DETECTION OF FIRE BY EASTERN RED BATS (*LASIURUS BOREALIS*):

AROUSAL FROM TORPOR

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INTRODUCTION

Eastern Red Bat

The eastern red bat (*Lasiurus borealis)* is in the Family Vespertilionidae in the Order Chiroptera. Other members of the family in Missouri include the hoary bat (*Lasiurus cinereus)*, eastern red bat (*Lasiurus borealis)*, eastern pipistrelle (*Pipistrellus subflavus*), big brown bat (*Eptesicus fuscus*), northern long-eared bat (*Myotis septentrionalis*), and the evening bat (*Nycticeius humeralis)*. The common name of the red bat is due to red fur that covers their body, the dorsal surface of the tail, and some parts of the membrane on the wings. The red color closely resembles that of dead leaves, which aids in camouflage. During winter, eastern red bats occur throughout the southeastern United States and northeastern Mexico, but concentrations are highest in coastal Atlantic and Gulf of Mexico regions (Cryan 2003). During spring, the range of the red bat expands into the Great Lakes and the Great Plains regions, followed by further expansion to the north and west during summer (Cryan 2003). Like other members of the family, they are insectivorous with a diet consisting of mostly moths (Lepidoptera), flies (Diptera), and beetles (Coleoptera) (Whitaker et al. 1997). Red bats mate from August to September and the sperm are stored over the winter. Fertilization occurs in the spring and young are born in June (Shump and Shump 1982).

Roosting behaviors differ among species of bats. Until recently, most of the information about bat roosts and roosting behavior came from observations made at caves, mines, or artificial structures (Menzel et al. 1998). Red bats almost never use these structures (Saugey et al. 1989). Instead, red bats roost individually in trees where they are rarely visible and infrequently encountered. During the day, red bats commonly roost in edge habitats adjacent to streams, open fields, and in urban areas (Shump and Shump 1982). During the summer months, red bats roost in foliage of deciduous trees or tree trunks (Mager and Nelson 2001).

In Missouri, winter temperatures can often be variable, and red bat roosting behavior corresponds with this variability. Daily temperatures can range from 0°C to 20°C night to night. Red bats often forage during warm evenings. However, if the temperature gets cold (0-5°C), they drop from the trees and go torpid in the leaf litter (Mormann 2005). There have been other observations that further support claims concerning use of leaf litter on the forest floor by bats in winter (Moorman et al. 1999). This behavior is uncommon among bats. Previously, it was believed that all red bats (and other species) migrated to more southern areas (Cryan 2003). However, recent studies in Missouri have shown that red bats remain throughout the winter months (Boyles et al. 2003, Mormann 2005).

Torpor

Mammals are endotherms, which means they keep their body temperatures relatively constant and produce body heat internally. During extreme temperatures, mammals must use different thermoregulation methods than when in moderate temperatures to conserve energy. Mammals can thermoregulate behaviorally or physiologically. Because the surface area/volume ratio of individuals increases with decreasing size, many small endotherms, like bats, must produce substantial amounts of heat to compensate for high heat loss during exposure to cold temperatures (Geiser 2004).

Red bats, like other temperate species of bats, go into deep torpor during the winter months to cope with cold temperatures (Mormann 2005). During deep torpor, or hibernation, heart rate, metabolic rate, respiration, and blood flow decrease drastically (Heller and Ruby 2003). Daily torpor, or shallow torpor, is not as extreme physiologically, but similar changes still occur in the body. In the summer, most temperate bats enter shallow torpor during the day except when they are pregnant or caring for young.

A factor that contributes to entry into deep torpor during winter months is the scarcity of food. Animals go into torpor when the net loss of energy due to remaining euthermic and finding food exceeds the energy used to stay torpid. It is unknown why bats arouse from torpor during the winter, but one reason may be to search for food (Whitaker et al. 1997). The cues that trigger bats to arouse from torpor are still being examined. According to thermoenergetics, the depths of torpor can vary, and the deeper the torpor, the longer it takes to arouse. Temperature affects arousal time, and the colder it is, the longer it takes the bat to arouse. It is energy costly to arouse from torpor and the longer it takes to arouse, more energy is needed.

Arousal is the process of coming out of torpor. Sympathetic nerves send messages to the brown fat. Norepinephrine is the neurotransmitter that binds to the surface of the brown fat to trigger non-shivering thermogenesis. This starts the process of arousal.

Since red bats hibernate in the leaf litter of mid-latitude forests, prescribed burns in late fall and early spring have the potential to affect these bats. The presence of torpid bats in forest leaf litter can be a challenge for conservation managers. For example, many wildlife areas use prescribed burns as a management tool. These burns typically occur during the months when red bats occupy the leaf litter. The purpose of my study is to determine whether environmental cues associated with fire (sound, smoke) cause red bats to arouse from torpor. Bats may take more than 30 minutes to arouse from hibernation (if they succeed at arousing at all), making it difficult for those not hibernating in more protected cave or mine refugia to reach a body temperature and activity level sufficient to escape a fire threatening a roost (Carter et al. 2002).

Fire Management

Prescribed burns are often used by wildlife managers to remove the low, dead, or unhealthy flora and to remove introduced species from an area. Until recently, fire disturbance was generally considered a bad thing because it replaces “mature” with “immature” communities, upsets a theoretical equilibrium state, and renders nature untidy (Rowe and Scotter 1973). However, there is evidence that forest productivity can be higher in early than in late stages of ecosystem development, so that rejuvenation by periodic perturbations (fires) may often prove desirable if high productivity is the goal (Rowe and Scotter 1973). Recent research suggests that shelterwood harvesting, followed several years later by fire, does favor oak regeneration (Brose et al. 1999). In Virginia, a study found that oak regeneration was more resistant to fire than yellow-poplar reproduction. Fire intensity was critical in controlling yellow-poplar regeneration improved the form and growth rate of sprouting oaks. Higher fire intensity (very hot fire) was needed for an increased succession of regeneration for oaks (Brose et al. 1999). A major problem in Missouri (and other states) is that native hardwood forests have been over-populated with red cedars (*Juniperus virginianus*) and other weedy species. Prescribed burning is an effective method of suppressing these invasive species.

Conservation managers have to decide what conditions are right for burning and which species will be affected by these burns. Wind speeds, wind direction, temperature, humidity, and slope are just a few factors that managers have to consider when setting a prescribed burn. These burns typically are done in late fall/early winter and late winter/early spring, when conditions are most favorable. Variation of inter-fire intervals through time appears to be primarily responsible for maintaining the presence of a wide variety of species in a particular community (Gill and McCarthy 1998). An invariant fire interval for maximizing the density of dominant species may be detrimental in the long term for plant-species diversity (Keith and Bradstock 1994).

Very little is known about how red bats, which might be torpid in the leaf litter, are affected by prescribed burns or natural fires, but they have been observed fleeing from a burning area into a nonburned area (Rodrigue et al. 2001). It has been reported that bats have been "smoked" from their hibernation sites during a prescribed winter burn in Arkansas, and it is believed that these bats were eastern red bats resting in leaf litter on the forest floor (Saugey et al. 1989). While conducting low-intensity strip-head prescribed fires in a hardwood forest in South Carolina, Moorman et al. (1999) observed that bats aroused during the burns and flew as the strip fires approached. During another burn in South Carolina, where two bats were observed to rouse, the ambient temperature of the day of the burn was 14°C and the previous night was 0°C. Red bats can be found torpid in the leaf litter during the time of prescribed burns. Fire conservation managers are not always aware of the mortality they may be inflicting on red bats. Destruction of roosts may be the most important factor in the decline of bat populations in North America (Menzel et al. 1998). In the case of red bats in winter, roosts are in the leaf litter on the ground where they are hibernating. Depending on the temperature, they may also be torpid in the leaves on the branches of trees.

Senses

Bats have a very acute sense of hearing. Bats can hear the frequencies that they use to echolocate. Red bats can echolocate between the frequencies of 35 – 56 kHz (Murray et al. 2001). In contrast, humans can only hear from 0.02 – 20 kHz. Red bats make audible (to humans) clicks and respond to a human's voice. The sound of the fire may be a factor that causes bats to arouse from torpor during burns.

The olfactory mucosa is used for sense of smell and is located within the nasal passage. Olfactory communication is used in many species of bats for kin-recognition, territorial markers, and reproductive status (Bloss et al. 2001). Little research has been done on the sense of smell in red bats, but it could be used in recognition of the smell of smoke.

Objectives

In this study, lab experiments were performed to: (1) determine how long it takes for red bats to arouse from torpor at 5°C and (2) determine whether the sounds or smells that signal an approaching fire can cause red bats to arouse from torpor. The treatments that will be tested are control sound (white noise), control scent (air without smoke), smoke, the sound of fire, and a combination of smoke and the sound of fire. I hypothesize that red bats: (1) will arouse quicker when exposed to smoke rather than the smoke-control; (2) will arouse quicker when exposed to the sound of fire rather than the sound-control (white noise); and (3) will arouse the fastest when exposed to the combination of smoke and the sound of fire.

METHODS AND MATERIALS

Eastern red bats used for this study were caught via mist net at Peck Ranch Conservation Area (PRCA) in Carter Co. Missouri. The area consists of approximately 23,048 acres (9,327 hectares) of forest, limestone and rhyolite glades, and wildlife food plots. Oak/pine forests dominate the area and are often managed by prescribed burns. Bats were captured in mist nets that were set across service roads during the evenings from November 2005 to March 2006. All bats used in this experiment were males (except for one female used in the arousal test). The sample size was 15 bats.

Basic Maintenance

During captivity, bats were kept in plastic cages (31 x 19 x 17cm) with a Styrofoam substrate (29 x 17 x 2cm) covered with leaves. Mealworms (11 per bat) and water was provided each day (unless the bats were torpid). They were allowed to fly in a large room (1080 x 750 x 300cm) once a week for exercise. Bats were kept at room temperature (20° - 25°C) when they were not being tested.

Arousal Test

Prior to hibernation (November of 2005), one male and one female eastern red bat were placed in a cage in an environmental chamber (240 x 220 x 160cm) at 5° C 24 hours prior to the test to induce torpor. To determine how long it takes for bats to arouse from torpor, each bat was removed from its cage (43 x 43 x 37cm) using a glove to minimize heat exchange, and placed on a table. A plastic probe was repeatedly used to gently agitate the bat by tapping it (on dorsal side of body) to induce arousal and this arousal process was timed. Arousal was determined as the moment when the bat moved on its own from one place on the table to another. Data from this trial provided baseline information for comparison with the other trials in this experiment. The female (#1) was tested once and the male (#2) was tested twice. For these preliminary trials, arousal times ranged from 50 – 70 minutes (mean ± SE = 60.3 ± 5.8; Table 1 in Appendix). Therefore, we used 1 hour as the time limit for the other arousal tests.

Treatments

From January to March 2006, 15 red bats completed the series of five tests. Arousal times were determined after exposure to five different treatments: A = fire sound with smoke; B = control sound (white noise); C = fire sound; D = smoke; and E = control smoke. To avoid any order-effects, the sequence of treatments was varied, and bats (3 bats per sequence) were assigned randomly to one of the following sequences, identified by numbers: 1 = ABCDE, 2 = EADCB, 3 = DEABC, 4 = CDBEA, 5 = BCEAD.

For each arousal test, a bat was placed in a test cage (31 x 19 x 17cm), which had a plastic base and metal wires for structure. Plastic mesh was placed on the inside surrounding the wires so the bats could climb and hang (Figure 1), but not escape or hurt themselves. A piece of Styrofoam (29 x 17 x 2cm) was placed on the cage floor to act as a buffer to simulate the ground of a forest floor. Oak leaves were added for cover. When an arousal test was to be conducted, the plastic cage with the bat inside was placed in a glass front environmental chamber (Figure 2) 24 hours prior to the test to induce torpor.

Figure 1. Plastic cage used to hold the bat during treatment tests.

Two glass front environmental chambers (Avanti model WC492D 47 x 43 x 83cm) were used for the tests to maintain cold temperatures (5± 0.5° C). One was used for the control smoke treatment and another was used for the smoke, sound, and sound/smoke combination tests; this protocol insured that the control smoke chamber was not contaminated with smoke. Once the bats completed the sequence of tests, they were released in PRCA at the point of capture. The position of the bat was also recorded, (i.e., hanging from the top of the cage or in the leaves on the floor).

For each arousal test, a stopwatch was started when the sound began to play or the smoke (real or control) was added. The time of first response, if any, was recorded. First response was defined as any movement or visibly increased respiration. The test was complete after 60 minutes or when the bat had aroused. Arousal was defined as movement from one location to another.

Control Sound and Fire Sound

White noise was used as the control sound. It was generated using the Cool Edit Pro Version 2.00 software (Syntrillium Software Corp.) and recorded onto a CD. The CD was looped to play for 60 minutes using a 16 bit mono sound at 44100 Hz. A computer speaker (Altec Lansing Multimedia model ACS41) was placed inside the wine chiller to emit the sound to the bat.

The sound of a real fire was recorded by means of burning a small pile (approx. 10cm high with a diameter of 20cm) of dead oak leaves and twigs (approx. 25cm away), and using a power module microphone (Audio-technica) and Compaq laptop computer. To make this small fire recording sound like a large forest fire, the Cool Edit Pro Version 2.00 software (Syntrillium Software Corp.) was used to manipulate the fire sound track.

The sound track was duplicated 5 times. Each track was off-set to one another and then joined together into one track. This final track (the recording of multiple tracks together) was then played to the bats for 60 minutes for the fire sound test. Fire sound was played using the same procedure as in the control sound test.

Smoke Control

Two 4cm holes were drilled into the sides of the glass front environmental chamber. On the left side, the hole was centered 17cm from the top and on the right side it was centered 7cm from the bottom to allow air flow. To start the test, a bellows was used to blow two puffs of air (approx. 1200mL) into the left hole, approx. 20cm away from where the bat cage was placed. Two additional puffs of air were blown into the chamber every 5 minutes.

Smoke

Dead oak leaves (8g) were placed inside a coffee can (16D x 16cmH). A metal lid with two central holes was made for the coffee can. A plastic tube (2.5cmD) was connected from one of these holes to the hole on the left side of the chamber (Figure 2). Another tube connected a bellows to the other hole in the lid to force air through the can and into the test chamber. A third tube was connected from the right side of the chamber to the side of another pair of bellows. At the beginning of each trial, a fire was lit inside the coffee can, the lid was placed on the coffee can, and two puffs of the bellows was used to blow the smoke into the test chamber to start the test. The tube was disconnected from the left side of the chamber, and after 30 seconds, 100 puffs of the bellows on the right side of the chamber was used to suck out the smoke. Two puffs of smoke were added and removed every 5 minutes (Figure 2 and Figure 3).

Figure 2. Smoke being added to the environmental chamber via bellows.

Figure 3. Smoke being withdrawn from the chamber via bellows after 30 seconds of smoke exposure.

Fire Sound and Smoke

The speaker was placed inside the chamber to provide the sound of fire as previously described, and the same methods were used for the smoke test.

Statistical Analyses

The Friedman nonparametric test was used to compare arousal times for the five treatments. Following a significant Friedman's test, Wilcoxon signed rank tests were used for pairwaise camparisons comparisons.

RESULTS

Sound

None of the bats (n=15) responded or aroused during the white noise test (Table 2 in Appendix). Only one of the bats (n=15) responded to the sound of fire during this test (at 35 minutes) and there was no arousal observed (Table 3 in Appendix).

Smoke

There were no responses or arousals during the control trials (pumping air) (Table 4 in Appendix). However, exposure to smoke elicited a rapid response by all bats (n=15), with response times varying from 4 seconds to 5.5 minutes. Arousal times (n=10) ranged from 11 to 40.5 minutes (mean ± SE = 36.55 ± 4.98), with 5 bats not arousing (Table 5 in Appendix).

Fire Sound and Smoke

When bats (n=15) were exposed to both the sound and smoke simultaneously, they all responded in 4 – 30 seconds. All bats also aroused for this test, and arousal times ranged from 10.5 to 42 minutes (mean ± SE = 21.92 ± 1.87) (Table 6 in Appendix).

Statistical Analyses

The Friedman nonparametric test on latency to first response times indicated difference among the five treatments ($S = 55.62$, $p<0.0005$) (Figure 4). In pairwise comparisons, first response times were faster for the smoke versus smoke control (Wilcoxon: $z = 3.379$, $p<0.005$). The sound of fire had no affect on first response times when compared to sound control (Wilcoxon: $z = 0$, $p = 1$). There was no difference between first response times for the fire sound and smoke combination versus just smoke (Wilcoxon: $z = -0.227$, $p>0.05$).

The Friedman nonparametric test indicated a difference in latency to arouse among the five treatments ($S = 48.65$, $p< 0.0005$) (Figure 5). In pairwise comparisons, arousal latencies were faster for the smoke versus smoke control (Wilcoxon: $z = 2.752$, $p<0.05$). The sound of fire had no affect on arousal times when compared to the sound control (Wilcoxon: $z = 3.379$, $p = 1$). The combination of fire sound and smoke had shorter arousal latencies when compared to smoke (Wilcoxon: $z = -2.471$, $p <0.05$).

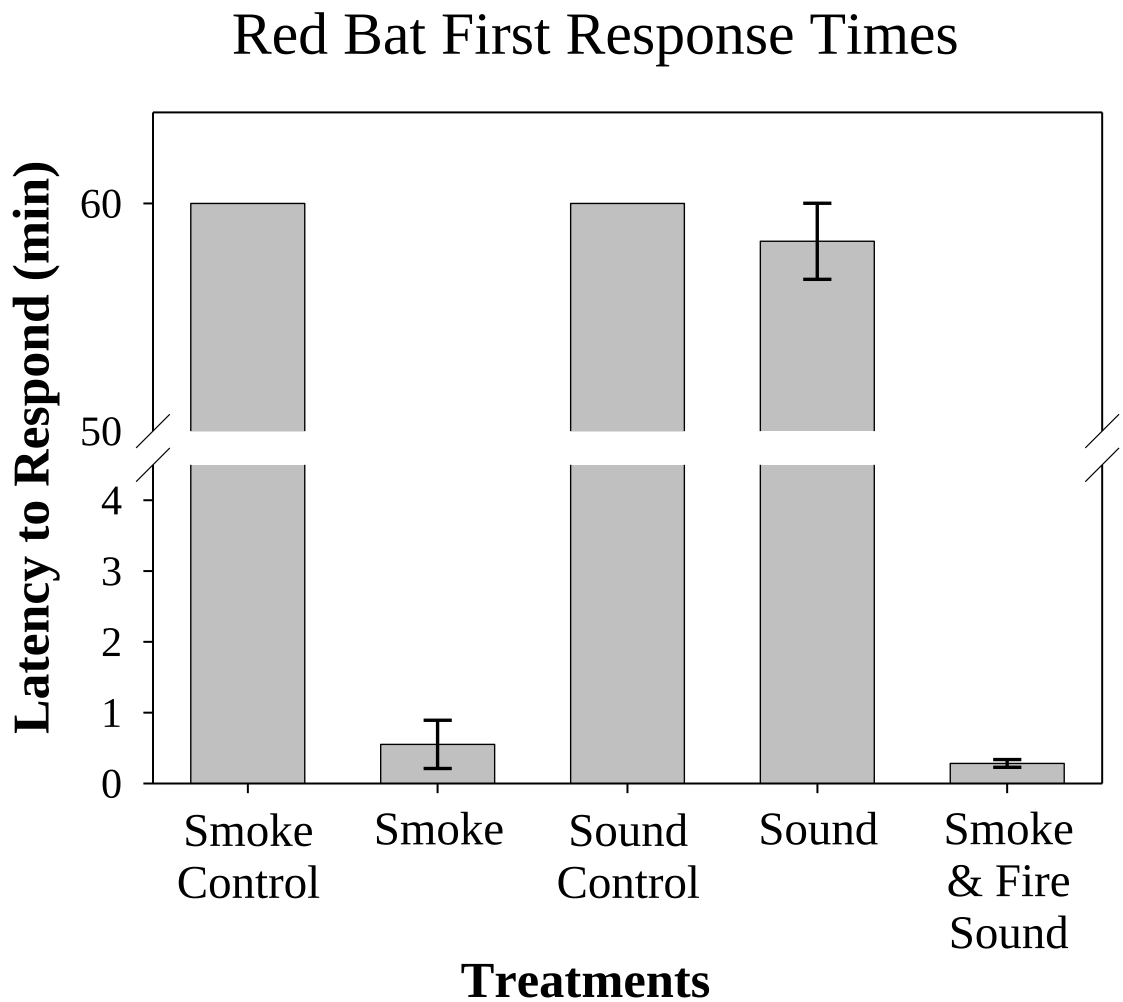

Figure 4. First response times of red bats (n=15) exposed to the different treatments. Bats that failed to have a first response during the 1 hour test were given a value of 60 minutes. There is a difference among treatments (Friedman $p<0.05$). Latency to respond was shorter in the smoke treatment than the smoke control (Wilcoxon $p<0.005$), and had no difference when compared to smoke and fire sound combination and the smoke treatment (Wilcoxon $p>0.05$).

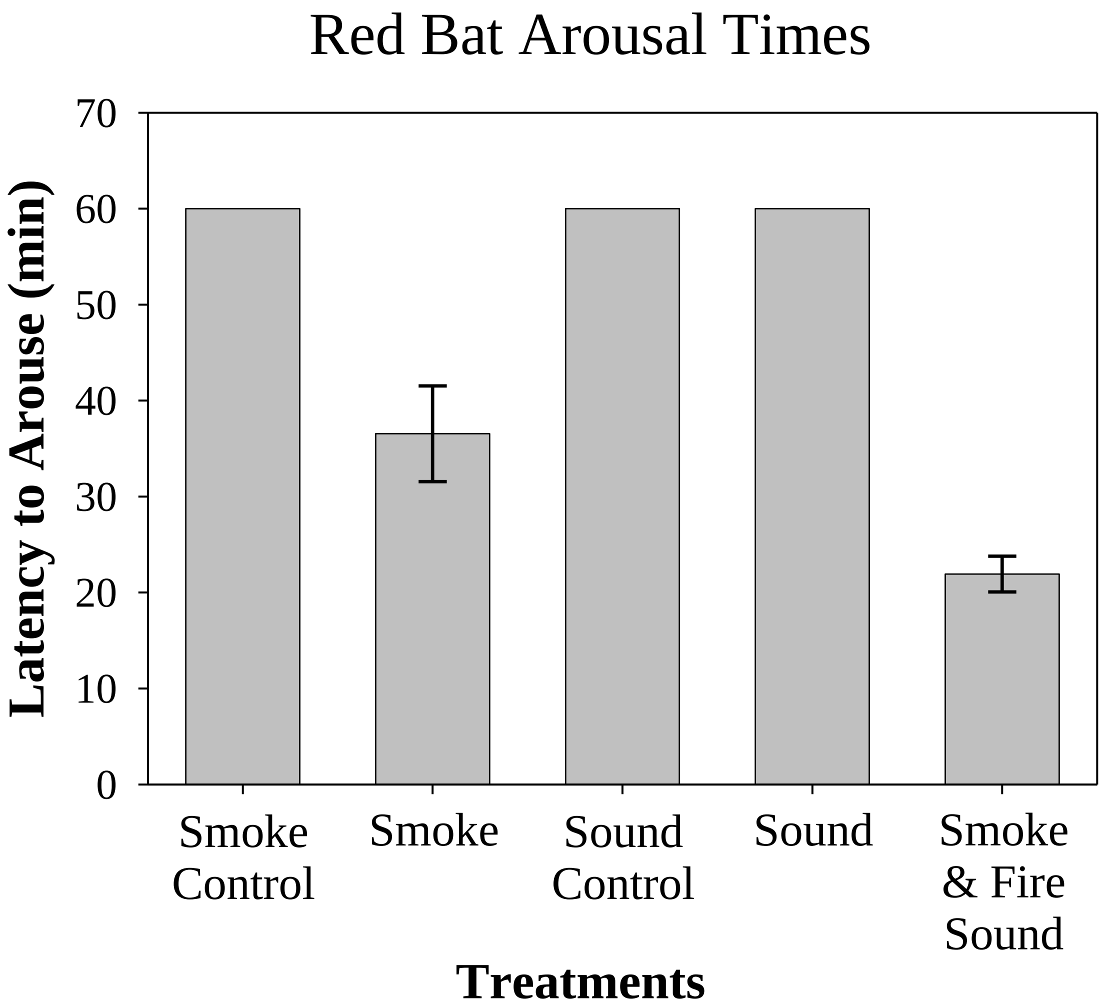

Figure 4. Arousal times of red bats (n=15) exposed to the different treatments. Bats that failed to arouse during the 1 hour test were given a value of 60 minutes. There is a difference among treatments (Friedman $p<0.05$). Latency to arouse was shorter in the smoke treatment than the smoke control, and shorter in the smoke and fire sound combination than in the smoke treatment (Wilcoxon $p<0.05$).

DISCUSSION

Neither sound (white noise or fire) stimulated the bats to arouse. This could be due to the equipment used during the tests. The audio equipment used only went up to 20 kHz. The sound of fire goes up to 60 kHz and red bats can echolocate up to around 56 kHz (Murray et al. 2001). The audio tests may not have affected the bats arousal times because they may not have been hearing the upper frequencies of the sounds, and therefore, did not recognize the fire sound. However, the higher the frequency, the less distance it can travel (attenuation). Red bats can be buried deep under the leaf litter where the sound, especially high frequency sounds, may not be able to penetrate. Since part of fire is <20 kHz, and bats respond to human voices (<20 kHz), some of the fire sound coming from the speaker should have been audible to the bats. In a study conducted in the Ivory Coast, frogs fled from the playback sound of fire (22 kHz) in the direction of safety (Grafe et al. 2002). These frogs were aestivating, which is a form of torpor. Frogs may rely more on hearing than olfactory, and visa versa for red bats.

Chemosensory detection of smoke significantly influenced arousal times. During most of the smoke tests, bats responded in less than 20 seconds from the time the smoke first entered the test chamber. This smoke stimulus may have triggered the "fight or flight" response because the bat was in danger. In this case, arousal would be "flight". The olfactory neurons may be sending messages to the brain to trigger arousal. The message is then sent from the brain to the sympathetic nerves to the brown fat located on the dorsal side of the bat near the shoulder blades. Norepinephrine is released to trigger non-shivering thermogenesis to occur in the brown fat which is necessary to start the process of arousal (Dr. Tom Tomasi pers.comm.). Other smells, for example air from the bellows, does not cause this reaction to occur.

There were significantly faster arousal times between the smoke/sound combination and the smoke alone. Because sound alone did not result in any arousals, bats may need the stimulus of smoke to start the arousal process, and use hearing secondarily to confirm the danger. This result could be explained if (1) bats do not hear while in deep torpor and so cannot detect the sound of fire until brought out of deep torpor by the smell of smoke, or (2) the sound of the fire is not considered an imminent threat without the smell of smoke. This indicates that smoke is a main factor that triggers the bats to arouse, but the addition of fire sound makes arousal occur more often and quicker.

Because smoke generally rises, bats in the leaf litter might not detect the smoke in time to escape. However, it is probable that smoke permeates into the leaf litter. In the laboratory I exposed a non-torpid bat to smoke from a fire and it tried to escape. Environmental factors play a huge part on affecting which way smoke travels. However, the smell of smoke can be detected from some distance away.

The information gathered from this study may help forest managers determine optimal conditions for prescribed burning and for red bats to be able to arouse from torpor to escape these fires. Survival of small mammals within a burn depends upon the uniformity, intensity, size and duration of the burn, as well as the mobility and position of the animal relative to the soil surface at the time of the passing fire (Geluso and Bragg 1986). Understanding these issues is important because there have been observations of negative effects on mammal populations. Edwards (1954) found that burning reduced marten (*Martes americana)* numbers for decades (Rowe and Scotter 1973). Observations in a number of burned areas in northern Saskatchewan indicated that red squirrels (*Tamiasciurus hudsonicus)* were eliminated for several years (Rowe and Scotter 1973). Preweaned harvest mice (*Reithrodontomys megalotis*) were vulnerable to prairie fires because they were unable to flee from nests located on the surface of the ground (Geluso and Bragg 1986).

For future studies, heat could be a variable to test in this experiment. Fire travels at different speeds (Rowe and Scotter 1973), which means that the heat of the fire also travels at different speeds. Heat could be an additional trigger that arouses the bats from torpor during burns. There may be a fine line between whether bats escape or get burned because the fire is traveling too fast. I did not test heat as a variable because I believe that by the time the heat of the fire reaches the torpid bat in the leaf litter, it is too late for the bat start the arousal process. The fire will engulf the bat before it can fully arouse to fly from the fire. In this experiment, I was able to separate heat from the smoke variables. A thermometer was placed inside the test chamber and was observed throughout the tests. When the smoke entered the chamber, the temperature did not increase. Red bats are exposed to solar (passive) heating in natural conditions (Mormann 2005), so heat may not be worth testing in terms of this study.

Exposure to different temperatures may be an important study. Using the same treatments in this study at different temperatures; 0°C, 5°C, 10°C, and 15°C might give some results that show quicker arousal times as the temperature increases. This information can be used by forest managers to determine burn at optimal conditions and give the red bats time to flee from the fire.

Another study that can be done is to test responses of different species of bats to smoke and the sound of fire. For example; cave bats versus forest dwelling bats would be an interesting comparison. By conducting these experiments, an evolutionary trend may be observed. Cave bats do not experience fires whereas foliage roosting bats do. Leaf-litter roosting bats may have adapted the ability to avoid fatality during fires by evolving a response trigger or anatomical structure that allows them to arouse from torpor. However, there are different kinds of smoke: exhaust smoke, cigarette smoke, etc. Whether or not bats respond to different kinds of smoke should also be tested. Certain chemicals in different kinds of smoke would have to be sorted out to determine the exact chemical that triggers arousal.

When being physically agitated by the plastic probe, arousal took much longer when compared to exposure to smoke. This may be due to different messages being sent from the brain. Being tapped with the probe is not as much as a threat when compared to being exposed to a fire. Messages from the brain may have traveled different pathways in these two experiments, depending on the danger the bat was in. This may be why bats aroused faster when exposed to smoke. Red bats are often subjected noise in nature; rain, trees falling, animals walking by, etc. Physical and hearing receptors are probably not used as much as chemosensory to warn the bats of danger.

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APPENDIX

Table 1. Results for the arousal tests. The dates that are bold indicate the pre-weight of the bat that day before the test. The dates that are bold indicate the day the bats were put inside the environmental chamber.

Arousal Test							
Date	**Temp °C**	**Mass (g)**	**Time (min)**	**Bat #**	**Sex**	**Days Torpid**	**Position**
Pre-Weight				2	m		
11/10/2005		7					
11/11/2005	5	7	70	2	m	1	leaves
Pre-Weight							
11/14/2005		12		1	f		
11/14/2005		8		2	m		
11/15/2005	5	11	50	1	f	1	hanging
11/15/2005	5	8	61	2	m	1	leaves
		Temp °C	**MEAN Arousal Time**				
		5	60.3 min.				

Table 2. Results to the control sound test.

Bat #	First Response (min)	Arousal (min)
14	0	0
15	0	0
16	0	0
18	0	0
19	0	0
20	0	0
21	0	0
22	0	0
24	0	0
26	0	0
27	0	0
28	0	0
29	0	0
31	0	0
32	0	0

Table 3. Results for the fire sound test.

Bat #	First Response (min)	Arousal (min)
14	0	0
15	0	0
16	0	0
18	0	0
19	0	0
20	0	0
21	0	0
22	0	0
24	35	0
26	0	0
27	0	0
28	0	0
29	0	0
31	0	0
32	0	0

Table 4. Results for the smoke control test.

Bat #	First Response (min)	Arousal (min)
14	0	0
15	0	0
16	0	0
18	0	0
19	0	0
20	0	0
21	0	0
22	0	0
24	0	0
26	0	0
27	0	0
28	0	0
29	0	0
31	0	0
32	0	0

Table 5. Results for the smoke test.

Bat #	First Response (min)	Arousal (min)
14	5.5	0
15	0.25	40.5
16	0.317	35
18	0.333	0
19	0.3	15
20	0.167	20.5
21	0.3	20.5
22	0.2	0
24	0.183	0
26	0.133	40.25
27	0.133	31
28	0.333	0
29	0.067	11
31	0.067	14
32	0.183	20.5

Table 6. Results for the sound of fire and smoke combination test.

Bat #	First Response (min)	Arousal (min)
14	0.167	30
15	0.67	20
16	0.25	10.5
18	0.417	25.5
19	0.5	18
20	0.5	26
21	0.1	15.5
22	0.25	21
24	0.67	42
26	0.067	22
27	0.067	21
28	0.233	20.33
29	0.117	20.5
31	0.1	20.5
32	0.133	16