USDA Interagency Research Forum on Gypsy Moth and Other Invasive Species
January 16-19, 2001
Loews Annapolis Hotel, Annapolis, Maryland

AGENDA

Tuesday Afternoon, January 16

REGISTRATION
POSTER DISPLAY SESSION I

Wednesday Morning, January 17

PLENARY SESSION .... Moderator: J. Robert Bridges, USDA-FS
Welcome
Michael McManus, USDA-FS

The Siege of Invasive Species in Midwestern Ecosystems
Robert N. Wiedenmann, Illinois Natural History Survey

The Brown Spruce Longhorn Beetle in Halifax: Pest Status and Preliminary Results of Research
Jon Sweeney, Natural Resources Canada

PLENARY SESSION .... Moderator: Robert Mangold, USDA-FS

The National Council on Invasive Species
Lori Williams, Department of the Interior

A Multi-year Project to Detect, Monitor, and Predict Forest Defoliator Outbreaks in
Central Siberia
Max McFadden, The Heron Group, LLC

Wednesday Afternoon, January 17

GENERAL SESSION .... Moderator: Cynthia D. Huebner, USDA-FS
Invasive Plants: Organismal Traits, Population Dynamics, and Ecosystem Impacts
Presenters: E. Nilsen, Virginia Polytechnic Institute & State University; D. Gorchov, Miami
University of Ohio; F. Wei, State University of New York at Stonybrook; K. Britton, USDA-FS;
C. D'Antonio, University of California at Berkeley

GENERAL SESSION .... Moderator: Kathleen Shields, USDA-FS
Research Reports
Presenters: J. Colbert, USDA-FS; J. Elkinton, University of Massachusetts; J. Cavey, USDA-APHIS

POSTER DISPLAY SESSION II

Thursday Morning, January 18

GENERAL SESSION .... Moderator: Victor Mastro, USDA-APHIS
Asian Longhorned Beetle
Presenters: M. Stefan, USDA-APHIS; D. Nowak, USDA-FS; S. Teale, SUNY College of
Environmental Science and Forestry; B. Wang, USDA-APHIS; R. Mack, USDA-APHIS

GENERAL SESSION .... Moderator: Kevin Thorpe, USDA-ARS
Research Reports
Presenters: S. Frankel, USDA-FS; B. Geils, USDA-FS; D. Gray, Natural Resources Canada

Thursday Afternoon, January 18

GENERAL SESSION .... Moderator: Vincent D'Amico, USDA-FS
Gypsy Moth in the Midwest
Presenters: D. McCullough, Michigan State University; A. Liebhold, USDA-FS; W. Kauffman,
USDA-APHIS; A. Diss, Wisconsin Department of Natural Resources; L. Solter, Illinois Natural
History Survey; K. Raffa, University of Wisconsin

GENERAL SESSION .... Moderator: Vincent D'Amico, USDA-FS
Research Reports
Presenters: B. Hrašovec, University of Zagreb, Croatia; E. Burgess, Hort-Research, Auckland,
New Zealand; C. Maier, Connecticut Agricultural Experiment Station

Friday Morning, January 19

GENERAL SESSION .... Moderator: Sheila Andrus, USDA-FS
Asian Longhorned Beetle: Detection and Monitoring Panel Discussion
Panel Participants: J. Aldrich and A. Zhang, USDA-ARS; R. Haack, USDA-FS; D. Lance and B.
Wang, USDA-APHIS; D. Williams, USDA-FS; S. Teale, SUNY College of Environmental
Science and Forestry; M.T. Smith, USDA-ARS; K. Hoover, The Pennsylvania State University

GENERAL SESSION .... Moderator: David Lance, USDA-APHIS
Asian Longhorned Beetle: Control Options Panel Discussion
Panel Participants: V. D'Amico, USDA-FS; T. Poland and R. Haack, USDA-FS; A. Hajek,
Cornell University; L. Hanks, University of Illinois at Champaign-Urbana; M. Keena, USDA-FS;
B. Wang and W. McLane, USDA-APHIS; Z. Yang, Chinese Academy of Forestry; M.T. Smith,
USDA-ARS

Closing Remarks

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PLENARY PRESENTATIONS

ABSTRACTS AND PAPERS OF PRESENTATIONS AND POSTERS

EFFECTS OF THE INVASIVE SHRUB, *LONICERA MAACKII*, AMUR HONEYSUCKLE, ON NATIVE PLANTS IN EASTERN DECIDUOUS FORESTS

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ABSTRACT

Invasive plants are often associated with reduced cover of native plants, but rarely has competition between invasives and natives been assessed experimentally. The shrub *Lonicera maackii* (Rupr.) Herder (Caprifoliaceae) is native to northeastern Asia and has invaded forests and old fields in numerous parts of eastern North America (Luken and Thieret 1995). In southwestern Ohio forests, it is associated with reduced tree seedling density and herb cover and diversity (Hutchinson and Vankat 1997) and reduced species richness and basal area of native shrubs (Medley 1997). *Lonicera maackii* expands leaves earlier and retains them later than any of the native woody species in this area (Trisel and Gorchov 1994).

We hypothesized that the early spring leaf expansion of *L. maackii* causes it to have greater negative effects on those native species that depend most on early spring photosynthesis. This hypothesis has been supported by studies by our lab on forest annuals (Gould and Gorchov 2000), but effects on tree seedlings were uncorrelated with leaf phenology (Trisel 1997).

We used field experiments to test the effects of *L. maackii* on the survival and growth of three species of perennial forest herbs of contrasting leaf phenology: a spring ephemeral, *Allium burdickii* (Hanes) A.G. Jones (Wild Leek), and two species that retain leaves through the summer, *Anemonella thalictroides* L. (Rue-Anemone) and *Viola pubescens* Aiton (Yellow Violet). For each species, 240 individuals were transplanted into each of two stands near Oxford, OH: Western Woods and Gregg's Woodlot. Western Woods is a mature stand (24.9 m^2/ha basal area (BA)) dominated by *Quercus rubra*, *Fraxinus* spp., *Acer saccharum*, and *Fagus grandifolia*. Gregg's Woodlot (21.4 m^2/ha BA) was selectively cut about 100 years ago, was regularly burned and grazed by cattle until about 1960, and is dominated by *Carya ovata*, *C. laciniosa*, *Fraxinus* spp., and *Quercus rubra* (Gould and Gorchov 2000). Herbs were transplanted into three treatments in Western Woods: *L. maackii* present, *L. maackii* removed, and *L. maackii* absent in a blocked design (each of 20 blocks had one plot of each treatment). In Gregg's Woodlot, we used 30 blocks, but only the first two treatments because high density of *L. maackii* precluded the "absent" treatment. Rhizomes or bulbs of the herbs were weighed and transplanted in 1995 (*Allium*), 1996 (*Anemonella*), and 1997 (*Viola*), and above-ground structures were monitored throughout each of the subsequent growing seasons.

Most transplants emerged the next spring, and subsequent survival was compared among treatments using survival analysis (PROC Lifetest, SAS version 8). Treatment effects on size (number of leaves or leaflets) and reproduction (number of seeds or fruits per flowering individual) each year were assessed using 2-way mixed model ANOVA, with block considered a random effect. In most cases, these variables were log-transformed to improve the normality of the distribution. Treatment effects on the proportion of individuals flowering each year were assessed with the G-test of independence.

Survival of *Allium* over the past 5 years was high regardless of *L. maackii* treatment, but survivors grew larger where *L. maackii* was removed. This effect was significant beginning in the second year after transplanting (1997) at Gregg's Woodlot, but not until the fifth year at the less-disturbed Western Woods. The proportion of survivors flowering was higher in the removal treatment in 3 of 5 years at Gregg's Woodlot, and in 1 of 5 years at Western Woods. Seed number per flowering plant was significantly greater in removal plots at Gregg's Woodlot (every year beginning in the second year) and Western Woods (only in the fifth year).

Survival over the past 4 years of *Anemonella* at Gregg's Woodlot was greater where *L. maackii* was present, whereas there was no difference at Western Woods. However, survivors at Gregg's Woodlot grew larger in the removal plots (significant beginning the third year after transplanting). While the proportion of survivors that flowered did not differ between treatments, flowering individuals averaged more seeds in the removal treatment at Gregg's Woodlot (significant beginning the second year) and Western Woods (only in 1999).

Removal of *L. maackii* did not affect *Viola* survival, but did increase size (number of leaves) of survivors in the second year after transplanting (1999) at both sites. Similarly, the proportion of plants flowering was higher where *L. maackii* had been removed (both sites, both second and third year). At Gregg's Woodlot, the number of fruits per flowering individual was also higher in the removal plots, in both the second and third years.

To estimate the overall effects of *L. maackii* on fitness of each herb species, we integrated these data on survival and reproduction to obtain the cumulative number of fruits (or seeds for *Allium*) produced per individual since transplanting. For each species at each site, fitness was greater in the *L. maackii* removal treatment. Furthermore, for each species the fitness difference was greater in Gregg's Woodlot, the more disturbed site where *L. maackii* occurred at greater density.

To more comprehensively assess the effects of this invasive shrub on the population biology of herb species, we recently initiated experiments to test the effects on seedling emergence and survival of these three species.

This is one of the first experiments to confirm negative effects of an invasive plant on native plant populations. While perennial herbs with different leaf senescence times were affected similarly by *L. maackii*, all of these expanded leaves in early spring. We predict that perennial herbs that expand leaves later in the season will not be as strongly affected by this invasive shrub.

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ASSESSING GYPSY MOTH SEASONALITY AND RISK OF ESTABLISHMENT

USING A GEOGRAPHICALLY ROBUST MODEL OF PHENOLOGY

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ABSTRACT

Among the requisites of each insect is the availability of food during the feeding stage(s) and suitable temperatures to complete its life cycle. These requisites can be summarized as a requisite seasonality. Seasonality is the predictable occurrence of a life stage event at roughly the same time each year (Lieth 1974). Implicit in this definition is that first instar gypsy moth (GM) (*Lymantria dispar* L.) larvae will hatch coincidentally with the emergence of new foliage of host plants, and that winter will coincide with the cold hardy diapause stage (Leonard 1968) of development, and that these events will coincide sufficiently each year for the continual survival of the population. These same requisites exist for the successful establishment of an introduced population to a novel environment.

The ontogeny of poikilothermic insects is controlled by temperature, and a phenology model simulates the developmental (ontogenetic) response to temperature. Thus a phenology model can directly assess one criterion of the risk of establishment of an introduced population to a novel environment. It can make this assessment by quantifying the likelihood that temperature regimes in the environment will consistently produce seasonal development. This method of assessing the risk of establishment has been utilized at least twice in the case of GM. Allen et al. (1993) used a partially developed three-phase model of GM egg phenology (Gray et al. 1991) and concluded that winter temperatures would limit the southern extent of GM by not satisfying diapause requirements. Phero Tech Inc. (1994) used the same partially developed phenology model and concluded that temperatures in at least a portion of British Columbia would probably satisfy the requirements of GM, and, therefore, a moderate risk existed for establishment.

The appropriate level of confidence that should be placed on estimated risks of establishment that are derived from phenology model output is directly related to the expected accuracy of model predictions for each location. This expected accuracy, measured on a large landscape scale, is the geographic robustness of the model. Gypsy moth egg hatch is a critical life-stage event in establishing seasonality. Unfortunately, the majority of GM egg phenology models have limited geographic robustness. This limited geographic robustness is largely due to the methods employed in modelling the multi-phase nature of GM egg development.

Gypsy moth egg development has been described as being comprised of three distinct phases. Embryos begin development in a prediapause phase that is characterized by high respiration rates (Gray et al. 1991), abundant morphological development (Leonard 1968), and developmental rates that are favoured by high temperatures (Gray et al. 1991). After

spending 25 to 14 days in prediapause (assuming a constant temperature regime of 20 to 30°C), gypsy moth enters the diapause phase as fully differentiate pharate larvae (Bell 1996). Diapause is characterized by low respiration rates (Gray et al. 2001), a virtual absence of morphological development, and developmental rates that are favoured by low temperature (Gray et al. 2001). During the postdiapause phase respiration rates are again high, and developmental rate is favoured by high temperatures (Gray et al. 1995). Eggs hatch upon completion of the postdiapause phase. Due largely to difficulty in observing, either directly or indirectly, the transition between successive phases, model developers have modelled only the postdiapause phase after assuming that diapause is completed by a particular day. Such an assumption weakens the geographic robustness of the model.

A notable exception is the model of Sawyer et al. (1993) that models diapause and postdiapause as a composite phase, without a clear distinction. After assuming that prediapause is completed by a particular day, development is modelled as a gradual transition between a low temperature developmental response and a high temperature developmental response by using 200 transitional sub-phases (Fig. 1). However, such a model can not produce the age-specific developmental responses estimated by Gray et al. (2001).
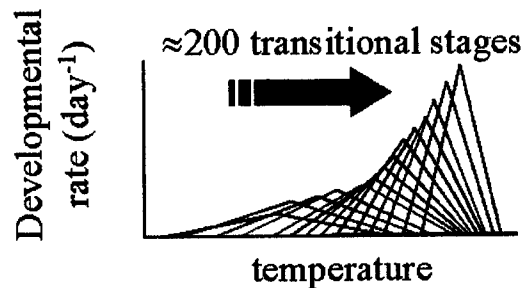
Figure 1. Illustration of the gradually increasing optimum temperature and maximum developmental rate of the Sawyer et al. model.

Another exception is the three-phase, sequential model of Gray et al. (1991, 1995, 2001) that includes no assumptions regarding completion of any phase. Utilizing precise measurements of respiration rates of individual eggs, they were able to distinguish clear transitions between successive phases. Age-specific developmental responses were estimated in the diapause (Gray et al. 2001) and the postdiapause (Gray et al. 1995) phases. An age-independent developmental response relationship with temperature was estimated for the prediapause phase (Gray et al. 1991).

In the three-phase, sequential model, the developmental response at the onset of postdiapause increases only slightly with increasing temperature (Fig. 2). A physiological trait such as this reduces the likelihood that eggs will hatch prematurely with exposure to the occasional warm day that commonly occurs during early spring. Developmental responses during diapause displayed extremely complicated patterns that were
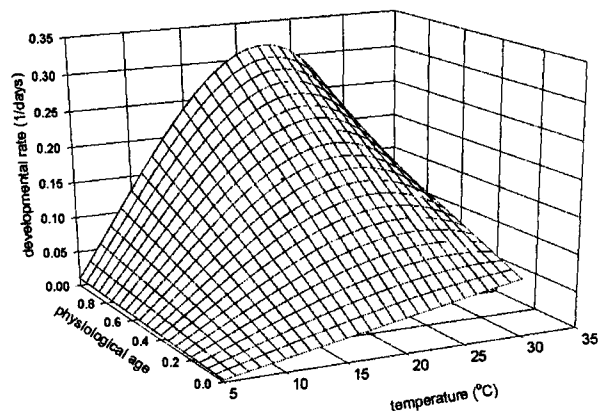
Figure 2. Age and temperature dependent developmental rates in postdiapause.

simulated by a dual process model (Gray et al. 2001). Developmental response at -5°C doubled during the first 30 days of diapause and then declined to original level after another 45 days. Developmental response at 25°C was absent for the first 50 days of diapause and then rose sharply. Developmental response at 20°C was also absent at the onset of diapause and then rose sharply (Fig. 3). However, it is interesting to note that the increase in response occurred *earlier* at 25 than at 20°C. The model of Sawyer et al. (1993), which uses a gradually increasing optimum temperature (Fig. 3), will not produce these observations. When presented in a different fashion (Fig. 4), these same data display another interesting feature. At day 50 (for example) of the experiment, developmental response was minimal at approximately 5°C, and was higher at either higher or lower temperatures. A dual process model of inhibitor-mediated development and removal of the inhibitor explained 94% of the variability in these observations (Gray et al. 2001).
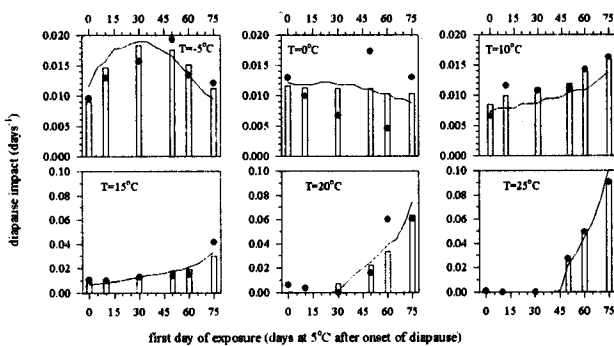
Figure 3. The effect of an exposure to the experimental temperatures during diapause. See Gray et al. (2001) for a full explanation.
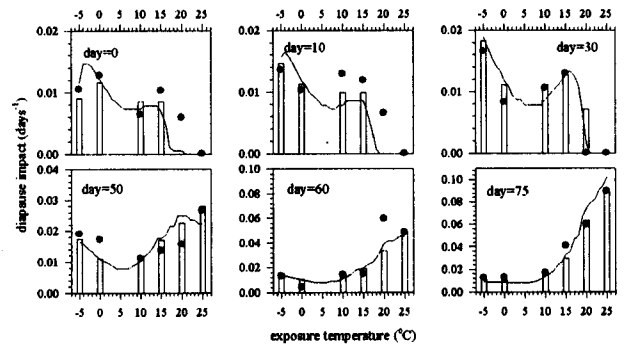
Figure 4. The effect of an exposure to the experimental temperatures during diapause. See Gray et al. (2001) for a full explanation.

A complete GM life cycle model is now possible with an egg development model that includes no arbitrary dates for completion of any phase. The Gypsy Moth Life Stage (GLS) model is a composite model of the stage specific models developed for the egg to adult stages. The acronym also designates the authors of the stage-specific models: Gray et al. (1991, 1995, 2001) for the egg stage; Logan et al. (1991) for the early larval stages; and Sheehan (1992) for the late larval to adult stages.
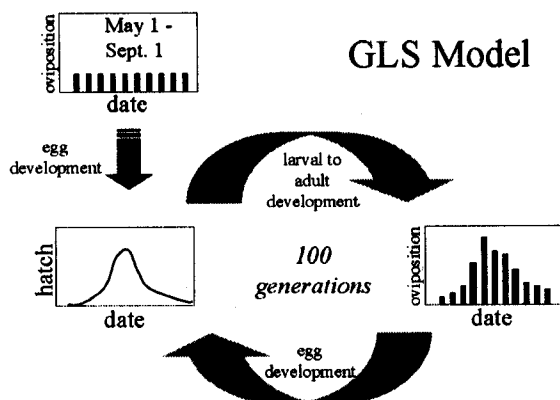
Figure 5. A schematic representation of the Gypsy Moth Life Stage Model.

The GLS model operates in the following manner (Fig. 5). The possibility of successful egg hatch in a location is maximized by simulating a protracted oviposition period, May to September, with 15 cohorts. The successful egg hatch constitutes the originating population and temporal distribution of hatch. Daily egg hatch creates larval cohorts. Each female adult lays 2 eggs 2 days after female adult emergence. The complete distribution of egg oviposition is described by 15 egg cohorts of variable sizes.

The GLS model can be run for any number of locations, for any number of generations. Specific years can be selected for which daily minimum and maximum temperatures exist. Alternately, GLS can be run in random mode where the user specifies a *number* of years, and GLS selects a random sequence of years from the available data. In this manner, GLS can be run for an infinite number of years in order to estimate mean dates for specific life-stage events and variability in those dates. The random mode is also useful to estimate a "climatic suitability index" (CSI) for the location, which is defined as the average proportion of the population that completes its life cycle in the climatic regime.

Climatic suitability is ≥ 0.9 for much of the United States (Fig. 6). Climatic suitability declines sharply in Florida, in Canada, and in a band along the Rocky Mountains, though not for the same reason in all locations. For example, cool and short summers in Combermere, Ontario (45:22N, 77:37E), cause slow larval and pupal development. Mean date of maximum egg oviposition is Sept. 6. Development in prediapause is not rapid at the low temperatures which are common at this time of year. Consequently, in many years only 50% of the population is able to complete prediapause and subsequently develop further to egg hatch. Conversely, hot summers in Ocala, Florida (22:12N, 82:5E), cause rapid larval and pupal development. Mean date of maximum egg oviposition is July 10, and eggs quickly complete prediapause in the high temperatures that still prevail. However, winter temperatures are not commonly low enough to satisfy diapause requirements, and in many years only 20% of the population is able to complete diapause and subsequently develop further to egg hatch.
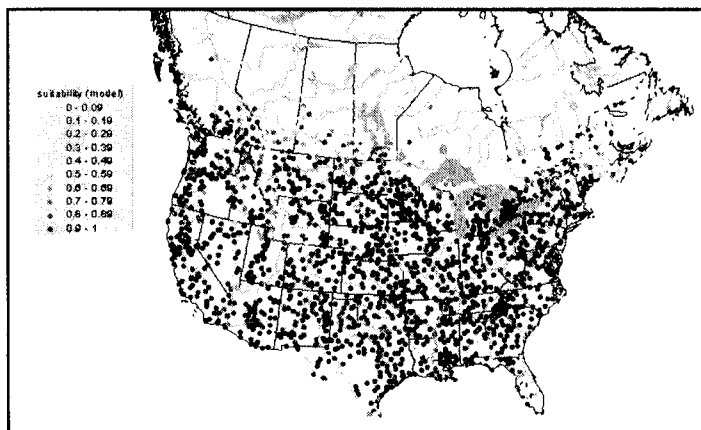
Figure 6. Climatic suitability of approximately 2000 North American locations for gypsy moth establishment.

Figure 7. Climatic suitability of Florida for gypsy moth establishment.

Estimated mean dates for specific life-stage events, or a CSI, can be graphically displayed as point data (Fig. 6), or an interpolative method can be employed to create a more continuous coverage. The risk of establishment of gypsy moth in Florida, based on CSI, is illustrated in Figure 7. To create Figure 7, a logistic function was fit to the CSI data using latitude and longitude as independent variables, a spherical semivariogram model was fit to the residuals, and the residuals were kriged using elevation as an external drift variable.

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ACOUSTIC DETECTION OF *ANOPLOPHORA GLABRIPENNIS* AND

NATIVE WOODBORERS (COLEOPTERA: CERAMBYCIDAE)

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ABSTRACT

Wood-infesting insect larvae generate acoustic signals as they feed and tunnel in trees. Studies on acoustic detection of *Anoplophora glabripennis* (Motschulsky) (Cerambycidae) larvae were conducted in 1999 and 2000. In the U.S., we have recorded acoustic data from *A. glabripennis* and several native cerambycid larvae, including cottonwood borer (*Plectrodera scalator* (Fabricius)), linden borer (*Saperda vestita* Say), locust borer (*Megacyllene robiniae* (Forster)), whitespotted sawyer (*Monochamus scutellatus* (Say)), red oak borer (*Enaphalodes rufulus* (Haldeman)), and sugar maple borer (*Glycobius speciosus* (Say)). In China, we have recorded acoustic data from *A. glabripennis*-infested elm, poplar, and willow trees. The specific objectives of this study are to determine how vibration data varies by insect species, tree species, larval instar, wood moisture content, and distance between the larva and the sensor. The goal of this work is to develop a field-portable acoustic detector that can identify trees infested with *A. glabripennis*.

Scientists at the Oak Ridge National Laboratory conducted extensive sound analyses on the vibration data and developed a mathematical algorithm that would recognize the acoustic signature produced by *A. glabripennis* larvae feeding in wood. The algorithm has been successfully tested on a variety of infested materials, including infested log samples and standing trees in both the U.S. and China. The algorithm is a real time filter that is optimized to respond to vibrations that match closely with pre-selected data sets of actual larval feeding vibrations. Incoming data first passes through the algorithm (filter). If the output is a close match to the pre-selected data set, then a high amplitude response is generated and a "bite" is recorded. On the other hand, if there is no match between the input data and the pre-selected data set, then no "bite" is recorded.

The detection algorithm has been incorporated into a data collection and analysis system that has been installed on a laptop computer. The system is fully portable. Data analysis is completed in real time. An indication of infestation (number of beetle "bites" detected) is displayed on the computer screen in real time. All components utilized in this system can be miniaturized and integrated into a smaller package.

Initial results confirm that larval feeding in wood produces detectable vibrations. The vibrations from *A. glabripennis* and other cerambycids are similar, although there are some unique acoustic features of *A. glabripennis* feeding. Vibrations are larger in amplitude for larval feeding in wood compared with larval feeding in inner bark.

Preliminary studies were conducted in 2000 to compare feeding vibrations among different sized larvae, different wood species, and different insect species. More detailed studies will be conducted in each of these areas in 2001. In addition, more detailed studies will be conducted in 2001 to (1) compare acoustic signals of larvae in live trees compared with infested crating, (2) determine how feeding vibrations vary with air temperature, and (3) determine over what distance feeding vibrations can be detected in trees. We are currently using trunks of cottonwood trees, 7 to 8 m long, into which we have inserted *P. scalator* larvae. In this way, we can vary the distance between the sensor and the larvae. We also hope to field test a prototype acoustic detector in 2001 on actual infested trees in the U.S..

ASIAN LONGHORNED BEETLE (*ANOPLOPHORA GLABRIPENNIS*)

IN THE UNITED STATES:

HISTORIC TIMELINE OF KEY DETECTION/INTERCEPTION EVENTS

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ABSTRACT

The Asian longhorned beetle (*Anoplophora glabripennis* (Motschulsky)) was first detected in the United States in August 1996. At the time of its discovery, it was heavily infesting various hardwood trees, mostly maples, along streets and in parks in Brooklyn, New York. It was found again in Chicago in July 1998. All historical and key detection/interception events surrounding the presence of this highly destructive exotic forest pest in the United States are highlighted.

THE GYPSY MOTH IN CROATIA

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ABSTRACT

Gypsy moth (*Lymantria dispar* L.) has a long history of being the most important species among several defoliators in Croatian forests. It causes serious detrimental impact in the highly valued and ecologically complex lowland stands of pedunculate oak (*Quercus robur*). These forests grow along main inland river flows, spreading over surrounding plains and merging into a higher zone of sessile oak forests (*Q. petraea*). Periodical flooding during the high water levels, from late fall until late spring, is considered a major ecological factor defining the tree species composition and viability and competitive status of *Q. robur*. Climatically, the area is characterized by mean annual precipitation between 700 and 1,000 mm and mean annual temperatures between 10.5 and 11.5 °C. These naturally growing forests once occupied more than 70% of the region (by late 19th century more than 350,000 ha were covered by this continuous "green sea"). Today's forests of pedunculate oak cover little more than 200,000 ha, this area being about 1/10 of the total forest cover in Croatia (2,100,000 ha or 37% of the total country area being under closed forest canopy). Most of the gypsy moth's (GM) outbreaks, in intensity as well as territorial spread, occurred and still occur in these forests. No wonder that the vast majority of GM research and closely related suppression activities focus on the same part of the country.

The recorded history of GM outbreaks goes back into the late 80's in 19th century. The largest outbreak periods lasted more or less continuously from 1874 until 1892, and from 1903 until 1935, with the heaviest attack from 1922 to 1927 during which infested forests comprised a more than 400-km long non-disrupted outbreak area. There was again one big outbreak from 1948 to 1950 with 187,000 ha of *Q. robur* forests and about 2,5 mil orchard trees defoliated. In 1953 another outbreak followed, covering nearly 200,000 ha, and during which the first sign of outbreak loci eastward shift (Vojvodina, northern Serbia) was noticed. One of the major characteristics of these continental outbreaks is a typical four-year duration period followed by 5 to 8 years of latency. This fluctuating gradation type persisted until these days. However, some changes on the long run are noticeable. The latest data on outbreaks in this lowland area most probably reflect those changes. The shrinkage of an area being once a continuous forest region, and several important ecological changes that have occurred during the past 30+ years have had some impact on GM populations and the latest outbreak history. Absence of periodical flooding, dropdown of groundwater level, a general shift toward dryer and warmer climate, loss of some constituent tree species (Dutch elm disease), occupancy of vacant niches by other tree species, rising outbreaks of other defoliators (formerly not recorded), and influences of suppression measures are among a few of the most documented and striking ones.

The average GM outbreak area in the last decades dropped from 156,732 ha in 1970s, to 97,185 ha in 1980s, and to 52,008 ha during the last decade of the 20th century. The last serious outbreak peaked in 1974 when over 100,000 ha were under defoliation threat. Aside from eastward shift of the outbreak loci, there was a new development on an European scale. By the beginning of the 1990s, outbreaks occurred in some central and western European countries, and recently in area east and southeast from Croatia (eastern and southern Serbia). Throughout Croatia, new outbreaks loci evolved. Some were known formerly and existed for years but new appeared and initiated dramatic outbreaks that swept the whole coastal area, again in the NW to SE direction. Susceptible xeric forests of the coastal margin are characterized by holm oak (*Q. ilex*) and downy oak (*Q. pubecscens*) and are growing in maritime climate. They are quite different in a structural and ecological way if compared with inland *Q. robur* forests but have recently been defoliated by GM in much more drastic way than in the past (versus the decline of outbreaks in inland Croatia).

One important factor, being closely related with GM outbreaks and its ecology, are several other defoliators that have been recorded both inland and in coastal, maritime forests. From the early outbreak recordings, the green leaf roller (*Tortrix viridana*) and the brown tail moth (*Euproctis chrysorrhoea*) were known to have periodic outbreaks. Loopers (*Erannis defoliaria* and *Operophtera brumata* as the most important two), the oak sawfly (*Apethymus abdominalis*), and the lackey moth (*Malacosoma neustria*) appeared later on, their outbreaks being new in a sense of outbreak magnitude known formerly for those species. Today, we experience an almost continuous outbreak condition where at least one of the above listed defoliators is in the higher population levels, causing local or more widely spread damages.

As one might expect, the natural enemy complex of GM in its natural habitat is quite rich and diverse. NPV, Bt, mycoses and microsporidia have been recorded during quite many outbreaks in the past, and among pathogens, NPV appears to have the biggest influence on outbreak cessation. Parasitoid fauna is well represented and some of the more often found species are: *Anastatus japonicus, Ooencyrtus Kuwanai, Phobocampe disparis, Apanteles glomeratus, Glyptapanteles liparidis, G. fulvipes, Exorista larvarum, Compsilura conncinata, Drino inconspicua, Carcelia lucorum, Blepharipa pratensis, Pimpla instigator, P. turionellae, Brachymeria intermedia*, and *B. femorata*. Predators are also well represented and some of the most common are: *Calosoma sycophanta, C. inquisitor, Carabus cancellatus, Silpha quadripunctata, Megatoma pici, M. pubescens, M. undata, Ctesias serra, Globicornis nigripes, Dermestes erichsoni, Julius floralis*, and *Malachus bipustulatus*. There are also records on avian predation but interestingly, no serious work or data on small mammal predation which is being well addressed and documented in the case of GM spread in the United States.

Suppression activities against GM are undertaken when classical monitoring procedures (yearly done egg masses surveys) predict an outbreak situation for the subsequent spring. Sprayings are the most commonly used techniques and thermal fogging has been replaced with LV and ULV applications of chemicals, the greater part of them belonging to synthetic pyrethroids. In some more vulnerable areas, like watersheds and periurban areas, IGR's and Btk based formulations are used instead. Compared with the past, much smaller areas are treated today. Average yearly-sprayed area against GM and other defoliators varies between

2,000 and 20,000 ha. One important role of the spraying is the prevention of the oak decline and growing cases of tree mortality. The typical chain of events is: defoliation – heavy attack of an oak mildew (*Microsphaera alphitoides*) – attack of bark beetles, cerambycids and agrilids – girdling and final attack by root rot fungus (*Armilaria mellea*). Successful control of GM and avoidance of defoliation is the key factor to the continuance of the heavily struck and generally more susceptible oak forests of today.

COMPARISONS OF NATURAL ENEMY POPULATIONS IN EASTERN AND MIDWESTERN GYPSY MOTH POPULATIONS

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ABSTRACT

In 1996 and 1997, we sampled eggs, small larvae, and large larvae of gypsy moth (*Lymantria dispar* (L.)) at 12 forest sites in the upper Midwest and the East Coast of the United States. Our objective was to determine what pathogens and parasitoids, known to be established in North America, now occur in gypsy moth's older, resident populations (6 sites in New Jersey [NJ]), later established populations (4 sites in Michigan [MI]), and newly established populations (2 sites in North Carolina [NC]). Species richness averaged 5.5 for NJ, 4.5 for MI, and 2.0 for NC. Two common pathogens, nuclear polyhedrosis virus (NPV) and a fungus (*Entomophaga maimaiga*), accounted for the highest mortality (25 to 35%) of larvae annually in the three regions sampled. NPV was present at all sites, whereas *E. maimaiga* was present at all sites in NJ and MI but absent at NC sites. An egg parasitoid (*Ooencyrtus kuvanae*) was present at all sites with <3.5% parasitism of eggs. Another egg parasitoid (*Anastatus disparis*) was present at all NJ sites with 8.9% parasitism of eggs, present at only one MI site (<1% parasitism), and absent at all NC sites. At least one larval parasitoid was collected from each site in NJ and MI but none from NC sites. *Cotesia melanoscelus* was present at all NJ sites (0.8% parasitism of larvae), present at two MI sites (2.3% parasitism of larvae), and absent in NC. *Compsilura concinnata* was present at only one site in NJ (18.9% parasitism), present at all MI sites (9.4% parasitism), and absent in NC. *Phobocampe disparis* was present only at two NJ sites (0.1% parasitism). We believe that the greater species richness of pathogens and parasitoids in older, resident gypsy moth populations in NJ is responsible for more stable, long-term biological control than experienced in newer, established populations in the midwestern and southeastern U.S.. This disparity warrants efforts to establish a more complete guild of natural enemies in these newer gypsy moth populations.

ANOPLOPHORA GLABRIPENNIS (COLEOPTERA: CERAMBYCIDAE)

FLIGHT PROPENSITY IN THE LABORATORY

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ABSTRACT

Anoplophora glabripennis (Motschulsky) (Coleoptera: Cerambycidae) is one of the more recently introduced nonnative invasive species to become a pest in the United States. Current surveys in urban areas are estimated to be only 30% successful because of uncertainty about the characteristics of *A. glabripennis* dispersal and capacity to spread. The studies described here document the proportion of the population that initiates flight under laboratory conditions, and the life history and host quality factors that lead to flight initiation (including age, feeding and mating status, and host moisture content). Flight-tested adults were from laboratory strains or infested wood obtained from the Chicago (IL) or Queens (NY) infestations. Thirty-two males and 30 females were flight tested on *Acer saccharum* logs dried for 3+ weeks, and 18 females and 14 males on fresh cut *A. saccharum* logs. Each individual was flight tested four times during the adult stage (always on the same log type): (1) at emergence, never fed, and unmated; (2) 1 week after emergence, unmated, and fed; (3) 1 day after mating and fed; and (4) 3 weeks after mating and fed. Each bioassay consisted of 1 to 4 adults on separate logs that were observed for 45 minutes.

Adults initiated flight more slowly at lower than at higher % RH. Males tended to fly more than females during the 45-minute observation period. A significantly higher percentage of females flew from dry logs than from fresh logs at all stages. Females chewed significantly more pits on fresh than on dry logs; of the females that chewed a pit, only 16% flew. Newly emerged and newly mated females were more likely to fly from fresh logs than 1-week-old virgins or females mated for 3 weeks. Newly emerged males were more likely to fly from fresh logs than males at the other stages. When disturbed, a higher percentage of both male and female beetles flew a longer distance than when they were allowed to initiate flight on their own. This result was most pronounced in the fresh log group. The results suggest that about half of the newly emerged adults of both sexes will fly from a log that has no twigs attached, probably in search of food. Nearly every beetle walked up and/or down on the log before initiating flight, so on living trees, fewer may have flown because they would encounter twigs to feed on. Well-fed females appeared to remain on a good-quality host and chew oviposition pits rather than fly. When the host quality is poor, >50% of females flew within the first 30 minutes and additional females would likely have flown after chewing pits and assessing host quality. Because > 85% of all males flew in this study, they would be expected to fly at some life stage regardless of host quality. Males were more likely to remain on a log than fly when they recently mated a female. Therefore, when populations are small and host trees are fresher, more males may fly in search of females while females likely would fly less than at higher population densities on deteriorating well-colonized hosts.

ANOPLOPHORA GLABRIPENNIS (COLEOPTERA: CERAMBYCIDAE)

DEVELOPMENT ON CUT LOGS OF FOUR SPECIES OF *ACER*

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ABSTRACT

Anoplophora glabripennis (Motschulsky) (Coleoptera: Cerambycidae) was first discovered in 1996 in the New York City metropolitan area and has since been found in the Chicago (IL) metropolitan area. In China, it is considered a major pest of maple (*Acer*), poplar (*Populus*), and willow (*Salix*). There is a critical need for information on the basic biology of *A. glabripennis* to predict the timing of biological events fundamental to the improvement of exclusion and eradication methodologies. This study reports on the attack rate and relative developmental rate of *A. glabripennis* on four species of *Acer*: *saccharum* (sugar), *rubrum* (red), *saccharinum* (silver), and *negundo* (boxelder).

Freshly cut logs (10 to 15 cm diameter and 90 cm long) with both ends waxed were exposed for 1 week to a single mating pair of *A. glabripennis* from a strain established from the Queens (NY) infestation. At 14, 28, 56, 84, and 112 days, three logs of each of the tree species were stripped and split to assess the larvae and eggs present on the log.

The number of eggs laid per log in 1 week was significantly lower on red maple than on the other three maple species. Significantly more oviposition pits were chewed on the boxelder and sugar maple logs than on the red or silver maple logs. The female beetles did not oviposit in all pits that were chewed, and the number of sites without eggs differed between tree species. Differences in attack rate and oviposition may be due both to log moisture levels and sap-sugar content since these beetles have been shown to prefer trees with a higher sugar content. Survival of *A. glabripennis* was significantly higher and development faster on the two softer wood species, boxelder and red maple, than on the harder wood species, silver and sugar maple. Survival significantly declined with log age and larval weight within each instar was reduced in the 112-day logs. Three 5th-instar larvae on 56-day boxelder were the only ones to enter the heartwood of the logs. These larval development results are consistent with our observations for cut infested wood and suggest that the beetle larvae are more likely to survive and develop from egg to adult in cut logs of softer than harder wood maples. This is particularly important since softer maples are more likely to be used for firewood or packing materials such as crates.

SYSTEMATICS OF ASIAN LONGHORNED BEETLES

OF THE GENUS *ANOPLOPHORA*

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ABSTRACT

The Asian longhorned beetle (*Anoplophora glabripennis* (Motschulsky)), native to mainland China and the Korean peninsula, was discovered infesting various hardwood trees along streets and in parks in the New York City area in August 1996 and in Chicago in July 1998. This represents the first known infestation of standing trees in North America by any member of the lamiine genus *Anoplophora*. This exotic wood-boring beetle also has been intercepted on multiple occasions in wood crating and pallets at many U.S. ports of entry. In addition, infested solid wood packing material has been detected at approximately 30 importer warehouse sites in at least 14 states of the U.S. and Canada. To better enable accurate and timely identification of the adult and immature stages of this important exotic forest pest, as well as those of the approximately 45 other described species of the genus, we are conducting a comprehensive taxonomic revision of the species of the Asian genus *Anoplophora* and producing an illustrated handbook for their identification. This research is funded by USDA's Agricultural Research Service (ARS).

CHARACTERIZING THE RESPONSE OF ARTIFICIALLY INSERTED

ASIAN LONGHORNED BEETLE LARVAE IN THREE HOST TREE SPECIES

UNDER GREENHOUSE CONDITIONS

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ABSTRACT

The introduction of Asian longhorned beetle into the United States has resulted in the destruction of thousands of street trees in Chicago and New York. Presently, our understanding of the susceptibility of trees to feeding and oviposition by ALB remains limited to field observations in China, Chicago, and New York and laboratory experiments on excised branches and cut logs. In China, the highly preferred trees include poplar (*Populus* spp.), willow (*Salix* spp.), and maple (*Acer* spp.), whereas chinaberry (*Melia* spp.), mulberry (*Morus* spp.), black locust (*Robinia pseudoacacia*), elm (*Ulmus* spp.), and some fruit trees (i.e. plums and pears) are occasionally attacked. Observational reports from the New York and Chicago infested sites listed several *Acer* species (Norway, sugar, silver, sycamore, and boxelder) as primary hosts. In addition, several new larval hosts were identified in these infestations, including birch (*Betula* spp.), horse chestnut (*Aesculus hippocastanum*), and green ash (*Fraxinus pennsylvanica*). Research results from a survey under laboratory conditions using cut logs by USDA/APHIS/PPQ suggest that the potential host range may be larger, although maples remain the preferred target in their studies. It is our goal to evaluate the host range of the Asian longhorned beetle among commonly planted urban landscape trees including: paperbark birch, gray birch, American beech, sweetgum, yellow-poplar, blackgum, Norway spruce, white spruce, American basswood, river birch, Whitespire birch, European hornbeam, common hackberry, yellowwood, Turkish filbert, hawthorn, gingko, honeylocust, Kentucky coffee tree, Golden raintree, Callery pear, bur oak, pin oak, willow oak, English oak, Tree lilac, Littleleaf linden, Silverleaf linden, alder, and Zelkova.

A preliminary experiment was conducted to develop a method for artificially inserting larvae into trees to evaluate larval survival under greenhouse conditions. Larvae were artificially inserted into container grown sugar maple (*Acer saccharum*), green ash (*Fraxinus pennsylvanica*), and red oak (*Quercus rubra*) trees. The trees were grown under greenhouse conditions for six months prior to the experiment. Two trees of each species were placed into two separate screened cages (3 x 2.7 x 2.1 meter). The larvae were inserted into the trees through 5-mm deep incisions made through the bark near the bark-cambium-phloem interface. Four insertions were made in each tree at 1, 1.5, 1.75, and 2 meters above the soil

line. At implantation, the tree species varied in caliper width: sugar maple was 25 ± 2.6 mm, green ash was 34 ± 3.5 mm, and red oak was 21 ± 2.2 mm.

Insertion sites were monitored daily until the larvae were no longer visible. Sixty days after implantation, the trees were destructively harvested to determine the progress, viability, and size of the larvae. The implanted section of trunk was removed from the tree and each implanted area was carefully split open with a chisel and hammer. Care was taken not to damage the larvae. Each larva was removed and weight recorded.

Fifteen days after insertion, a 19% mortality rate was observed for larvae inserted into both sugar maple and green ash. No larval mortality was recorded in the red oak. Larval mortality that occurred through day 15 was most likely due to injury during handling or the insertion process. The percent larval mortality from day 10 to 60 in each tree species was sugar maple 15.4%, green ash 69.2%, and red oak 37.5%. Larvae reared on green ash weighed significantly more (18 mg) than larvae reared on sugar maple (9 mg) or red oak (12 mg).

The larval insertion technique used for this study resulted in low mortality during the first two weeks of the study. We observed significant sap flow in green ash using this technique, and it is likely that this was responsible for the high larval mortality we observed in green ash. Red oak and sugar maple also exhibited sap flow, but not to the same extent as green ash. Larvae reared in green ash weighed more than the larvae reared in sugar maple or red oak. This indicates that the larvae were capable of surviving in ash if they were not "drowned" initially by high sap flow.

Over the next three years, we will screen common landscape trees for susceptibility to ALB oviposition and larval development. This research will provide vital information for field identification of susceptible trees and permit recommendation of non-susceptible trees. By characterizing oviposition activities, identifying susceptible trees, and confirming non-susceptible trees, we can reduce the direct financial and indirect economic impact this pest may have on forest, landscape, and nursery industries. Identifying non-susceptible cultivars will accelerate the re-greening of infested sites throughout the U.S., thereby assisting in controlling the spread of the beetle.

METHODS DEVELOPMENT FOR THE EXCLUSION OF

ASIAN LONGHORNED BEETLE

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ABSTRACT

Methods developed to exclude Asian longhorned beetle (ALB) from future shipments containing solid wood packing materials were initiated in China during the spring of 2000 as part of a cooperative agreement between China Inspection and Quarantine (CIQ) and USDA-APHIS-PPQ. Heat treatment experiments were conducted on solid wood packing material at a commercial pallet manufacture plant in Xiaoshan, Zhejiang Province, China. Poplar wood in thicknesses of 2.5, 5, 7.5, 10, and 20 cm was artificially seeded with late instar larvae of ALB and heated to 60 °C in a kiln. Results are forthcoming and will serve to strengthen the existing wood products treatment schedule (T404-b-4) printed in the USDA-APHIS-PPQ Treatment Manual. Fumigation trials were conducted in Hohhot, Inner Mongolia, using fabricated Lexan chambers (15 cu. ft.) placed in refrigerated shipping containers. Poplar timbers (10 cm x 10 cm), both naturally infested and artificially seeded with larvae of ALB, were exposed to currently accepted concentrations of methyl bromide, sulfuryl fluoride, and phosphine at temperatures of 4.4, 10, 15.5, and 21.1 °C. Preliminary results indicate that the current treatment schedule for methyl bromide on wood products (T404-b-1-1) is adequate. Sulfuryl fluoride trials proved inconclusive due to poor fumigant penetration as a result of the high moisture content of freshly sawn wood. The evolution of CO_2 gas from green wood also had influence on the readings of both methyl bromide and sulfuryl fluoride. Phosphine trials resulted in reduced efficacy at lower temperatures and were hampered by slow evolution of the Chinese phosphine formulation. Further testing of fumigants on solid wood packing is planned for the 2001 season.

DISTRIBUTION, HOSTS, AND SEASONAL ACTIVITY OF THE EXOTIC JAPANESE CEDAR LONGHORNED BEETLE, *CALLIDIELLUM RUFIPENNE* (COLEOPTERA: CERAMBYCIDAE)

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ABSTRACT

The small Japanese cedar longhorned beetle (*Callidiellum rufipenne* (Motschulsky)) is an eastern Asian cerambycid recently discovered in the wild in the eastern United States. The first record was represented by a single adult found at a coastal location in Dare Co., North Carolina, in 1997 (E.R. Hoebeke, personal communication). In the fall of 1998, infestations of larvae and adults were found in live landscape plants in garden centers in southern Connecticut (Maier and Lemmon 2000). These findings were the first records of larval boring in live, apparently healthy, plants. Shibata (1994) previously had reported that *C. rufipenne* bored into only dead and dying cedars. After its discovery in live landscape plants in the United States, federal officials reclassified *C. rufipenne* as an actionable insect (J. Cavey, personal communication), and regulatory officials in Connecticut quarantined the infested counties. Maier and Lemmon (2000) reported that most of the live plants infested by *C. rufipenne* were arborvitae (*Thuja occidentalis* L.) which had been balled and burlaped before infestation. It is possible that the infested live plants had been stressed by root breakage during removal from the ground; inadequate watering before, during, or after shipping; branch breakage during shipping; or inadequate care during or after planting.

Based on my observations in southern Connecticut, *C. rufipenne* has one generation per year. The adults emerge from wood in spring and mate on the host. Females lay eggs singly or in small batches in cracks and crevices in the bark of branches and trunks. In the laboratory, females lay an average of 65 eggs. After hatching, larvae bore into the cambium and phloem, completing their development by late summer or early autumn. They then bore into the sapwood and carve an ellipsoidal pupal chamber. Before pupating, larvae plug the entrance to their individual pupal cells with chewed wood. Adults eclose in autumn, but they remain in the pupal cells until the following spring.

During an initial survey in 1999, I determined that *C. rufipenne* was established in three coastal counties in Connecticut; that it bored into live or dead wood of cupressaceous plants in garden centers, in residential yards, and in the wild; and that it was attracted to trap-logs of eastern red cedar (*Juniperus virginiana* L.) and northern white cedar (*T. occidentalis*) (Maier 2000).

To expand my initial research on distribution and host range, I reared adults of *C. rufipenne* from >140 samples of dead wood collected in northeastern states between autumn 1999 and spring 2000. One or more beetles emerged from wood sampled in Massachusetts, Rhode Island, Connecticut, New York, and New Jersey. Based on data from the rearing project and from other sources (Ken Ahlstrom, personal communication; T. Denholm, personal communication; NAPIS 2000), *C. rufipenne* now occurs in the coastal states of Massachusetts (1 county), Rhode Island (1 county), Connecticut (4 counties), New York (5 counties), New Jersey (5 counties), and North Carolina (1 county). The exotic beetle apparently is confined to counties that border the Atlantic Ocean or a major river.

In spring 2000, I reared over 3,800 cerambycid beetles of eight species from the dead wood of Atlantic white cedar (*Chamaecyparis thyoides* (L.) B.S.P.), common juniper (*J. communis* L.), *J. virginiana*, and *T. occidentalis*, collected in the northeastern states of Vermont, Massachusetts, Rhode Island, Connecticut, New York, and New Jersey. Nine of 18 (50%) of the host records were new. Adults of *C. rufipenne* emerged from the dead wood of *C. thyoides*, *J. virginiana*, and *T. occidentalis*. Based on these host records and others (Maier 2000, unpublished data; Maier and Lemmon 2000), *C. rufipenne* is now known to bore into the wood of seven species of Cupressaceae in the Northeast.

To determine the seasonal activity of *C. rufipenne* in groves of eastern red cedar in Connecticut, I captured adults with sticky bands placed on logs (0.7 m long), cut trees, and live trees, and with unbaited sticky yellow traps put on live trees. At Middletown (Middlesex Co.), most of the 45 adults were caught on cut trees (57.8% of total) and trap-logs (26.7%). No beetles were caught on sticky bands on live trees, suggesting that *C. rufipenne* may not be attracted to healthy trees.

Based on weekly captures on trap-logs or cut trees at Stamford (Fairfield Co.), Milford (New Haven Co.), and Middletown, the period of adult activity in 2000 lasted 7 weeks between early April and mid June. The period of activity was later as the latitude of the sites increased. Males outnumbered females in catches at every location, and the mean date of capture tended to be earlier for males than females.

To record adult emergence, logs of *T. occidentalis* were removed from Stamford in spring and monitored daily in screened cages at Hamden (New Haven Co.). Beetles emerged between 6 April and 15 May in 1999 and between 25 March and 10 May in 2000. In both years, the pattern of emergence was erratic, although most of the beetles emerged during dry, warm days in May. The start of emergence preceded the first catch on trap-logs at Stamford in 1999 and 2000 by 1 to 2 weeks. In both years, the emergence was significantly earlier in males than females, and the sex ratio was 1.0.

In the three years since its discovery in the eastern United States, the distribution, hosts, and seasonal activity of *C. rufipenne* have been investigated in Connecticut and, to a lesser extent, in a few other northern states. It would be desirable to elucidate the seasonal activity of *C. rufipenne* in the southernmost part of its range. With information from the northern and southern end of its range, it would be possible to predict more accurately when adult surveys at in-between locations should be conducted.

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