

**Injury and Mortality Risks from Wildland Fire Smoke and Heat Exposures for  
Endangered Indiana Bats (*Myotis sodalis*) in Maternity Roosts**

**Announcement for Proposals and Task Statement:** JFSP AFP 2005–2, Local Projects.

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**Abstract -** Burning within the summer (growing season) range of the endangered Indiana bat (*Myotis sodalis*) may adversely affect the species by injuring or killing individual bats. Accordingly, the USDI Fish and Wildlife Service (USFWS) usually requests that Federal land managers strictly limit or eliminate this activity. Countering the need to protect individual Indiana bats is the value of using both growing and dormant season fires for managing Eastern mixed-oak forests. The Daniel Boone National Forest (DBNF) has planned an ambitious burning program, their goals include mitigating the effects of the pending gypsy moth invasion and restoring historical ecosystems. A better understanding of the risks of injury and death for neonate and adult Indiana bats exposed to heat and smoke in maternity roosts is needed to help the DBNF assess and carry out their program. We propose a study with the following components. First, toxicology models of gas and heat effects on bats will be assembled and parameterized with data from the literature. Second, characteristic time courses of smoke concentrations and temperatures above surface fires and smoke concentrations in nighttime inversions after fires will be estimated. Third, a field study will be conducted to characterize maternity roosting crevices over the summer range of the Indiana bat. Using these data, suitable roosting crevices will be identified on the DBNF and field experiments will be conducted to enable us to predict smoke exposures for bats within crevices during fires. Finally, the above project components will be synthesized to produce a risk assessment. A workshop and accompanying publication will be used to provide guidance on minimizing bat risk from fires for USFS and USFWS personnel with responsibilities for the Indiana bat.

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## **PROBLEM STATEMENT**

The following problem statement has been provided by BENJAMIN WORTHINGTON, Forest Supervisor, Daniel Boone National Forest, Winchester, KY

# Injury and Mortality Risks from Wildland Fire Smoke and Heat Exposures for Endangered Indiana Bats (*Myotis sodalis*) in Maternity Roosts

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## INTRODUCTION

### PROJECT OBJECTIVES

The overall objective of this project is to produce general models of small mammal injury and mortality from smoke and heat. Those models will be applied to endangered Indiana bats (*Myotis sodalis*) in the Daniel Boone National Forest (DBNF) exposed to hot gases in maternity roosts during typical growing season wildland fires and in nighttime inversions after those fires. The research and science delivery will be completed in five phases:

1. *Assemble toxicology models of gas and heat effects.* Heat and smoke gas effects data and models will be assembled from the literature and modified in order to apply them to neonate (neonate) and adult bats under expected wildland fire exposures. No experiments on animals will be conducted in this study, a future possibility if significant risks are identified in this study.
2. *Characterize smoke in sub-canopy plumes above surface fires and during nighttime inversions after fires.* Gas concentrations and temperatures typical of the plumes above surface fires (short duration, high smoke concentration and temperature) and in nighttime inversions after fires in hilly terrain (long duration, low smoke concentration) will be estimated from the literature-based calculations. Plumes are the columns of hot gases that rise above fires. For plumes above surface

fires, gas concentrations and temperatures will be extrapolated to heights at which bats roost. Wildland fires of interest are those covering the range of variability in surface fires in hardwood fuels in the DBNF.

3. *Mixing of plume gases into roosting crevices.* Bats in roosting crevices may often be sheltered from plume gases. A field study will be conducted to characterize mixing of hot plume gases into suitable Indiana bat maternity roosting crevices during fires. To accomplish this objective, the characteristics of known maternity roosting crevices will be determined from a rangewide study. Then, these characteristics will be applied to select a sample of suitable roosting crevices on the DBNF. Experiments and modeling will then be conducted to determine rates of gas and heat transfer (mixing) into these crevices for the range of plume characteristics determined above.
4. *Risk assessment.* Toxicology models, ranges of expected plume and nighttime inversion characteristics for the DBNF, and the exposures expected for Indiana bats in maternity roosts will form the basis for the risk assessment. Wildland fire scenarios that pose risks of injury and death for Indiana bats in maternity roosts will be identified.
5. *Science delivery.* Annual meetings at the DBNF and an end-of-project joint workshop including USFS and US Department of Interior Fish and Wildlife Service (USFWS) personnel will be used to aid science delivery. A publication based on the risk assessment and targeted to forest managers will form the basis of the workshop.

## PROJECT JUSTIFICATION

This project addresses JFSP AFP-2005-2 Task 1 with its emphasis on knowledge gaps associated with implementing and planning an extensive prescribed fire program at the DBNF. The local knowledge gaps we propose to address are important well beyond the DBNF, affecting prescribed burning throughout the summer range of the endangered Indiana bat (a large portion of the Eastern US). Burning during the growing season creates the potential to harm adult female and neonate bats in maternity roosts. Flightless neonates may be particularly vulnerable. In addition, field biologists hypothesize that male Indiana bats that often roost near ground level and exhibit torpor during cool periods may also be at risk from growing season burning. Accordingly, the USFWS recommends strict limits on growing season burning and a prohibition on burning during the months when female and neonate bats are present in maternity roosts. While burning risks harming bats, the DBNF, in consultation with the USFWS, is proposing an ambitious prescribed burning program to restore and maintain oak-hickory forests and prepare for the imminent arrival of the gypsy moth. The DBNF burning program will require growing season burning because dormant season burning opportunities are severely limited by weather. A better understanding of the effects of heat and smoke exposure on roosting Indiana bats is needed to reduce risks of growing season prescribed burning and, potentially, help determine appropriate suppression responses to future wildfires. Our proposal will complement other proposed projects in an overall effort to describe risks and benefits of fire for endangered Indiana bats. In concert with this study, an investigation will be conducted on behavioral responses to fires of a surrogate species (the northern bat, *Myotis septentrionalis*), including telemetry-determined roost abandonment during prescribed fires. Also planned is a study on the effects of forest thinning and under-burning on bat foraging behavior and insect food resources in the DBNF. Evidence suggests that Indiana bats may benefit from forest thinning and the maintenance of thinned forests with fire. In the future, it may be necessary to look at the potential for arousal of hibernating bats, an energetically costly phenomenon, because of exposure to smoke drawn into hibernacula during nighttime inversions after dormant-season fires.

Ethical and practical considerations dictate that the first step in a project such as this should be a literature and modeling study. Accordingly, no experiments will be done on live animals. Once risk levels associated with prescribed and wildfires are estimated theoretically and if they are found to be significant, future experimentation on a surrogate species (not endangered Indiana bats) might be warranted.

As far as we are aware, this study on the mechanisms by which a wildlife species is affected by fires is a first of its kind. Once published in the refereed literature, the methodology will be available for others with concerns about effects of fires on other species. With appropriate modifications, the general principles may apply broadly across terrestrial vertebrates exposed to smoke and heat during forest fires. Because of its novelty and potential generality, this study is likely to open opportunities for future research and provide benefits for management beyond those associated with the Indiana bat.

## **BACKGROUND**

### **INDIANA BAT**

The Indiana bat (*Myotis sodalis*) is a federally listed species whose populations have declined substantially over the past 40 years (see papers and references in Kurta and Kennedy 2002). The bats hibernate in caves during the winter (~October to March), often in large numbers, and roost in trees and other locations (e.g., bridges) during the warmer months across a large portion of the Eastern US. Kentucky, Indiana, and Missouri are home to the largest numbers of hibernating bats. Female bats give birth to their young in roost trees with births peaking in July. Pregnant and lactating females tend to aggregate in maternity colonies (review in Menzel *et al.* 2001, Britzke *et al.* 2003). Maternity colonies are fluid in the sense that pregnant and lactating females move among one or more primary and secondary roosts, at least up to the time at which flightless young are too heavy to carry. Primary maternity roosts are often dead trees with exfoliating bark that are exposed to solar radiation, accommodating 10's of individuals (Figure 1). Across years, female bats move among primary roosting sites, in part because of the attrition of dead trees. A large number of tree species have been used as primary roosts. Secondary maternity roosts, accommodating fewer individuals, may provide more shelter from rain and solar radiation than primary roosts. A substantial number of secondary roosts have been described as live trees with bark structure that provides crevices (e.g., shagbark hickory). Both primary and secondary roost trees tend to be large and both are necessary to meet the maternity requirements of Indiana bats. Crevices in which bats roost occur at a range of heights above ground, an important consideration for fire effects. Though Indiana bat roost trees and their setting has been described (references in Britzke *et al.* 2003), a comprehensive description of roosting crevices themselves does not exist and will be required for this project.

Information on the direct effects of fire on bats in general and Indiana bats in particular is exceedingly limited (Bat Conservation International, 2001) and largely anecdotal. Red bats (*Lasiurus borealis*) hibernating in leaf litter may be particularly vulnerable to burns on cool winter days because of the time required for arousal. Male Indiana bats (Figure 1), which tend to roost singly and in cooler microsites than pregnant and lactating females, enter torpor during cool or rainy periods when they are outside hibernacula. Flightless young too heavy to be moved by their mothers and males that undergo torpor during cool burning periods may be particularly vulnerable to smoke and heat from fires.



Figure 1 – Indiana bat maternity roost and a male Indiana bat in a roosting crevice. This project is concerned with estimating the risk from smoke and heat for female and neonate bats roosting below bark in trees such as the one shown on the left. Male bats, such as the one shown in the small crevice on the right, may also be vulnerable during cool periods if they are in torpor. Photo: James Kiser, DBNF.

## TOXICOLOGY

Impacts of wildland fire smoke on firefighter health have been considered (e.g., McKenzie et al. 1995, Booze et al. 2004), however, we are not aware of analogous work relating realistic wildland fire smoke and heat exposures to injury and mortality for other mammals or vertebrates in general. A large literature exists which allows extrapolation of combustion gas effects on other mammals (e.g., rats and mice) to neonate and adult bats in roosts. That literature begins with basic physiological descriptions of bats, particularly during maternity, needed to provide model parameter values (e.g., Szewczak 1997, Kunz *et al.* 1995, Boggs et al. 1999, Maina 2000). Mechanistic models are then needed that predict injury and mortality from combustion gas exposures. These models are available and have been applied to small mammals and humans in building fires (Hartzell *et al.* 1985, Levin *et al.* 1987a and 1987b, Babrauskas *et al.* 1998). The combustion gases may prove to be a major source of adverse health effects for bats. Typically, damaging gases include carbon monoxide, carbon dioxide, and acrolein. These gases have the potential to be both narcotics and irritants. Carbon monoxide binds to hemoglobin in the blood, thus preventing the transportation of oxygen to the tissues. Carbon dioxide can stimulate the respiratory system thereby resulting in increased respiration rates, causing a quicker loading of the toxicants into the bat's body. Acrolein is a predominant irritant in wood smoke. Its presence can decrease the respiration

rate and tidal volume causing a reduction in the available amount of oxygen to the bat's physiological system. Another impact on the bat in a fire environment may be reduced oxygen concentrations. These combined effects may impede the bat's ability to escape the fire environment as well as inducing death as a consequence of the smoke exposure. We will also examine the effects of physiological state during torpor (e.g., Thomas et al. 1990) on the potential effects of combustion gases.

Skin and airway burn models will be applied to predict burn injury for bats in crevices exposed to hot plume gases above fires (e.g., Takata 1974, Diller *et al.* 1991, Cribs *et al.* 1998). We will examine the hypothesis that respiration of hot gases and resulting airway injury is a more important problem than skin burns because of increased heat transfer rates during inhalation. As well, we will examine the possibility of a synergistic effect between gas and heat injury (Dubick 2002).

## SMOKE AND HEAT EXPOSURES

Gas concentrations, temperatures, velocities, and residence times in plumes that rise above surface fires and into the canopy will be important in determining the exposures experienced by bats in crevices. Plume characteristics are themselves determined by fire intensity (kW/m, a rate of heat release), wind, and whether the heat output is from a roughly linear fire line (e.g., see review in Mercer and Weber 2001). A longstanding and substantial theoretical and experimental literature exists on the dynamics of hot gas plumes above heat sources ranging from industrial smoke stacks, laboratory burners, pool fires, and forest fires (e.g., Rouse et al. 1952, Morton et al. 1956). Relatively simple, two-dimensional models of plume dynamics can be used to give a first approximation of gas concentrations, temperatures, velocities, and residence times at heights at which bats roost. These relatively simple approaches have been applied successfully to ecological effects of fires (review in Dickinson and Johnson 2001) such as crown scorch (e.g., Van Wagner 1973, Gould et al. 1997) and aerial fruit (Mercer et al. 1994) and conifer cone heating (Johnson and Gutsell 1993).

A separate literature has focused on the production of gases and particulates in forest fires (see review in Ward 2001). Major contributions to that literature have been made by the Fire Chemistry group at the USFS Missoula Fire Sciences Laboratory, cooperators on this project (see references at <http://www.firelab.org/fcp/fchome.htm>). Of particular interest, for our purposes, is separating gas emissions from the main flaming front from gas emissions from residual combustion after the flaming front has passed (e.g., smoldering of duff and large woody material, e.g., Ward *et al.* 1993). Gas emissions from the main flaming front are those of interest for understanding plume effects. A typical approach to estimating the mass of a given gas released from combustion involves calculating an emission factor for the gas and fire of interest (e.g., Ward and Hardy 1991). Emission factors for the gases of interest are multiplied by the dry fuel consumption to estimate gas release.

Also critical to understanding bat exposures to plume gases is how these hot gases are mixed from the plume into roosting crevices. In this case, because no data exist, it will be necessary to follow an experimental approach guided by theory (see below) to estimate the mixing characteristics of roosting cavities. An important question for a given crevice is whether the time scale of gas mixing into cavities is much longer than the residence time of plumes above surface fires. Mixing may take a considerable amount of time if crevices are closed on three sides. We expect that the range crevice configurations will lead to a range of answers to the question of how sheltered bats are in crevices. Crevice temperatures are not the same as the temperatures of the bat tissues. Once roosting crevice temperature and air flow regimes can be characterized for the range of crevice configurations seen in the field, convection heat transfer coefficients to skin and airway tissue can be estimated (e.g., Budaraju *et al.* 1997). These convection coefficients couple crevice temperatures with bat skin and airway temperatures.

The typical flow pattern over a cavity comprises an external boundary layer, a region of mixing (shear layer), and a recirculating flow within the cavity (Chyu and Kapat 1988). All of these will affect changes in cavity temperature and the concentration of gas species. Heat transfer to cavities may be described experimentally by relating dimensionless numbers that describe the mixing process. Dimensionless variables of interest are the Reynolds number, which characterizes the flow of heated gas over the cavity by combining an aspect ratio (e.g., width / depth) of the cavity with the plume velocity; and the Nusselt number, indicating the effective ratio of convective to conductive heat flow into the cavity (Welty *et al.* 1976). The engineering correlations describing mass transfer of gases are analogous to those described above for heat transfer, that is, they take the same form and involve the many of the same dimensionless numbers (Soloukhin and Afgan 1985). The Reynolds number is again used to describe mass transfer along with a third dimensionless number, the Sherwood number, which indicates the effective ratio of gas species dispersion to diffusion, and thus is analogous to the Nusselt number. Measurements of temperature inside and outside of a cavity, along with those of gas concentration(s) and free stream (plume) velocity, will all be required to estimate the above dimensionless numbers and their component variables and, thereby, describe heat transfer and gas mass transfer into cavities. With these experimental results, we will be able to describe the time course of temperatures and gas concentrations within roosting cavities from fire intensity (~flame length) and residence time and cavity characteristics.

Flightless young and adult bats may also be affected by high gas concentrations during nighttime inversions after wildland fires, particularly where there is substantial residual smoldering. Nighttime measurements of the vertical structure of smoldering smoke plumes showed near-surface smoke mass concentrations exceeding those above the inversion by a factor of approximately 1000 (Ferguson *et al.* 2003a). The range in inversion smoke concentrations after fires is considerable and we can only expect to put large bounds on risk of bat injury and mortality. A working hypothesis is that mixing of inversion gases into crevices will not be limited by crevice configuration because inversions occur over many hours. Ferguson *et al.* (2003b) show that inversion strength (the degree of temperature stratification in the lower atmosphere) for US airsheds follows distinct seasonal patterns that we will consider for the DBNF when assessing risks of smoke for bats.

## **MATERIALS AND METHODS**

### **TOXICOLOGY**

The first information that will be needed is the physiological parameters of the bat. These will include the respiratory rate and tidal volume. These are necessary to assess the rate of carbon monoxide uptake by the bat in a carbon monoxide-contaminated and/or oxygen-deprived environment. Secondly, the tolerance and susceptibility of the bat to carbon monoxide poisoning will also be investigated with emphasis on the hematological components of the bat. Thirdly, these sets of values will then be compared to the known values of other similar species, such as rats and mice. Fourthly, from these comparisons, an extrapolation will be proposed to establish the critical carbon monoxide exposure concentrations and exposure time. This information can then be related to the forest fire environments for determining injury and mortality risk for the bat. If any equivalent data can be found in both the bat and in other species, the extrapolation will be tested to determine if the extrapolation can be validated. In all steps, information will have to be obtained to enable comparison of neonatal and adult female bats.

Another class of chemicals present in wood smoke that can pose a health hazard is irritants. The impact of these chemicals will also be investigated as described for carbon monoxide.

In a similar investigative manner, the other source of risk to bats, thermal injury, will be addressed. A working hypothesis is that thermal injury to the airways as bats inhale heated gases will be the first avenue of thermal injury, to be followed by skin injury. To model thermal injury, one first needs to be

able to estimate tissue temperature regimes in fires. Skin and airway characteristics for the bat will be sought and from them heat transfer coefficients will be estimated by approaches developed for other mammal species in similar thermal environments. We may expect that neonatal bats would be particularly prone to dermal injury because of poorly developed fur. An existing literature on the thermal tolerance of mammalian cells and tissues will be reviewed for appropriate parameter values for the above-noted models that have been used to describe thermal injury. Given an ability to predict temperature exposures and resulting thermal injury, an extrapolation will be developed to assess the burn risk for bats in wildland fire scenarios.

If appropriate information is available, the combination effect of both toxicological and thermal insults on the bat will be considered. The range of possible combination effects between the two insults includes independence, additivity, potentiation, and synergism.

## SMOKE AND HEAT EXPOSURES

***Plume and Inversion Characteristics.*** At a minimum, the following approach will be followed to describe plume gas concentrations and temperatures above wildland surface fires. A literature review will be used to describe gas production from the main flaming front in surface fires, with particular attention to hardwood fuels. Emission factors for flaming combustion will be used to translate the expected range of fuel consumption during the main fire front to the production of gases of interest (see above). It must be understood that smoke emission models for large-scale plume and atmospheric pollution work are not suitable for the small-scale, canopy-level plumes of interest in this study. Under the assumptions that mixing rates of gas species are similar and the heat budget of the plume is dominated by mixing with ambient air (i.e., convection), classical plume theory will be used to describe plume mixing and expansion with height above ground and, thus, gas concentrations and residence times at increasing heights above ground.

Smoke concentrations during inversions will be taken from the published and unpublished literature or calculated from assumptions about the amount of nighttime combustion (often smoldering alone) after prescribed fires and wildfires. The durations of exposures will be estimated from consideration of inversion climatology. As a first approximation, it will be assumed that bats in maternity crevices are exposed to the full gas concentrations in the inversions, that is, mixing rates into crevices are high relative to inversion duration. Unfortunately, the previously noted work by Ferguson *et al.* (2003a) appears to be the only published study of the vertical structure of nighttime smoke plumes from smoldering biomass. This study lasted a full week, during which nighttime stability varied, and thus gives a valuable indication of the range of vertical variability to be expected. More data are available in the non-refereed literature. Inversion climatology for the area of DBNF will be drawn from the report by Ferguson *et al.* (2003b) at the USDA Forest Service Pacific Northwest Research Station which is based on a 40 year database of windspeed, mixing height, and ventilation index. The report supplies the mean, median, standard deviation, and range of the ventilation index by regional airshed and by month. Using the inversion climatology and literature or calculated values of inversion smoke concentrations typical of wildland fires in hardwood forests, it should be possible to estimate the likely range of smoke exposures under nighttime inversions at different burning seasons, and to make a preliminary determination of whether bats are likely to be at risk from these exposures. A detailed treatment of mixing under the canopy is complicated because the usual daytime assumptions of similarity for different fluxes (heat, momentum, particles, and trace gases) are not generally valid (Mahrt *et al.* 2000, and references therein). Because the timescale of interest is long (the entire nighttime period), it should be sufficient for this project to estimate the average concentration and range of concentrations expected under the canopy. We note, however, that a strong subcanopy inversion can form under an open canopy under clear conditions, which would lead to strong stratification beneath the canopy and possibly much higher exposures nearer ground level (Mahrt *et al.*

2000, and references therein). This seems unlikely given the probable conditions in DBNF during a growing season burn, but will be explored as a possibility.

If we find in this study that bat risks associated with smoke concentrations typical of nighttime inversions after fires appear to be substantial, land managers might be served by the implementation of a smoke dispersion model. Gary Achtemeier (USFS, Southern Research Station) has developed a model to predict nighttime plume movement over uneven terrain via drainage flows given topographical information and detailed weather data (see Achtemeier 2002 and 2003). This “PB-Piedmont” model provides a smoke/no smoke prediction for a particular location on the terrain that might overlap with maternity roosts.

***Roosting crevice description.*** The crevices where female and neonate bats roost require a comprehensive description so that experimental measurement of gas mixing from simulated sub-canopy plumes can be made on suitable surrogate crevices. Known maternity roosts from across the summer range of the Indiana bat will be described during periods in which bats are not present. A mixture of quantitative and qualitative roost and crevice descriptors will be used. Safety considerations require that all measurements on crevices in dead roost trees be conducted remotely (from the ground or adjacent trees). Tree climbing ladders will be used to access crevices in live trees. Among other descriptors, crevice volume, opening characteristics (e.g., separation from tree bole, orientation, percentage of volume contiguous with outside air), and surface area of exfoliating bark plates will be estimated using non-destructive methods. Known maternity crevices will be compared with random crevices. With quantitative criteria of what constitutes a suitable crevice, suitable roosting crevices will be identified at the DBNF. This sample of suitable crevices will then be used to estimate the range of rates at which hot gases mix into crevices when surface fires pass below a roost tree. Local Indiana bat experts, including James Kiser (DBNF), will be consulted to identify a sample of suitable male Indiana bat roosting crevices for comparison with maternity roost crevices.

***Mixing of plume gases into roosting crevices.*** Gas mixing into suitable crevices will be determined for plume (vertical flow along trunk) and wind conditions (cross flow) for samples of different categories of roosting crevices. Categories will include crevices below exfoliating bark in dead primary maternity roost trees, crevices in live secondary maternity roost trees of different species (e.g., shagbark hickory, white oak), and male bat roosting crevices. Suitable crevices will be identified quantitatively from descriptions of known roosting crevices as described above.

To simulate the flow of a fire plume over roosting crevices, a flexible duct will be used to direct heated air from a blower across cavity entrances. The blower will be powered by a gas generator and an in-line heater will provide the required temperature differential between air flowing across the crevice and air inside the crevice. A hot-wire anemometer set will be placed both inside the crevice and outside in the simulated plume to measure temperatures and gas flow velocity. A small (~1cm<sup>2</sup>) CO<sub>2</sub> detector will be placed both within the crevice and in the simulated plume to measure CO<sub>2</sub> concentration. These small, rapid response electrochemical CO<sub>2</sub> sensors are built by Robert Kremens of the Rochester Institute of Technology. Carbon dioxide will be injected into the blower system at a rate calculated to provide an average concentration similar to that in a fire plume. The inner and outer cavity data will be combined with a characteristic cavity dimension (such as the volume to opening area ratio) to provide a general correlation for gas-mixing and temperature change within roosting cavities under a range of likely plume velocities (and thus fire intensities). For the analyses it will be assumed that turbulent mixing into crevices, and not diffusion, is the predominant mixing process, thus simplifying extrapolation from CO<sub>2</sub> to other gases (Over length scales > 1 cm and with flow speeds of as little as 1 cm/s, the assumption of turbulent [convective] mixing is reasonable [see Welty *et al.* 1976]).

Crevices in live trees will be accessed by tree climbing ladders. Safety considerations prevent work on crevices in dead trees. Two approaches will be used to describe gas mixing into crevices in dead trees

(snags). Snags are routinely felled along roadways in the DBNF. Prior to felling, a rented cherry picker will be used to access crevices and perform mixing experiments. If necessary, and as possible, snags will be felled and experiments performed on the ground.

## **RISK ASSESSMENT**

A program will be written to estimate risk to bats of injury and death as a function of nighttime inversion smoke concentrations and the characteristics of plumes above surface fires. The program will first produce time courses of gas concentrations and temperatures as a function of fire intensity (proportional to flame height), height above the ground, and wind speed from plume models. The ranges in typical prescribed and wildfire behavior will be considered. Bat exposures in crevices above fires will then be calculated from mixing equations parameterized for a range of cavities as noted above. Ranges in inversion gas concentrations and their durations will be based on the literature search and associated calculations. Finally, bat toxicology models will be run on the time courses of gas concentrations and skin and airway burn models will be run on time courses of cavity temperatures (after calculation of suitable convection heat transfer coefficients from hot gas to bat skin and airways).

## **COOPERATORS AND LINKAGES WITH OTHER PROJECTS**

JAMES BENNETT (Forest T&E Biologist, USDA Forest Service, Daniel Boone National Forest. Tele: 859-745-3173, Email: jimbenett@fs.fed.us) is the point person for this project on the DBNF. The DBNF will contribute substantial field support to this project if funded (see Budget). WEI MIN HAO (Project Leader, USDA Forest Service, Fire Chemistry Project, Fire Sciences Lab, Missoula, Montana. Tele: 406-329-4838, Email: whao@fs.fed.us) has agreed to provide assistance on obtaining smoke information for wildland fires. A large body of work on wildland fire smoke production has been completed through their Project. Data not included in refereed publications may be valuable.

This project will be an integral part of a larger group of Indiana bat projects being proposed at the DBNF on both the positive and negative effects of ecosystem management with fire (see Justification). If successful, we would coordinate with DBNF biologists to conduct a study on bat movement during prescribed burns (radio telemetry) in order to determine the extent to which adult roosting bats (females and males) change roosts when fires approach. The bat movement study would be conducted on a suitable Indiana bat surrogate species (e.g., the northern bat).

A 2005 Joint Fire Science Program proposal (Dickinson, Kremens, and Mell, "Fire Behavior and Effects Maps from Airborne IR Imagery") will produce predictions of plume behavior (temperatures, velocities, and gas concentrations) for a range of fire behavior and environmental settings (wind and slope) from a sophisticated coupled fire-atmosphere model. Experimental burns for that study would be conducted on the DBNF. If both projects were funded, there would be two strong linkages between the projects. For example, the bat effects modeling work would be added to the suite of ecological effects models proposed for estimating the effects of prescribed burns and wildfires from airborne IR imagery. In return, the current project could directly use the plume modeling results from the airborne IR project. In addition, experimental burns proposed for the airborne IR project on the DBNF would provide opportunities to further test bat exposures predicted in this study.

## **SCIENCE DELIVERY AND APPLICATION**

As requested by our DBNF cooperators, PI's will hold an annual meeting at the DBNF to report and discuss progress. At the end of the project, a workshop will be held including PI's and USFWS and USFS personnel with responsibilities for the Indiana bat. The workshop will be used to discuss the results of this and related projects on positive and negative effects of fire on Indiana bats and to deliver a USFS

technical document describing bat risk from heat and smoke generated by prescribed burning and wildfires.

**PROJECT DURATION, ACTIVITIES, RESPONSIBILITIES, AND TIMELINE**

This project will require approximately three years to complete (see Table 1). At the end of the third year, a risk analysis based on nomograms (a common tool in fire management for conveying multi-variable information) will be produced relating fire behavior (e.g., fire intensity and residence time) with plume characteristics (gas concentrations and temperatures), and bat injury and death in maternity roosts. Components completed concurrently by Norris, Young, Lacki, and Bova (see Table 1) during the first two years of the project are required to perform the risk analyses. Other deliverables and their due dates are described in Table 2.

A refereed publication will be produced on the risk analysis that synthesizes the toxicology, smoke, and roosting crevice work the year following completion of the project. Refereed publications will also be produced on each individual component of the project in years 2 and 3. These publications will be the responsibility of the individual Investigator(s) conducting the component study (Table 1).

Table 1—Activities, primary responsibilities of investigators, and timeline.

Activity	Primary Responsibility	Year 1		Year 2		Year 3	
Bat physiology and toxicology model development for predicting smoke and heat effects	Norris	■	■	■			
Assembly of literature data on inversion smoke concentrations and plume gas concentrations and temperatures	Young	■	■				
Model-based extrapolation of plume gas concentrations, velocities, and temperatures to bat roosting heights	Young		■	■			
Quantitative description of primary and secondary maternity roosting crevices and random crevices.	Lacki	■	■	■			
Identification of suitable roosting crevices in DBNF.	Lacki			■	■		
Methods development for field determinations of gas and heat mixing into cavities	Bova		■	■			
Field tests at DBNF to determine cavity mixing coefficients	Bova/Lacki			■	■		
Synthesize bat toxicology, plume and inversion characteristics, and cavity mixing to produce bat risk assessment	Dickinson				■	■	■

## DELIVERABLES

The primary deliverable for wildlife and land managers with responsibilities for the endangered Indiana bat will be a workshop and accompanying document on Indiana bat risk from wildland fire smoke and heat exposures. In addition, annual reports will be delivered by February 15 each year (Table 2). The final report to JFSP will be delivered by the project termination date (end-Year 3). Dickinson will be responsible for these reports. Refereed journal papers are discussed above.

Table 2 – Deliverables and delivery dates.

<b>Deliverable</b>	<b>Description</b>	<b>Delivery Date(s)</b>
Annual report	Report will cover initial results on all phases of the project (see above)	15 Feb. 2006
Annual Report	Report will cover final results from all phases of the project (see above)	15 Feb. 2007
Final Report	Final results and the synthesis model will be presented	15 Feb. 2008
USFS General Technical Report for USFWS and DBNF personnel with responsibilities for the endangered Indiana bat	Link bat toxicology models, plume and inversion characteristics, and cavity mixing to produce nomograms of bat injury/death for fire behavior associated with prescribed burns and wildfires	15 March 2008
Workshop for USFWS and USFS personnel with responsibilities for the endangered Indiana bat	Workshop will be based on the General Technical Report noted above and will be held at the DBNF.	15 May 2008 (to avoid conflicts with spring burning season)

## BUDGET

Funds will be distributed by the USFS Northeastern Research Station, Project 4153 (see Table 3). For administrative support, the Northeastern Research Station retains 10% on passthrough funding and 15% on direct Project 4153 costs. Agreements, below, are limited to a 20% maximum indirect rate, the remainder of indirect costs are contributed to the project. The field equipment to be purchased by NERS will include thermocouples, anemometers, data loggers, and electrochemical gas concentration sensors. The electrochemical sensors will be assembled by Robert Kremens of the Rochester Institute of Technology. The cherry picker will be used to access road-side snags on DBNF for describing plume gas mixing (estimated cost \$500/day).

We estimate that total in-kind and financial contributions will be considerably more than \$133K. A proposal has been submitted to Bat Conservation International to support the smoke toxicology work (\$2,000). These funds would be contributed towards Norris' costs and would reduce the JFSP grant by that same amount. Project 4153, Northeastern Research Station, will contribute Dickinson's salary (0.3 FTE, ~\$25,000/year) and a Project Manager's salary (0.1 FTE, ~\$4,000/year). Project 4153 will also contribute costs of the end-of-project workshop at DBNF (primarily travel at approximately \$5,000). Thus, total contributed costs from NERS, Project 4153, are expected to be \$92,000 over the three year project not including contributed equipment. Ohio University and University of Kentucky will both contribute 26% of their direct costs (total \$41,000). The Daniel Boone National Forest has agreed to assist with field work to (1) identify a sample of suitable maternity roost trees and crevices and (2)

estimate how smoke from a fire would mix into them. A vehicle would be provided for this effort for use on the DBNF by the University of Kentucky graduate student and NERS Physicist. As well, tree climbing ladders and safety equipment would be provided for work on crevices in live trees. Labor for any dead tree felling that is needed would also be provided. The value of these contributions is difficult to estimate and is not included in the estimate of contributed costs.

Table 3 - Project budget. Amounts are in thousands of dollars (\$1000 = \$1K).

	YEAR 1	YEAR 2	YEAR 3	Total
<b>USFS Northeastern Research Station, Project 4153</b>				
Salary - Term Physicist (0.5 FTE)	\$30.0K	\$31.0K	\$32.0K	\$93.0K
Travel - JFSP PI's meeting, field, and project meetings	2.0	2.0	2.0	6.0
Equipment - field equip/sensors for estimating cavity mixing	7.0	1.0		8.0
Equipment rental - cherry picker for accessing cavities		4.0		4.0
<b>Cooperative and Other Agreements</b>				
<u>Norris Consulting Services</u>				
Physiology and Toxicology modeling	18.0	18.0		36.0
Travel - meetings	2.0	2.0	1.0	5.0
<u>University of Kentucky</u>				
Phd Student stipend (3 years)	24.0	25.0	26.0	75.0
Travel – meetings, range range wide Indiana bat crevice assessment	4.0	4.0	1.0	9.0
Equipment and supplies for cavity quantification	4.0	1.0	1.0	6.0
Indirect costs (20%)	6.4	6.0	5.6	18.0
<u>Ohio University</u>				
MS student stipend (2.5 years)	21.0	22.0	12.0	55.0
Faculty time (2 weeks)	3.0	3.0	3.0	9.0
Travel - meetings	1.0	1.0	1.0	3.0
Indirect costs (20%)	5.0	5.2	3.2	13.4
<b>USFS Northeastern Research Station Indirect Costs</b>				
On passthrough funding (10%)	8.8	8.7	5.4	22.9
On direct costs (15%)	5.9	5.7	5.1	16.7
<b>Total per year and for project</b>	<b>142.1</b>	<b>139.6</b>	<b>98.3</b>	<b>380.0</b>

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## QUALIFICATIONS OF INVESTIGATORS

Following are CVs from Dickinson, Norris, Lacki, and Young. A summarized biographical sketch is also included for Bova.

### MATTHEW B. DICKINSON

#### Education

1998 Ph.D., Biology (Ecology and Evolution), Florida State University  
1991 M.S., Biology (Ecology and Evolution), Florida State University  
1988 B.S., Marine Biology, Texas A&M University, Galveston (Magna Cum Laude)

#### Professional Experience (since 1995)

2001-present Research Ecologist, USDA Forest Service  
1997-2001 Postdoctoral Associate, University of Calgary  
1994-1995 Research Associate, Smithsonian Environmental Research Center (in Mexico)  
1995-1996 Research Assistant, Tall Timbers Research Station

#### Research Interests

Tree mortality in wildland fires, mechanistic modeling of ecological processes, forest fire extinction, forest fire spread and effects in a landscape context, ecosystem process modeling.

#### Selected Publications and Presentations

- Bova, A. S., Kremens, R., and **Dickinson**, M. B. 2004. Calibrating aerial IR imagery with ground-level observations of a prescribed burn for predicting ecological effects. Ecological Society of America, 89th Annual Meeting, Portland, OR. CD-ROM p.57.
- Bova, A. S., and **Dickinson**, M. B. 2004. Linking surface fire behavior, stem heating and tissue necrosis. Canadian Journal of Forest Research, accepted.
- Bova, A. S., and **Dickinson**, M. B. 2004. Estimating fire intensity and fuel consumption from thermocouple probe response to surface fires. Canadian Journal of Forest Research, in review.
- Dickinson**, M. B., and E. A. Johnson. 2004. Temperature-dependent rate models of vascular cambium cell mortality. Canadian Journal of Forest Research 34:546-559.
- Dickinson**, M. B., Jolliff, J., and Bova, A. S. 2004. Vascular cambium necrosis in forest fires: using hyperbolic temperature regimes to estimate parameters of a tissue-response model. Australian Journal of Botany, in press.
- Jones, J. L., Webb, B. W., Butler, B. W., **Dickinson**, M. B., Jimenez, D., Reardon, J., and Bova, A. S. 2004. Prediction and Measurement of Thermally-Induced Mortality in Tree Stems. Canadian Journal of Forest Research, in review.
- Wildman, R. A., Hickey, L. J., **Dickinson**, M. B., Berner, R. A., Robinson, J. M., Dietrich, M., Essenhigh, R. H., Wildman, C. B. 2004. Burning of forest materials under late Paleozoic high atmospheric oxygen levels. Geology 32(5):457-460.
- Yaussy, D. A., M. B. **Dickinson**, and A. S. Bova. 2004. Prescribed surface-fire tree mortality in southern Ohio: equations based on thermocouple probe temperatures. *Proceedings of the 14<sup>th</sup> Central Hardwoods Forest Conference*, March 16-19, Wooster, Ohio. USDA Forest Service, General Technical Report NE-316. P. 67-75.
- Dickinson**, M. B. 2002. Heat transfer and vascular cambium necrosis in the boles of trees during surface fires. In : X. Viegas (ed.) *Forest Fire Research & Wildland Fire Safety*, Millpress, Rotterdam.
- Dickinson**, M. B., and E. A. Johnson. 2001. Fire effects on trees. In E. A. Johnson and K. Miyanishi (eds) *Forest Fires: Behavior and Ecological Effects*. Academic Press.
- Gutsell, S. L., E. A. Johnson, K. Miyanishi, J. E. Keeley, M. B. **Dickinson**, and S. R. Bridge. 2001. Varied ecosystems need different fire protection. Letter, Nature 409:977.

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- Dickinson**, M. B., and E. A. Johnson. Predicted spread and extinction of surface fires in aspen and conifer fuels in the Canadian mixedwood boreal forest. Ecological Society of America Annual Meeting, Snow Bird, Utah. August 2000.
- Dickinson**, M. B. Fire effects on trees. National Center for Ecological Analysis and Synthesis, Santa Barbara, California. April 1999.

#### **Professional Societies**

Ecological Society of America, American Association for the Advancement of Science, International Association for Fire Ecology.

#### **Competitive Grants**

- Agenda 2020 Program, Northeastern Research Station, \$120,000, " Mapping Landscape Forest Canopy Structure with High Resolution Satellite Imagery", with Dr. Conghe Song, 2005-2007.
- National Science and Engineering Research Council of Canada, National Centers of Excellence, Sustainable Forest Management Network, \$45,000, "Fire Ignition and Extinction in the Mixed-Wood Boreal Forest", with Prof. E. A. Johnson, 1999-2001.
- US Man and the Biosphere Program, \$20,000, with D. F. Whigham, N. V. L. Brokaw, and L. Poot-Chan, for work on mahogany regeneration in Mexico and Belize, 1995-1997.
- Smithsonian Institution, \$36,000, for work on tree regeneration and bird response to logging in Quintana Roo, Mexico, 1992-1995.

### **JAMES C. NORRIS**

#### **Certifications**

Diplomate of the American Board of Toxicology (D.A.B.T.)  
Eurotox Registered Toxicologist

#### **Education**

Ph.D., Pharmacology/Toxicology, University of Mississippi Medical Center  
M.S., Chemistry, University of Mississippi  
B.S., Chemistry, University of Montevallo

#### **Professional Experience**

- June 1986-Present: Consultant for industrial projects, industrial representative, on-site industrial crisis management member, testimonial witness to governmental agencies, and expert witness for litigation.
- March 2003-Present: General Manager. Toxicology Laboratory. Redfield, AR.
- March 2001-March 2003: Assistant Vice President, Toxicology and Carcinogenicity, IITRI, Chicago, IL
- March 1998-March 2001: Head, Inhalation Toxicology, Harrogate, North Yorkshire, England.
- August 1995-November 1997: Toxicologist, Oak Ridge National Laboratory.
- February 1990-July 1995: Toxicologist, Bushy Run Research Center (BRRC)/Union Carbide Corporation.
- June 1986-February 1990: Toxicologist, Fire Technology Unit, Weyerhaeuser Company.

#### **Professional Societies and Affiliations**

Society of Toxicology (Full member)  
British Toxicology Society (Full Member)  
Editorial Board

*Inhalation Toxicology*  
*Journal of Fire Sciences*  
International Organization for Standardization  
Convenor (Fire Models)  
Designated expert (Fire Safety Engineering)  
American Society of Testing and Materials (past Subcommittee chair)  
National Fire Protection Association

### **Areas of Expertise**

Central nervous system, inhalation toxicology, biochemistry, combustion or fire toxicology, fire retardant chemicals, multiple chemical sensitivity, human health risk assessment, industrial chemicals, pharmaceuticals, pesticides, anesthetic agents, cyanide, and carbon monoxide.

### **Presentations/Abstracts**

- Norris, J.C. Dupont Plaza Fire – Toxicological Considerations. International Conference on Fire Research & Engineering. Society of Fire Protection Engineers and the National Institute of Standards and Technology. September 1995.
- Norris, J.C. Combustion Toxicology and Fire Safety Engineering in the International Standardization Organization. Fire Retardant Chemicals Association's Fire Safety Developments from Around the World. Orlando, FL. March 1995.
- Norris, J.C. Combustion Toxicity Problems. International Union of Forestry Research Organisations, Nancy, France. August 1992.
- Norris, J.C. Investigation of the Dual LC50 Values of Woods Using the University of Pittsburgh Combustion Toxicity Apparatus. Fifteenth Annual Fire Product Safety Conference, San Francisco, CA. January 1990.
- Norris, J.C. Toxicity of Smoke. Underwriter's Laboratories' Professional Awards Program. Santa Clara, CA. February 1989.

### **Chapters**

- Norris, J.C. and Ballantyne, B. 1993. Combustion Toxicology. In: General and Applied Toxicology. Editors: Ballantyne, B., Marrs, T., and Turner, P. Macmillan Press Ltd.
- Norris, J.C., Nabeshima, T., Fontenot, H.J., Wilson, R.D. and Ho, I.K. 1984. Phencyclidine and GABA System. In: Cellular and Molecular Basis of Neurotoxicity of Environmental Agents. Editor: T. Narahashi. Raven Press, New York.

### **Papers**

- Norris, J.C. and Tyler, T.R. 2000. Inhalation Toxicity Studies of Aqueous Dispersion Resin. *Inhalation Toxicology* 12: 101-116.
- Norris, J.C., Nachreiner, D.J., Tyler, T.R., Kliminish, H.J., and Zimmerman, D.D. 1997. Acute Inhalation Toxicity Studies of n-Butyl Acetate. *Inhalation Toxicology* 9: 623-646.
- Cushman, J.R., Norris, J.C., Dodd, D.E., Darmer, K.I. and Morris, C.R. 1995. Subchronic Inhalation Toxicity and Neurotoxicity Assessment of Cumene in Fischer 344 Rats. *J. Amer. Coll. Tox.* 14(2): 129-147.
- Norris, J.C., Edwards, D.A., Soranno, T.M., Frick-Miranda, S., Janke, B., and Gephart, L.A. 1993. Pilot Studies of the Thermal Emissions for Several Polymeric Substances Using a Modified DIN 53 436 Apparatus. *Toxicologist* 13(1): 48.
- Norris, J.C., Utley, W.S. and Hume, A.S. 1990. Mechanism of Antagonizing Cyanide-Induced Lethality by alpha-Ketoglutaric Acid. *Toxicology* 62: 275-283.
- Norris, J.C. and Hume, A.S. 1987. In Vivo Release of Cyanide from Sodium Nitroprusside. *British J. Anaesthesia* 59: 236-239.

- Norris, J.C., Moore, S.J. and Hume, A.S. 1986. Synergistic Lethality Induced by the Combination of Carbon Monoxide and Cyanide. *Toxicology* 40: 121-129.
- Norris, J.C., Nabeshima, T. and Ho, I.K. 1983. Effects of Phencyclidine on gamma-Aminobutyric Acid Receptors in the Mouse. *Res. Commun. Subst. Abuse* 3: 409-420.

## MICHAEL J. LACKI

### Employment History

- 2000 - 2004 Assoc. Professor, Dept. Forestry, Univ. Kentucky
- 1996 - 1999 Assoc. Prof. & Director of Graduate Studies, Dept. Forestry, Univ. Kentucky
- 1995 Assist. Prof. & Acting Director of Graduate Studies, Dept. Forestry, Univ. Kentucky
- 1990 - 1994 Assist. Professor, Dept. Forestry, Univ. Kentucky
- 1986 - 1989 Assist. Prof. & Program Leader, Wildlife Technology Program, The Pennsylvania State Univ.
- 1984 - 1986 Visiting Assist. Prof., Center for Earth & Environ. Sci., SUNY at Plattsburgh

### Education

- 1981 - 1984 North Carolina State Univ. - Ph.D. in Zoology, **Dissertation:** The effects of rooting by wild boar on tree growth and nutrient cycling in Great Smoky Mountains National Park
- 1978 - 1980 The Ohio State Univ. - M.S. in Zoology, **Thesis:** A survey of bats in Wayne National Forest
- 1974 - 1978 Univ. of Dayton - B.S. in Biology, (Graduated **Magna Cum Laude**)

**Grants & Contracts:** (number awarded = **27**; amount awarded = **\$1,185,356.00**). Includes recent grants on bat roost characteristics (2001-2005: Roost-site selection and roost microclimates of tree-roosting bats in coniferous forests of the Pacific Northwest - **\$273,175.00** – Northwest Bat Cooperative [PI]; 2000-2001: Selection of day roosts by eastern small-footed bats - **\$4,330.00** – U.K. Research Committee Grant [PI]; 1999-2000: A comparison of natural versus artificial maternity roosts of *Myotis septentrionalis* - **\$3,750.00** - Bat Conservation International [Co-PI]).

### Selected Publications & Manuscripts in Review Post-1995

- Baker, M. D., and M. J. **Lacki**. Roosting habitat of female long-legged myotis in Ponderosa pine forests. *Journal of Wildlife Management*, in review
- Lacki**, M. J., and M. D. Baker. 2003. A prospective power analysis and review of habitat characteristics used in studies of tree-roosting bats. *Acta Chiropterologica* 5:199-208.
- Miller, D. A., E. B. Arnett, and M. J. **Lacki**. 2003. Habitat management for forest-roosting bats of North America: a critical review of habitat studies. *Wildlife Society Bulletin* 31:30-44.
- Hutchinson, J. T., and M. J. **Lacki**. 2001. Possible microclimate benefits of roost site selection in the red bat, *Lasiurus borealis*, in mixed mesophytic forests of Kentucky. *Canadian Field-Naturalist* 115:9-13.
- Lacki**, M. J., and J. H. Schwierjohann. 2001. Day-roost characteristics of northern bats in mixed mesophytic forest. *Journal of Wildlife Management* 65:482-488.
- Lacki**, M. J. 2000. Effect of trail users at a maternity roost of Rafinesque's big-eared bats. *Journal of Cave and Karst Studies* 62:163-168.
- Hutchinson, J. T., and M. J. **Lacki**. 2000. Roosting behavior and foraging activity of a female red bat with nonvolant young. *Bat Research News* 41:36-38.
- Hutchinson, J. T., and M. J. **Lacki**. 2000. Selection of day roosts by red bats in mixed mesophytic forests. *Journal of Wildlife Management* 64:87-94.

Hurst, T. E., and M. J. **Lacki**. 1999. Roost selection, population size and habitat use by a colony of Rafinesque's big-eared bats (*Corynorhinus rafinesquii*). *American Midland Naturalist* 142:363-371.

#### **Additional Selected Publications & Published Abstracts**

**Lacki**, M. J. 2003. The need for scientific rigor in habitat studies of forest bats. *Bat Research News* 44:17-18.

Baker, M. D., and M. J. **Lacki**. 2002. Importance of slope position and type of bark in selection of day roosts by *Myotis volans*. *Bat Research News* 43:134.

**Lacki**, M. J. 2002. Conference summary. Pp. xi-xii, in Kurta, A., and J. Kennedy, editors. *The Indiana bat: biology and management of an endangered species*. Bat Conservation International, Inc., Austin, Texas. 253 pp.

Perkins, J. M., and M. J. **Lacki**. 2000. An assessment of a snag model for roosting bats in Douglas fir forests. *Bat Research News* 41:134.

Hutchinson, J. T., and M. J. **Lacki**. 1997. Roost site selection of red bats in mixed mesophytic forests. *Bat Research News* 38:115.

#### **Selected Papers, Workshops & Seminars Presented (Post-1995)**

**Lacki**, M. J. 2004. Use of day roosts by *Myotis volans* and *Myotis thysanodes* in coniferous forests on the east side of the Cascade Crest. Oregon Chapter of The Wildlife Society Annual Meeting. Bend, Oregon. **Invited**.

**Lacki**, M. J. 2001. The 2001 Indiana bat symposium: Introductory remarks. *The Indiana Bat Symposium: Biology and Management of an Endangered Species*. Lexington, Kentucky.

Perkins, J. M., and M. J. **Lacki**. 2000. An assessment of a snag model for roosting bats in Douglas fir forests. 30<sup>th</sup> Annual North Amer. Symp. on Bat Research. Coral Gables, Florida.

**Lacki**, M. J., and J. H. Schwierjohann. 1999. Selection of day roosts by northern bats (*Myotis septentrionalis*) in mixed mesophytic forest. 9<sup>th</sup> Colloquium on Conservation of Mammals in the South-Central United States.

**Lacki**, M. J. 1998. Roosting ecology of a Nearctic phytophilic bat. Seminar presented at the University of Kentucky (Dept. of Biological Sciences).

**Lacki**, M. J. 1995. The role of research on conserving bats in managed forests. *Bats and Forests Symposium*. Victoria, British Columbia. **Invited**.

**Advising:** PhD Students (2), MS Students (15), Post-doctoral Scholars (1)

**Professional Memberships:** American Society of Mammalogists, Society for Conservation Biology, Southeastern Bat Diversity Network, and The Wildlife Society (Kentucky State Chapter, Southeast Section, & National Chapter)

#### **Selected Professional Activities (Leadership roles are highlighted)**

2004 **Chair of the Publications Committee** for the 2<sup>nd</sup> Bats and Forests Symposium and Workshop. Hot Springs, Arkansas.

2001 **Host and Chair** for The Indiana Bat Symposium: Biology and Management of an Endangered Species. Lexington, Kentucky.

1992-1998 Ad-Hoc Recovery Team for the Virginia Big-eared Bat U.S. Fish and Wildl. Service.

1997 Workshop Participant Evaluating the HSI Model of the Indiana Bat U.S. Fish and Wildl. Service. St. Louis, Missouri.

## VALERIE L. YOUNG

### Education:

- 1992 Ph.D., Virginia Polytechnic Institute and State University, major: Chemical Engineering  
1988 B.S., Lehigh University, major: Chemical Engineering

### Experience Relevant to Atmospheric Chemistry Research

- 1996 - Present DEPARTMENT OF CHEMICAL ENGINEERING, OHIO UNIVERSITY Associate Professor (Assistant Professor 1996 – 2003). Development and implementation of methods for quantifying trace organic species in the troposphere; importance of local sources vs. transport in rural air quality; source apportionment. Measurement of ambient non-methane hydrocarbons (NMHCs) and other trace gases as part of multiple collaborative investigations of regional air quality, photochemical smog, particulate matter, and biomass burning. Collaboration with National Oceanic and Atmospheric Administration, US EPA, Ohio EPA, Pacific Northwest National Labs, several universities. Partner in Consortium for Energy, Economics, and the Environment at Ohio University.
- 1992 - 1996 CENTRE FOR ATMOSPHERIC CHEMISTRY, YORK UNIVERSITY Post-doctoral Fellow for Professor Hiromi Niki (*deceased April 1, 1995*). Study of reactive trace atmospheric gases, both in laboratory kinetics experiments and by identification and quantitation of species in the field. Ambient NMHC measurements in the boreal forest (BOReal Ecosystem Atmosphere Study), the Arctic (Polar Sunrise Experiment 1994, 1995), the eastern United States and Canada (Southern Oxidant Study 1995, 1996, Southern Ontario Oxidant Study), Africa (Southern Africa Fire-Atmosphere Research Initiative), and Newfoundland (Arctic Outflow Study). Collaboration with NOAA, Brookhaven, environment Canada, Ontario Ministry of Environment and Energy, several universities. Determination of atmospheric reaction mechanisms of hydrocarbons and halocarbons using long-path FTIR spectroscopy. Contract research to determine global warming and ozone depletion potential of proprietary chemicals.

**Professional Qualifications:** Certificate of Engineer-in-Training awarded in Pennsylvania on April 16, 1988. Member Tau Beta Pi, Omega Chi Epsilon, American Geophysical Union, American Society for Engineering Education, American Chemical Society, American Institute of Chemical Engineers.

### Peer-Reviewed Publications Related to Biosphere-Atmosphere Interactions

- DiCarlo, P., W.H. Brune, M. Martinez, H. Harder, R. Leshner, X. Ren, T. Thornberry, M.A. Carroll, V. Young, P.B. Shepson, D. Riemer, E. Apel, and C. Campbell, "Missing OH Reactivity in a Forest: Evidence for Unknown Reactive Biogenic VOCs", *Science*, 30 April 2004, 722 – 725.
- Sumner, A.L., P.B. Shepson, T.L. Couch, T. Thornberry, M.A. Carroll, S. Sillman, M. Pippin, S. Bertman, D. Tan, I. Faloona, W. Brune, V. Young, O. Cooper, J. Moody, W. Stockwell, "A Study of the Formaldehyde Budget above a Forest Canopy", *The Journal of Geophysical Research*, 106(D20), 24387-24405, 2001.
- Hurst, J.M., D.J. Barket, Jr., O. Herrera-Gomez, T.L. Couch, P.B. Shepson, I. Faloona, D. Tan, W. Brune, H. Westberg, T. Biesenthal, V. Young, J.W. Munger, M.A. Carroll, "Investigation of the Nighttime Decay of Isoprene", *The Journal of Geophysical Research*, 106(D20), 24335-24346, 2001.

- Stroud, C.A., J.M. Roberts, P.D. Goldan, W.C. Kuster, P.C. Murphy, E.J. Williams, D. Hereid, D. Parrish, D. Sueper, M. Trainer, F.C. Fehsenfeld, E.C. Apel, D. Riemer, B. Wert, B. Henry, A. Fried, M. Martinez-Harder, H. Harder, W.H. Brune, G. Li, H. Xie, V.L. Young, "Isoprene and its oxidation products, methacrolein and methylvinyl ketone, at an urban forested site during the 1999 Southern Oxidants Study", *The Journal of Geophysical Research*, 106(D8), 8035-8046, 2001.
- Roberts, J.M., J. Williams, K. Baumann, M.P. Buhr, P.D. Goldan, J. Holloway, G. Hübler, W.C. Kuster, S.A. McKeen, T.B. Ryerson, M. Trainer, E.J. Williams, F.C. Fehsenfeld, S.B. Bertman, G. Nouaime, C. Seaver, G. Grodzinsky, M. Rodgers, and V.L. Young, "Measurements of PAN, PPN and MPAN made during the 1994 and 1995 Nashville Intensives of the Southern Oxidant Study: Implications for Regional Ozone Production from Biogenic Hydrocarbons", *The Journal of Geophysical Research*, 103(D17):22473-22490, 1998.
- Williams, J., J.M. Roberts, F.C. Fehsenfeld, S.B. Bertman, M.P. Buhr, P.D. Goldan, G. Hübler, W.C. Kuster, T.B. Ryerson, M. Trainer, and V. Young, "Regional ozone from biogenic hydrocarbons deduced from airborne measurements of PAN, PPN, and MPAN", *Geophysical Research Letters*, 24(9), 1099-1102, 1997.
- Young, V. L., B. N. Kieser, S. P. Chen and H. Niki, "Seasonal Trends and Local Influences on Non-Methane Hydrocarbon Concentrations in the Canadian Boreal Forest", *The Journal of Geophysical Research*, 102, 5913-5918, 1997.

#### **ANTHONY BOVA**

Anthony received a B.S. in physics from The Evergreen State College in Olympia, Washington. Working as a laboratory technician in the college's scientific computing facility brought him into frequent contact with environmental scientists and kindled his interest in the application of physics to ecological systems. As an undergraduate he developed an original method, published in the *International Journal of Fluid Dynamics*, to visualize vortex formation over delta wings. His work with the Forest Service focuses on heat transfer, fluid dynamics and fire effects. Along with Dr. Matt Dickinson, he has an upcoming publication in the *Canadian Journal of Forest Research* on tree tissue necrosis resulting from fires, and manuscript in review on new methods for thermocouple use in fires. Anthony presented the preliminary results of Wildfire Airborne Sensor Project (WASP) data from a prescribed burn in SE Ohio at the 2004 meeting of the Ecological Society of America, and he and Dr. Dickinson are invited co-speakers at a fire ecology symposium on fire effects at the 2005 ESA meeting. Anthony's most recent work includes coding subroutines that combine with mesoscale meteorological predictions to predict fuel moisture and fire intensities, and implementing inverse heat conduction algorithms to estimate surface heat flux of stems exposed to fire.

**US FISH AND WILDLIFE SERVICE LETTER OF SUPPORT**

BRIAN COLE, Field Supervisor with the US Department of Interior, Fish and Wildlife Service has provided a letter of support for this project. BRIAN COLE and his staff have primary responsibility for the endangered Indiana bat.