Acoustic Deterrence of Bats:
A Guidance Document

(Agreement No. 43A0219)

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Prototype ultrasonic acoustic deterrent installed below deck of Cappell Creek Bridge, Highway 169, near Weitchpec, CA. The complex arrangement of timber stringers and irregular surfaces of this temporary replacement bridge created a challenging situation for physical exclusion of bats and acoustic exclusion provided an attractive alternative.

Caltrans

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Introduction

This guidance document presents background, available technology, testing, results, and recommendations for using ultrasonic acoustic broadcast as an alternative means to exclude bats from bridges and other structures. These recommendations can be implemented as needed prior to maintenance or demolition work. Caltrans procedures require biological assessment of structures prior to initiation of maintenance and construction activity. The results of the Natural Environment Study are incorporated into planning and scheduling to minimize impacts to natural resources and to help prevent future listings of species. Requirements to consider effects to bats exist under the California Environmental Quality Act (CEQA), the California Endangered Species Act (CESA) as appropriate, California Department of Fish and Game Code, and other applicable regulations.

At least half of California's twenty-five bat species may at times roost on or in anthropomorphic structures. In particular, bridges often provide secure roosting opportunities having the appropriate environmental conditions for bats. Bridges often span favorable bat foraging resources of riparian or riverine habitat and this contributes to their frequent selection as roosts.

Bats carry out different roosting behaviors on bridges. For example, male bats may enter physiological torpor during day roosting throughout the year, as may both genders late in summer and throughout the winter. During torpor, bats allow their body temperature to drop to ambient temperature to spare metabolic energy. In this state, bats cannot immediately respond to threats, and could literally be caught off guard by bridgework and harmed before they could arouse and evacuate a roost. During the spring and early summer, to optimize reproductive success while gestating and lactating, females must maintain a normal body temperature at great energetic expense against ambient temperatures. Roost disturbance during this time can prove particularly deleterious to reproductive success as alternate roosts may not be available, or have less favorable conditions that can lead to reproductive failure. During part of the reproductive season, non-volant pups cannot move at all from roosts and any disturbance will lead to mortality, even if the adult bats can evacuate to an alternate roost, if available.

Preventing mortality and reproductive disruption from maintenance and construction on structures with roosting bats requires carrying out such activity without bats present. Scheduling project activity during seasonal absence of bats offers a straightforward solution in some situations. However, in many situations bridge maintenance or construction cannot be scheduled or completed during seasonal absences of bats, or bats may occupy the structure throughout the year. Such situations require preventing bats from reoccupying roosts or excluding bats from the structure, if present prior to maintenance or construction activity.

Abiotic - Physical Exclusion Methods

Current exclusion methods include temporarily filling slots or joints or physically covering structural components that bats occupy (or roost), to prevent access using screens, plywood, flexible tubing, or expanding foam (Figures1 & 2). However, complex and irregular structures such as those found on older timber structures or access issues can make exclusion by routine

methods problematic, costly, and unlikely to succeed, as bats can negotiate slots nearly as small as one quarter inch. Physical exclusion amounts to precision work on a macro structure.

Figure 1. Physically excluding bats from joints in a culvert by filling them with poly foam tubing and sealer. Photo provided by Greg Tatarian, Wildlife Research Associates.

Figure 2. Physical exclusion installed in joints on the Bidwell Viaduct. Unless the entirety of all joints or recesses can be clearly seen to ensure the absence of bats, then bats should be assumed present. If bats may be present then eviction chutes, or other one-way exits, must be installed to allow bats to exit but not return (detail, right photograph). *Exclusion and eviction should never be performed during times when there may be nonvolant juveniles*. Physical exclusion requires thoroughness and precision as small species of bats can pass through slots as small as one quarter inch. Photos provided by Greg Tatarian, Wildlife Research Associates.

Biotic Exclusion Methods

With support from, and in cooperation with Bat Conservation International and the Bats and Wind Energy Cooperative, Humboldt State University developed and tested technology to broadcast ultrasonic and biological sounds to deter bats from approaching wind turbines. Field testing demonstrated such acoustically treated airspace could deter bats within a 15meter (m) radius of the broadcasts (Szewczak and Arnett 2006, 2008). The AT800 deterrent device (Binary Acoustic Technology) broadcasts a broadband ultrasonic masking signal from eight transducer elements. The broadcast signal essentially loads the air with ultrasound in a

frequency band from 20 to 80 KHz, loading the air with approximately 120 decibel (dB) sound pressure level (SPL) at 1 m (Figure 3). This unit can also play back other high frequency sound recordings.

Although bats use vision to perceive objects at a distance and for landscape-scale orientation, bats rely on echolocation for near-scale and detailed spatial perception in low light, and for spatial perception and navigation in the complete absence of light. To successfully echolocate, bats need to hear the returning echoes of their vocalizations. Because of dissipation and scatter, the return echoes of a bat's outgoing calls have very little of the original energy, i.e., amplitude or loudness, compared to the outgoing call. The smaller the target, (e.g., an insect), the fainter echo. For this reason, bats need very sensitive hearing, and just as it becomes difficult to carry on a conversation in a loud setting, ambient sounds can make it difficult for bats to echolocate.

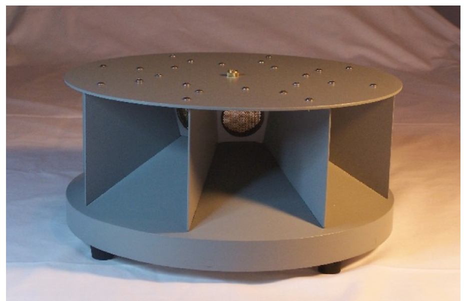

Figure 3. AT800 prototypes ultrasound broadcast unit developed by Binary Acoustic Technology, Tucson, AZ.

Shining a bright light into someone's eyes at night provides a visual perception analogy of echolocation disruption from a loud effusion of sound. The light or sound overwhelms and masks perception of objects. Just as a person would prefer to move away from a strong light directed into their eyes, in addition to disruption of echo perception, overstimulation of the bat's auditory receptors likely elicits a contra-phonotactic movement, (i.e., away from the source of the sound). This movement would presumably regain perception or relief from the sound if discomforting. This anticipated reaction summarizes the operational hypothesis of the acoustic deterrent, because bats prefer to avoid and will vacate airspace with sound pressure levels above some threshold (and having frequencies overlapping with those bats use for echolocation).Applying this technology to exclude bats from older timber bridges or bridges with difficult access could provide an alternative, and in some situations, simpler methods than physical exclusion.

Background and Prior Work

Field and Laboratory Studies

Few studies have investigated the influence of ultrasound broadcast on bat behavior and activity in the field. Mackey and Barclay (1989) concluded that ultrasound broadcasts reduced bat activity and attributed this reduction to disruption of the bats' ability to hear the echoes of their calls and thus reduced feeding efficiency. Szewczak and Arnett (2006) previously reported that a regime of presumably jamming or disorienting ultrasound could deter bats from occupying such a treated airspace (Figure 4). That study tested bat response to ultrasound broadcast at

selected ponds small enough to concentrate bat activity, but sufficiently large to provide bats with an opportunity to forage over water or drink beyond the treatment effect. That site criterion

was used to prevent any compulsion to penetrate an uncomfortable airspace to reach a resource with limited availability (e.g., a roost). This arrangement tested the response of bats to ultrasound broadcast in a situation where the bats could choose freely whether to occupy the treated airspace or not. Testing under this condition produced an immediate effect on the first night of treatment, with bat activity within the ultrasound treated airspace reduced to 10% of control levels within the 15 m radius of treated airspace.

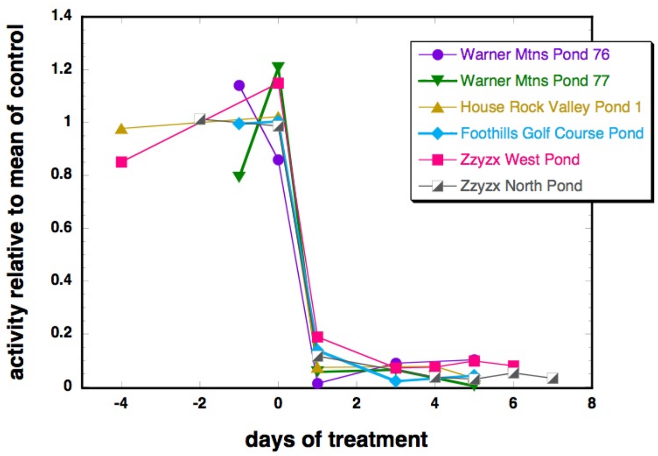

Figure 4. Change in bat pass activity at six pond sites within 15 m of ultrasound broadcast compared to normalized pretreatment bat passes. (Figure 9 from Szewczak and Arnett 2008.)

Laboratory studies using the same prototype ultrasonic deterrent demonstrated a consistent avoidance of treated airspace, and also confirmed a disruptive effect upon echolocation (Spanjer 2006). Bats trained to take mealworms suspended by a thread could capture them 36% of the time under control conditions, but the ultrasonic acoustic broadcast entirely eliminated their capture success.

Wind Turbine Studies

Arnett et al. (2011) recently completed a two-year study to test the effectiveness of an ultrasonic acoustic deterrent for reducing bat fatalities at wind turbines at the Iberdrola Renewables Locust Ridge I and II Wind Farms located in Columbia and Schuylkill Counties, Pennsylvania (Figure 5). Of 65 turbines at these sites, the investigators randomly selected 15 control and 10 experimental turbines fit with six prototype acoustic deterrent devices to broadcast from the turbine nacelles. Daily carcass searches were performed to assess bat mortality at both control and experimental turbines during the study. During the course of the study, searchers found 417 bat carcasses of six species. After adjusting for searcher efficiency, vegetation cover visibility, and scavenger removal, the deterrent turbines had a 37% lower average fatality rate than the control turbines ($F_{1,23} = 14.7$, $p = 0.0009$). Although this investigation used higher power broadcast units that extended the effective range out to approximately 20 m compared to the 15

m of the AT800 units used in the pond and laboratory studies, that still only covers approximately 23% of the rotor-swept area of the wind turbines studied.

Figure 5. Senior Engineer Tom McRoberts (Deaton Engineering, Austin, TX) attaches a deterrent to a turbine nacelle (M. Baker, Bat Conservation International).

Field Testing of Ultrasonic acoustic Exclusion on Bridges

Case Study Background

In 2008 Caltrans initiated a project to replace four deteriorating bridges along State Highway 169, in Humboldt County, CA. The bridges span Cappell, Mawah, Rube Ranch, and Martins Ferry School Creeks, all short streams that flow directly into the Klamath River below the town of Weitchpec, located on the Yurok Tribal reservation (Figure 6). At each site, the project included removal of the existing bridges; driving small piles; construction of temporary center supports and foundation pads for staged construction; roadway alignment shifts at both ends of the bridges; new bridge construction; widening the roadways to accommodate smooth shoulder transitions to and from the new bridges; placement of rock slope protection; diversion and dewatering of creeks and use of upslope areas near Martins Ferry Bridge and Cappell Creek for staging and concrete production. All four structures were originally planned to be replaced using half width construction, meaning that half of the bridge would be constructed at one time, allowing traffic to pass on the other half. However, the project plans were changed to allow erection and use of temporary Bailey bridges for Cappell and Mawah Creek Bridges.

While working on the permitting phase for this project, a Caltrans biological survey performed in September 2008 noticed the presence of guano below the deck of the Cappell Creek Bridge. Guano accumulation of the quantity discovered indicated the presence of bats roosting on the

bridge, and a likely maternity roost, which is an important biological resource. Subsequent exit surveys were conducted at Cappell Creek and Rube Ranch Creek Bridges to survey for the

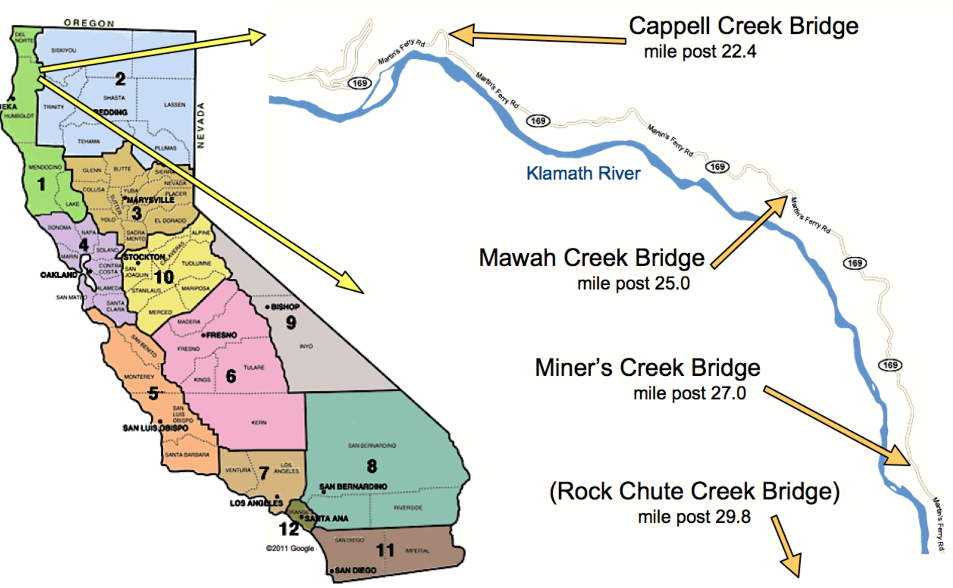

Figure 6. Location of bridges used for testing acoustic deterrence of bats. California Highway 169 runs for just 20 miles from Weitchpec to Johnsons along the Klamath River. Highway 169 joins California Highway 69 at Weitchpec 6.8 miles south of the Miner's Creek Bridge.

presence of bats. These surveys concluded that the bats used these bridges as a day roost. At this point, Caltrans biologists contacted bat biologist Professor Joseph Szewczak to identify the bat species using the bridges and assess the possible solutions for exclusion. Analysis of acoustic recordings of bats flying under the Cappell Creek Bridge revealed the presence of Yuma myotis (*Myotis yumanensis*), and potentially little brown bat (*M. lucifigus*); both species that commonly roost on bridges. The predominant call type recognized was from Yuma myotis, and mostly likely only this species occupied the bridge. Compared to open air flight, which bats present more consistent and recognizable calls, bats flying near roosts often present uncharacteristic call varieties, some of which likely appeared as little brown bat. Acoustic bat monitoring performed near the bridge site but in open foraging areas found Yuma myotis, but did not indicate the presence of little brown bat. In addition, the roost location in close proximity to the Klamath River was consistent with the habitat preference of Yuma myotis to forage on emergent aquatic insects.

In this project region these species follow a seasonal pattern of leaving the summer roost for the winter around mid-October, and returning around April. The standard strategy to protect bats from harm or disturbance during construction or demolition entails scheduling construction activities during the bats' winter absence, or excluding them from reoccupying a roost upon their return in the spring. The 1964-vintage timber construction of these bridges would render

conventional physical exclusion a challenge. With the development of the ultrasonic acoustic bat deterrents underway in his lab, Szewczak suggested a trial application of the deterrent technology on these bridges as an experimental alternative to physical exclusion on the two bridges scheduled for removal in 2009. As part of any exclusion operation, bats must have alternate roost locations to accommodate them when excluded. Although these bats probably have alternate roost locations along the Klamath River corridor, as an assurance, Caltrans crews attached roost boxes on Miner's Creek and Rock Chute Creek Bridges, also along Highway 169 (Fig. 6).

Methods

Equipment Set Up, Placement, and Deployment

The ultrasound broadcast units developed for deterring bats from wind turbines (AT800 ultrasound emitters, Binary Acoustic Technology, Tucson, AZ) were installed (two per bridge) under the decks of the Mawah Creek and Cappell Creek bridges on 16 March 2009 in advance of the expected return date of roosting bats (Figures. 7 & 8). The emitters were attached below the bridge deck, centered at about a third of the distance from each end of the span (Figure 9). These positions were selected to provide full coverage of the expected ~15 m effective acoustic broadcast to parts of the span previously and potentially used by bats as roosting locations. Binary Acoustic Technology GTools software was used to program the emitters to broadcast a broadband sound regime from 20–80 kHz (see link to GTools software manual in Appendix 2).

With the absence of line power at the site, and the potential for vandalism of solar panels, four 90 Amp-hour 12 Volt batteries at each bridge powered the broadcast units. Locked repurposed traffic control cabinets installed at each bridge protected the batteries and associated power conversion electronics and timing controllers. Batteries were replaced weekly along with survey

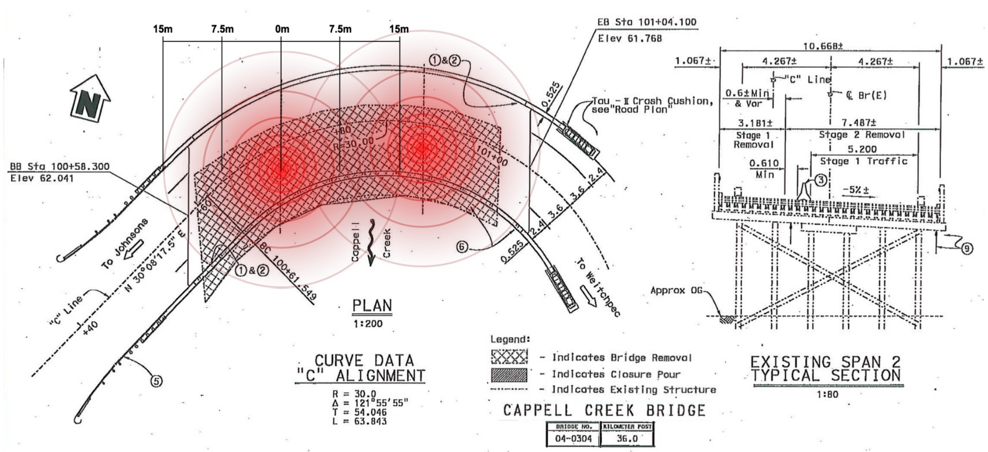

Figure 7. Placement and estimated effective coverage of AT800 ultrasound emitters shown on plan view of Cappell Creek bridge. Drawing shows plan for the replacement bridge; emitters were placed on the previous span indicated by crosshatching.

and monitoring of bat presence and activity. The broadcasting units successfully operated with only one minor disruption due to forced entry and theft of a power component at the Mawah Creek Bridge. The power limitation at the sites prevented continuous operation. To compensate, a timing system based on a low power lawn sprinkler controller was assembled that activated and deactivated the ultrasound emitters via a 12 Volt relay circuit. The timer was programmed to operate for three, two hour intervals: sunset ±1h, midnight ±1h, and sunrise ±1h. These times were selected to deter any bats from using the roost in the times of highest activity just following dusk, around midnight when bats would be most likely to use the bridge as a night roost, and just before dawn when bats would return to the roost to occupy it for the day. Operation of the units was confirmed with an ultrasonic detector during each weekly site visit. Originally, the deterrent units exclusively broadcast high intensity (~120 dB at 1 m) broad spectrum (~20–80 kHz) white noise. On 14 July 2009 we added Binary Acoustic Technology FG125 sound generators and programmed them using GTools (Appendix 2) to

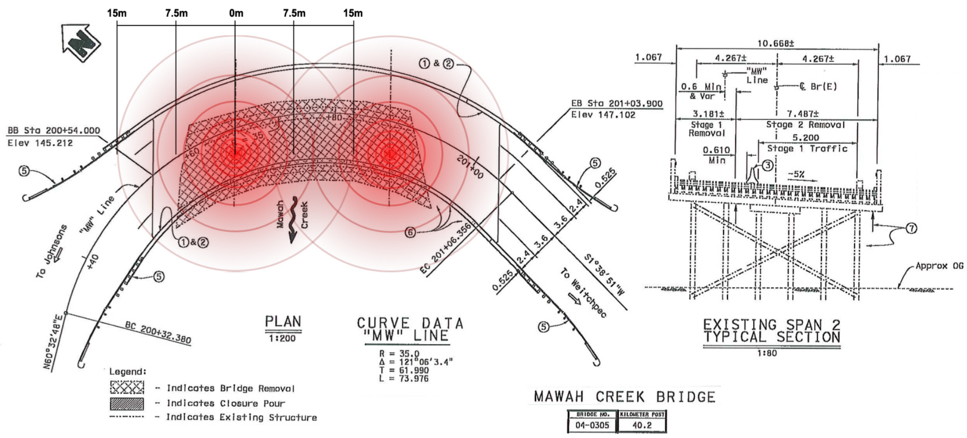

Figure 8. Placement and estimated effective coverage of AT800 ultrasound emitters represented in red overlaid on plan view of Mawah Creek bridge. Drawing shows plan for replacement bridge; emitters were placed on the previous span indicated by crosshatching.

Figure 9. Ultrasound emitter shown installed below deck of Cappell Creek Bridge. The AT800 emitter broadcasts a horizontal beam of ultrasound in the plane of the device (Appendix 2), mounted horizontally here. Bats previously roosted up in the spaces between the timber stringers.

alternate playback of broadband white noise with playback of hoary bat (*Lasiurus cinereus)* social calls, known to deter smaller species such as Yuma myotis (Reyes and Szewczak 2010). Playback of hoary social calls will attract conspecifics, but as an arboreal foliage rooster this species would not roost on the bridge. Any hoary bats that the playback might attract toward the bridge would likely only enhance the deterring effect for the smaller bats that would roost on the bridge.

Monitoring Protocol

Bat activity near mitigation roosts and project bridges was monitored acoustically and visually using spotlights and infrared video. During weekly site visits for battery replacement, we inspected below the deck for day or night roosting bats by thoroughly scanning potential roosting locations in between each stringer and other bridge structural components with a spotlight. We also set out recording bat detectors before dusk to record for approximately two hours after sunset, the time of day when bats are most active on the wing (Pettersson D240x bat detectors with SonoBat analysis software). We also monitored bats in real time with a detector when at project sites. On several field visits we set an infrared video camera to record for one hour after dusk to detect any bat activity under the Cappell Bridge deck around the previously used roost location. In addition, we also looked for fresh guano that would indicate bat presence.

Results and Discussion

When the presence of bat roosting activity was first noticed on the Cappell Creek Bridge in September 2008, the species, their presence at that time of year, and the accumulation of guano were consistent with a maternity roost. After a winter absence, bats in this region would be expected to begin reoccupying a summer maternity roost sometime in April, but perhaps as early as late March, and strongly expected by May. Acoustic broadcasts intended to deter bats from occupying the potential roost on the Mawah Creek Bridge and to deter bats from reoccupying the roost on the Cappell Creek Bridges began on 16 March 2009 in advance of the expected return date of the bats from their winter absence. Acoustic monitoring of bats below the span of the nearby Rock Chute Creek Bridge on 20 March 2009 revealed the presence of both *M, yumanensis* and *M. californicus*, (California myotis). This indicated the early season local presence of bats, although at this time of year these bats might be roosting at sites more appropriate for winter conditions than on the project bridges.

Subsequent acoustic surveys (24 March, 28 April, and 30 June 2009) below the Rock Chute Creek Bridge revealed activity and presence of big brown bat (*Eptesicus fuscus*), hoary bat, long-eared myotis (*M. evotis*) (), and Yuma myotis, the latter indicating its presence in the project area despite its absence on project bridges during this time. Infrared video monitoring and on site observations revealed two instances of bats flying under the Cappell Creek Bridge during acoustic broadcasts, but neither were observed to stop or return. Only individual guano pellets were found until early July, consistent with intermittent bat flight under the bridge and contraindicative of roosting activity.

In the absence of roost occupancy data from previous years, the expected time of summer re-occupancy of these bridges remained unknown. Nevertheless, weekly surveys found no day roosting bats in March, April, May, or June. At that time, it was deemed acceptable to begin construction activity in preparation of demolition of the Cappell Creek Bridge as no bats had been observed and so none would be affected. However, circumstances delayed the scheduled initiation of construction, and the 7 July 2009 site survey discovered approximately 100 bats roosting on that bridge despite the ultrasound broadcast. This was confirmed on 10 July 2009, with the observation of more than 200 bats day roosting on the bridge. The bats appeared consistent with the Yuma myotis that were identified acoustically the previous September. It was surprising to discover bats occupying a day roost as a maternity roost that late in the season, as they typically establish roost occupancy prior to parturition. In fact, these bats appeared to have arrived with pups that appeared more than a week old. This mid-season occupancy indicated that these bats must have an alternate local roost, and with this consideration we elected to maintain the ultrasound broadcast in speculation that if it did not initially deter them, continued broadcast may deter them from remaining and induce them to return to their alternate roost. On the 10 July 2009 site visit, we adjusted the acoustic broadcast to play for three hours instead of two, for each of the three broadcast periods.

In addition, using equipment not available for the original installation, on 14 July 2009 we began broadcasts using a programmed signal generator that, along with the broadband ultrasound, played additional biotic sounds that other tests had shown to disperse Myotis, specifically, broadcasts of hoary bat social calls. We deemed this worth attempting because the position of the bats up behind the beams would have provided them some protection from the ultrasound broadcast that travels mostly by line of sight due to its short wavelengths. The lower frequency hoary bat social calls (~10 kHz) would not be as affected in that way and also deters them behaviorally, in addition to the physiological deterrent mechanism of the ultrasound. Hoary bats are known to eat smaller bats; smaller bats seem to know this, and in previous tests retreated in the presence of these sounds (Reyes and Szewczak 2010).

As a contingency, an alternate plan was developed to deter roost occupancy using water mist to eliminate the physiologically thermal advantages of the roost, and to deploy that no earlier than two weeks after all pups became volant. This option seemed reasonable because the late season arrival of the bats indicated they must have at least one local alternate roost. However, this became unnecessary as subsequent further delays of construction activity enabled the monitoring of bat roost activity through the end of any expected occupancy in mid-October. After the initial re-occupancy of the roost, the number of bats roosting on the bridge declined weekly to eight bats observed on 18 August 2009, and none the following week. No more bats were observed during weekly surveys through to the final weekly survey on 19 October 2009. The absence of roosting bats throughout September, the only month with an observation of roosting bats prior to treatment, suggests that the acoustic treatment contributed to excluding bats from roosting on the bridge.

Discussion

Griffin first demonstrated that broadband ultrasonic noise could partly disrupt the ability of bats to echolocate effectively (1963). A typical bat emits calls at about 110 dB sound pressure level (SPL) at 10-cm (Surlykke and Kalko 2008). In open air search phase flight[1], a typical North American bat emits about 12 calls per second, each about 5 milliseconds in duration (Fenton 2004, Parsons and Szewczak 2009). Given the speed of sound at 340 m/sec and the duration of an open air call, the bat's own call will mask echoes returning from objects within about 1.5-m. An echo from a target about 1.5-m away will return about 45 dB less than the original 110 dB signal, or at about 65 dB. The bat's next call would mask echoes returning from about 25-m away. Thus as a first order estimation, with each call bats perceive over a range from about 1.5–25-m from echoes about 65 dB and less.

Consistent with that expectation, the field study of bats foraging at ponds described above indicated that bats voluntarily avoided airspace having sound pressure levels above 65 dB (Szewczak and Arnett 2006). This confirms that 65 dB SPL and above serves as an operational target sound level for effective ultrasonic acoustic deterrence of bats.

Selection of Ultrasonic Bat Deterrents

Ultrasonic acoustic deterrents may be indicated for excluding bats for the same reasons that physical might be employed. The decision to select acoustic deterrence as an alternative to physical exclusion should be assessed on a project by project basis. In many instances, physical exclusion may provide a simpler and more cost-effective solution. Generally, the more complex the physical exclusion procedure, the more attractive the option of acoustic exclusion becomes. As bats can negotiate slots as small as one centimeter, complex and irregular structures having multiple gaps and cavities can result in challenging and expensive projects to effectively exclude bats by physical means. A comparative cost-benefit analysis that considers the cost and scheduling of the exclusion requirement should help select the alternative to pursue. For example, acoustic bat deterrence may offer a preferred solution to prevent bats from roosting on temporary or changing structures such as formwork.

At the time of this project, each AT800 unit cost approximately $4,100 (with shipping). The Deaton Engineering units will likely cost a comparable amount, and may decrease in cost if they go into large scale production for the wind power industry. For a project to project comparison, initial cost may prove prohibitive, but amortizing the cost of these reusable units from project to project offers more economic benefit. And similarly, the selection of acoustic deterrents for projects with changing requirements such as staging construction or maintenance work across a span may prove more cost effective than physical exclusion.

[1] In search phase flight, bats emit calls at regular intervals to detect obstacles and search for prey. Bats will adjust the duration and cadence of calls for other tasks, e.g., when approaching to land or capture prey.

Effective Range of Acoustic Bat Deterrence

As sound frequency increases the propagating wavelengths shorten and the energy of the signal attenuates more rapidly (ISO 9613-1 1993). In addition, because sound propagates by oscillating pressure disturbance in air, there is an upper limit to the amount of energy that can be transferred to air to generate sound. That is, you cannot simply keep amplifying or increasing the energy to a transducer (speaker) to increase the range of broadcast. For ultrasound in the range of frequencies used by bats, the effective upper limit occurs at about 134 dB SPL (Mark Jensen, Binary Acoustic Technology, personal communication). This limits the effective range of ultrasonic bat deterrent broadcast from a point source. The prototype deterrent units built by Deaton Engineering (Austin, TX) for the wind turbine study (Arnett et al. 2010, 2011) approach that limit. As part of that project, Deaton Engineering prepared tables of estimated decibel levels at different frequencies for two different levels of relative humidity (Arnett et al. 2011). These tables (Appendix 1) provide guidance for placement of acoustic deterrents on structures.

Different bat species use different parts of the frequency spectrum. Although they may sweep through a wide range of frequencies, North American bats most rely on frequencies ranging from 20 kHz to about 60 kHz (range 10–130 kHz). Despite the species differences, the tables of estimated decibel levels (Appendix 1) enable some first order implementation guidelines for coverage. In lower humidity (<20% relative humidity) environments, high power Deaton Engineering type deterrent units could be placed to cover up to 25 m[2]. In locations with higher humidity (humidity typically rises at night) reduce this to 15 m. The lower broadcast power of Binary Acoustic Technology AT800 units would reduce the coverage range by about 5 m. Note that humidity rises at night during the time when bats are active, and local conditions can affect humidity. The water that bridges often span can create microhabitats of increased humidity.

As a general guideline, acoustic deterrent broadcast units should be positioned with a 20 m center to center spacing as shown in Figures 7 & 8. For wider spans, space at 20-m centers on a hexagonal array for best coverage from the circular coverage of each unit. Further field testing and field experience with other units may indicate effectiveness with greater spacing.

Power Requirements for Acoustic Deterrent Units

Binary Acoustic Technology specifies their AT800 units consume <40 W when broadcasting 106 dB SPL. Tests of the AT800 units used for the Highway 169 project determined they consumed 22 W. Power requirements for the prototype Deaton Engineering units remain unavailable at the time of this report preparation, but they likely require about 10 times the power as the AT800 units require.

[2] Deaton Engineering units broadcast directionally. Two units would be required to project in a 360° planar sweep. Each Binary Acoustic Technology AT800 units covers a full 360° sweep.

Safety Issues

Human

Various industrial procedures and diagnostic methods use ultrasound and the US Occupational Health and Safety Administration (OSHA) has established guidelines for occupational exposure to ultrasound. Although investigations have not found specific bandwidths of ultrasound to cause hearing loss, some studies have indicated temporary reductions in hearing threshold (Acton and Carson 1967, Knight 1968). Other studies found that ultrasound exposure could cause nausea, fatigue, and headache (Howard et al. 2005). OSHA ultrasound guidelines had followed the consensus of the findings published by the International Radiation Protection Agency (1984). These guidelines recommend limiting ultrasound exposure to 110 dB SPL below 30 kHz and 115 dB SPL above 31.5 kHz. OSHA has maintained these Threshold Limit Values, as recommended by the American Conference of Governmental Industrial Hygienists (OSHA 29 CFR 1910.95, Appendix I:D Ultrasonics).

Even using the more conservative guidelines, humans would experience safe exposures 5-m from Deaton Engineering deterrent units and 1-m from Binary Acoustic Technology AT800 deterrent units. Although workers operating near these units would not perceive the ultrasound broadcast, it would still be prudent to wear hearing protection; even simple ear plugs would reduce risk below all acceptable levels. However in most implementations of ultrasonic acoustic deterrents this should not become an issue as the units can remain inactive during the day when most human exposure would occur.

Concerns about Harm to Bats with Acoustical Exposure

The effects on bats of prolonged exposure to ultrasound remain uninvestigated, but can be speculated from human guidelines. The OSHA human ultrasound guidelines cover frequencies beyond human perception. However, for humanly perceived frequencies, i.e., audible sound, OSHA guidelines for permissible exposures vary according to duration (OSHA standard 1910.95). OSHA permits 90 dB for 8 hours (hr) of exposure and the level increases up to a ceiling exposure level of 115 dB for 15 min or less. Although the morphological arrangement of bat and human ears tunes their perception to different frequencies, the neural receptor action functions similarly so it is reasonable to expect similar effects for similar levels of sound energy. By this assumption, bats would experience risk from long term exposure within about 10-m from Deaton Engineering deterrent units and 5-m from Binary Acoustic Technology AT800 deterrent units.

Because subjecting bats to long term exposure to the ultrasonic broadcasts from acoustic deterrents may potentially damage their hearing, these units should never be deployed in a situation in which the bats cannot voluntarily and safely evacuate the acoustically treated airspace. For example, never activate an acoustic deterrent near roosting bats during the day. Daylight flight places bats at considerable risk of predation and although they may feel compelled to leave from the ultrasound, they could choose to endure the exposure to avoid the risk of daytime flight, and suffer hearing damage. Similarly, bats should not be exposed to ultrasonic deterrents in a closed roost space where they have no option to move out of range of the treated airspace.

With physical exclusion the preferred implementation entails treatment in the absence of bats to prevent roost access upon their return. Similarly, to minimize risk to bats, ultrasonic acoustic deterrents should only be set up and activated in the absence of bats to deter roost access upon their return. Where coordination with California Department of Fish and Game is necessary, biologists should emphasize this point that no bats will be involuntarily subjected to a deterring ultrasonic broadcast.

Contraindicated Applications

An ultrasound acoustic deterrent broadcast should not be initiated during the reproductive season of a bat maternity roost. Nor should an ultrasound acoustic deterrent broadcast be initiated during the day at an occupied bat roost, or in an enclosed space where the bats have no option to move out of range of the broadcast.

Why Caltrans Must consider Bats

Because no federally-listed bats occur regularly in the State of California, the Federal Endangered Species Act (FESA) does not normally apply to projects involving bat species in California. Although California has no state-listed bat species, the California Department of Fish and Game does list many California bats as Species of Special Concern and they partly protect all species of bats from taking through restrictions on scientific collection. Additionally, Section 4150 of the California Department of Fish and Game Code protects all native non-game mammals, including bats.

Projects cannot interfere substantially with the movement of any bat species or with established migratory corridors. Projects and programs must avoid, minimize, mitigate, and provide enhancement for potentially substantial adverse effects, either directly or through habitat modifications, on any species identified as a candidate, sensitive, or special status species in local or regional plans, policies, or regulations, or by the California Department of Fish & Game or U.S. Fish and Wildlife Service.

Projects and programs cannot substantially reduce the habitat of bat species, cause harm to sensitive habitat by species removal, cause a population to drop below self-sustaining levels, unnecessarily disrupt local populations, or reduce the number and restrict the range of a rare species.

Caltrans may consider the providing new habitat consistent with species recovery plans by the Department of Fish and Game or U.S. Fish and Wildlife Service where: candidate conservation agreements, safe harbor, or similar agreements are in force; enhancement is consistent with the local natural and built environment; and there is a fundable and feasible engineering solution. These considerations should be described and addressed in the CEQA documentation and avoidance, minimization, and mitigation measures should be developed as appropriate.

Effects of Ultrasonic Bio-Acoustical Deterrence

Effects of ultrasonic bio-acoustical deterrence's to bats may be insignificant under certain circumstances, or may include effects such as: producing significant changes in behavior (e.g., the bat having to go further from its roosting site to find food). The latter effect would be the same whether using physical or acoustic exclusion. Ultrasound broadcast could potentially mask signals bats use to communicate between conspecifics or recognize biological signals; impairing detection of sounds of predators and/or prey by masking; decreasing hearing sensitivity temporarily or permanently; and/or increasing stress and altering reproductive and other hormone levels. There may be more substantial and enduring impacts that potentially interfere with breeding by individuals and populations; thereby threatening the survival of individuals or species. However, the rapid attenuation of ultrasound limits any such effects to a limited area (Appendix 1).

Set Up and Operating Ultrasonic Acoustic Deterrence of Bats

To minimize harmful effects on bats, activation of an ultrasonic acoustic deterrents should only commence in the absence of bats as a means to deter bats from roosting on or in a structure upon their return. Bats will occupy roosts both during the day and during parts of the night, and may occupy separate night roosts from their day roosts. But in each situation, actively flying bats approach the roost to land, and it is during this time that a deterrent can hopefully dissuade a bat from proceeding, and opt to go elsewhere. To fully address these roost movement behaviors, a deterrent should be scheduled to operate from a half hour prior to astronomical sunset to a half hour past astronomical sunrise.

- Never activate an acoustic deterrent near bats in an enclosed space. Wait until the bats have left before activating in such a situation.
- Never activate an acoustic deterrent in any situation in which bats have no safe option to vacate the space.
- Never activate an acoustic deterrent during the day as that could force bats to take flight during daylight hours and subject them to increased predation and risk.
- Exclusion and eviction should never be performed during times when there may be nonvolant juveniles.

In some parts of California bats follow seasonal movements and provide periods (typically winter) when deterrents could be deployed prior to the return of the bats. In milder parts of California bats could potentially roost on structures throughout the year. In such a situation a biologist knowledgeable of bat behavior and natural history could help guide when to deploy acoustic deterrence. For example, if not a maternity roost during the reproductive season, it may be possible to activate a deterrent on one section of a span after bats leave at dusk. This could deter them from returning to that treated section of the span and serve to displace them to another section and so allow work to proceed on that section.

Binary Acoustic Technology AT800 units have a USB port for connecting to a laptop for specifying broadcast options using Binary Acoustic Technology GTools interface software. Once

programmed, the units will boot up and follow the pre-programmed settings and enable daily activation using conventional 24 h timing switches. (Binary Acoustic Technology specifications for the AT800 and a link to the GTools software manual can be found in Appendix 2.) In addition to built in broad spectrum ultrasound regimes, GTools enables the playback of sound files. Although inappropriate for application to deterring bats from wind turbines, including playback of hoary bat social calls will help deter all other bats from the source of this playback. Although this will attract hoary bats during broadcast at night (Reyes and Szewczak 2010), hoary bats roost in the foliage of trees and will not roost on structures. Any hoary bats attracted would likely further encourage smaller bats to roost elsewhere.

At the time of this report preparation the Deaton Engineering units remain in the prototype stage and an operation manual and further specifications were unavailable.

Because ultrasonic acoustic deterrents broadcast sound inaudible to humans, assessing whether a unit is properly connected and programmed requires an ultrasonic detector such as a bat detector. Although unsuitable for bat species identification, a simple heterodyne bat detector could be used to determine the presence of ultrasonic broadcast, e.g., a Pettersson D100 (~$350 http://www.batmanagement.com/Ordering/acoustic/hardware5.html) or Belfry bat detector ($100 from Edmund Scientific http://www.scientificsonline.com/belfry-bat-detector.html).

Ultrasound Broadcast Unit Set Up

Binary Acoustic Technology supplied the AT800 ultrasonic broadcast units used in this project to power on and broadcast broadband ultrasound as a default mode. A USB connection on each unit enabled changing the specified playback regime using GTools software, however the default broadband ultrasound setting should provide a sufficient deterrent and prevent any need for change. Check with Binary Acoustic Technology for current recommendations and procedures. Although we programmed a Binary Acoustic Technology FG125 to alternate broadband ultrasound with hoary bat social calls, we did not perform any controlled experiments to determine whether this additional sound regime enhances the deterrent effect above simple broadband ultrasound broadcast. Until further experimental studies may demonstrate any such enhanced effect, use the basic broadband ultrasound broadcast.

Equipment

Table 1 presents an equipment list as used for the Cappell Creek and Mawah Creek Bridges. Without line power that set up required battery power; remove rows 2–8 of that equipment list if line power is available. If using batteries, follow a scheme shown in Fig. 10. Each AT800 unit draws 1.7 Amps of current (22 Watts at 12.7V); 2.2 Amps when also operating an FG125 (28 Watts at 12.7V). Requirements and operation duration can be calculated from the Amp load and battery Amp Hour specifications (Fig. 11). For best results, operate the ultrasound broadcast from dusk to dawn, but to optimize battery life, program the timer to cycle on and off at critical times, e.g., three, two hour intervals: sunset ±1h, midnight ±1h, and sunrise ±1h. A 9V battery powered hose end irrigation timer (DIG Irrigation Products model 9001D) can be adapted to serve as a low power programmable timer to power the ultrasound units on and off. The timer

battery in this device will last up to one year. Take the wires that go to the valve control and use them to operate a relay to open a switch in the 12V power connection leading to the power inverter. If using an FG125, it can be programmed for timed operation, e.g., on at dusk, off at dawn.

Table 1. Parts list per bridge for ultrasound broadcast system used on Cappell Creek and Mawah Creek Bridges.

Item	qty	units	model	price ea	price extended
ultrasonic broadcast unit (UBU)	2	each	AT-800	$4,100.00	$8,200.00
watering timer and board	2	1 per 2 UBU	DIG 9001D with relay board	$150.00	$300.00
inverter	2	1 per 2 UBU	Tripp Lite 150 watt	$50.00	$100.00
Polarized quick-connect harness	8	set per battery	PowerPole SER003	$3.00	$24.00
Polarized quick-connect harness	1	set per inverter	PowerPole SER003		$0.00
Fuse holder	8	per battery cable		$3.00	$24.00
Storage Batteries	8	2 sets of 4	Grp 29 HD deep cycle	$90.00	$720.00
30 amp battery charger	1		Iota DLS-30M	$130.00	$130.00
Extension cord	2	100 ft		$40.00	$80.00
Vented enclosure	1			n/a	n/a
GFCI	1	ground fault protection	in electrical box	$25.00	$25.00
				total	**$9,603.00**

The AT800 ultrasound broadcast units have a tripod standard ¼-20 mounting thread at the base of the unit. Suspend from the point when mounting below a bridge deck. The AT800 housing should provide protection from water drips, but in anticipation of regular water exposure, protect the top of the unit with plastic or other water impervious material to direct the water off the unit (but do not occlude the broadcast ports).

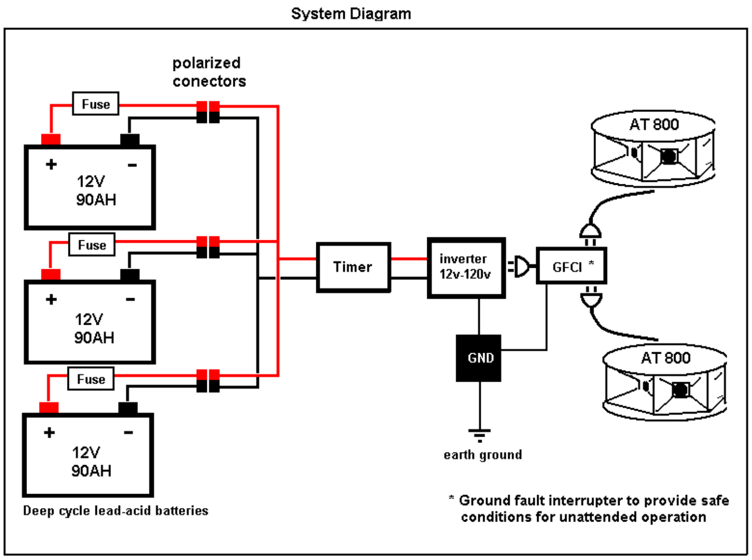

Figure 10. Diagram of suggested set up of AT800 ultrasound broadcast units for operation by battery power. The systems at Cappell Creek and Mawah Creek Bridges used four batteries. See Table 1 for parts.

Power system Calculation per AT800										
Inverter 12v Amps:	1.7		Total battery AH:	180	safety factor:	0.75	.75=calc. + 75%	Calcs. with one FG125 added		
Inverter Amps	Hrs per day	Daily Amp Hours	overkill factor	adjusted AH	Battery AH	Days estimate		Add'l load	Total w/FG125	Days estimate
1.7	4	6.8	0.75	11.9	180	15.1		4.0	15.9	11.3
1.7	5	8.5	0.75	14.9	180	12.1		4.4	19.3	9.3
1.7	6	10.2	0.75	17.9	180	10.1		4.8	22.7	7.9
1.7	7	11.9	0.75	20.8	180	8.6		5.2	26.0	6.9
1.7	8	13.6	0.75	23.8	180	7.6		5.6	29.4	6.1
1.7	9	15.3	0.75	26.8	180	6.7		6.0	32.8	5.5
1.7	10	17	0.75	29.8	180	6.1		6.4	36.2	5.0
1.7	11	18.7	0.75	32.7	180	5.5		6.8	39.5	4.6
1.7	12	20.4	0.75	35.7	180	5.0		7.2	42.9	4.2

Figure 11. Battery power calculations for operating a single AT800 ultrasound broadcast units without and with an FG125 signal generator. This calculation shows the results for two 90 Amp Hour batteries (Table 1) and a safety factor of 75%. The systems at Cappell Creek and Mawah Creek Bridges used four batteries for two units on each bridge along with one FG125, and were successfully powered for 6 hours per night with a one week battery replacement cycle, consistent with the 7.9 day prediction shown here.

Mitigation Strategies

Bats have low reproductive rates of one birth per year with most species having just a single pup, and so cannot quickly recovering from population declines. This renders them particularly susceptible to mortality events (Kunz 1982, Racey and Entwistle 2000). For this reason the conservation of bat populations requires anticipatory and preventative management rather than reactionary. Similarly, any mitigation should focus on avoidance first, as many potential mitigation strategies do not completely meet the specialized habitat and roost requirements of bats. If avoidance is not possible, impacts should be minimized. Replacement should only be used as a last resort and must be species-specific, or increased harm to bat assemblages could occur. Therefore, it is important to note that acoustical deterrence/exclusion may only be part of a mitigation strategy depending on the impacts of the project. The best solutions are simple and fit within the parameters of normal operations. Refer to “Mitigation Strategies” in the “Hitchhikers Guide to Bat Roosts” for mitigation strategies (Erickson et al. 2002) and in “California bat mitigation techniques, solutions, and effectiveness” (Johnston et al. 2004) for further guidance on assessing bat presence. Monitoring and close biologist oversight is essential for deterrence and avoidance measures to be successful.

Monitoring Deterrent Effectiveness

Follow the same methods used to assess bat presence at roost structures to assess the effectiveness of acoustic bat deterrence with the exception of acoustic monitoring methods during deterrent operation. Within the range of the deterrent the ultrasound broadcast will overwhelm a bat detector and disrupt or prevent acoustic detection of bats. Daytime assessment augmented with spotlights and binoculars may be preferred in situations where bats can be seen. Bats often make audible vocalizations during the day that knowledgeable bat biologists can recognize. Monitoring for fresh droppings (guano) can also indicate presence; e.g., sweep areas clear of old guano or place sheeting between visits to discern current usage. Visible monitoring (with night vision if needed) of dusk roost emergence, especially if bats can be counted, provides an indisputable method to assess roost occupancy where bats roost in interior space not otherwise readily visible. Refer to “Survey and Evaluation Protocols” in the “Hitchhikers Guide to Bat Roosts” (Erickson et al. 2002) and “California bat mitigation techniques, solutions, and effectiveness” (Johnston et al. 2004) for further guidance on assessing bat presence.

Potential Strategies for Ineffective Acoustic Deterrence

Although tested in the field with a valid experimental control and proven effective, and despite the apparent success on the Cappell Creek Bridge, acoustic deterrence of bats on structures remains a nascent method. Until establishing a record of effectiveness, projects considering acoustic deterrence of bats on structures should also establish a provisional alternative exclusion plan(s) should monitoring reveal bats occupying a structure despite ultrasonic acoustic broadcast. Alternative strategies to consider:

- Continue broadcasting. As apparently happened on the Cappell Creek Bridge after some bats returned, continuing the broadcast seemed to eventually deter the bats, or perhaps as different groups of bats attempted to roost on the bridge. Mark Jensen of Binary Acoustic Technology reported a similar experience with application of ultrasonic acoustic deterrence in a building in Arizona.

- If broadcasting intermittently rather than the entirety of the night, sunset to sunrise, increase the broadcast duration to all night, if possible. If operating by batteries, that may entail more frequent battery replacement.

- Decrease the spacing between ultrasound broadcasting units if using multiple units. Experience may prove, for example, a 15 m spacing provides more effective deterrence than the initially recommended 20 m spacing. The complexity of the structure may also influence the effective spacing of broadcast units, i.e., if bats have deep recesses into which they can move and enter an effective "shadow" from the ultrasound broadcast.

- Fall back to physical exclusion (with one way exits for any remaining bats), at least for the section of the structure the bats seem intent on occupying. *Never physically exclude bats during the reproductive season. Follow guidelines in the "Hitchhikers Guide to Bat Roosts" for mitigation strategies (Erickson et al. 2002) or in "California bat mitigation techniques, solutions, and effectiveness" (Johnston et al. 2004).*

- Initiate another means of rendering the structure unpreferable for roosting. Bats prefer a secure, warm, dry, and secure roost space. For example, spraying a fine mist of water would render a roost cool, damp, and unsuitable for roosting[3]. *Do not apply such a method when bats are present; initiate such a method when bats leave, and never perform such a treatment during the reproductive season.*

Lessons Learned and Miscellaneous Recommendations

- Construction and maintenance schedules can change unpredictably. Try to maintain communication with managers that can keep you updated on schedules. Unfortunately, exclusion may need to be performed before bats make a seasonal return and this may be far in advance of any unanticipated scheduling changes. for example, we unnecessarily excluded bats from bridges in this project, only to find that construction was delayed and work did not begin that construction season. As a result bats were excluded needlessly from a maternity roost.

- As a consequence of the short wavelengths of ultrasound, it essentially travels by line of sight with much less scatter and diffraction around obstacles than audible sound. Keep mindful of this effect when placing ultrasound broadcast units to avoid "acoustic shadows" in large recesses of structures.

- Reference Site? In relation to monitoring, such as Rock Chute Creek

[3] Check that any such procedure proceeds appropriately under any relevant environmental guidelines.

- Include monitoring in mitigation costs and time allocation. Make sure you scope for bat considerations in the early stages of a project.
- Be sure that objectives and deliverables are understood by both Caltrans Biologists, Maintenance/Construction, Project Managers, as well as any cooperating and permitting agencies.
- The natural seasonal cycles of bats can trump construction schedules. It is essential to schedule and initiate exclusion prior to construction activity. Make sure to finalize or acquire any required permits or contracts in advance of initiated monitoring or exclusion.
- Before attempting acoustic exclusion, read and understand all manufacturer's supporting materials (and this and the cited exclusion guidelines (Erickson et al. 2002, Johnston et al. 2004), and contact the manufacture if needed to clarify any uncertainties.
- From the start, involve project biologists with proper training and qualification to detect bats on structures to perform initial inspection of bridges (or other structures) for bats. In the case of this project, this did not happen until a few days prior to Ready To List. Prior bat biologist failed to detect guano under two of the four bridges. This could have been taken care of during the Project Approval and Environmental Documentation phase.
- Off-site alternative roosting habitat does not often work as bats have highly specific requirements for roost environmental conditions, and the often smaller replacement roosts cannot replicate the conditions of a large structure. The off-site habitat needs to have the same environmental characteristics as the original habitat if it is to be successful. Temperature loggers that record roost conditions during occupancy prior to exclusion can establish the primary variable that needs to be replicated, roost temperature.

Conclusion and Future Recommendations

As a newly emerged method, acoustic deterrence and exclusion of bats will advance with new lessons learned through experience, or perhaps fade way if subsequent implementation proves ineffective. However, the initial application described here, and the experimental field trials and implementation on wind turbines, suggests that it provides an effective deterrent. Although initially expensive, the ultrasonic broadcast units are reusable on subsequent projects, reducing cost, and potentially simplifying exclusion where needed. Although the effectiveness of deterring different species from structures using ultrasound broadcast remains untested, the biology of echolocation suggests that it should similarly deter all bat species, and the experience from wind turbine studies also supports that speculation (Arnett et al. 2010, 2011).

Projects that require the exclusion of bats should consider acoustic deterrence and exclusion where appropriate and potentially advantageous, and if implemented, report their experiences and results to the Caltrans Division of Environmental Analysis to support the research and development of this methodology.

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Appendix 1

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Comment: Add new appendices for Cappell and Mawah Bridges Fig. 7 and 8. Possible the equipment set up schematic from Broadcaster to Battery

Calculated decibel level at different distances and frequencies from Deaton Engineering prototype acoustic deterrents. Calculations assume ambient temperature of 20° C and air pressure of 101.325 kPa (kilopascal). For Binary Acoustic Technology AT800 deterrents, assume approximately 5 m less than these tabulated values. From Arnett et al. (2011).

Calculated Decibel Level at Distance and Frequency

(Assumes 20° C at 10% relative humidity and pressure of 101.325 kPa)

	Frequency (kHz)								
Distance (m)	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
1	102	107	112	122	122	117	114.5	114.5	117
5	87.0	91.6	96.2	105.6	104.7	99.1	95.7	94.5	95.8
10	79.7	83.9	87.9	96.6	94.4	88.1	83.7	81.0	80.8
15	74.8	78.7	82.0	90.1	86.7	79.7	74.2	70.0	68.3
20	71.0	74.5	77.2	84.6	80.0	72.3	65.7	60.0	56.8
25	67.8	70.8	73.0	79.6	73.9	65.4	57.7	50.6	45.8
30	64.9	67.5	69.1	75.0	68.1	58.9	50.2	41.6	35.3
35	62.3	64.5	65.5	70.7	62.6	52.6	42.8	32.7	24.9
40	59.8	61.6	62.0	66.5	57.2	46.5	35.7	24.1	14.8
45	57.5	58.8	58.7	62.5	52.0	40.6	28.6	15.6	4.7
50	55.3	56.2	55.5	58.6	46.9	34.8	21.7	7.2	-5.2
55	53.2	53.7	52.4	54.7	41.8	29.0	14.9	-1.1	-15.0
60	51.1	51.2	49.3	51.0	36.9	23.3	8.1	-9.4	-24.8

Calculated Decibel Level at Distance and Frequency

(Assumes 20° C at 40% relative humidity and pressure of 101.325 kPa)

	Frequency (kHz)								
Distance (m)	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
1	102	107	112	122	122	117	114.5	114.5	117
5	85.7	89.3	93.2	102.0	100.8	94.9	91.3	90.1	91.4
10	76.8	78.5	81.2	88.4	85.8	78.7	73.8	71.0	70.9
15	70.4	70.3	71.7	77.3	73.3	65.0	58.8	54.5	52.9
20	65.0	63.1	63.2	67.2	61.8	52.4	44.8	38.9	35.9
25	60.1	56.4	55.2	57.8	50.8	40.3	31.3	23.9	19.4
30	55.6	50.2	47.7	48.6	40.3	28.5	18.3	9.3	3.4
35	51.4	44.1	40.3	39.7	29.9	17.0	5.4	-5.1	-12.5
40	47.3	38.2	33.2	31.0	19.8	5.7	-7.2	-19.3	-28.1
45	43.4	32.5	26.1	22.4	9.7	-5.5	-19.8	-33.4	-43.7
50	39.6	26.9	19.2	13.9	-0.2	-16.5	-32.2	-47.3	-59.1
55	35.9	21.3	12.4	5.5	-10.0	-27.5	-44.5	-61.2	-74.4
60	32.2	15.9	5.6	-2.8	-19.8	-38.4	-56.8	-75.0	-89.7

Upper Target (dB) 65 Lower Target (dB) 35

Appendix 2

Binary Acoustic Technology specifications for the AT800 ultrasonic broadcast unit.

Product Details

AT800 Ultrasonic Transmitter

Product Summary

The BAT AT800 wide bandwidth ultrasonic transmitter. It is sold bundled with GTools playback software.

SKU/Item Number: AT800-HP

Price: $3500

The AT800 is a portable ultrasonic transmitter that is designed for field research. It employs eight wide bandwidth ultrasonic elements along with a multi-element horn enclosure to produce ultrasonic transmissions over a full 360 degree field of view in azimuth and 30 degrees in elevation.

The AT800 is designed to be operated by a Windows based lap-top computer. It connects a lap-top through a high speed USB 2.0 interface. The bundled GTools playback software allows the user to select prerecorded files and play them through the AT800. The software supports the industry standard WAV file format and works with files generated by SPECT'R as well as time expanded detectors recorded by SonoBat (www.sonobat.com). Optionally, a Flash memory capability can be incorporated to allow the device to operate as a stand-alone transmitter.

The AT800 requires less than 40 Watts of operating power. It is designed to be powered using 115V AC power, which can be supplied by a 12V battery along with a suitable power inverter.

Product Specification:

download spec sheet (PDF 229K)

Product Highlights

- **360° Coverage**
- **Transmit power: 106 dB SPL @ 1m**
- **Wide frequency range: 20 to 120 KHz**
- **Low operating power: <40 Watts**
- **High speed USB 2.0 interface**
- **Durable aluminum enclosure**
- **1/4-20 camera mount thread**
- **Bundled with GTools playback software.**

Binary Acoustic Technology diagram and description of AT800 ultrasound projection.

Elevation Beam Pattern Considerations:

The elements of the AT800 are tipped slightly to bias the beam pattern downward by 15 degrees. This optimizes the overall pattern such that the AT800 can be employed from either an elevated position that is near a ceiling or from a position near the floor. The AT800 includes 1/4-20 mounting thread on both the bottom and the top to allow mounting the AT800 in either an upright or inverted orientation. When operated from an elevated position or near a ceiling, the AT800 should be operated in an upright orientation (figure 3). When operated in non-elevated position or near a floor, the AT800 should be operated in an inverted orientation (figure 4). This optimizes the pattern to cover the widest possible area.

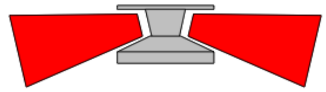

Figure 3: Upright response
(for use elevated or near ceiling)

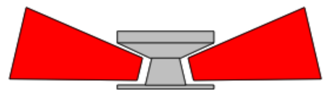

Figure 4: Inverted response
(for use non-elevated or near floor)

Link to GTools software manual for programming operation of AT800:
ftp://anonymous:@ftp.binaryacoustictech.com/ftp/pub/GTools%20Manual%20V1p6.pdf