoring technique. *L. monarcha* is also attracted to standard disparlure.

Alex Gustafsson, Wood Borer Programs Manager.

William Keegan, Manufacturing Manager.

John Lafontaine, Senior Chemist.

Visited field site at Fraser River, Vancouver, to see Lindgren Funnel Traps in use for detection of ambrosia beetles. Set up in groups of three traps, which have proved a more effective way of spreading the pheromone plume and increasing catch.

There is an excellent working relationship between Simon Fraser University research staff and PheroTech. Inc. advancing technology transfer to commercial implementation.

Port of Vancouver.

A visit to the port of Vancouver imports facility saw the use of Lindgren funnel traps in grain storage facilities for both import and export. Traps are also placed at dunnage storage piles and in whare-houses where containers are opened. Very few inland cargo deports have routine trapping. Trap collections are sorted by quarantine inspectors on site. Records of species and numbers are not recorded due to time restraints. Any unidentified species are sent to specialists for formal identification.

Troy Komoto and David Holden. Canadian Food Inspection Agency. Port Quarantine Officers.

Vancouver Island, Victoria.

Eveline Stokkink. (Woodstock Management Inc.)

Supplies ambrosia beetle trapping programs using PheroTech funnel traps to forest industry companies throughout Vancouver Island. Eveline ran the PheroTech ambrosia beetle program from 1982 to 1995 and was involved in research and development of pheromone products.

Royal British Columbia Museum, Victoria.

The major diagnostic entomological collection in western Canada specialising in scolytid and platypodid species.

Rob Cannings, Curator of Entomology.

Chicago, Illinois, USA.

21st June to 23rdth June 2003.

Asian Longhorn Beetle project.

Dennis Haugen USDA-Forest Service

Joe Schafer, USDA Program Manager ALB Project.

Visited the Headquarters of the Asian Longhorned Beetle (ALB) program in Chicago and the initial infestation sites at Ravenswood. The first trees containing ALB were found outside the gates of a machinery unpacking depot. Solid wood packing from China stacked near gate. The overhead subway runs directly outside the gate and is thought to have been a means of transporting adults to other parts of the city. Viewed replanting operations in the streets and saw the municipal chipper where all ALB infested material is mulched. Eight three man crews each with a cherry picker examine all trees within a 25-mile radius of the city centre on a 3 year cycle. Cherry pickers are used to ensure that close examination of the upper crown of trees is made. This is especially important on overcast, dull days when seeing exit holes or egg deposition sites is impossible from the ground. It costs $US1500 to find, remove and process a tree and $US600 to replace that tree with mature stock. (3-4 metres tall).

Oakwood, Indiana, USA.

23thth June to 25th June 2003.

Asian Gypsy Moth Pheromone Disruption Program for Indiana 2003 Season.

Within the 'slow the spread' strategy the following six treatment options may be considered: 1) *Bacillus thuringiensis var. kurstaki* (Btk) diflubenzuron (Dimilin), 3) nucleopolyhedrosis virus (Gypchek), 4) mass trapping, 5) mating disruption (Pheromone flakes), and 6) sterile insect release. The treatment method depends on population density, site description, non-target organisms, safety, and availability of product. Public meetings are held in February each year in each of the districts to be treated. The Indiana Eastern Plant Board estimates that there is an economic benefit to the State of $US22.00 for each dollar invested in treatment. A public document is released following public meetings outlining the options, including no treatment, and includes dates, maps of each site and a detailed description of the operation. All public queries are answered and some people are invited to attend ta section of the operation with which they may have a concern. In 2003 a total of 17,591 acres in Indiana to be treated over a two week period with a combination of *Btk* application and pheromone disruption applications. In the operations at LaPorte County that I attended there was one lady who had concerns about the application of flakes over her house. An officer was stationed at her home throughout the spray operation to explain what was happening. People now tend to accept the aerial operations over their homes as necessary and very few complaints are received.

Btk. This treatment option uses two applications of Btk at 30 billion international units (BIU) per acre applied from the air. Timed for early larval instar stage, generally in April-May in Indiana. The second application is applied 7-10 days after the first spray operation. This treatment option uses one aerial application of pheromone flakes prior to the emergence of male moths generally in mid-June to early July in Indiana.

Mating disruption. The objective of mating disruption is to saturate the treatment area with enough pheromone (disparlure) sources to confuse the male moths and prevent them finding and mating with female moths. The pheromone is specific to some *Lymantria* species. Mating disruption involves the aerial application of plastic flake impregnated with disparlure. The plastic flakes are approximately 1-3 mm in size. A sticker is applied to the flakes as they are dispersed from the aircraft, which sticks the flakes to all parts of the forest canopy (and white cars!). The flakes are green in colour and applied at a rate of 6, 15, or 30 grams active ingredient (disparlure) per acre dependant on larval density.

Figure11: Loading pheromone flakes into hopper beneath wing.

The Oakwood site contained 1932 acres of rural forest, farmland and residential subdivisions. The forest area consisted of oak, maple, other hard woods and conifers.

Five fixed wing spray planes fitted with modified hoppers were used for all operations moving from State to State. The two hoppers per plane carry enough flakes to cover 800 acres.

Figure 12: Hopper, mixing tank, and delivery apparatus for pheromone flakes.

There were some lost time during the operation due to the sticker gumming the tubes leading to the flake /mix chamber which made calibration difficult. Several planes were grounded for most of a day with this problem due to adaptations made to the original equipment. Application at 6 grams a.i. per acre equates to one flake per square foot area in a swath width of 120 feet. Field staff are positioned at each site under the swath to calibrate the flake density.

Figure 13: Calibration of delivery systems for pheromone flakes.

A team of 6 ground crew attended to the loading of hoppers and refuelling of aircraft while two persons manned computers to record pilot flight time, recording areas covered and loads applied for each day. An Indiana police officer was assigned to the airstrip for security during the operational period including night watch over the aircraft.

Figure 14: Fleet of fixed wing aircraft prepare to apply pheromone flake.

Bill Hatfield, USDA Forest Service, Site Spray Supervisor.

Phil Marshall, Forest Health Specialist, Division of Forestry, Indiana.

Gayle Jansen, Entomologist Supervisor, Indiana.

Kasey Stellema, Assistant Airport Manager. Michigan City Municipal Airport.

Urbana, Illinois.

25th June to 26th June 2003.

Visit to the University of Illinois. Several programs involving cerambycid trapping technology and chemical development of host attractants. Some work with molasses has given indications of attraction for cerambycids but to date results not repeatable. As molasses ferments over several days it becomes attractive to cerambycids. The volatiles released during that fermentation process are extracted and tested against a range of cerambycid species. The work could have implications for an ALB attractant/trap combination. Trapping programs for timber insects using vane traps have had good results in southern Illinois. Larry Hanks fully supported the concept of urban monitoring using static trapping techniques for exotic timber insects. It is a concept gathering support in United States especially with the impact of programs such as ALB on municipal budgets.

Larry Hanks, Associate Professor of Entomology, University of Illinois.

Charles Helm, Entomologist, University of Illinois.

Chicago, Illinois.

26th June to 28th June 2003.

The Field Museum is one of the largest private museums in the world and contains a huge insect collection. It is one of the main depositories of exotic insects collected at US port inspections. I was able to compare the range of morphological features of many of the important incursion species. I also obtained the records for the Tasmanian insects held in the Museum. Most of these were collected in the early 1900's and are historically important. Several specimens of the endangered Tasmanian lucanid *Hoplogonus simsoni* were located, collected in 1957. These were the only specimens collected during a period from 1933 to 1981 when the beetle was thought to be extinct.

Margaret Thayer, Assistant Entomology Curator, Field Museum.

Phil Parrillo, Entomology Curator, Field Museum.

Quarantine, Inspection Unit, Chicago O'Hare International Airport.

Visited the quarantine Inspection area facility at O'Hare Airport. Several thousand insect specimens collected annually from passenger's luggage and freight cargo inspections. All specimens sent to the Field Museum for identification. No vouchers are held at the Airport, all material collected goes to Field Museum. Inspectors are trained at the Museum under a fee arrangement with APHIS in seed, wildlife and insect identification using specimens in the Museum collection. Annual refresher day courses are mandatory. A roster of three shifts a day each with five inspectors on duty in the quarantine inspection area. Trapping is not conducted at O'Hare with reliance on hand collection.

San Francisco, California.

28th June to 30th June 2003.

Don Dahlsten, Professor of Entomology, Berkeley Campus, University of California.

Recognised as a world expert biology and distribution of Douglas-fir tussock moth and scolytid parasitoid complexes. Has acted in consultancy roles in many control programs for exotic insects, in particular cerambycid and elm leaf beetle parasitoid interactions. Forestry Tasmania has collaborated with Don in the past providing him with blue gum psyllid parasitoids for release in California. Unfortunately Don was not well during my visit so we were not able to visit his research trials using funnel traps for bark beetles. Don passed away in October 2003. I visited the large insect collection at Berkeley that contains a unique collection of insects utilising *Pinus radiata* and a large collection of exotic insects; much of it intercepted quarantine material.

Quarantine Service, APHIS, Port of San Francisco.

I visited the Port Quarantine Facility which was recently was transferred to the new Department of Homeland Security. They are not doing any quarantine trapping within the port area. A collection of timber insects including termites is held at the Port Centre but most specimens collected from cargo are sent to APHIDS specialists. Most cargo is transported in containers directly to customers with a great reliance on country of origin certification. Port inspectors within the new Department of Homeland Security conduct inspections of timber products.

I was able to see traps used at San Francisco Airport for Japanese Beetle (a serious pest of grasses and shrubs) as part of the domestic program of APHIS. A set of twelve yellow dual-lure traps is used at each monitored airport. Dual-lure traps contain both food and pheromone lures. Traps are set up in direct sunlight and in the proximity of favoured trees, shrubs and vines. Traps are set at two feet above the ground and are checked twice a week. California is a Japanese beetle free State.

David Talpas, Port Director. Helen Wright, Aphis Inspector.

Los Angeles, California.

1st July to 2nd July 2003.

Tim Paine, Professor of Entomology, Riverside Campus, University of California.

A specialist in the biology of insects in urban environments in particular those insects affecting woody ornamental plants. Introduced biological control programs against ash whitefly and eucalyptus longhorned borer. Tim has collaborated with Forestry Tasmania in the past resulting in the introduction of several Australian cerambycid parasitoids to assist in the *Phoracantha* control program in San Francisco. Part of the departments research program has been the development of trapping attractants for *Phoracantha* and assessment of traps for urban use. The vane trap design seems to function best for this species since the beetle utilises visual cues rather than semiochemical cues until the beetles actually reach the host tree.

Portland, Oregon.

2nd July 2003.

IPM Tech Inc.

Darak Czokajilo, Research Manager.

Philipp Kirsch, President.

Ron Olson, Vice President, Sales.

IPM Tech has developed niche markets in pheromone development especially for insect pests that threaten crops, orchards and more recently forests. The development of the Intercept Panel Trap for surveying and detection of longhorned beetles, wood wasps and other larger woodborer insects. A current project, in cooperation with Dan Miller, USFS, Athens, is testing the efficiency of a plastic film pipe trap which would be very cheap and disposable. There are problems with degrade of the plastic due to UV rays in exposed sites. This company that supplies a wide range of trapping technology products as well as custom made requirements for pheromones of non-commercial pest species.

A new initiative is the research program to investigate the control of Western Pine Shoot Borer and European Pine Tip Moth using the company's proprietary 'attract and kill technology". This technology combines pheromones with very low doses of insecticide into a stable droplet for use in orchards. The treatment is applied with a pole applicator to the trunk or branch of the pest host tree without ever coming in contact with the fruit.

IPM Tech is currently supplying the Belgium Government with mass trapping technology to fight a serious outbreak of Ambrosia Bark Beetle. The contract worth $US350, 000 is based on the Intercept panel trap and specifically designed pheromone attractants.

In China 300 panel traps are in service for a research project trapping *Monochamus* spp. (Cerambycidae).

3rd July 2003.

World Forestry Center Museum. Washington Park.

The World Forestry Center is dedicated to educating and informing people about the world's forests and trees and their relationship to all life in order to promote a balanced and sustainable future. I visited the Centre and saw exhibits on tropical rainforests, the Forestry Discovery Lab with its interactive displays for children, ritual art of the Amazon Rainforest, and the life and legacy of Ansel Adams photograph exhibit.

Review of projects at the H. J. Andrews Experimental Forest at Blue River.

Visited the Portland office of the Andrews Experimental Forest. Discussed the long term log decay study and associated invertebrates in relation to the similar project at the Warra Long Term Ecological Research (LTER) site in southern Tasmania. Decay rates at Andrews are mush faster and the invertebrate fauna restricted to about a decade of utilisation. Some results are in press. Contacts made for Andrews staff to visit Warra LTER following the International Entomology Congress in Brisbane, 2004.

John Taylor, Research Scientist.

Salem, Oregon.

4th July 2003.

Oregon Department of Agriculture.

Visited the Plant Division of State Department of Agriculture. Several interesting projects utilising static trapping are in progress.

1) Due to concerns over the continued introduction of exotic wood-boring insects, a pilot project to rapidly detect newly introduced or established exotic Scolytidae (bark and ambrosia beetles) was initiated in 2001 with cooperation from USDA Forest service and APHIS. Ten target scolytid species were selected based on APHIS port interception data. A total of 116 12-funnel Lindgren funnels were set up at each of 29 ports/airports in the port area, dunnage sites and adjacent native forest sites. At a number of native forest sites logs have been left on the forest floor for attack by borer species. After one season the logs are transported to storage area where they are placed in individual tin canisters with a collection bottle fixed at one end for the collection of emerging adults. Although labour intensive this has been the most successful method of collecting indigenous species and provides a good control for the traps. Five new exotic scolytids have been detected. The addition of 80 panel traps in 2003 season at all sites for the capture of cerambycids and buprestids should provide interesting results. Two specimens of an Eurasian longhorn beetle, new to the United States, *Tetropium castaneum,* was captured since my visit in these traps.

2) Lures, which have little non-target effects, are the most desirable for surveys targeting specific pests because target species are more readily identified in the resulting samples. The response of non-target wood-boring insect taxa to specific lures is being tested using Lindgren funnel and vane traps. Results to date show that there is great variation between specific target lures in attracting non-target woodborers.

3) A monitoring program was commenced in 2003 for the detection of four exotic moth species not currently recorded from North America. Two tortricid species, light brown apple moth, *Epiphyis postvittana*, and plum fruit moth, *Grapholita funebrana*, and two noctuids, the European bollworm, *Helicoverpa armigera*, and silver-Y moth, *Autographa gamma*, all pose a serious threat to agricultural and natural resources. A total of 40 (10 traps per moth species) Pherocon Ica sticky traps baited with synthetic sex pheromones were run for three months. Funding was provided by Homeland Security and will be for three years.

4) Gypsy moth trapping (Asian and European strains). A total of 16,194 delta sticky traps set up in Oregon in 2003. Inmates at the local prison have done folding and gluing of the traps since 1995 resulting in considerable cost savings. One hundred and sixty acres treated with Btk for European strain.

5) Japanese beetle. A total of 4,810 JB traps run in 2002 resulting in a total of 10 Japanese beetles collected all at Portland Airport adjacent to the FedEx cargo facility. Program funded 50:50 Oregon State and Port of Portland.

Jim LaBonte, Insect Program Specialist, Plant Division.

Alan Mudge, Japanese Beetle Program Specialist, Plant Division.

Boston, Massachusetts.

5^{th} July to 6^{th} July 2003.

Visited the port inspection area. Trapping is not conducted in port area. Quarantine voucher collection held at port for specimen identification. Quarantine inspection of visiting yachts and private ships a major program. Same inspector team monitor the Airport where a large number of private aircraft arriving mainly from Europe, need quarantine certification and cargo clearance on entry to USA.

Port Inspection Officers, APHIS.

Otis, Mashpee, Massachusetts.

7^{th} July 2003.

Otis Plant Protection Center.

The mission of the OPPC is to enhance the performance of APHIS-PPQ and State Cooperative programs by providing current and appropriate technology, scientific information, and support services related to the exclusion, detection, and control of invasive pests. Current programs to develop technology transfer to control programs of Asian longhorned beetle, gypsy moth, Japanese beetle, and exotic pest monitoring.

Major USDA research facility especially for ALB. Impressive rearing facility for ALB providing adult and other life stages for research use. Testing of a range of trap designs for ALB and coordinating the development of pheromone and host attractant work. Facility is housed in a 30,000ft^2 one-story building on Otis Air National Guard Base. Along with numerous offices and laboratories, the OPPC includes a prototype insect mass-rearing facility, greenhouse, outdoor insectaries, two ^{60}Co irradiators, and an insect rearing facility.

The development of research cooperatives between USDA and universities, commercial companies and funding issues for those programs and subsequent technology transfer, major functions of the Centre.

Vic Mastro, USDA, APHIS, Entomologist.

David Lance, USDA APHIS, Entomologist.

Boade Wang, USDA APHIS, Entomologist.

Alan Sawyer, USDA APHIS, Ecologist.

New York, New York State.

Asian Longhorn Beetle Eradication Program.

Visited the three ALB program centers in New York.

Amityville, Long Island.

8th July, 2003.

Administrative centre of the Asian Longhorned Beetle Program. Involved in public requests for information, GPS mapping coordination, financial audits, and staff recruitment.

Joe Gittleman, USDA APHIS . Program Director

Fort Totten, Queens.

9th July 2003.

Field station for organisation of street tree surveys within Queens. Four teams of two people conduct street surveys in grid system to examine all trees. Involves cooperation with NYPD and Council staff to ensure access to private property. Tree removal and replacement contracted out to private arborists and nurseries. Removed trees are chipped on site and carted away for incineration.

ALB Field Day.

Morning. Delivery of AGM information leaflets, door-hangers and fridge magnets to all homes in four urban blocks prior to surveys. Information leaflets, in several languages, tells people what symptoms look for, what information is required and who to contact.

Figure 15: Asian Longhorn beetle damage.

Afternoon. Survey team conducted inspection of four street blocks examining all trees both on streets and in gardens. If entry to a property is refused a New York Police department (NYPD) officer is called who effects entry and attends until inspection completed. Suspect trees are climbed with ladders and ropes. If too difficult a cherry picker is booked for the next day. Inspectors have a photo flip booklet containing tree identification details and ALB symptoms. A form is completed for every tree and a numbered microchip inserted in the truck of the tree. Previously examined trees are scanned to provide an electronic record of inspection date, tree locality, and tree condition. Trees infested with ALB are marked with spray paint. For privately owned trees a consent form needs signature and a replacement tree species nominated. Trees are removed that day or the next. All wood material including the stump is removed and put through a chipper set at one centimetre square chip size. The residue is either burnt or bagged for mulch. There is currently a delay of several months before replanting of an advanced growth tree.

Figure 16: Maple street tree with branch death caused by Asian Longhorn beetle.

Brooklyn Division.

10th July 2003.

Field station for organisation of street surveys within Brooklyn and Manhatten. Trees within central Park have stem injection of imacloprin systemic insecticide to limit the impact of adult feeding on terminal branches and to reduce larval establishment within the trees.

ALB Field Day.

Morning. Assisted with stem injection with imidacloprid of trees in Central Park, Manhattan to reduce the severity of attack by ALB. Up to fifty trees injected in a day by a three-person team. Stem injection is conducted from 6:30am to 10:30am each morning to allow chemical uptake during the day and to avoid parking problems for team truck. A lot of public interest in what is happening to 'our' trees.

Figure 17: Concerned neighbours examining street tree attacked by Asian longhorned beetle.

Afternoon. Survey of several Brooklyn park areas including Greenpoint where the first beetle infestation was located in 1996. Most trees in the park are replanted young trees replaced since 1998. These trees are growing well and already provide shaded areas over lawns.

Ashima Sengupta USDA APHIS Manager.

John Jen USDA APHIS IT Specialist.

JFK International Airport

11th July 2003.

Visited the JFK airport quarantine cargo facility. All invertebrates and plant material is inspected in the facility following collection from cargo on pallets. Staff comprises three entomologists and two seed identifiers. Each year some 5000 insect specimens are identified. Records are entered onto the Emergency Action Notification database (EAN Database) operated by Port Operations-QPAS at Riverdale, MD. A small spirit voucher collection, mainly aphids, held at JFK. Query specimens are digitally photographed in the facility. All specimens are destroyed apart from specimens sent to American Museum of Natural History, NY for identification.

Manhattan.

12th July 2003.

American Museum of Natural History.

Museum holds one of the largest insect collections in the United States. Specialists identify much of the exotic material intercepted at American entry ports and unloading facilities. There are 4 million pinned insect specimens in the Collection. A large collection of *Anoplophora* species enabled the range of species and morphological features to be examined. Some DNA analysis works being done at the Museum attempting to determine the origin of some exotics especially *Monochamus* species. A DNA database is being constructed from specimens of known origin with which to match up incursion specimens. Talked with Amy Berkov about her work in identifying lignin decomposition products as attractants in traps. Depending on the species of cerambycid they exhibit considerable interest in pieces of wood of differing ages and stages of decomposition. A range of volatile combinations is emitted which change as the logs age. Matching the right volatile combination to a specific cerambycid species is time consuming but can be done for the major incursion species.

Amy Berkov, Assistant Curator.

Phillip Parrillo, Assistant Collection Manager.

London, England.

British Museum of Natural History.

14th July to 15th July2003.

The largest insect collection in the world with holdings of 28 million specimens.

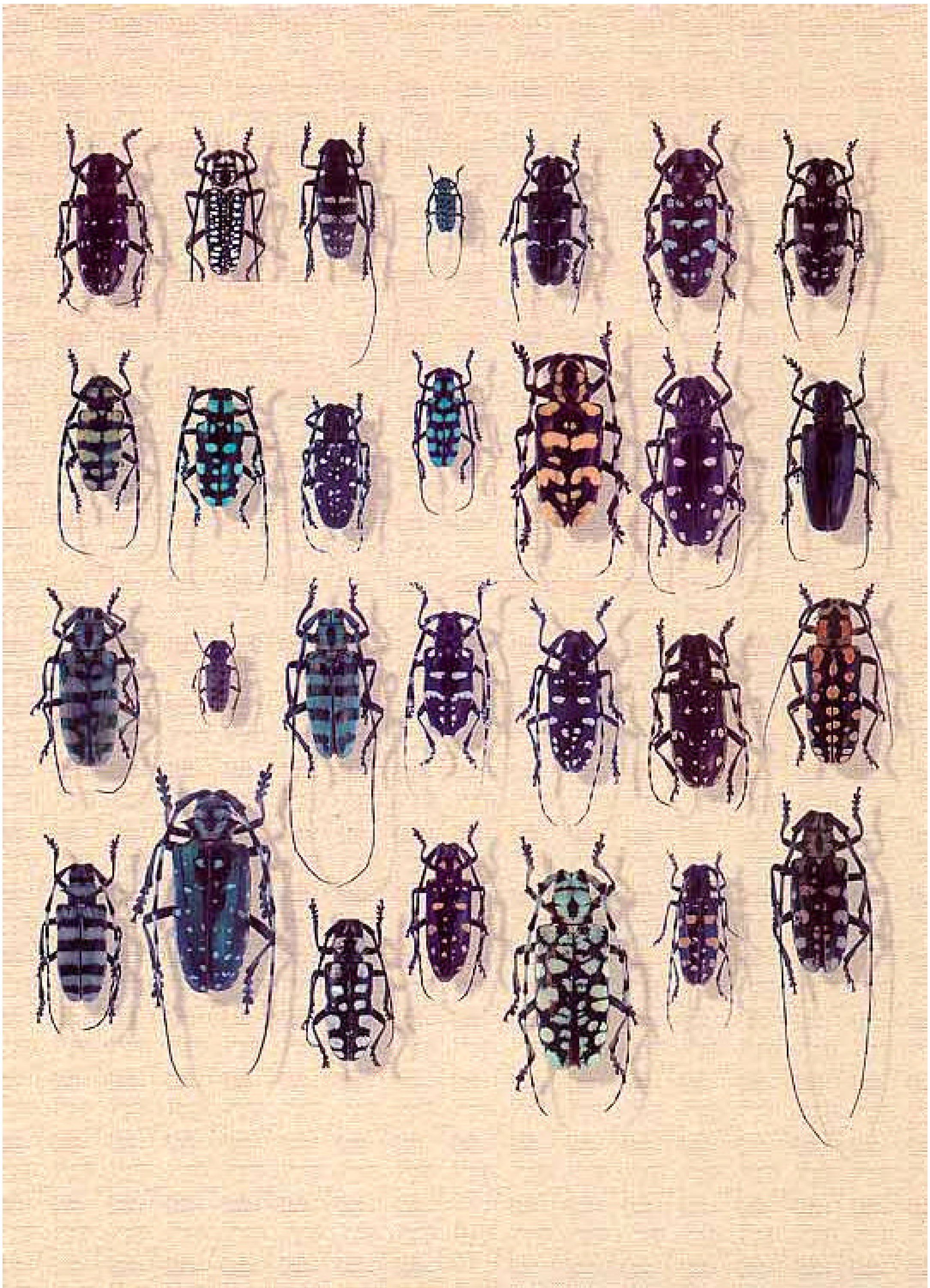

Figure 18: A series of *Anoplophora* species including Asian longhorned beetle.

Examined specimens of many exotic coleoptera of quarantine importance to Australia and Pacific Islands. Considerable taxonomic help from Museum specialists especially Sharon Shute to identify closely related species. Examination of series of specimens will assist in determining exotic species from Australian port quarantine collections. All UK port interception material is lodged in the Museum following identification.

Howard Mendel, Collections Manager, Entomology.

Sharon Shute, Curator, Cerambycidae.

Port of London Authority.

16th July 2003.

Department for Environment, Food and Rural Affairs (DEFRA).

Trapping is not conducted within the Port of London areas except for stored grain imports. Pheromone traps for scolytids are run at several other ports in UK. Visual examination of timber cargo within ships hold before discharge and of pallet wooden crate cargo. Less than 10% of containers opened prior to release from port area. Very high proportion of containers is transported to destination sites by road before opening. There are no port surround insect trap monitoring conducted for any exotic pest species. Numerous monitoring trap programs conducted within orchards, crop sites and nurseries mainly for agricultural pests. Under the EC single marketing arrangements for plant health, the onus is on the exporter to ensure freedom from pest or disease status if produce is being exported to the UK. A series of pest information sheets is provided to UK producers who are registered with DEFRA to passport plant material under EC market agreements. The onus is therefore on the exporter within the EC market agreement to ensure pest free status. A major problem in preventing exotics entering the UK is the volume of Channel Tunnel transport, both trucks, cars and trains. The current policy is to deal with outbreaks of exotic pest species as they occur, knowing that a very high proportion will be of European origin and often already established.

John Treadlow, Plant Health and Seed Inspector. Port of London Authority.

Eden Project, Cornwall.

17th July 2003.

The Eden project is a developing complex of linked biomes. Currently consisting of the Humid Tropics Biome, containing tropical plants established in settings equivalent to the natural environment sited in the world's largest conservatory. The second biome is the warm temperate zones. Both biomes aim to relate the trees and food plants to the people utilising those plants. A program of insect control has been developed to suit both the plants and visitor health problems within a closed geodome. It is hoped that biological control will maintain a balance between pest control and public health. A breeding program for several predacious coccinellid species has commenced with planned release against some native aphid species to commence in November 2003. The use of a static trap system to monitor early pest establishment was discussed. I have been asked to provide suggestions for such a monitoring scheme.

Brixham, Devon.

18th July to 20th July 2003. Rest and Recreation.

21st July to 22nd July 2003. Travel to Australia via Singapore.

Appendix 2.

Examples of recent exotic forest insects established in North America.

There are well over 400 species of exotic (non-native) invasive forest insects established in the United States. Exotic invasive forest insects can build quickly to damaging levels once established in a new country because: a) they typically arrive with few or none of their natural biological control agents, b) the trees in the new country of establishment often lack evolved defences against these new arrivals. The annual economic losses related to invasive forest insects in the United States are estimated in the hundreds of millions of dollars. The number of exotic forest insects becoming established continues to grow despite high levels of sophisticated quarantine measures. However the number of detection's that prevent establishment is also increasing.

Emerald Ash Borer *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae)

An Asian native recorded from China, Korea, Japan, Mongolia, Russian Far East and Taiwan. Attacks all ash trees (*Fraxinus* spp.) Also recorded from *Juglans* and *Ulmus* spp Tunnelling larvae kill branches and entire trees while adults feed on leaf tissue.

Discovered in Southeastern Michigan in 1998 and formally identified in 2002. Is now present in Ontario, Canada as well as Ohio and Maryland.

Gypsy Moth *Lymantria dispar* (Lepidoptera: Lymantriidae)

An important pest of hardwoods in 19 States of the United States since the initial introduction in Massachusetts in 1869. Prefers oaks with apple, sweetgum, basswood (*Tilia*), birch, poplar, willow and many other tree species also attacked. Older larvae will also feed on a number of conifers including *Pinus*.

Rate of natural spread is 13 miles per annum but this is greatly accelerated by transport of forest products and human transport vehicles.

Asian Gypsy Moth *Lymantria dispar* (Lepidoptera: Lymantriidae).

First recorded in 1991 in Portland and Vancouver To date all infestations of Asian gypsy moth have eradicated. The females of this subspecies are capable of flight and are attracted to lights. They also develop at a faster rate, feed on a wider range of host trees, and are slightly larger than the established gypsy moth. The main source of entry into US is as egg masses in containers and on the superstructure of ships from Asian ports. Adult AGM are located each year in monitoring traps in western North America. These sites are controlled using Btk spray. Asian gypsy moth is now widely distributed in Europe.

Asian Longhorned Beetle *Anoplophora glabripennis* (Coleoptera: Cerambycidae).

A pest in China and Korea attacking hardwood trees mainly in roadside planting's, shelterbelts and plantations.

In United States maples, alders, birches, elms, horsechestnut, poplars and willows have been recorded as hosts.

Introduced into New York and Chicago, in separate incursions, both entering in solid wood packing material from China.

Red-haired bark beetle *Hylurgus ligniperda* F. (Coleoptera: Scolytidae).

Discovered in 2000 at Rochester, New York in a Christmas tree plantation. Between 1985 and 1994 there were 169 interceptions at ports in United States.

Breeds in stumps, fresh logs and logging slash of pine, spruce, fir, and larch. The overwintering adults girdle and kill seedlings.

The beetle is a vector of the pine root pathogen *Leptographium* wagneri (blackstain root disease).

This beetle species has also established in South Africa, Japan, Australia, New Zealand, Brazil, Uruguay and Chile.

Common pine shoot beetle *Tomicus piniperda* (L.)

Discovered near Cleveland, Ohio, in 1992. Has spread to eleven States. A native of Europe and Asia. Adults colonise fresh stumps or logs. In high populations adults may breed in spruce, fir, and larch. Various species of blue stain fungi are associated with the beetle.

Volatile baited traps (alpha-pinene) attract adults. Adult beetles fly to feed in the crown shoots of healthy trees especially Scotch pine and other *Pinus* species. In China and Poland this beetle attacks and kills healthy *Pinus* spp. trees.

European spruce bark beetle *Ips typographus* (L.) (Coleoptera: Scolytidae).

Collected in 1993 in Port of Erie, Pennsylvania. Native to Europe and Asia attacking Norway Spruce and occasionally feeds on fir, pine, and larch. Attacks weakened or storm damaged trees but in outbreaks kills healthy trees. Carries several fungi pathogenic to conifers including the blue stain fungus *Opiostoma polonicum*. This fungus causes death by wilting and staining reduces commercial value of timber.

Frequently intercepted on solid timber packing material.

Adult beetles attracted to the pheromone Ipslure.

Japanese cedar longhorned beetle Callidiellum *rufipenne* (Motschulsky).

A beetle of Asian origin first detected in Vancouver BC in 1927.Further finds at Seattle in 1954, eastern United States at Mateo, NC in 1897, 1998 in Connecticut and 2000 in New Jersey in natural stands of cedar. Reared from red cedar, *Juniperus virginiana* and northern white cedar, *Thuja occidentalis*. In Asia the beetle is regarded as attacking only weakened or freshly felled trees. However in United States apparently healthy trees are killed.

Endemic to East Asia, China, Korea, Japan and Taiwan. Has also become established in New Zealand, Italy and Spain. From 1978 to 1983 there are 213 port interception records. All Taxodiaceae and Cupressaceae families susceptible. There are several native *Callidiellum* species in North America.

Brown Spruce Longhorned Beetle *Tetropium fuscum* (F.)

Native to Europe and Japan. First found in 1990 at Halifax, Nova Scotia and formally identified in 1999. Hosts include *Picea, Pinus, Abies* and *Larix*. Attacks healthy and stressed trees. Currently has limited distribution and attempts being made to eradicate by infested tree removal.

Xyleborinus alni (Niisima) Scolytidae

Found in Vancouver in 1995 and in Oregon in 1997. A native of Eastern Europe, Russia and Japan.

Xyleborus eili (Ratzeburg) Scolytidae.

Trapped in Oregon in 1997 and in eastern United States in 2000. Indigenous to Africa, Asia and Europe. Introduced into New Zealand in 1992.Attacks deciduous trees including alder, beech, elm, maple, oak, poplar and several conifers.

Satin Moth *Leucoma salicis* L. (Lymantriidae)

Native to Europe. Present in North America from 1984. Defoliates deciduous trees mainly poplars and willows. Severe outbreaks in British Columbia and Alberta in 1995/96.

Ash Whitefly *Siphoninus phillyreae.*

In United States recorded in Arizona and California where it was discovered in 1988. Feeds on a variety of broadleaved deciduous and evergreen shrubs and trees. High populations can cause severe defoliation and host plant death.

A native of British Isles, Europe, North Africa and India.

Appendix 3.

Interception of timber Coleoptera of quarantine significance in England.

Forest Research Annual Report 2001-02. Forestry Commission, UK.

Scolytidae

Ips calligraphus.	Port inspection.
Ips typographus.	Port inspection and pheromone traps at 5 locations.
Ips grandicollis	Port inspection.
Hylurgops ligniperda.	Pheromone trap at one site.

Cerambycidae

Monochamus titillator.	Port inspection.
Monochamus galloprovincialis.	Port inspection.

Bostrychidae

? sp (false powderpost beetles)	Port inspection.

Appendix 4.

Interception of insects of economic importance into New Zealand in the past twelve months.

Tropical Fire Ant. *Solenopsis geminata*

Native to United States and South America. Recently established in Australia.

Since 1958 more than 250 new forest pests have become established in New Zealand (Dyck 2002). Exotic insect species established in NZ plantations have averaged 2.2 per annum in the period 1950- 1985. (Cooper 1989).

Painted Apple Moth

During 2003 two aerial eradication operations have been conducted over an area of 6500 ha in west Auckland.

Gum Leaf Skeletonizer, *Uraba lugens*.

Eucalyptus Psyllid, *Creiis literatus*.

A pest of Eucalyptus species grown in plantations in Australia.

Nathrius brevipennis (Mulsant). Cerambycidae. 1993.

Dicranosterna semipuntata (Chapuis) Chrysomelidae 1996. Australia.

Trachymela catenata (Chapuis) Chrysomelidae 1992. Australia.

Fall webworm, *Hyphantria cunea* Arctidae.

Detected in an Auckland suburb in March 2003. A native of North America and Mexico. Has become established in Europe and parts of Asia feeding on a wide range of deciduous tree species including most fruit trees. A program of pheromone trap monitoring to determine the infested area is currently in place.

Appendix 5.

Interceptions of exotic timber insects at Australian ports by AQIS 2001-2002.

Anobiidae	11 species
Bostrichidae	32 species
Buprestidae	3 species
Cerambycidae	21 species
Scolytidae	8 species
Note: Lymantriidae	4 species.

Appendix 6.

Some exotic forest Lepidoptera which, in addition to those listed as established in USA and Canada, could be major economic pests in Australia.

Pink Gypsy Moth *Lymantria mathura* Moore (Lymantriidae)

Widespread in Asia including China, Japan, Taiwan and India. Feeds on *Quercus, Malus. Rhus, Zelkowa* and *Fagus*.

Nun Moth *Lymantria monacha* (L.) (Lymantriidae)

Eurasian pest of conifers. *Picea, Pinus, Abies, Larix.* Also recorded on *Fagus, Carpinous, Betula and Quercus*. One of the most damaging defoliators of spruce and pine forests in central Europe and Siberia.

Introductions of lymantriids likely as adult stowaways or egg masses on cargo ships loaded under lights.

Other Lymantria species.

L. lucescens. Native of Japan and Korea. Feeds on *Quercus*.

L. serva. Native to Taiwan, southern China, Nepal and India. Feeds on *Ficus*.

L. xylina Native of Japan, Taiwan and southern China. Feeds on *Casuarina* .

L. fumida Native of Japan, Taiwan and eastern China. Feeds on Larch and Japanese Fir.

White spotted Tussock Moth *Orgyia thyellina* (Lymantriidae)

Native to eastern Asia, Japan, Korea, Taiwan, eastern China and Russia. Larvae feed on willows, birch, oak, elm and maple. Present in New Zealand since 1996. An area of 40 km^2 of Auckland treated from the air 9 times using *Bacillus thuringiensis var. kurstaki* (Btk)(Foray 48B) in an attempt to eradicate. Further ground spraying of 300 properties using mist-blowers conducted in 1997. The moth is still present but contained.

European Pine Shoot Moth *Rhyacionia bouliana*.

A native of Europe, Asia and North Africa was introduced into North America in 1914. The moth has since established in Canada, Argentina, Uruguay and Chile. Has been recorded feeding on thirty species of *Pinus*.

Monochamus spp. (Cerambycidae)

Vector of the pine wilt nematode, *Bursaphelenchus xylophilus*. The nematode is now established in Japan, southern China, Taiwan and Portugal.

Appendix 7.

Cost of incursions: Monitoring and Control.

Current Forest Health Budgets: Forest Insect Pest Management.

United States of America.

Financial Year 2004 Budget for Cooperative management $US 65,609,000 which included new funding for 'Emerging Pest and Pathogens Fund' totalling $US 11,968,000.

The following activities are to be accomplished from the combined funds.

* Forest pest suppression of major native insect and disease infestations.

* Provide professional technical assistance in Forest Health to all forestland managers.

* Work jointly with APHIS to promptly eradicate new introductions of non-native insect and disease pests of forestry and trees.

* Conduct suppression, prevention and management activities on native and non-native insect and disease forest pests.

* Continue detection surveys to rapidly detect biosecurity threats to the Nation's forests.

* Map forest areas at risk to future impacts of insects, disease and other agents.

* Fully implement the gypsy moth 'Slow –the –Spread' program.

- Continue delivery in cooperation with the States of the Forest Health Monitoring Program to identify and monitor trends.

These activities are to be accomplished on all federal and tribal land. State and private lands.

Reference: **Connecting Forestry to People in 2004**. State and Private Forestry and Wildland. Fire Management Appropriations 2004. USDA Forest Service. Congress Appropriations.

New Zealand.

Cost of systematic pest and disease forestry surveillance $NZ 7,200,000 for 2003/04. Cost of eradication of a single insect pest within two years of its introduction. $NZ 926,657. Cost of eradication verses benefit ratio is 1:18. Cost of control of a single insect pest conducted for two years. $NZ 472,872. Cost of control verses benefit ratio is 1:3. Current forest health programs for the control of forestry pests and diseases have an estimated benefit in 2002/03 of $NZ 11.71 million in extra resource.

Australia

Cost of annual post barrier trapping, at twenty-two seaports, for Asian gypsy moth, funded by NAQS, is approximately $300,000 (2003/04). This is the only post barrier monitoring for a forest-related exotic insect currently conducted.

Appendix 8.

Visit follow up contacts.

Specimens of *Sirex noctilio* have been sent to Otis in exchange for specimens of Asian Longhorn Beetle and Emerald Ash Borer.

Data transfer to IMP Tech on use of panel traps in Tasmania for conference use in Canada.

Copies of AFFA booklet on exotic incursion species sent to a number of sites visited.

Cooperation between Portland Department of Agriculture, USDA-Forest Service and Forestry Tasmania in running parallel design trials trapping for exotic wood-borer species in commercial forests.

Collaborating with Vic Mastro (Otis Centre) and Jim LaBonte (Portland, Oregon Department of Agriculture), researchers associated with monitoring for exotic incursion of forest insects, to present join papers at the IUFRO Biosecurity Conference in New Zealand in 2004.

Orders for more traps and attractants sent to IPMTech and PheroTech to enhance the Tasmanian port-trapping program. Order based on advice obtained during the trip on combinations of attractants for specific target use.

Contract with Queensland DPIE Forest Services for the establishment of a static trap system to monitor for exotic forest insects in Queensland plantations.

Appendix 9.

A Selected Bibliography.

A complete set of the above references, along with numerous leaflets, pamphlets, and posters, has been lodged in the Forestry Tasmania library.

Allison, J.D., Borden, J.H., McIntosh, R.L., de Groot, P., and Gries, R. 2001. Kairomonal response by four *Monochamus* species (Coleoptera: Cerambycidae) to bark beetle pheromones. Journal of Chemical Ecology, 27: 633-646.

Allison, J.D., and Borden, J.H. 2001. Observations on the behaviour of *Monochamus scutellatus* (Coleoptera: Cerambycidae) in northern British Columbia. J. Entomol. Soc. Brit. Columbia. 98: 195-200.

Alm, S., Yeh, T., Dawson, C., and Klein, M. 1996. Evaluation of trapped beetle repellency, trap height and string pheromone dispensers on Japanese beetle adults.(Coleoptera: Scarabaeidae). J. Econ. Entomol. 25(6):1274-1278.

America's Forests 2003: Health Update. USDA Forest Service. AIB-776. 15 pgs.

APEC Symposium on detection, monitoring and management of invasive pests: Summary record. October 2002, Chinese Taipei. 21 pgs.

Asian Longhorned Beetle USDA web site. http://www.na.fs.fed.us/spfo/alb/

Asian Longhorned Beetle: First Line of Defense. USDA Forest Service, Forest Health Priotection 2000. Video 12.30 min.

Australia Quarantine: A shared responsibility. 1996. Eds: M.E.Nairn, P.G.Allen, A.R.Inglis and C. Tanner. Department of Primary Industries and Energy, Canberra. 284 pgs.

Baddeley, C. 1989. Detection of new insects and diseases in indigenous forests in New Zealand. N.Z. J. Forestry Science. 19: 250-255.

Baker, R., and Cowley, J. 1989. Evaluation of the economic impact of newly introduced pests. N. Z. Journal of Forestry. 19: 330-334.

Bark beetles in North American Conifers: A system for the study of Evolutionary Biology. Eds: Mitton, J.B. and Sturgeon, K.B. University of Texas Press, 1882.527.

Bashford, R. 2002. The use of sticky trap bands as a long term monitoring tool for exotic saproxylic insects of importance to forestry. Victorian Entomologist 32: 42-44.

Britton, K.O. and Sun, J.H. 2002. Unwelcome Guests: Exotic Forest Pests. Acta Entomologica Sinica 45: 121-130.

Broberg, C.L. and Borden, J.H. 2001. Host range, attack dynamics, and impact of *Cryptorhynchus lapathi* (Coleoptera: Curculionidae) on *Salix* (Salicaceae) spp. Can. Entomol. 133: 119-130.

Broberg, C.L., Borden, J.H. and Humble, L.M. 2002. Distribution and abundance of *Cryptorhynchus lapathi* on *Salix* spp. in British Columbia. Can. J. For. Res. 32: 561-568.

Brockerhoff, E.G. and Bain, J. 2000. Biosecurity implications of exotic beetles attacking trees and shrubs in New Zealand. New Zealand Plant Protection 53:321-327.

Buth, J.L. and Ellis, R.A. 1981. Trapping elm bark beetles in the city of Winnipeg, with a new record for *Scolytus multistriatus*, (Coleoptera: Scolytidae) in Manitoba. Can Entomol. 113: 263-264.

Cambell, F.T. and Schlarbaum, S.E. 1994. Fading forests in North America and the threat of exotic pests. Natural resources Defence Council, New York. 47 pgs.

Canaday, C.L. 1987. Comparison of insect fauna captured in six different trap types in a Douglas-fir forest. Can. Ent. 119: 1101-1108.

Carter, P.C.S. 1989. Risk assessment and pest detection surveys for exotic pests and diseases which threaten commercial forestry in New Zealand. N. Z. J. of Forestry Science 19:353-374.

Chenier, J.V.R. and Philogene, B.J.R. 1989. Evaluation of three trap designs for the capture of conifer-feeding beetles and other forest Coleoptera. Can. Ent. 121: 159-167.

Ciesla, W.M. 1993. Recent introductions of forest insects and their effects: a global view. FAO Plant Protection Bulletin 41(1): 3-13.

Clare, G., Suckling, D.M., Bradley, S.J., Walker, J.T.S., Shaw, P.W., Daly, J.M., McLaren, G.F. and Wearing, C.H. 2000. Pheromone trap colour determines catch of non-target insects. N.Z Plant Protection 53: 216-220.

Cooper, J. 1989. New species of forest insects in plantation forests and trees. NZ. Journal of Forest Science. 19: 318-329.

Cooter, J. 1998. *Anoplophora chinensis* (Forster, 1771) (Coleoptera: Cerambycidae) in Herefordshire. Entomologist's Monthly Magazine. 135:196.

de Groot, P. and Nott, R. 2001. Evaluation of traps of six different designs to capture pine sawyer beetles (Coleoptera: Cerambycidae) Agricultural and Forest Entomology 3: 107-111.

Decision Notice and Environmental Assessment. Cooperative Gypsy Moth Project for Indiana 2003. USDA Forest Service. 23 pgs.

Detecting and Monitoring of Invasive Species. Proceedings of the Plant Health Conference 2000. USDA-APHIS. Technical Bulletin.79 pgs.

Dodds, K.J. and Ross, D.W. 2002. Sample range and range of attraction of *Dendroctonus pseudotsugae* pheromone-baited traps. Can Entomol 134: 343-355.

Dodds, K.J and Ross, D.W. 2002 Relative and seasonal abundance of woodborers (Buprestidae, Cerambycidae) and Cucujidae trapped in Douglas-fir beetle pheromone-baited traps in northern Idaho. Pan-Pacific Entomologist 78(2): 120-131.

Driesche, R.G., Healy, S. and Reardon, R.C. 1996. Biological Control of Arthropod Pests of the North eastern and North central Forests in the United States: A review and Recommendations. USDA Forest Service FHTET-96-19. 257 pgs.

Dyck, B 2002. Complacent about biosecurity? Ten reasons why you should't be. NZ. Journal of Forestry 47(2):3-4.

Eradication of Exotic Pests. 1989. Eds. Dahlsten,D.L and Garcia, R. Yale University Press.296 pgs.

Fettig, C.J., Fidgen, J., McClellan, Q.C. and Salom, S.M. 2001. Sampling Methods for Forest and Shade Tree Insects of North America. USDA Forest Service FHTET-2001-01. 273 pgs.

First Annual Asian Longhorned Beetle Research and Development Review, November 6-8, 2001, USDA Forest Service, 128 pgs.

Forest Disease Contingency Plan. Industry Version. 1996. Ministry of Forestry, New Zealand. 46 pgs.

Forest Insect and Disease Conditions in the United States 2002. USDA Forest Service, Forest Health Protection. 124 pgs.

Gadgil, P.D.2000.Responding to incursions: a generic incursion management plan for forest pests and diseases. Standing Committee on Forestry, Ausinfo, Canberra, Australia.

Gibbs, N. 1996. Environmental Impact Assessment of Aerial Spraying Btk (*Bacillus thuringiensis var. kurstaki*) in New Zealand to Eradicate White-Spotted Tussock Moth (*Orgyia thyellina*). Ministry of Forestry. 1-68.

Global Invasive Species Database: www.issg.org/database

Goyer, R.A., Lenhard, G.J., Nebeker, T.E. and Jarrard, L.D.1980. How to Identify Common Insect Associates of the Southern Pine Beetle. USDA Agriculture Handbook 563. 33 pgs.

Gregoire, J.C., Liebhold, A.M., Stephen, F.M., Day, K.R., and Salom, S.M. 1996. Integrating Cultural Tactics into the Management of Bark Beetle and Reforestation :

Proceedings. Pests. USDA Forest Service, General Technical Report NE-236. 243 pgs.

Gries, G., Clearwater, J., Gries, R., Khaskin, G., King, S. and Schaefer, P. 1999. Synergistic sex pheromone components of white-spotted tussock moth, J. Chemical Ecology. 25: 1091-1104.

Gries, G., Gries, R., Khaskin, G., Slessor, K.N., Grant, G.C., Liska, J. and Kapitola, P. 1996. Specificity of Nun and Gypsy Moth Sexual Communication through Multiple-Component Pheromone Blends. Naturwissenschaften 83: 382-385.

Gries, G., Gries, R., Schaefer, P. W., Gotoh, T. and Higashiura, Y. 1999. Sex pheromone components of Pink Gypsy Moth, *Lymantria mathura*. 1999.Naturwissenschaften 86: 235-238.

Gries, G., Schaefer, P.W., Gries, R. Liska, J. and Gotoh, T. 2001. Reproductive character displacement in *Lymantria monacha* from northern Japan. J. Chemical Ecology 27: 1163-1176.

Gries, G., Schaefer, P.w., Gries, R., Fan, Y.B., Higashiura, Y. and Tanaka, B. 2002. Sex pheromone of allopatric *Lymantria lucescens* and *L. serva*. J. Chemical Ecology 28: 469-478.

Gries, G., Schaefer, P.W., Khaskin, G., Hahn, R., Gries, R. and Chao, J.T. Sex pheromone components of Casuarina Moth, *Lymantria xylina*. J. Chemical Ecology. 25: 2535-2545.

Gries, G., Slessor, K.N., Gries, R., Khaskin, G., Wimalaratne, P.D.C., Gray, T.G., Tracy, A.S., and Hulme, M. 1997. Synergistic sex pheromone component of Douglas-fir Tussock Moth, *Orgyia pseudotsugata* (McDunnough) (Lepidoptera: Lymantriidae).J. Chemical Ecology 23:19-34.

Harmful Non-native Species: Issues for Congress 111. 1999.Congressional Research service Report RL30123 1-12.

Harmon, M.E. 1992. Long-Term Experiments on Log Decomposition at the H. J. Andrews Experimental Forest. USDA Forest Service General Technical Report PNW-GTR-280. http://www.fsl.orst.edu/LTER

Hayes, J.L. and Ragenovich, I. 2001. Non-native Invasive Forest Insects of Eastern Oregon and Washington. Northwest Science 75: 77-84.

Hosking, G. 2002. Incursion Response-back to basics. NZ Journal of Forestry 47(2): 24-27.

Hosking, G., Bulman, L., Bradbury, P., Barr, C. and Rogan, B. 1999. Hazard site Review: Report and Recommendations. Ministry of Agriculture and Forestry, Rotorua.33 pgs.

Hoskings, GP and Gadgil, P.D. 1987. Development of contingency plans for use against exotic pests and diseases of trees and timber: 4. Forest Insects and disease protection in New Zealand: an integrated approach. Australian Forestry 50:37-39.

http://www.pfc.forestry.ca/biodiversity/exotics/index_e.html

Humble, L.M., Allen, E.A. and Bell, J.D. 2001.Exotic Wood-Boring Beetles in British Columbia: Interceptions and Establishments. Natural Resources Canada.

Ikeda, T., Oda, K., Yamane, A and Enda, N. 1980. Volatiles from pine logs as the attractant for the Japanese pine sawyer *Monochamus alternatus* Hope (Coleoptera: Cerambycidae). J. Japanese Forestry Society, 62:150-152.

Insects and Diseases of Trees of the South. USDA Protection report R8-PR 16, 1989. 98 pgs.

Interception of Coleoptera of Quarantine Significance 2002. In “Forest Research Annual Report 2001-02” Forestry Commission UK. Pgs 19-20.

Invasive Alian Species: A toolkit of prevention and management practices. 2001. Eds:Wittenberg, R. and Cock, M.J.W. CABI Publishing on behalf of the Global Invasive Species Programme. 1-228.

Liebhold, A.M., MacDonald, W.L., Bergdahl, D. and Mastro, V.C. 1995. Invasion by Exotic Forest Pests: a threat to forest ecosystems. Forest Science. Monograph 30. 1-49.

Lindgren, B.S. 1983. A multiple funnel trap for scolytid beetles (Coleoptera). Can Ent. 115:299-302.

Lindgren, B.S. and Miller, D.R. 2002. Effects of verbenone on attraction of predatory and woodboring beetles (Coleoptera) to kairomones in lodgepole pine forests. Environmental Entomology 31:766-773.

Lingafelter, S.W. and Hoebeke, E.R. (2002) ‘Revision of *Anoplophora* (Coleoptera: Cerambycidae). Pub. Entomological Society of Washington.236 pgs.

MAF Biosecurity Authority 2002. Specification for Surveillance for Wood Boring and Bark Beetles (Coleoptera: Buprestidae, Cerambycidae, Curculionidae, Scolytidae). Ministry of Agriculture and Forestry, Biosecurity Authority, Wellington, NZ. 1-11.

McCullough, D.G. and Zablotny, J.E. 2002. Directory of Exotic Forest Insect and Disease Pests. Michigan State University Extension Bulletin E-2811.42 pgs.

McIntosh, R.L., Katinic, P.J., Allison, J.D., Borden, J.H. and Downey, D.L. 2001. Comparative efficacy of five types of trap for woodborers in the Cerambycidae, Buprestidae and Siricidae. Agricultural and Forest Entomology. 3: 113-120.

Montgomery, M.E. 1983. Ethanol and other host-derived volatiles as attractants to beetles that bore into hardwoods. J. of Chemical Ecology. 9: 181-190.

Morewood, P, Gries, G., Haubler, D, Moller, K., Liska, J., Kapitola, P. and Bogenschutz, H. 1999. Towards pheromone-based detection of *Lymantria monacha* (Lepidoptera: Lymantriidae) in North America. Can. Entomol. 131: 687-694.

Morewood, P., Gries,G., Liska, J., Kapitola, P., Haubler, D., Moller, K. and Bogenschutz, H. 2000. Towards pheromone-based monitoring of nun moth, *Lymantria monacha* (L.) (Lep., Lymantriidae) populations. J. Appl. Ent. 124: 77-85.

Morewood, W.D, Hein, K.E., Katinic, P.J. and Borden. J.H. 2002. An improved trap for large wood-boring insects, with special reference to *Monochamus scutellatus* (Coleoptera: Cerambycidae) Can. J. For. Res. 32: 519-525.

Morewood, W.D., Simmonds, K.E., Wilson, I.M., Borden, J.H. and Mcintosh, R.L. 2002. A-pinene and ethanol: Key host volatiles for *Xylotrechus longitarsis* (Coleoptera: Cerambycidae) J. Entomol. Soc. Brit. Columbia 99: 6pgs..

Mudge, A.D., LaBonte, J.R., Johnson, K.J.R. and LaGasa, E.H. 2001. Exotic woodboring coleoptera (Micromalthidae, Scolytidae) and hymenoptera (Xiphydriidae) new to Oregon and Washington. Proc. Entomol. Soc. Wash. 103:1011-1019.

Muirhead-Thomson, R.C. 1991. Trap responses of flying insects. Academic Press, New York. 134 pgs.

Murphy, W.L. 1985. Proceedure for the removal of insect specimens from sticky-trap material. Ann. Entomol. Soc. Am. 78: 881.

Nairn, M.E., Allen, P.G., Inglis, A.R. and Tanner, C. 1996 Australian Quarantine: a shared responsibility. Department of Primary Industries and Energy, Canberra. 284 pgs.

Nowak, D.J., Pasek, J.E., Sequeira, R.A., Crane, D.E. and Mastro, V.C. 2001. Potential Effect of *Anoplophora glabripennis* (Coleoptera: Cerambycidae) on Urban Trees in the United States. J. Econ. Entomol. 94(1): 116-122.

On Gypsy Moth and Other Invasive Species. Proceedings USDA Interagency Research Forum, Jan 16-19 2001. General technical Report NE-285. 10 pgs.

Ostrand, F. and Anderbrant, O. 2003. From where are insects recruited? A new model to interpret catches of attractive traps. Agricultural and Forest Entomology. 5: 163-171.

Plant Division Annual Report 2002. Oregon Department of Agriculture. 48 pgs.

Reardon, R.C., Leonard, D.S., Mastro, V.C. and Leonhardt, B.A. 1998. Using Mating Disruption to Manage Gypsy Moth: A Review. USDA Forest Service. FHTET-98-01. 85 pgs.

Reay, S.D. and Walsh, P.J. 2001. Observations of the flight activity of *Hylastes ater* and *Hylurgus ligniperda* (Curculionidae: Scolytinae) in *Pinus radiata* forests in the central North Island, New Zealand. N.Z. Entomologist 24: 79-85.

Reay, S.D. and Walsh, P.J. 2002. Relative attractiveness of some volatiles to the introduced pine bark beetles, *Hylastes ater* and *Hylurgus ligniperda* (Curculionidae: Scolytinae). N.Z. Entomologist 25:51-56.

Rykken, J.J. and Hanson, T. 1999. A guide to common bark beetles (Coleoptera: Scolytidae) endemic to the northern United States. USDA Forest Service. Forest Health Technology Enterprise Team: Technology Transfer. FHTET-98-15. 36 pgs.

Sakakibara, Y., Kikuma, A., Iwata, R. and Yamane, A. 1998. Performance of Four Chemicals with Floral Scents as Attractants for Longicorn Beetles (Coleoptera: Cerambycidae) in a Broadleaved Forest. J. For. Res. 3: 221-224.

Schaefer, P. W., Gries, G., Gries, R. and Holden, D. 1999. Pheromone components and deil periodicity of pheromonal communication in *Lymantria fumida.* J. Chemical Ecology 25: 2305-2312.

Schlyter, F. 1992. Sampling range, attraction range, and effective attraction radius: Estimates of trap efficiency and communication distance in coleopteran pheromone and host attractant systems. J. Appl. Ent. 114: 439-454.

Shibata, E., Okuda, K. and Ito, T. 1986. Monitoring and sampling adult populations of the sugi bark borer, *Semanotus japonicus* (Coleoptera: cerambycidae), by the sticky trap banding method in Japanese cedar stands. Appl. Ent. Zool. 21: 525-530.

Sinberloff, D. 1996. Impacts of Introduced Species in the United States. Consequences, 2(2): 1-12.

Solomon, J.D. 1995. Guide to Insect Borers in North American Broadleaf Trees and Shrubs. USDA Forest Service Agriculture Handbook AH-706. 735 pgs.

Stoyenoff, J., Witter, J. and Leutscher, B. 1998. Forest Health in the North Central States. University of Michigan. Unnumbered publication. 32 pgs.

The Gypsy Moth: Research Towards Integrated Pest Management. 1981. USDA Forest Service. Technical Bulletin 1584. 739 pgs.

U.S. Congress, Office of Technology Assessment, Harmful Non-Indigenous Species in the United States, OTA-F-565 (Washington, DC: U.S. Government Printing Office, September 1993.

Wagner, D.L., Ferguson, D.C., McCabe, T.L. and Reardon, R.C. 2001. Geometroid Caterpillars of Northeastern and Appalachian Forests. USDA Forest Service FHTET-2001-10. 239 pgs.

Wagner, D.L., Giles, V., Reardon, R.C. and McManus, M.L. 1997, Caterpillars of Eastern Forests. USDA Forest Service FHTET-96-34. 113 pgs.