STATE OF NEW HAMPSHIRE SITE EVALUATION COMMITTEE

RE: Application of Antrim Wind, LLC for Certificate)
of site and facility to construct up to 30 MW of wind electric)
generation in Antrim, New Hampshire and operate the same.)

PRE-FILED DIRECT TESTIMONY OF SUSAN MORSE WITH SUPPLEMENTAL MATERIAL PROVIDED BY GEOFFREY T. JONES, BRUCE HEDIN, RICHARD BLOCK

Q: Please state your name and address.

A: Susan Morse, 55A Bentley Lane, Jericho, Vermont 05465.

Q: What is the name of your business?

A: Morse & Morse Forestry and Wildlife Consultants.

Q: What services do Morse & Morse Forestry and Wildlife Consultants provide?

A: Morse & Morse Forestry and Wildlife Consultants is a four-generation family forestry business in which I have introduced our specific focus on wildlife habitat enhancement practices and documentation of important habitats through field reconnaissance.

Q: What are your qualifications and background?

A: In order to more fully answer this question I am including in this document text from the Keeping Track® website:

> Throughout North America, Susan Morse is highly regarded as an expert in wildlife ecology, natural history and tracking. Ms. Morse has more than thirty-eight years experience monitoring wildlife and interpreting wildlife habitat uses. Her research and teaching has focused on cougar, bobcat, black bear, and Canada lynx, but has recently expanded to include wide-ranging cervids, including moose, and more recently caribou. She has given technical workshops on wild felids and other

carnivores to a wide range of audiences, including the general public, conservation leaders and professional biologists.

In 2001 Morse received the Franklin Fairbanks Award for her lifelong creative and dedicated service to enriching the awareness and understanding of the natural world among the residents of New England. She and Keeping Track® were recently recognized by the Adirondack Council for decades of conservation work in the Champlain basin bio-region. Ms. Morse has authored numerous articles and writes a quarterly column on wildlife in *Northern Woodlands Magazine*. Her work has been featured in many other publications, including *Smithsonian*, *Audubon*, *Amicus Journal*, *Forest Magazine*, *Wild Earth*, *Vermont Life, Adirondack Life, The Nature Conservancy*, *and Ranger Rick*, as well as on National Public Radio's "Morning Edition".

Eighteen years ago, Morse founded Keeping Track®, an organization devoted to training professional biologists and citizen scientists alike in wildlife monitoring skills. Keeping Track's mission is to empower multiple stakeholders to use their knowledge to detect, record and monitor the status of wildlife and wildlife habitat in their communities. Data collected by Keeping Track teams has influenced the conservation of over 33,550 acres; 23,550 in New England and California and 10,000 in Quebec.

Q: What are your responsibilities for Morse & Morse?

A: I am the sole proprietor, and I conduct all the wildlife-related field work and research for projects we undertake.

Q: Have you ever testified before state-level committees or agencies?

A: Yes, over many years I've been called upon to provide my expertise relating to the residential presence of certain wildlife species within habitats that may become compromised as a consequence of a variety of development proposals.

Q: What is the purpose of your testimony?

A: To challenge the findings of the applicants' biological consultants. My field work and literature review have convinced me that the proposed site of Antrim Wind, LLC's industrial wind turbine project is **core habitat** – home to a variety of residential mammal species that are special because they are indicative of larger unfragmented habitats. Furthermore, my findings in the field have convinced me that development of an industrial wind project in this area would severely and negatively impact exemplary habitat which has been described by the State of New Hampshire as "Highest ranked wildlife habitat by (as assessed by) ecological condition." These highest ranked habitats in New Hampshire were analyzed by professional biologists. Major considerations included the biological landscape as well as human impact factors which could most affect a given habitat type. **Biological factors** included consideration of rare plant and animal species, as well as overall biodiversity. **Landscape factors** included the size of a given habitat and how close it is to other patches of habitat. **Human impact factors** included measuring the density of roads around the habitat as well as the relative presence of other anthropogenic influences, including dams, recreational use and pollution.

(See Exhibit SM1: Highest Ranked Wildlife Habitat map.)

Q: Would you briefly describe the methods used during your field investigation of the habitat conditions found along the Tuttle-Willard Ridgeline and adjoining habitats?

A: Though my field work was limited to one day, I have confidently conducted many similar brief habitat reconnaissance outings during which time I and my assistants physically spread out and carefully search the area for evidence of focal species uses of habitats therein. On this particular outing on the Tuttle-Willard Ridgeline, I and my colleagues looked for evidence of past and present focal species' tracks and sign. Such evidence builds the case that the area in question is part of "core habitat" whose food, cover and travel attributes are therefore highly important to the wildlife using these resources here on the Tuttle-Willard Ridgeline, as well as within the surrounding wildlands. The attached photographs and captions section discusses in detail our findings

Q: What is core habitat and will you describe the ways in which this project will introduce habitat fragmentation and therefore damage the habitat values found therein?

A: The following is a brief answer to a very complex question whose answer has huge implications for healthy wildlife and plant populations. Core habitats consist of large unfragmented blocks of natural habitat in which human presence is minimal. Ideally, core habitats are connected with one another through "linkage areas" and "corridors".

A growing number of conservation biologists are alarmed about how habitat fragmentation irreversibly damages core habitat, and as a consequence, healthy ecological functions. Removing more forest and inviting more roads, human access and noise into an otherwise unfragmented habitat dramatically increases disturbance and wildlife mortality. Crucial security habitat becomes degraded and wildlife recruitment is compromised, threatening the long-term viability of populations. Acre by acre, disruptions and disappearing habitats represent incremental and cumulative losses. Fragmentation results in habitat patches that are too small and too insular to provide adequate food and security for wildlife. Increased human, pet and vehicle recreational uses will undoubtedly increase along the Tuttle-Willard Ridgeline and such disturbances will disrupt, if not destroy, certain wildlife species' daily and seasonal movement patterns. In some cases increased mortality will also occur as a consequence of malnutrition, increased vulnerability to predation, road kill and poaching.

Q: What are the specific impacts that negatively affect core wildlife habitat and necessary refugia?

A: Roads, and even trails that follow along power line corridors, introduce significant stress factors within the foraging, resting and denning habitats that sustain numerous species of invertebrates, birds, amphibians, reptiles and mammals. For example, nesting birds and denning mammals are often displaced, if not killed as a result of increased numbers of people, their pets and vehicles regularly using habitats that were formally undisturbed. For example, Vermont's Fish and Wildlife Department bear biologist, Forrest Hammond, has acknowledged that proposed utility-scale wind facilities in Vermont may disturb or displace black bears from accessing and utilizing critical concentrated food resources, as well as important forested wetlands and ridgeline travel corridors.

Q: Could you discuss some specific negative impacts that would result from the construction of the road and wind tower facility as well as future increased human access in what is today a largely unvisited habitat?

A: Overall, negative impacts to ecosystems include habitat fragmentation, soil erosion, nutrient loading, water quality degradation, pollution, poaching and the introduction of non-native plant and animal species. In the following paragraphs I will elaborate on specific negative impacts:

- DISRUPTION OF MOVEMENT CORRIDORS – The Tuttle-Willard Ridgeline and other New Hampshire ridges function as preferred travel routes and corridors that many wildlife species use as they access local habitat amenities as well as move about the larger landscape in order to find mates and/or disperse. Migrating birds, bats, moose, bobcats, bears and other species regularly use these important pathways, and as such, ridgeline travel routes facilitate species and genetic exchange throughout an impressive assemblage of connected habitats both locally and throughout the northeast and neighboring Canada. Landscape linkages and corridors offer vital opportunities for demographic rescue—the ability for new individuals to reach and replenish a habitat should some stochastic event or disease cause an entire population to perish. Such intact habitats along New Hampshire, and indeed New England's ridgelines will play an increasing and integral role as global climate change forces countless species of plant and animals to seek new habitats in which to adapt and survive.

- ALTERED WILDLIFE BEHAVIOR AND CONSEQUENT ENERGY LOSSES – When wild animals are frightened and flushed needlessly and repeatedly their alarm and flight behaviors affect them in many ways. The cumulative effects of increased energetic demands resulting from such activities may prove too costly for some animals, especially during winter or other periods of food shortage. Biologists have long recognized and warned about this hazard with respect to the vital need for whitetail deer on "critical winter range" to conserve their limited energy budget and *not* be harassed or disturbed by us or our dogs. Numerous studies have also demonstrated that increased mortality is a harsh reality for species that are flushed and displaced over extended periods of time. For example, birds have exhibited decreased nest fidelity and other species completely forsake what would otherwise be preferred foraging and nesting habitats. Such altered behaviors and missed opportunities for optimal food and cover insidiously compromises the fitness, sustainability and diversity of species over time.

- IMPACTS BEYOND THE ROAD OR POWERLINE CUT – A road or trail alters the surrounding area far beyond its actual footprint, and has been shown to impact wildlife thousands of feet into the adjacent forest. These "distance effects", as they are called, within an area of influence surrounding a road or trail may cause displacement of wildlife from otherwise suitable habitats. For example, when a songbird's primary song is interrupted by human disturbance some bird species are reluctant to establish nesting territory. Even a single pedestrian traveling through a bird's breeding territory causes a decline in that bird's inclination to engage in courtship and breeding behavior.

Q: Do these threats pertain only to larger core habitats?

A: As I explained previously, the Tuttle-Willard Ridgeline (and its large intact assemblage of forested lands which surround it) is certainly best described as "core wildlife habitat". I will remind us that this is an extensive natural area that the State of New Hampshire has given the highest possible score for its wildlife habitat values. However, even small isolated parks and unnamed hilltops overlooking lands which are considerably more developed are of inestimable value to the wild plants and animals that live there. In many places these quieter natural lands are the last stand habitats for wildlife—wildlife that would otherwise face the uncountable hazards of being pushed closer to us, where they are not welcome and where premature death most often awaits them.

Q: Are there concerns about the ill-effects of wind turbine noise on wildlife?

A: Yes, absolutely. The two citations I have provided below will elucidate the many concerns. Briefly, chronic noise exposure associated with wind energy construction and operations has definitely been documented to contribute to a broad range of problems which threaten the bio-energetics, foraging success, anti-predation strategies, acoustic social communications success, reproductive success and fitness of many taxa. Ecological consequences of chronic noise exposure have also caused changes in the density and diversity of various bird and mammal species populations, as well as changes in community structure.

(See Exhibit SM2:
The costs of chronic noise exposure for terrestrial organisms, Jesse R. Barber, Kevin R. Crooks, Kurt M. Fristrup, *Trends in Ecology & Evolution* - 1 March 2010 (Vol. 25, Issue 3, pp. 180-189))

(See Exhibit SM3:
The Effects of Noise on Wildlife, research prepared by Meghan C. Sadlowski, Environmental Scientist, Division of Migratory Bird Management, US Fish & Wildlife Service, available at http://www.fws.gov/windenergy/docs/Noise.pdf)

Q: Briefly discuss the impacts of industrial-scale wind towers on birds and bats.

A: IMPACTS TO BATS **-** At a time when northeastern bat species are severely threatened by a new disease in North America, White-nosed syndrome (WNS), any measures we can take to eliminate other causes of mortality are now more important than ever. A recent study led by Boston University researchers predicts that even New England's most common bat species, the Little Brown Myotis, is threatened with extinction within the next 20 years, even if current losses due to WNS lessens over time. At least 7 species of bats are known to be affected by this rapidly spreading disease, and scientists are now alarmed that significant damages to ecosystem health, structure and functions may occur as a result of this serious epidemic. Bats are obligate insectivores and contribute immeasurably to human society by their daily consumption of millions of insects that would otherwise destructively affect forest and wildlife health, agricultural crops, and pose health hazards to people, livestock and pets. According to a new study published in *Science Magazine* bats save U.S. farmers an estimated 53 billion dollars each year as a result of their consumption of insects. Closer to home, the million bats that have already been killed in the northeast due to WNS would have consumed approximately 1,320 metric tons of insects. Just one Little Brown Myotis foraging during one night may consume as many as 4,000 mosquitoes and other insects. Wind power turbines kill bats and birds by the thousands. Wind turbines kill migratory bats as well; by 2020 an estimated 33,000 to 111,000 bats are predicted to be killed by turbines in the mid-Atlantic Highlands alone. Air pressure drops caused by spinning turbine blades results in bat and songbird deaths. These animals die of lung damage as a consequence of being sucked into a low pressure area behind the turbine blades. In Montana, a 90 turbine wind farm near Judith Gap killed more than 1,200 bats in one year during the animals' fall and spring migrations. Given the severity of the White-nosed syndrome epidemic any losses of bats cannot be justified or found to be acceptable in my view—not when other energy-saving and producing alternatives exist!

With respect to birds we should keep in mind this following sobering statistic recently published in a University of California study. While the towers that have caused the significant mortality discussed are tall communication towers, it appears that lighted towers are lethal to migrating birds. Nearly 7 million migrating birds die in a given year as a result of the 84,000 towers that dot the American skyline*****. Coupled with habitat loss it is no wonder that so many of our beloved and familiar songbirds are now declining!

*****Longcore T, Rich C, Mineau P, MacDonald B, Bert DG et al. (2012) An Estimate of Avian Mortality at Communication Towers in the United States and Canada. PLoS ONE 7(4): e34025. doi:10.1371/journal.pone.0034025

Q: Could you discuss the comprehensive science called "cumulative effects assessment" and its relevance to an industrial project of this scale?

A: "Cumulative effects" are now recognized as an aggregate of combined and often synergistic human-caused effects which negatively impact wildlife, their habitat and other valued ecosystem components. Described by conservation scientists* as "death by a thousand cuts", individual impacts may be regarded as minor. However, these disturbances are now recognized to be incremental and are collectively significant when measured over time and space. For example, scientists now recognize that global scale problems that confront healthy ecosystems today are actually the accumulation of a staggering number of separate and seemingly inconsequential human-caused effects which now have combined to seriously threaten life as we know it. In this way global climate change, acid precipitation, genetic isolation, habitat fragmentation and the bioaccumulation of toxins within the food web are really the deadly result of decades of unregulated cumulative effects.

Cumulative Assessment is a relatively new applied environmental science which seeks to more comprehensively measure and predict anthropogenic stresses which have negatively influenced wildlife in the past, are now occurring, and will harmfully influence wildlife in the future. Large scale habitat loss and disturbances as a consequence of industrial energy exploration and development, mining, timber extraction and backcountry recreation have been demonstrated to contribute to wildlife population declines. Over time, and across vast habitats, the cumulative effects of a multitude of stresses causes wildlife to experience behavioral, physiological, demographic and distributional changes. These challenges result in reduced fitness, unnecessary and costly energetic expenditures, and avoidance of altered habitats and human infrastructure. In addition, resulting population declines have been further attributed to lowered reproductive rates and recruitment success. The assumption that animals will "adjust" and possibly even benefit from these habitat modifications through "habituation" is utterly unfounded. Furthermore, the complexities of species interactions with each other, as well as reactions to habitat alterations as a consequence of industrial wind facilities have not been comprehensively studied over time and geographic space. To conclude, I believe that Cumulative Effects Assessment (CEA) should be required of companies seeking to disturb New England's limited core habitat and the wild species that thrive there. Wind facility impacts to wildlife and habitat must be more comprehensively studied and monitored over time. In my opinion, it appears that the entire northeast is rushing into wind energy development without responsibly undertaking CEA. While this science is certainly highly technical and requires a long term research commitment and a much larger budget, we must insist on doing these projects properly, or not at all.

*Therivel, R. and B. Ross. 2007/ Cumulative effects assessment: Does scale matter? Environmental Impact Assessment Review 27:365 to 385.

Q: Can you identify who accompanied you on your day of reconnaissance (July 10, 2012) during which time you investigated most of the Tuttle-Willard Ridgeline and proposed wind tower installations? Can you review the qualifications of those who accompanied you?

A: Accompanying were Geoffrey T. Jones, licensed New Hampshire forester and former Director of Land Management for the Society for the Protection of New Hampshire Forests; R. Scott Semmens, graduate of Keeping Track's KTMP wildlife habitat monitoring training and biology teacher; Bruce Hedin, bird expert and contributor to the *Atlas of Breeding Birds in New Hampshire*; Francie von Mertens, Trustee of New Hampshire Audubon and graduate of Keeping Track's KTMP wildlife habitat monitoring training; Richard Block, cartographer and graduate of Keeping Track's KTMP wildlife habitat monitoring training; Brenda Schaefer, abutting landowner and amateur naturalist; and Nathan Schaefer, naturalist student.

Q: How have the discoveries you made on July 10, 2012 convinced you that this is core habitat?

A: First, a review of State and other conservation organization maps of the region quickly impress us with the exceptional assortment of contiguous and conserved habitats throughout the region, including the Tuttle-Willard Ridgeline. This knowledge certainly led me to expect that I would find evidence of a variety of wide-ranging mammal species that require intact core habitats connected on a regional scale. Such mammal species include bobcat, black bear and moose – all of which we quickly documented and readily found throughout the day. (See Exhibit SM4: photographs by Sue Morse with captions which document the residential presence of these species over time).

Q: What additional impressions do you have that compel you to so value this ridgeline and adjacent habitats?

A: Professional forester, Geoffrey Jones and I were both deeply moved by the impressive diversity of plant community types and habitat types which one encounters along Tuttle-Willard Ridgeline and adjacent habitats. A corresponding diversity and abundance of food and cover attributes enjoyed by wildlife must have significantly influenced the State of New Hampshire's high score for wildlife habitat in this region.

(See Exhibit SM5: NH Wildlife Habitat Land Cover map.)

Q: Tell us about some of the other discoveries which you and your colleagues made on your day of reconnaissance on July 10, 2012.

A: Please see Exhibit SM6 for natural community observation reports by Forester Geoffrey T. Jones and Exhibit SM7 for a report of the 26 species of birds observed by ornithologist Bruce Hedin.

Q: How will the proposed road impact portions of the ridgeline? In particular, please discuss your impressions regarding the currently pristine boulder field and glacial erratic terrain along the east-facing slope of Tuttle and Willard Mountain Ridgeline.

A: The rugged and sometimes massive boulders – evidence of Pleistocene surficial geology – are as exquisitely beautiful as they are impressively rugged! Huge erratics augmented by post-glacial fracturing create a unique environment in which mosses, lichens, ferns and herbaceous species flourish and embody life's tenacious but fragile hold on this once stark landscape. All who were present on our field walk that day were deeply disturbed to think that this remarkable landscape would be blasted, blown up, and reduced to rubble that would then be used to surface a road that shouldn't be there. This is steep and sensitive habitat. This ridgeline should be conserved. This natural area is too special and deserves much more study of its additional potential treasures, including unique geological features and rare plants. (See Exhibit SM8: photographs by Richard Block.)

Q: Could you offer us some concluding thoughts about the ecological and cultural significance of this habitat within the larger eco-region of noteworthy conserved habitats?

A: Again, if one examines a variety of regional conservation planning maps, the tremendous and successful community commitment to conserving these lands is most evident. It flies in the face of reason to ruin what so many people have worked so hard to achieve for so many years. The proposed industrial wind turbine project is located directly in the middle of Antrim's Rural Conservation District, a zone set aside over two decades ago to "protect, conserve and preserve the remote mountainous portions of Antrim from excessive development pressures and/or activities that would be detrimental to the unique environmental characteristics and qualities of this district" by prohibiting industrial uses. This zone is a significant part of the greater Monadnock Supersanctuary and its adjacent conservation lands in Hancock, Stoddard, and Windsor. It also abuts Willard Pond and New Hampshire Audubon's dePierrefeu-Willard Pond Wildlife Sanctuary, their largest in the state. All of this is central to the Quabbin to Cardigan Initiative, a 100-mile wildlife corridor running from central Massachusetts to the White Mountains. This is part of a huge region and a conservation work-in-progress, and not appropriate for industrial and commercial exploitation which will only result in the fragmenting and undoing of decades of efforts by conservation leaders.

(See Exhibit SM9: maps of conservation lands.)

Q: What is really at risk here if this project goes forward?

A: It appears that the public is unaware that the scientific community is not necessarily in favor of ridgeline wind energy development. For example, in June of 2009 thirty scientists with backgrounds in industry, government, non-government organizations and universities convened at a special workshop and agreed on a small set of key research priorities with respect to wind energy and its impacts on migratory wildlife. With millions of wind energy units being proposed nationwide, cumulative environmental impacts must be considered and understood in order to promote responsible expansion of this renewable energy source. Workshop participants came to consensus on the "urgent need" to disseminate these following research priorities to all stakeholders. Workshop participants suggested four areas where improved science is most needed to evaluate the impacts of wind energy development on migrating animals: 1. Standardized protocols and definitions; 2. New methods and models for assessing and forecasting risk; 3. Documenting lethal and sub-lethal effects at existing wind facilities; and 4. Improved facility-site access, data access, and data management for researchers.*

The public is largely unaware of findings like these. It also appears that professional resource managers may not always be aware of these research priorities either. Because of limited budgets, personnel, or political will, our agencies entrusted with protecting natural resources may be unable to assess project parameters and outcomes and should thus be extremely cautious in permitting all proposed ridgeline wind energy development until Cumulative Effects Assessment is thoroughly and rigorously practiced over a reasonable time frame.

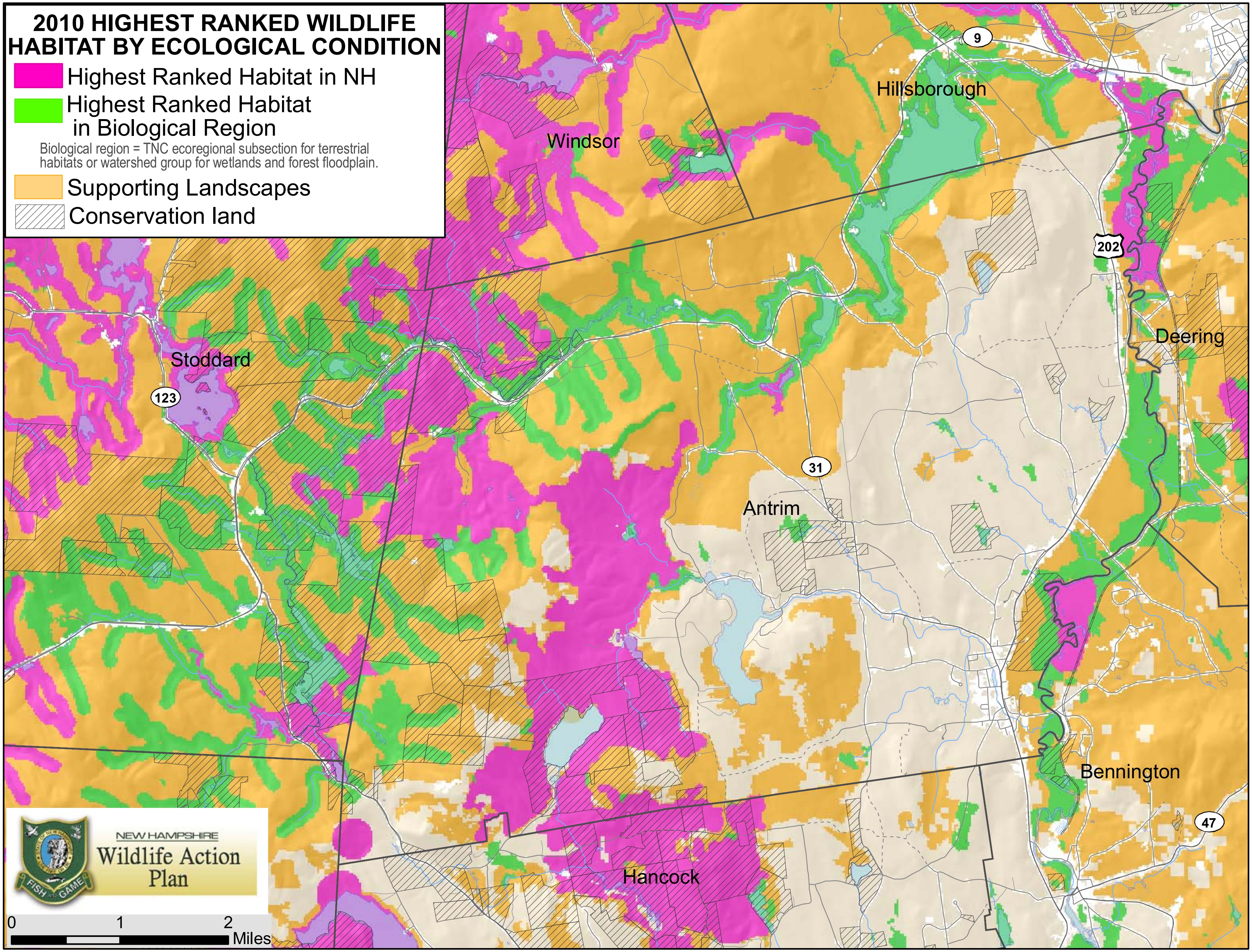
I am convinced that the proponents of Antrim Wind's proposed development cannot possibly answer the scores of questions that must be legitimately answered if we are to truly safeguard the region's wildlife, water quality, ecosystem functions, biodiversity and sanctity of place. New Hampshire's ridgelines and mountain summits – from our loftiest White Mountains to the foothills which grace our lives – are vital for the wildlife that lives there. In the context of sobering habitat losses here in New Hampshire and throughout America, our choice today should be to permanently conserve these wildlands. Nation-wide, we lose an estimated 22 million acres of habitat each year – that is an area greater than 3 times the size of New Hampshire!

To be sure, global climate change and the severe threats it poses to ecosystems worldwide, requires that each and every one of us make necessary sacrifices, change our fossil fuel-burning ways, and boldly define how we will live and share this planet with all other life in the future. Industrial wind power on New Hampshire's Tuttle-Willard Ridgeline is not the answer, however, simply because of the habitat fragmentation and destruction of biodiversity that we *know* will result.

*Piorkowski, M. D., Farnsworth, A. J., Fry, M., Rohrbaugh, R. W., Fitzpatrick, J. W. and Rosenberg, K. V. (2012), Research priorities for wind energy and migratory wildlife. The Journal of Wildlife Management, 76: 451–456. doi: 10.1002/jwmg.327

Exhibit SM1

2010 Highest Ranked Wildlife Habitat by Ecological Condition Map — Antrim



2010 HIGHEST RANKED WILDLIFE HABITAT BY ECOLOGICAL CONDITION
Highest Ranked Habitat in NH
Highest Ranked Habitat in Biological Region
Biological region = TNC ecoregional subsection for terrestrial habitats or watershed group for wetlands and forest floodplain.
Supporting Landscapes
Conservation land
Windsor
Hillsborough
Stoddard
Deering
Antrim
Bennington
Hancock
9
202
123
31
47
NEW HAMPSHIRE
Wildlife Action Plan
FISH GAME
0
1
2
Miles

Exhibit SM2

“The costs of chronic noise exposure for terrestrial organisms”

The costs of chronic noise exposure for terrestrial organisms

Jesse R. Barber[1], Kevin R. Crooks[1] and Kurt M. Fristrup[2]

[1] Department of Fish, Wildlife and Conservation Biology, Colorado State University, Fort Collins, CO 80523, USA
[2] National Park Service, Natural Sounds Program, Fort Collins, CO 80525, USA

Growth in transportation networks, resource extraction, motorized recreation and urban development is responsible for chronic noise exposure in most terrestrial areas, including remote wilderness sites. Increased noise levels reduce the distance and area over which acoustic signals can be perceived by animals. Here, we review a broad range of findings that indicate the potential severity of this threat to diverse taxa, and recent studies that document substantial changes in foraging and anti-predator behavior, reproductive success, density and community structure in response to noise. Effective management of protected areas must include noise assessment, and research is needed to further quantify the ecological consequences of chronic noise exposure in terrestrial environments.

Anthropogenic noise and acoustic masking

Habitat destruction and fragmentation are collectively the major cause of species extinctions [1,2]. Many current threats to ecological integrity and biodiversity transcend political and land management boundaries; climate change, altered atmospheric and hydrologic regimes and invasive species are prominent examples. Noise also knows no boundaries, and terrestrial environments are subject to substantial and largely uncontrolled degradation of opportunities to perceive natural sounds. Noise management is an emergent issue for protected lands, and a potential opportunity to improve the resilience of these areas to climate change and other forces less susceptible to immediate remediation.

Why is chronic noise exposure a significant threat to the integrity of terrestrial ecosystems? Noise inhibits perception of sounds, an effect called masking (see Glossary) [3]. Birds, primates, cetaceans and a sciurid rodent have been observed to shift their vocalizations to reduce the masking effects of noise [4–7]. However, compromised hearing affects more than acoustical communication. Comparative evolutionary patterns attest to the alerting function of hearing: (i) auditory organs evolved before the capacity to produce sounds intentionally [8], (ii) species commonly hear a broader range of sounds than they are capable of producing [9], (iii) vocal activity does not predict hearing performance across taxa [9,10], (iv) hearing continues to function in sleeping [11] and hibernating [12] animals; and (v) secondary loss of vision is more common than is loss of hearing [13].

Masking is a significant problem for the perception of adventitious sounds, such as footfalls and other byproducts of motion. These sounds are not intentionally produced and natural selection will typically favor individuals that minimize their production. The prevalence and characteristics of adventitious sounds have not been widely studied [14–16], although their role in interactions

Glossary

Alerting distance: the maximum distance at which a signal can be perceived. Alerting distance is pertinent in biological contexts where sounds are monitored to detect potential threats.
Atmospheric absorption: the part of transmission loss caused by conversion of acoustic energy into other forms of energy. Absorption coefficients increase with increasing frequency, and range from a few dB to hundreds of dB per kilometer within the spectrum of human audibility.
Audible: a signal that is perceptible to an attentive listener.
A-weighting: A method of summing sound energy across the frequency spectrum of sounds audible to humans. A-weighting approximates the inverse of a curve representing sound intensities that are perceived as equally loud (the 40 phon contour). It is a broadband index of loudness in humans in units of dB(A) or dBA. A-weighting also approximates the shapes of hearing threshold curves in birds [20].
Decibel (dB): a logarithmic measure of acoustic intensity, calculated by 10 $\log_{10}$(sound intensity/reference sound intensity). 0 dB approximates the lowest threshold of healthy human hearing, corresponding to an intensity of 10^{-12} Wm^{-2}. Example sound intensities: -20 dB, sound just audible to a bat, owl or fox; 10 dB, leaves rustling, quiet respiration; 60 dB, average human speaking voice; 80 dB, motorcycle at 15 m.
Frequency (Hz and kHz): for a periodic signal, the maximum number of times per second that a segment of the signal is duplicated. For a sinusoidal signal, the number of cycles (the number of pressure peaks) in one second (Hz). Frequency equals the speed of sound ($\sim$340 ms^{-1}) divided by wavelength.
Ground attenuation: the part of transmission loss caused by interaction of the propagating sound with the ground.
Listening area: the area of a circle whose radius is the alerting distance. Listening area is the same as the ‘active space’ of a vocalization, with a listener replacing the signaler as the focus, and is pertinent for organisms that are searching for sounds.
Masking: the amount or the process by which the threshold of detection for a sound is increased by the presence of the aggregate of other sounds.
Noticeable: a signal that attracts the attention of an organism whose focus is elsewhere.
Scattering loss: the part of transmission loss resulting from irregular reflection, diffraction and refraction of sound caused by physical inhomogeneities along the signal path.
Spectrum, power spectrum and spectral profile: the distribution of acoustic energy in relation to frequency. In graphical presentations, the spectrum is often plotted as sound intensity against sound frequency (Figure 1, main text).
1/3 octave spectrum: acoustic intensity measurements in a sequence of spectral bands that span 1/3 octave. The International Standards Organization defines 1/3rd octave bands used by most sound level meters (ISO 266, 1975). 1/3rd octave frequency bands approximate the auditory filter widths of the human peripheral auditory system.
Spreading loss: more rigorously termed divergence loss. The portion of transmission loss attributed to the divergence of sound energy, in accordance with the geometry of environmental sound propagation. Spherical spreading losses in dB equal 20*log10(R/R_0), and result when the surface of the acoustic wavefront increases with the square of distance from the source.
White noise: noise with equal energy across the frequency spectrum.

Corresponding author: Barber, J.R. (barber.jesse@gmail.com).

0169-5347/$ – see front matter doi:10.1016/j.tree.2009.08.002 Available online 15 September 2009

Box 1. Geographic extent of transportation noise in the USA

Transportation noise is a near ubiquitous component of the modern acoustical landscape. The method used here to estimate the geographic extent of airway (Figure Ia,b), railway (Figure Ic) and roadway (Figure Id) noise in the continental USA is calculated using the average human 'noticeability' of noise. Noise was deemed noticeable when the modeled noise intensity from transportation [in dB(A)] exceeded the expected noise intensity as predicted from population density [also dB(A)]. Although noticeability is a conservative metric of the geographic extent of transportation noise, this analysis only indicates the potential scope of the problem. How anthropogenic noise changes the temporal and spectral properties of naturally-occurring noise (Figure 1, main text) and the life histories of individual species will be crucial components of a more thorough analysis.

The maps in Figure I reflect the following calculations: (i) noise calculations are county-by-county for a typical daytime hour; (ii) county population density is transformed into background sound level using an EPA empirical formula (see Ref. [84]); higher density implies higher background sound levels; (iii) the geographic extent of transportation noise is determined by calculating the distance from the vehicle track at which the transportation noise falls below the background sound level, multiplying twice that distance by the length of the transportation corridor in the county (giving a noticeability area), and comparing that area with the total area in the county to compute the percentage land area affected. A low percentage noticeability can result if either the population density is high or the number of transportation segments is low in the county. This analysis indicates that transportation noise is audible above the background of other anthropogenic noise created by local communities in most counties in continental USA. See Ref. [84] for more details.

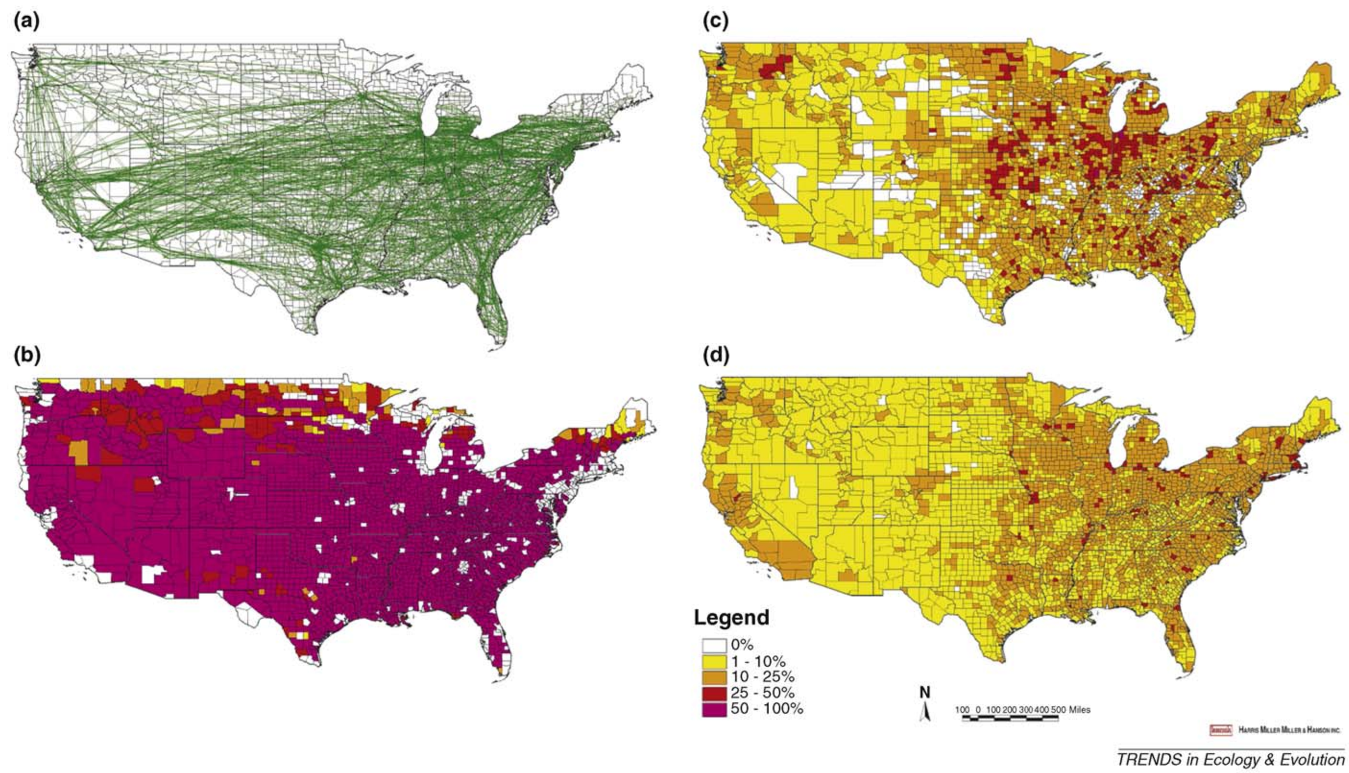


Figure I. Percent of US county areas in which transportation noise is noticeable. **(a)** Jet departures that occurred between 3 and 4 pm on Oct. 17, 2000, tracked to first destination. **(b)** Data from (a) were used to estimate the geographic extent of high altitude airway noise in the USA. The geographic extent of noise from railway and highway networks is depicted in **(c)** and **(d)**, respectively. The color-coded divisions (see legend; divisions increase in size as the percent increases) were chosen assuming that, as noticeability increases, so do estimate errors due to noticeability area overlap from different transportation segments. Adapted with permission from Ref. [84].

among predators and prey is unquestionable. In animal communication systems, both the sender and receiver can adapt to noise masking, but for adventitious sounds the burden falls on listeners.

Anthropogenic disturbance is known to alter animal behavioral patterns and lead to population declines [17,18]. However, animal responses probably depend upon the intensity of perceived threats rather than on the intensity of noise [19]. Deleterious physiological responses to noise exposure in humans and other animals include hearing loss [20], elevated stress hormone levels [21] and hypertension [22]. These responses begin to appear at exposure levels of 55–60 dB(A), levels that are restricted to relatively small areas close to noise sources [20].

The scale of potential impact

The most spatially extensive source of anthropogenic noise is transportation networks. Growth in transportation is increasing faster than is the human population. Between 1970 and 2007, the US population increased by approximately one third (http://www.census.gov/compendia/statab). Traffic on US roads nearly tripled, to almost 5 trillion vehicle kilometers per year (http://www.fhwa.dot.gov/ohim/tvtw/tvtpage.cfm). Several measures of aircraft traffic grew by a factor of three or more between 1981 and 2007 (http://www.bts.gov/programs/airline_information/air_carrier_traffic_statistics/airtraffic/annual/1981_present.html). Recent reviews of the effects of noise on marine mammals have identified similar trends in shipping noise (e.g. Refs [23,24]). In addition to transportation, resource extraction and motorized recreation are spatially extensive sources of noise on public lands.

Systematic monitoring by the Natural Sounds Program of the US National Park Service (http://www.nature.nps.gov/naturalsounds) confirms the extent of noise intrusions. Noise is audible more than 25% of the hours between 7am and 10pm at more than half of the 55 sites in 14 National Parks that have been studied to date; more than a dozen sites have hourly noise audibility percentages exceeding 50% (NPS, unpublished). Remote wilderness areas are not immune, because air transportation noise is widespread, and high traffic corridors generate substantial noise increases on the ground (Box 1). For example, anthropogenic sound is audible at the Snow Flats site in Yosemite National Park nearly 70% of the time during peak traffic hours. Figure 1 shows that typical noise levels exceed natural ambient sound levels by an order of magnitude or more.

Roads are another pervasive source of noise: 83% of the land area of the continental US is within 1061 m of a road [25]. At this distance an average automobile [having a noise source level of 68 dB(A) measured at 15 m] will project a noise level of 20 dB(A). This exceeds the median natural levels of low frequency sound in most environments. Trucks and motorcycles will project substantially more noise: up to 40 dB(A) at 1 km. Box 2 provides a physical model of the reduced listening area that can be imposed by these louder background sound levels.

Acoustical ecology

Intentional communication, such as song, is the best studied component of the acoustical world, and these signals are often processed by multiple receivers. These communication networks enable female and male songbirds, for example, to assess multiple individuals simultaneously for mate choice, extra-pair copulations and rival assessment [26]. Acoustic masking resulting from increasing background sound levels will reduce the number of individuals that comprise these communication networks and have unknown consequences for reproductive processes [27].

Reproductive and territorial messages are not the only forms of acoustical communication that operate in a network. Social groups benefit by producing alarm calls to warn of approaching predators [28] and contact calls to maintain group cohesion [29]. A reduction in signal transmission distance created by anthropogenic noise might decrease the effectiveness of these social networks. The inability to hear just one of the alarm calling individuals can result in animals underestimating the urgency of their response [30].

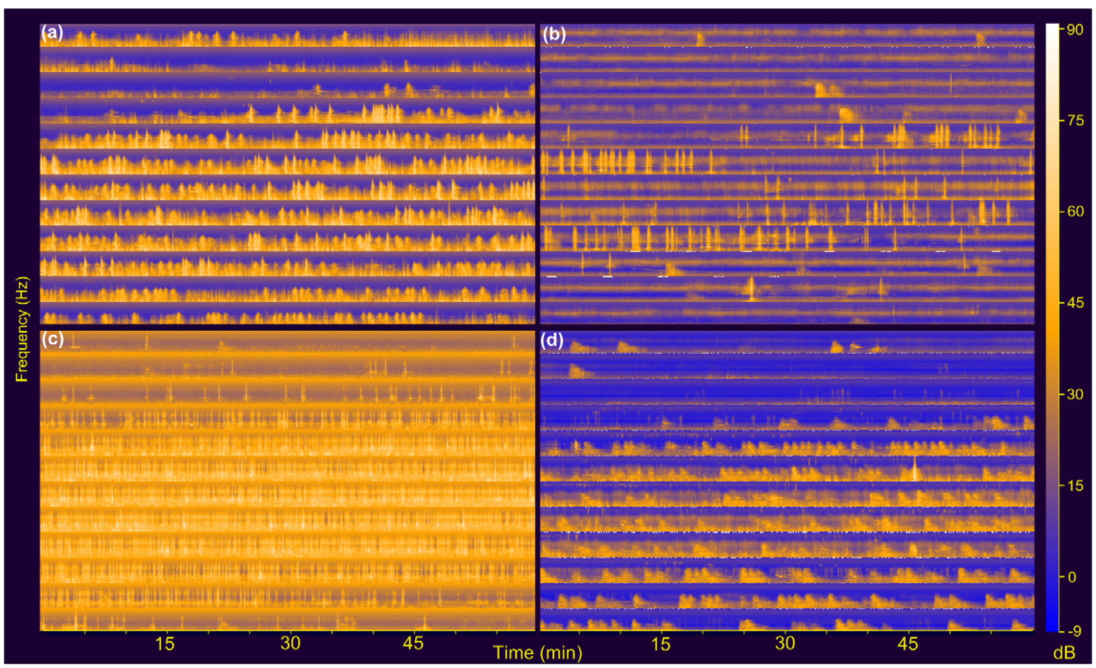


Figure 1. 24-hour spectrograms of Indian Pass in Lake Mead National Recreation Area **(a)**, Madison Junction in Yellowstone National Park **(b)**, Trail Ridge Road in Rocky Mountain National Park **(c)**, and Snow Flats in Yosemite National Park **(d)**. Each panel displays 1/3 octave spectrum sound pressure levels, with two hours represented horizontally in each of 12 rows. The first three rows in each panel represent the quietest hours of each day, from midnight to 6 am. Frequency is shown on the y axis as a logarithmic scale extending from 12.5 Hz to 20 kHz, with the vertical midpoint in each row corresponding to 500 Hz. The z axis (color) describes sound pressure levels in dB (unweighted); the color scaling used for all four panels is indicated by the color bar on the right hand edge. The lowest 1/3 octave levels are below 0 dB, the nominal threshold of human hearing. White dots at the upper edge of some rows in the panels on the right side denote missing seconds of data. Low-frequency, broadband signatures from high altitude jets are present in all four panels. Distinct examples are present just before 6 am in (a), near 12:45 am in (b) and (c), and between midnight and 12:30 am in (d). Fixed wing aircraft signatures (tonal contours with descending pitch) are present in (a) and (d), with a good example at 1:15 am in (d). Broadband signatures with very low frequency tonal components in (a) are due to low-altitude helicopters, that are prominent from ~7 am until 8 pm. Another prominent helicopter signature is at 11:30 am in (d). (b) illustrates snowmobile and snowcoach sounds recorded ~30 m from the West Entrance Road in Yellowstone. (c) illustrates traffic noise recorded 15 m from Trail Ridge Road in Rocky Mountain National Park, during a weekend event featuring high levels of motorcycle traffic. Background sound levels at the Rocky Mountain site were elevated by sounds from the nearby river.

Box 2. Physical model of reduced listening area in noise

The maximum detection distance of a signal decreases when noise elevates the masked hearing threshold. The masked detection distance: original detection distance ratio will be the same for all signals in the affected frequency band whose detection range is primarily limited by spreading losses. For an increase of N dB in background sound level, the detection distance ratio is: $k = 10^{-N/20}$. The corresponding fraction of original listening area is: $k = 10^{-N/10}$. A 1-dB increase in background sound level results in 89% of the original detection distance, and 79% of the original listening area. These formulae will overestimate the effects of masking on alerting distance and listening area for signals that travel far enough to incur significant absorptive and scattering losses. More detailed formulae would include terms that depend upon the original maximum range of detection.

Figure I illustrates the expected noise field of a road treated as a line source (equal energy generated per 10 m segment). An animal track is marked by ten circular features, that depict the listening area of a signal whose received level (expressed as a grey-scaled value for each possible source location) decreases with the inverse square of distance from the listener. The apparent shrinkage of the circles is due to masking by the increasingly dark background of sound projected from the road, just as noise would shrink the listening area. The circles span 9 dB in road noise level, in 1-dB steps from the quietest location (upper right) to the noisiest (at the crossing).

Masking effects are reduced with increasing spectral separation between noise and signal. The model presumes that the original conditions imposed masked hearing thresholds, so organisms that are limited by their hearing thresholds will not be as affected by masking. A diffuse noise source is illustrated, but the same results would be obtained if some spatial release from masking were possible, so long as the original conditions implied masked hearing thresholds (see Ref. [85] for a review of release strategies).

These measures of lost listening opportunity are most pertinent for chronic exposures. They imply substantial losses in auditory awareness for seemingly modest increases in noise exposure. Analyses of transportation noise impacts based on perceived loudness often assert that increases of up to three dB have negligible effects; this corresponds to a 50% loss of listening area.

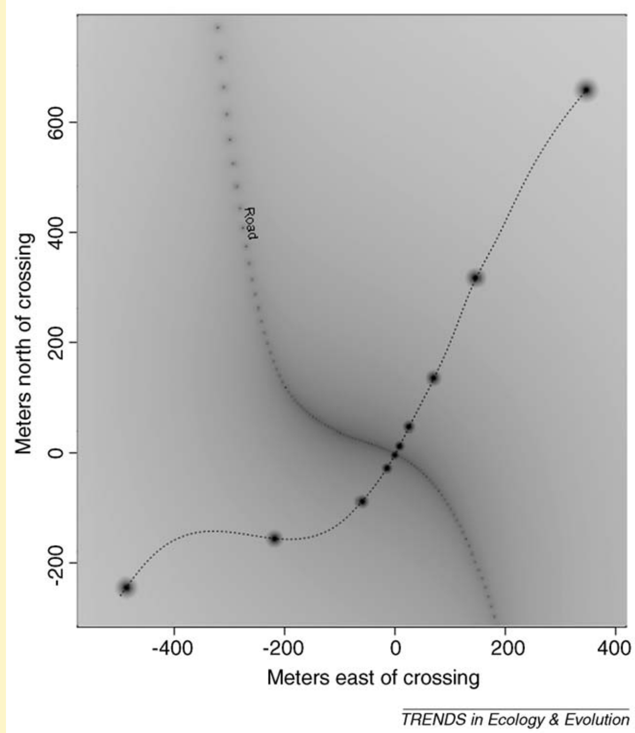


Figure I. A physical model of reduced listening area as an animal approaches a road.

Many vertebrate and invertebrate species are known to listen across species' boundaries to one another's sexual (e.g. Ref. [31]), alarm (e.g. Ref. [32]) and other vocalizations. Recent examples include gray squirrels, *Sciurus carolinensis*, listening in on the communication calls of blue jays, *Cyanocitta cristata*, to assess site-specific risks of cache pilfering [33]; and nocturnally migrating songbirds [34] and newts (Ref. [35] and Refs therein) using heterospecific calls to make habitat decisions. Reduced listening area imposed by increased sound levels is perhaps more likely to affect acoustical eavesdropping than to interfere with deliberate communication. The signaler is under no selective pressure to ensure successful communication to eavesdroppers and any masking compensation behaviors will be directed at the auditory system and position of the intended receiver rather than of the eavesdropper.

Acoustical communication and eavesdropping comprise most of the work in bioacoustics, but the parsimonious scenario for the evolution of hearing involves selection for auditory surveillance of the acoustical environment, with intentional communication evolving later [8]. Adventitious sounds are inadequately studied, in spite of their documented role in ecological interactions. Robins can use sound as the only cue to find buried worms [36]; a functional group of bats that capture prey off surfaces, gleaners, relies on prey-generated noises to localize their next meal [37]; barn owls (*Tyto alba*; [38]), marsh hawks (*Circus cyaneus*; [39]), and grey mouse lemurs (*Microcebus murinus*; [15] have been shown to use prey rustling sounds to detect and localize prey; big brown bats, *Eptesicus fuscus*, have the ability to use low-frequency insect flight sounds to identify insects and avoid protected prey [40]. In addition to prey localization, spectrally unstructured movement sounds are also used to detect predators. White-browed scrubwren (*Sericornis frontalis*) nestlings become silent when they hear the playback of footsteps of pied currawong, *Strepera graculina*, their major predator [41]; and tungara frogs, *Physalaemus pustulosus* avoid the wingbeat sounds of an approaching frog-eating bat, *Trachops cirrhosus* [42]. We are aware of only one study that has examined the role of adventitious sounds other than movement noises; African reed frogs, *Hyperolius nitidulus* flee from the sound of fire [43]. It is likely that other ecological sounds are functionally important to animals.

It is clear that the acoustical environment is not a collection of private conversations between signaler and receiver but an interconnected landscape of information networks and adventitious sounds; a landscape that we see as more connected with each year of investigation. It is for these reasons that the masking imposed by anthropogenic noise could have volatile and unpredictable consequences.

Separating anthropogenic disturbance from noise impacts

Recent research has reinforced decades of work [44,45] showing that human activities associated with high levels of anthropogenic noise modify animal ecology: for example, the species richness of nocturnal primates, small ungulates and carnivores is significantly reduced within ~ 30 m of roads in Africa [46]; anuran species richness in Ottawa, Canada is negatively correlated with traffic density [47]; aircraft overflights disturb behavior and alter time budgets in harlequin ducks (*Histrionicus histrionicus*; [48]) and mountain goats (*Oreamnos americanus*; [49]); snowmobiles and off-road vehicles change ungulate vigilance behavior and space use, although no evidence yet links these responses to population consequences [50,51]; songbirds show greater nest desertion and abandonment, but reduced predation, within 100 m of off-road vehicle trails [52]; and both greater sage-grouse (*Centrocercus urophasianus*; [53]) and mule deer (*Odocoileus hemionus*; [54]) are significantly more likely to select habitat away from noise-producing oil and gas developments. Thus, based on these studies alone, it seems clear that activities associated with high levels of anthropogenic noise can re-structure animal communities; but, because none of these studies, nor the disturbance literature in general, isolates noise from other possible forces, the independent contribution of anthropogenic noise to these effects is ambiguous.

Other evidence also implicates quiet, human-powered activities, such as hiking and skiing, in habitat degradation. For example, a paired comparison of 28 land preserves in northern California that varied substantially in the number of non-motorized recreationists showed a five-fold decline in the density of native carnivores in heavily used sites [55]. Further evidence from the Alps indicates that outdoor winter sports reduce alpine black grouse, *Tetrao tetrix* populations [17] and data from the UK link primarily quiet, non-motorized recreation to reduced woodlark, *Lullula arborea* populations [18]. A recent meta-analysis of ungulate flight responses to human disturbance showed that humans on foot produced stronger behavioral reactions than did motorized disturbance [45]. These studies strengthen a detailed foundational literature suggesting that anthropogenic disturbance events are perceived by animals as predation risk, regardless of the associated noise levels. Disturbance evokes anti-predator behaviors, interferes with other activities that enhance fitness and, as the studies above illustrate, can lead to population decline [44]. Although increased levels of noise associated with the same disturbance type appear to accentuate some animal responses (e.g. Refs [44,48]), it is difficult to distinguish reactions that reflect increasingly compromised sensory awareness from reactions that treat greater noise intensity as an indicator of greater risk.

To understand the functional importance of intact acoustical environments for animals, experimental and statistical designs must control for the influence of other stimuli. Numerous studies implicating noise as a problem for animals have reported reduced bird densities near roadways (reviewed in Ref. [56]). An extensive study conducted in the Netherlands found that 26 of 43 (60%) woodland bird species showed reduced numbers near roads [57]. This research, similar to most road ecology work, could not isolate noise from other possible factors associated with transportation corridors (e.g. road mortality, visual disturbance, chemical pollution, habitat fragmentation, increased predation and invasive species along edges). However, these effects extended for over a mile into the forest, implicating noise as one of the most potent forces driving road effects [58]. Later work, with a smaller sample size, confirmed these results and contributed a significant finding: birds with higher frequency calls were less likely to avoid roadways than birds with lower frequency calls [59]. Coupled with the mounting evidence that several animals shift their call frequencies in anthropogenic noise [4–7], these data are suggestive of a masking mechanism.

A good first step towards disentangling disturbance from noise effects is exemplified by small mammal translocation work performed across roadways that varied greatly in traffic amount. The densities of white-footed mice, *Peromyscus leucopus* and eastern chipmunks *Tamias striatus* were not lower near roads and both species were significantly less likely to cross a road than cover the same distance away from roads, but traffic volume (and noise level) had no influence on this finding [60]. Thus, for these species, the influence of the road surface itself appears to outweigh the independent contributions of direct mortality and noise.

Recent findings on the effects of anthropogenic noise

Two research groups have used oil and gas fields as 'natural experiments' to isolate the effects of noise from other confounding variables. Researchers in Canada's boreal forest studied songbirds near noisy compressor stations [75–90 dB(A) at the source, 24 hrs a day, 365 days a year] and nearly identical (and much quieter) well pads. Both of these installations were situated in two to four ha clearings with dirt access roads that were rarely used. This design allowed for control of edge effects and other confounding factors that hinder interpretation of road impact studies. The findings from this system include reduced pairing success and significantly more first time breeders near loud compressor stations in ovenbirds (*Seiurus aurocapilla*; [61]), and a one-third reduction in overall passerine bird density [62]. Low territory quality in loud sites might explain the age structuring of this ovenbird population and, if so, implicates background sound level as an important habitat characteristic. In addition to the field data above, weakened avian pair preference in high levels of noise has been shown experimentally in the lab [63]. These data suggest masking of communication calls as a possible underlying mechanism; however the reduced effectiveness of territorial defense songs, reduced auditory awareness of approaching predators (see Box 3 for a discussion of the foraging/vigilance tradeoff in noise), or reduced capacity to detect acoustic cues in foraging, cannot be excluded as explanations of the results.

A second research group, working within natural gas fields in north-west New Mexico, US, used pinyon, *Pinus edulis*-juniper, *Juniperus osteosperma* woodlands adjacent to compressor stations as treatment sites and woodlands adjacent to gas wells lacking noise-producing compressors as quiet control sites [64]. The researchers were able to turn off the loud compressor stations to perform bird counts, relieving the need to adjust for detection differences in noise [62]. This group found reduced nesting species richness but in contrast to Ref.

Box 3. Do rising background sound levels alter vigilance behavior?

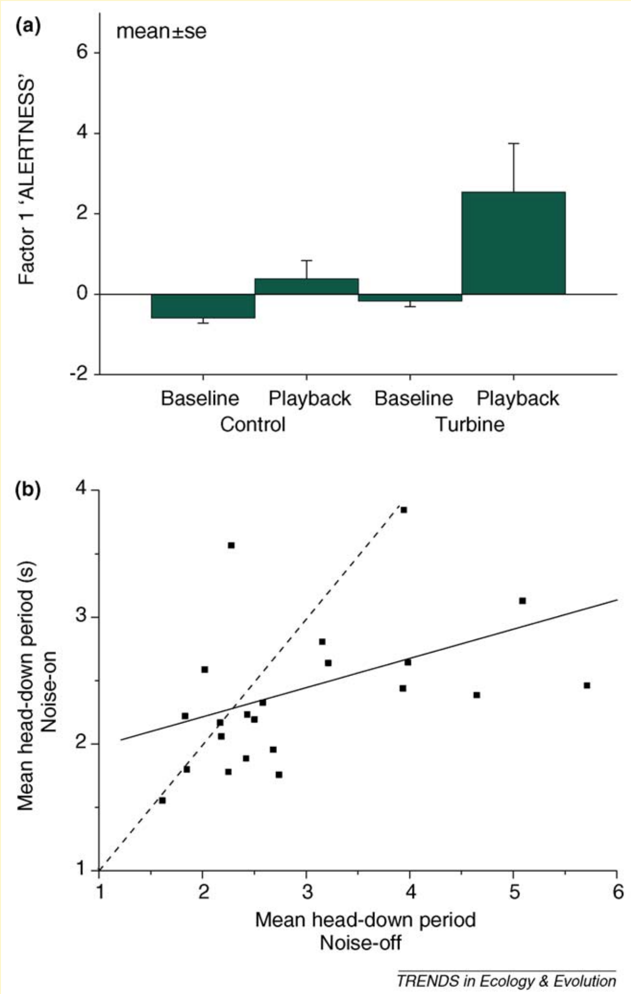


Figure I. Examples of increased vigilance behavior in noise. (**a**) When predator-elicited alarm calls are played back to California ground squirrels (*Spermophilus beecheyi*), adults show a greater increase in vigilance behavior at a site heavily impacted by anthropogenic noise, under power-generating wind turbines, than in a quiet control site [67]. (**b**) Further work on vigilance behaviors in noise comes from controlled, laboratory work with foraging chaffinches (*Fringilla coelebs*). In noise these birds decrease the interval between head-up scanning bouts, which results in fewer pecks and, thus, reduced food intake [90]. Dots depict the mean head-down period for each individual with and without white noise playback. Points below the dashed line (slope = 1) document individuals who increased scanning effort in noise. The solid regression line shows that the general trend was a more dramatic response from individuals with the lowest scanning effort. (a) adapted and (b) reproduced, with permission from Refs [67] and [90], respectively.

Predation risk and human disturbance increase vigilance behaviors (e.g. Refs [50,86]), at a cost to foraging efficiency [87,88]. Habitat features that influence predator detection, such as vegetation height, predict predation risk [88]. If background sound level interferes with the ability of an animal to detect predators, risk can increase. Do animals perceive background sound level as a habitat characteristic that predicts predation risk? Two recent studies document increased vigilance behaviors in high levels of noise (Figure I). It seems probable that these increased anti-predator behaviors are the result of attempted visual compensation for lost auditory awareness. Evidence from ungulates near roads suggests this is the case (Figure II); however, the distinct contributions of traffic as perceived threat and traffic noise as a sensory obstacle are confounded in road studies. Experimental research with birds and mammals suggests that lost visual awareness owing to habitat obstruction reduces food-searching bouts and increases vigilance (reviewed in Ref. [89]). Although no evidence exists (but see Ref. [64]), if noise shifts the spatial distribution of foraging effort, then plant growth and seed dispersal could also be altered.

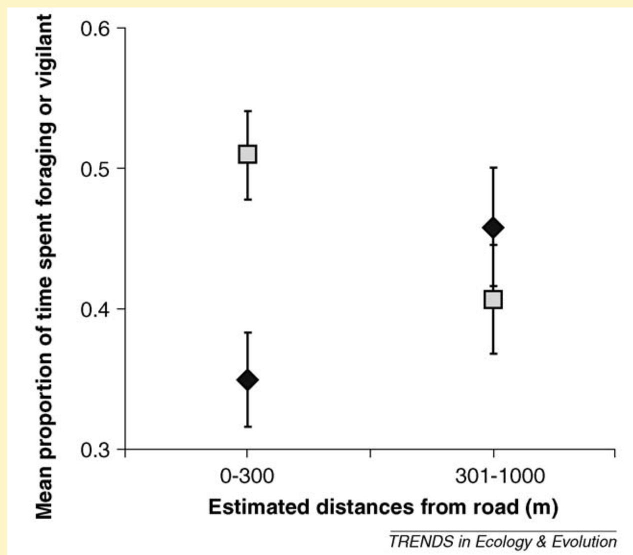


Figure II. An example of the foraging–vigilance tradeoff. Pronghorn (*Antilocapra Americana*) spend more time being vigilant (squares) and less time foraging (diamonds) within 300 meters of a road [86]. Future experiments should attempt to separate the roles of traffic as perceived threat and reduced auditory awareness on these tradeoffs. Reproduced, with permission, from Ref. [86].

[62], no reduction in overall nesting density. Unexpectedly, nest success was higher and predation levels lower in loud sites (also see Ref. [52]). The change in bird communities between loud and quiet sites appears to be driven by site preference; the response to noise ranged from positive to negative, with most responses being negative (e.g. three species nested only in loud sites and 14 species nested only in quiet, control sites). However, given the change in community structure, habitat selection based on background sound level is not the only interpretation of these data, as birds might be using cues of reduced competition pressure or predation risk to make habitat decisions [64]. The major nest predator in the study area, the western scrub jay, *Aphelocoma californica*, was significantly more likely to occupy quiet sites, which might explain the nest predation data [64]. It is probable that nest predators rely heavily on acoustic cues to find their prey. The study also found that the two bird species most strongly associated with control sites produce low-frequency communication calls. These observations suggest masking as an explanatory factor for these observed patterns. This work highlights the potential complexity of the relationship between noise exposure and the structure and function of ecological systems.

Adjusting temporal, spectral, intensity and redundancy characteristics of acoustic signals to reduce masking by noise has been demonstrated in six vertebrate orders [4–7,65]. These shifts have been documented in a variety of signal types: begging calls of bird chicks [66], alarm signals in ground squirrels [67], contact calls of primates [68], echolocation cries of bats [65] and sexual communication signals in birds, cetaceans and anurans [4–7,69]. Vocal adjustment probably comes at a cost to both energy balance and information transfer; however, no study has addressed receivers.

Masking also affects the ability of animals to use sound for spatial orientation. When traffic noise is played back to grey treefrog, *Hyla chrysoscelis* females as they attempt to localize male calls, they take longer to do so and are significantly less successful in correctly orienting to the male signal [70]. Similar studies with the European tree frog, *Hyla arborea* show decreased calling activity in played back traffic noise [71]. *H. arborea* individuals appear to be unable to adjust the frequency or duration of their calls to increase signal transmission, even at very high noise intensities (88 dB(A), [71]); although other frogs have been shown to slightly shift call frequencies upward in response to anthropogenic noise [69]. These are particularly salient points. It is likely that some species are unable to adjust the structure of their sounds to cope with noise even within the same group of organisms. These differences in vocal adaptability could partially explain why some species do well in loud environments and others do poorly [5,7,72].

Under many conditions, animals will minimize their movement sounds. For example, mice preferentially select quieter substrates on which to move [73]. Adventitious sounds of insects walking contain appreciable energy at higher frequencies (main energy ~3–30 kHz [16]) and are thus unlikely to be fully masked by most anthropogenic noise (<2 kHz [4–7]) but the spectral profile near many noise sources contains significant energy at higher frequencies (e.g. Ref [74]). Foundational work with owls and bats has shown that frequencies between approximately three and eight kHz are crucial for passive sound localization accuracy [38,75]. In fact, a recent laboratory study demonstrated that gleaning bats avoided hunting in areas with played back road noise that contained energy within this spectral band ([74]; Box 4).

Adapting to a louder world

Animals have been under constant selective pressure to distinguish pertinent sounds from background noise. Two

Box 4. Effects of acoustic masking on acoustically specialized predators

Laboratory work has demonstrated that gleaning bats (who use prey-generated sounds to capture terrestrial prey; Figure Ia) avoid noise when foraging (Figure Ib). Interestingly, treefrogs, a favorite prey of some neotropical gleaning bats, tend to call from sites with high ambient noise levels (primarily from waterfalls) and bats prefer frog calls played back in quieter locations [91]. Extinction risk in bats correlates with low wing aspect ratios (a high cost and low wing-loading morphology), a trait that all gleaning bats share [92]. A recent analysis indicates that urbanization most strongly impacts bats with these wing shapes [93]. However, low wing aspect ratio is also correlated with habitat specialization, edge intolerance and low mobility [92,93], obscuring the links between a gleaning lifestyle, louder background sound levels and extinction risk as urbanization reduces available habitat, fragments landscapes and generates noise concomitantly.

A radio-tag study showed that a gleaning bat, *Myotis bechsteinii*, was less likely to cross a roadway (three of 34 individuals) than was a sympatric open-space foraging bat, *Barbastella barbastellus* (five out of six individuals; [94]), implicating noise as a fragmenting agent for some bats. The latter species hunts flying insects using echolocation (an auditory behavior that uses ultrasonic signals above the spectrum of anthropogenic noise) [94]. Similar findings suggest acoustically mediated foragers are at risk: terrestrial insectivores were the only avian ecological guild to avoid road construction in the Amazon [95] and human-altered landscapes limited provisioning rates of saw-whet owls [96]. That these animals plausibly rely on sound for hunting might not be coincidental.

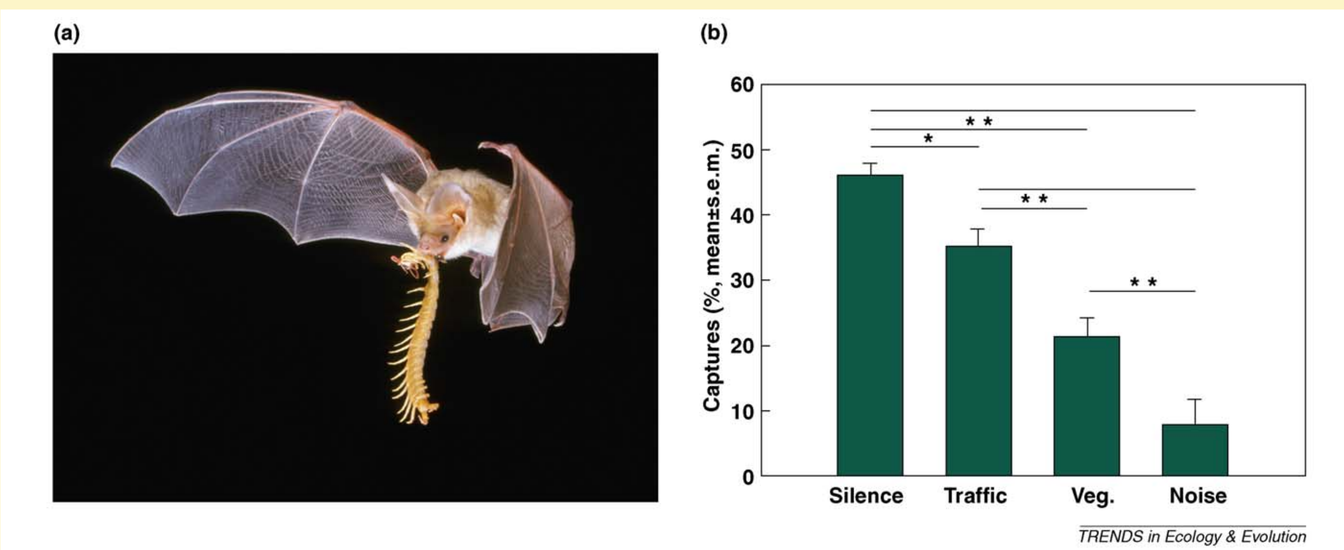


Figure I. Gleaning bats avoid hunting in noise. The pallid bat, *Antrozous pallidus* **(a)**, relies upon prey-generated movement sounds to localize its terrestrial prey. Recent work demonstrates that another gleaning bat, the greater mouse-eared bat, *Myotis myotis*, avoids foraging in noise [74]. **(b)** A laboratory two-compartment choice experiment showed that this bat preferred to forage in the compartment with played-back silence versus the compartment with played-back traffic, wind-blown vegetation or white noise. This pattern held true whether the percentage of flight time, compartment entering events, the first 25 captures per session or overall capture percentage were compared across silent and noise playback compartments. Asteriks indicate the results of post repeated-measure ANOVA, paired t-tests (**$P<0.01$, *$P<0.05$, N=7 bats). The differences between noise types (traffic, vegetation and white noise) probably reflect increased spectral overlap between prey-generated movement sounds and the spectral profile of the noise. Reproduced with permission from Scott Altenbach (a) and Ref. [74] (b).

Box 5. Outstanding questions

- Multiple studies with birds have demonstrated signal shifts in anthropogenic noise that does not substantially overlap in frequency with the birds' song [4–7,72]. To what extent does low-frequency anthropogenic noise inhibit perception of higher frequency signals? Mammals appear more prone to the 'upward spread' of masking than do birds [85,97]. Noise commonly elevates low frequency ambient sound levels by 40 dB or more, so small amounts of spectral 'leakage' can be significant. Laboratory studies should be complimented by field studies that can identify the potential for informational or attentional effects [98]. This work should use anthropogenic noise profiles and not rely on artificial white noise as a surrogate. Furthermore, we suggest that future studies measure or model sound levels (both signal and background) at the position of the animal receiver (*sensu* Ref. [23]).
- What roles do behavioral and cognitive masking release mechanisms [85] have in modifying the capacity of free-ranging animals to detect and identify significant sounds? Only one study has examined the masked hearing thresholds of natural vocal signals in anthropogenic noise [97]. This work found that thresholds for discrimination between calls of the same bird species were consistently higher than were detection thresholds for the same calls [97]. This highlights the lack of knowledge concerning top-down cognitive constraints on signal processing in noise. Can noise divide attention and reduce task accuracy by forcing the processing of multiple streams of auditory information simultaneously [99]?
- Do animals exploit the temporal patterning of anthropogenic noise pollution (see Ref. [4])? Alternatively, what constitutes a chronic exposure and how does this vary in relation to diel activity schedules?
- Does noise amplify the barrier effects of fragmenting agents, such as roads [94,100]?
- What routes (exaptation, behavioral compensation, phenotypic plasticity and/or contemporary evolution) lead to successful tolerance of loud environments?
- What role does audition have in vigilance behaviors? Are visually mediated predators at an advantage in loud environments when prey animals rely upon acoustical predator detection?
- Do animals directly perceive background sound level as a habitat characteristic related to predation risk? A noise increase of 3 dB(A) is often identified as 'just perceptible' for humans, and an increase of 10 dB(A) as a doubling of perceived loudness. These correspond to 30% and 90% reductions in alerting distance, respectively. Do organisms assess reduced alerting distance by monitoring other acoustical signals?

examples include penguin communication systems being shaped by wind and colony noise [76] and frog systems driven to ultrasonic frequencies by stream noise [77]. A meta-analysis of the acoustic adaptation hypothesis for birdsong (the idea that signals are adapted to maximize propagation through the local habitat) found only weak evidence for this claim [78]. Physiological constraints and selective forces from eavesdropping could explain this weak relationship [78], in addition to variation of noise profiles across nominally similar habitat types (e.g. insect noise, [79]).

Phenotypic plasticity enables one adaptation to anthropogenic noise. The open-ended song learning documented in great tits, *Parus major* helps explain the consistent song shifts observed in all ten comparisons between urban and rural populations [72]. Contemporary evolution (fewer than a few hundred generations) has now been quantified in several systems [80] and we might anticipate similar microevolutionary changes in many species with rapid generation times that consistently experience acoustical environments dominated by noise, particularly in increasingly fragmented landscapes.

Perhaps the greatest predictors of the ability of a given species to succeed in a louder world will be the degree of temporal and spectral overlap of biologically crucial signals with anthropogenic noise (Figure 1), and their flexibility to compensate with other sensory modalities (e.g. vision) when auditory cues are masked. Given known sensory biases in learning [81], many animals will be constrained in their ability to shift from acoustical inputs to other sensory cues for dynamic control of complex behavioral sequences.

Conclusions and recommendations

The constraints on signal reception imposed by background sound level have a long history of being researched in bioacoustics, and it is increasingly clear that these constraints underlie crucial issues for conservation biology. Questions have been raised about the value of behavioral studies for conservation practice (for a review see Ref [82]), but ethological studies of auditory awareness and the consequences of degraded listening opportunities are essential to understanding the mechanisms underlying ecological responses to anthropogenic noise (Box 5). These studies are more challenging to execute than observation of salient behavioral responses to acute noise events, but they offer opportunities to explore fundamental questions regarding auditory perception in natural and disturbed contexts.

Chronic noise exposure is widespread. Taken individually, many of the papers cited here offer suggestive but inconclusive evidence that masking is substantially altering many ecosystems. Taken collectively, the preponderance of evidence argues for immediate action to manage noise in protected natural areas. Advances in instrumentation and methods are needed to expand research and monitoring capabilities. Explicit experimental manipulations should become an integral part of future adaptive management plans to decisively identify the most effective and efficient methods that reconcile human activities with resource management objectives [83].

The costs of noise must be understood in relation to other anthropogenic forces, to ensure effective mitigation and efficient realization of environmental goals. Noise pollution exacerbates the problems posed by habitat fragmentation and wildlife responses to human presence; therefore, highly fragmented or heavily visited locations are priority candidates for noise management. Noise management might also offer a relatively rapid tool to improve the resilience of protected lands to some of the stresses imposed by climate change. Shuttle buses and other specialized mass transit systems, such as those used at Zion and Denali National Parks, offer promising alternatives for visitor access that enable resource managers to exert better control over the timing, spatial distribution, and intensity of both noise and human disturbance. Quieting protected areas is a prudent precaution in the face of sweeping environmental changes, and a powerful affirmation of the wilderness values that inspired their creation.

Acknowledgements

We thank colleagues in the Natural Sounds Program and the NPS personnel who support monitoring projects and foster the development of acoustical resource management. We thank Lisa Angeloni, Casey Brown, Amanda Hardy, Chris Burdett and Olivier Devineau for productive discussion; Charlotte Formichella, Damon Joyce and Emma Lynch for assistance in creating figures; Shan Burson for Yellowstone monitoring data and Jessie Rinella for Lake Mead monitoring data; the researchers who shared their data and three anonymous reviewers who improved this review. The preparation of this manuscript was supported by a Postdoctoral Fellowship to J.R.B. from the National Park Service/ Natural Sounds Program and Colorado State University.

References

1 Wilcove, D.S. *et al.* (1998) Quantifying threats to imperiled species in the United States. *Bioscience* 48, 607–615
2 Crooks, K.R. and Sanjayan, M., eds (2006) *Connectivity Conservation*, Cambridge University Press
3 Klump, G.M. (1996) Bird communication in a noisy world. In *Ecology and Evolution of Acoustic Communication in Birds* (Kroodsma, D.E. and Miller, E.H., eds), pp. 321–328, Cornell University Press
4 Brumm, H. and Slabbekoorn, H. (2005) Acoustic communication in noise. *Adv. Stud. Behav.* 35, 151–209
5 Patricelli, G.L. and Blickley, J.L. (2006) Avian communication in urban noise: causes and consequences of vocal adjustment. *Auk* 123, 639–649
6 Warren, P.S. *et al.* (2006) Urban bioacoustics: it's not just noise. *Anim. Behav.* 71, 491–502
7 Slabbekoorn, H. and Ripmeester, E.A. (2008) Birdsong and anthropogenic noise: implications and applications for conservation. *Mol. Ecol.* 17, 72–83
8 Fay, R.R. and Popper, A.N. (2000) Evolution of hearing in vertebrates: inner ears and processing. *Hearing Res.* 149, 1–10
9 Fay, R.R. (1988) *Hearing in Vertebrates: A Psychophysics Databook*, Hill-Fay Associates
10 Bradbury, J.W. and Vehrencamp, S.L. (1998) *Principles of Acoustic Communication*, Sinauer
11 Rabat, A. (2007) Extra-auditory effects of noise in laboratory animals: the relationship between noise and sleep. *J. Am. Assoc. Lab. Anim. Sci.* 46, 35–41
12 Lyman, C.P. and Chatfield, P.O. (1955) Physiology of hibernation in mammals. *Physiol. Rev.* 35, 403–425
13 Fong, D.W. *et al.* (1995) Vestigialization and loss of nonfunctional characters. *Annu. Rev. Ecol. Syst.* 26, 249–268
14 Siemers, B.M. and Güttinger, R. (2006) Prey conspicuousness can explain apparent prey selectivity. *Curr. Biol.* 16, R157–R159
15 Goerlitz, H.R. and Siemers, B.M. (2007) Sensory ecology of prey rustling sounds: acoustical features and their classification by wild grey mouse lemurs. *Funct. Ecol.* 21, 143–153
16 Goerlitz, H.R. *et al.* (2008) Cues for acoustic detection of prey: insect rustling sounds and the influence of walking substrate. *J. Exp. Biol.* 211, 2799–2806
17 Patthey, P. *et al.* (2008) Impact of outdoor winter sports on the abundance of a key indicator species of alpine ecosystems. *J. Appl. Ecol.* 10, 2–8
18 Mallord, J.W. *et al.* (2007) Linking recreational disturbance to population size in a ground-nesting passerine. *J Appl. Ecol.* 44, 185–195
19 Bowles, A.E. (1995) Responses of wildlife to noise. In *Wildlife and Recreationists: Coexistence through Management and Research* (Knight, R.L. and Gutzwiller, J., eds), pp. 109–156, Island Press
20 Dooling, R.J. and Popper, A.N. (2007) The effects of highway noise on birds. Report to California Department of Transportation, contract 43A0139. (http://www.dot.ca.gov/hq/env/bio/avian_bioacoustics.htm)
21 Babisch, W. (2003) Stress hormones in the research on cardiovascular effects of noise. *Noise Health* 5, 1–11
22 Jarup, L. *et al.* (2008) Hypertension and exposure to noise near airports: the HYENA study. *Environ. Health Persp.* 116, 329–333
23 Nowacek, D.P. *et al.* (2007) Responses of cetaceans to anthropogenic noise. *Mammal Rev.* 37, 81–115
24 Weilgart, L.S. (2007) The impacts of anthropogenic noise on cetaceans and implications for management. *Can. J. Zool.* 85, 1091–1116
25 Ritters, K.H. and Wickham, J.D. (2003) How far to the nearest road? *Front. Ecol. Environ.* 1, 125–129
26 McGregor, P. (ed.) (2005) *Animal Communication Networks*, Cambridge University Press
27 Hansen, I.J.K. *et al.* (2005) Communication breakdown? Habitat influences on black-capped chickadee dawn choruses. *Acta Ethol.* 8, 111–120
28 Caro, T. (2005) *Antipredator Defenses in Birds and Mammals*, The University of Chicago Press
29 Marler, P. (2004) Bird calls: a cornucopia for communication. In *Nature's Music: The Science of Birdsong* (Marler, P. and Slabbekoorn, H., eds), pp. 132–176, Elsevier
30 Sloan, J.L. and Hare, J.F. (2008) The more the scarier: adult Richardson's ground squirrels (*Spermophilus richardsonii*) assess response urgency via the number of alarm signalers. *Ethology* 114, 436–443
31 Zuk, M. and Kolluru, G.R. (1998) Exploitation of sexual signals by predators and parasitoids. *Q. Rev. Biol.* 73, 415–438
32 Ridley, A.R. *et al.* (2007) Interspecific audience effects on the alarm-calling behavior of a kleptoparasitic bird. *Biol. Lett.* 3, 589–591
33 Schmidt, K.A. and Ostefeld, R.S. (2008) Eavesdropping squirrels reduce their future value of food under the perceived presence of cache robbers. *Am. Nat.* 171, 388–393
34 Mukhin, A. *et al.* (2008) Acoustic information as a distant cue for habitat recognition by nocturnally migrating passerines during landfall. *Behav. Ecol.* 19, 716–723
35 Slabbekoorn, H. and Bouton, N. (2008) Soundscape orientation: a new field in need of a sound investigation. *Anim. Behav.* 76, e5–e8
36 Montgomerie, R. and Weatherhead, P.J. (1997) How robins find worms. *Anim. Behav.* 54, 143–151
37 Neuweiler, G. (1989) Foraging ecology and audition in echolocating bats. *Trends Ecol. Evo.* 4, 160–166
38 Knudsen, E.I. and Konishi, M. (1979) Mechanisms of sound localization in the barn owl (*Tyto alba*). *J. Comp. Physiol. A* 133, 13–21
39 Rice, W.R. (1982) Acoustical location of prey by the marsh hawk: adaptation to concealed prey. *Auk* 99, 403–413
40 Hamr, J. and Bailey, E.D. (1985) Detection and discrimination of insect flight sounds by big brown bats (*Eptesicus fuscus*). *Biol. Behav.* 10, 105–121
41 Magrath, R.D. *et al.* (2007) How to be fed but not eaten: nestling response to parental food calls and the sound of a predator's footsteps. *Anim. Behav.* 74, 1117–1129
42 Bernal, X.E. *et al.* (2007) Sexual differences in the behavioral response of túngara frogs, *Physalaemus pustulosus*, to cues associated with increased predation risk. *Ethology* 755–763
43 Grafe, T.U. *et al.* (2002) Frogs flee from the sound of fire. *Proc. R. Soc. Lond. B* 269, 999–1003
44 Frid, A. and Dill, L. (2002) Human-caused disturbance stimuli as a form of predation risk. *Conserv. Ecol.* 6 In: http://www.ecologyandsociety.org/vol6/iss1/art11/main.html
45 Stankowich, T. (2008) Ungulate flight responses to human disturbance: a review and meta-analysis. *Biol. Conserv.* 141, 2159–2173
46 Laurance, W.F. *et al.* (2008) Impacts of roads, hunting, and habitat alteration of nocturnal mammals in African rainforests. *Conserv. Biol.* 22, 721–732
47 Eigenbrod, F. *et al.* (2008) The relative effects of road traffic and forest cover on anuran populations. *Biol. Conserv.* 141, 35–46
48 Goudie, R.I. (2006) Multivariate behavioural response of harlequin ducks to aircraft disturbance in Labrador. *Environ. Conserv.* 33, 28–35
49 Goldstein, M.I. *et al.* (2005) Mountain goat response to helicopter overflights in Alaska. *Wildlife Soc. B.* 33, 688–699
50 Borkowski, J.J. *et al.* (2006) Behavioral responses of bison and elk in Yellowstone to snowmobiles and snow coaches. *Ecol. Appl.* 16, 1911–1925
51 Preisler, H.K. *et al.* (2006) Statistical methods for analyzing responses of wildlife to human disturbance. *J. Appl. Ecol.* 43, 164–172
52 Barton, D.C. and Holmes, A.L. (2007) Off-highway vehicle trail impacts on breeding songbirds in northeastern California. *J. Wildl. Manage.* 71, 1617–1620
53 Doherty, K.E. *et al.* (2008) Greater sage-grouse winter habitat selection and energy development. *J. Wildl. Manage.* 72, 187–195

54 Sawyer, H. *et al.* (2006) Winter habitat selection of mule deer before and during development of a natural gas field. *J. Wildl. Manage.* 70, 396–403
55 Reed, S.E. and Merenlender, A.M. (2008) Quiet, nonconsumptive recreation reduces protected area effectiveness. *Conserv. Lett.* 1, 146–154
56 Reijnen, R. and Foppen, R. (2006) Impact of road traffic on breeding bird populations. In *The Ecology of Transportation: Managing Mobility for the Environment* (Davenport, J. and Davenport, J.L., eds), pp. 255–274, Springer
57 Reijnen, R. *et al.* (1995) The effects of car traffic on breeding bird populations in Woodland. III. Reduction of density in relation to the proximity of main roads. *J. Appl. Ecol* 32, 187–202
58 Forman, R.T.T. and Alexander, L.E. (1998) Roads and their major ecological effects. *Ann. Rev. Ecol. Syst.* 29, 207–231
59 Rheindt, F.E. (2003) The impacts of roads on birds: Does song frequency play a role in determining susceptibility to noise pollution? *J. Ornithol.* 144, 295–306
60 McGregor, R.L. *et al.* (2007) Do small mammals avoid roads because of the traffic? *J. Appl. Ecol.* 45, 117–123
61 Habib, L. *et al.* (2007) Chronic industrial noise affects pairing success and age structure of ovenbirds *Seiurus aurocapilla*. *J. Appl. Ecol.* 44, 176–184
62 Bayne, E.M. *et al.* (2008) Impacts of chronic anthropogenic noise from energy-sector activity on abundance of songbirds in the boreal forest. *Conserv. Biol.* 22, 1186–1193
63 Swaddle, J.P. and Page, L.C. (2007) High levels of environmental noise erode pair preferences in zebra finches: implications for noise pollution. *Anim. Behav.* 74, 363–368
64 Francis, C.D. *et al.* (2009) Noise pollution changes avian communities and species interactions. *Curr. Biol.* 19, 1415–1419
65 Gillam, E.H. and McCracken, G.F. (2007) Variability in the echolocation of *Tadarida brasiliensis*: effects of geography and local acoustic environment. *Anim. Behav.* 74, 277–286
66 Leonard, M.L. and Horn, A.G. (2008) Does ambient noise affect growth and begging call structure in nestling birds? *Behav. Ecol.* 19, 502–507
67 Rabin, L.A. *et al.* (2006) The effects of wind turbines on antipredator behavior in California ground squirrels (*Spermophilus beecheyi*). *Biol. Conserv.* 131, 410–420
68 Egnor, S.E.R. *et al.* (2007) Tracking silence: adjusting vocal production to avoid acoustic interference. *J. Comp. Physiol. A* 193, 477–483
69 Parris, K.M. *et al.* (2009) Frogs call at a higher pitch in traffic noise. *Ecol. Soc.* 14, 25 In: http://www.ecologyandsociety.org/vol14/iss1/art25
70 Bee, M.A. and Swanson, E.M. (2007) Auditory masking of anuran advertisement calls by road traffic noise. *Anim. Behav.* 74, 1765–1776
71 Lengagne, T. (2008) Traffic noise affects communication behaviour in a breeding anuran, *Hyla arborea*. *Biol. Conserv* 141, 2023–2031
72 Slabbekoorn, H. and den Boer-Visser, A. (2006) Cities change the songs of birds. *Curr. Biol.* 16, 2326–2331
73 Roche, B.E. *et al.* (1998) Route choice by deer mice (*Peromyscus maniculatus*): reducing the risk of auditory detection by predators. *Am. Midl. Nat.* 142, 194–197
74 Schaub, A. *et al.* (2008) Foraging bats avoid noise. *J. Exp. Biol.* 211, 3174–3180
75 Fuzessery, Z.M. *et al.* (1993) Passive sound localization of prey by the pallid bat (*Antrozous p. pallidus*). *J. Comp. Physiol. A* 171, 7667–7777
76 Aubin, T. and Jouventin, P. (2002) How to vocally identify kin in a crowd: the penguin model. *Adv. Stud. Behav.* 31, 243–277
77 Arch, V.S. and Narins, P.M. (2008) 'Silent' signals: selective forces acting on ultrasonic communication systems in terrestrial vertebrates. *Anim. Behav.* 76, 1423–1428
78 Boncoraglio, G. and Saino, N. (2007) Habitat structure and the evolution of bird song: a meta-analysis of the evidence for the acoustic adaptation hypothesis. *Funct. Ecol.* 21, 134–142
79 Kirschel, A.N.G. *et al.* (2009) Birdsong tuned to the environment: green hylia song varies with elevation, tree cover, and noise. Behav. Ecol. Published online July 14, 2009
80 Stockwell, C.A. *et al.* (2003) Contemporary evolution meets conservation biology. *Trends Ecol. Evol.* 18, 94–100
81 Garcia, J. *et al.* (1974) Behavioral regulation of the milieu interne in man and rat. *Science* 185, 824–831
82 Angeloni, L. *et al.* (2008) A reassessment of the interface between conservation and behavior. *Anim. Behav.* 75, 731–737
83 Blickley J.L. and Patricelli, G.L., Impacts of anthropogenic noise on wildlife: Research priorities for the development of standards and mitigation. *J Int. Wildlife Law Policy.* (in press)
84 Miller, N.P. (2003) Transportation Noise and Recreational Lands. *Noise/News International* 11(1), 1-20, International Institute of Noise Control Engineering, (http://www.hmmh.com/presentations-papers.html)
85 Moore, B.C.J. (2003) *An Introduction to the Psychology of Hearing*, (5th edn), Academic Press
86 Gavin, S.D. and Komers, P.E. (2006) Do pronghorn (*Antilocapra Americana*) perceive roads as predation risk? *Can. J. Zool.* 84, 1775–1780
87 Fortin, D. *et al.* (2004) Foraging costs of vigilance in large mammalian herbivores. *Oikos* 107, 172–180
88 Verdolin, J.L. (2006) Meta-analysis of foraging and predation risk trade-offs in terrestrial systems. *Behav. Ecol. Sociobiol.* 60, 457–464
89 Bednekoff, P.A. and Blumstein, D.T. (2009) Peripheral obstructions influence marmot vigilance: integrating observational and experimental results. Behav. Ecol. Published online July 16, 2009
90 Quinn, J.L. *et al.* (2006) Noise, predation risk compensation and vigilance in the chaffinch *Fringilla coelebs*. *J. Avian Biol.* 37, 601–608
91 Tuttle, M.D. and Ryan, M.J. (1982) The role of synchronized calling, ambient light, and ambient noise, in anti-bat-predator behavior of a treefrog. *Behav. Ecol. Sociobiol.* 11, 125–131
92 Jones, K.E. *et al.* (2003) Biological correlates of extinction risk in bats. *Am. Nat.* 161, 601–614
93 Duchamp, J.E. and Swihart, R.K. (2008) Shifts in bat community structure related to evolved traits and features of human-altered landscapes. *Landsc. Ecol.* 23, 849–860
94 Kerth, G. and Melber, M. (2009) Species-specific barrier effects of a motorway on the habitat use of two threatened forest-living species. *Biol. Conserv.* 142, 270–279
95 Canaday, C. and Rivadeneyra, J. (2001) Initial effects of petroleum operation on Amazonian birds: terrestrial insectivores retreat. *Biodiv. Conserv.* 10, 567–595
96 Hinam, H.L. and St. Clair, C.C. (2008) High levels of habitat loss and fragmentation limit reproductive success by reducing home range size and provisioning rates of Northern saw-whet owls. *Biol. Conserv.* 141, 524–535
97 Lohr, B. *et al.* (2003) Detection and discrimination of natural calls in masking noise by birds: estimation of the active space of a signal. *Anim. Behav.* 65, 763–777
98 Gutschalk, A. *et al.* (2008) Neural correlates of auditory perceptual awareness under informational masking. *PLoS Biol* 6, 1156–1165
99 Barber, J.R. *et al.* (2003) Can two streams of auditory information be processed simultaneously? Evidence from the gleaning bat *Antrozous pallidus*. *J. Comp. Physiol. A* 189, 843–855
100 St. Clair, C.C. (2003) Comparative permeability of roads, rivers, and meadows to songbirds in Banff National Park. *Conserv. Biol.* 17, 1151–1160

Exhibit SM3

"The Effects of Noise on Wildlife"

The Effects of Noise on Wildlife

Research prepared by Meghan C. Sadlowski, Environmental Scientist,
Division of Migratory Bird Management, US Fish & Wildlife Service

Noise standards for wind turbines developed by countries such as Sweden and New Zealand and some specific site level standards implemented in the U.S. focus primarily on sleep disturbance and annoyance to humans. However noise standards do not generally exist for wildlife, except in a few instances where federally listed species may be impacted. Findings from recent research clearly indicate the need to better address noise-wildlife issues. As such, noise impacts to wildlife should clearly be included as a factor in wind turbine siting, construction and operation. Some of the key issues include 1) how wind facilities affect background noise levels; 2) how and what fragmentation, including acoustical fragmentation, occurs especially to species sensitive to habitat fragmentation; 3) comparison of turbine noise levels at lower valley sites – where it may be quieter – to turbines placed on ridge lines above rolling terrain where significant topographic sound shadowing can occur having the potential to significantly elevate sound levels above ambient conditions; and 4) correction and accounting of a 15 decibel (dB) underestimate from daytime wind turbine noise readings used to estimate nighttime turbine noise levels (e.g. van den Berg 2004, J. Barber Colorado State Univ. and National Park Service pers. comm., K. Fristrap National Park Service pers. comm.).

Turbine blades at normal operating speeds can generate significant levels of noise. Based on a propagation model of an industrial-scale 1.5 MW wind turbine at 263 ft hub height, positioned approximately 1,000 ft apart from neighboring turbines, the following decibel levels were determined for peak sound production. At a distance 300 ft from the blades, 45-50 dBA were detected; at 2,000 ft, 40 dBA; and at 1 mi, 30-35 dBA (Kaliski 2009). Declines in densities of woodland and grassland bird species have been shown to occur at noise thresholds between 45 and 48 dB, respectively; while the most sensitive woodland and grassland species showed declines between 35 and 43 dB, respectively. Songbirds specifically appear to be sensitive to very low sound levels equivalent to those in a library reading room (~30 dBA)[1] (Foreman and Alexander 1998). Given this knowledge, it is possible that effects to sensitive species may be occurring at ≥ 1 mile from the center of a wind facility at periods of peak sound production.

Noise does not have to be loud to have negative effects. Very low frequency sounds including infrasound are also being investigated for their possible effects on both humans and wildlife. Wind turbine noise results in a high infrasound component (Salt and Hullar 2010). Infrasound is inaudible to the human ear but this unheard sound can cause human annoyance, sensitivity, disturbance, and disorientation (Renewable Energy World 2010). For birds, bats, and other wildlife, the effects may be more profound. Noise from traffic, wind and operating turbine blades produce low frequency sounds (< 1-2 kHz; Dooling 2002, Lohr et al. 2003). Bird vocalizations are generally within the 2-5 kHz frequency range (Dooling and Popper 2007) and birds hear best between 1-5 kHz (Dooling 2002). Although traffic noise generally falls below the frequency of bird communication and hearing, several studies have documented that traffic noise can

---

[1] CA Department of Transportation 1998

have significant negative impacts on bird behavior, communication, and ultimately on avian health and survival (e.g., Lohr et al. 2003, Lengagne 2008, Barber et al. 2010). Whether these effects are attributable to infrasound effects or to a combination of other noise factors is not yet fully understood. However, given that wind-generated noise including blade turbine noise produces a fairly persistent, low frequency sound similar to that generated by traffic noise (Lohr et al. 2003: Dooling 2002), it is plausible that wildlife effects from these two sound sources could be similar.

A bird's inability to detect turbine noise at close range may also be problematic. For the average bird in a signal frequency of 1-4 kHz, noise must be 24-30 dB above the ambient noise level in order for a bird to detect it. As noted above, turbine blade and wind noise frequencies generally fall below the optimal hearing frequency of birds. Additionally, by the inverse square law the sound pressure level decreases by 6 dB with every doubling of distance. Therefore, although the sound level of the blade may be significantly above the ambient wind noise level and detectable by birds at the source, as the distance from the source increases and the blade noise level decreases toward the ambient wind noise level, a bird may lose its ability to detect the blade and risk colliding with the moving blade. A bird approaching a moving blade under high wind conditions may be unable to see the blade due to motion smear, and may not hear the blade until it is very close – if it is able to hear it at all (Dooling 2002). Another concern involves the effect of ambient noise on communication distance and an animal's ability to detect calls. For effects to birds, this can mean 1) behavioral and/or physiological effects, 2) damage to hearing from acoustic over-exposure, and 3) masking of communication signals and other biologically relevant sounds (Dooling and Popper 2007). Of the 49 bird species whose behavioral audibility curves and/or physiological recordings have been determined, Dooling and Popper (2007) developed a conceptual model for estimating the masking effects of noise on birds. Based on the distance between birds and the spectrum level, bird communication was predicted to be "at risk" (e.g., at ~ 755 ft distance where noise was 20 dB), "difficult" (.e.g., at ~755 ft where noise was 25 dB) and "impossible" (e.g., at ~755 ft where noise was 30 dB). While clearly there is variation between species and there is no single noise level where one- size-fits-all, this masking effect of turbine blades is of concern and should be considered as part of the cumulative impacts analysis of a wind facility on wildlife. It must be recognized that noise in the frequency region of avian vocalizations will be most effective in masking these vocalizations (Dooling 2007).

Barber et al. (2010) assessed the threats of chronic noise exposure, focusing on grouse communication calls, urban bird calls, and other songbird communications. They determined that while some birds were able to shift their vocalizations to reduce the masking effects of noise, when shifts did not occur or were insignificant, masking could prove detrimental to the health and survival of wildlife (Barber et al. 2010). Although much is still unknown in the real world about the masking effects of noise on wildlife, the results of a physical model analyzing the impacts of transportation noise on the listening area[2] of animals resulted in some significant findings. With a noise increase of

[2] The listening area is the active space of vocalization in which animals search for sounds (Barber et al. 2010).

just 3 dB – a noise level indentified as "just perceptible to humans" – this increase corresponded to a 50% loss of listening area for wildlife (Barber et al. 2010). Other data suggest noise increases of 3 dB to 10 dB correspond to 30% to 90% reductions in alerting distances[3] for wildlife, respectively (Barber et al. 2010). Impacts of noise could thus be putting species at risk by impairing signaling and listening capabilities necessary for successful communication and survival.

Swaddle and Page (2007) tested the effects of environmental noise on pair preference selection of Zebra Finches. They noted a significant decrease in females' preference for their pair-bonded males under high environmental noise conditions. Bayne et al. (2008) found that areas near noiseless energy facilities had a total passerine density 1.5 times greater than areas near noise-producing energy facilities. Specifically, White-throated Sparrows, Yellow-rumped Warblers, and Red-eyed Vireos were less dense in noisy areas. Habib et al. (2007) found a significant reduction in Ovenbird pairing success at compressor sites (averaging 77% success) compared to noiseless well pads (92%). Quinn et al. (2006) found that noise increases perceived predation risk in Chaffinches, leading to increased vigilance and reduced food intake rates, a behavior which could over time result in reduced fitness. Francis et al. (2009) showed that noise alone reduced nesting species richness and led to a different composition of avian communities. While they found that noise disturbance ranged from positive to negative, responses were predominately negative.

Schaub et al. (2008) investigated the influence of background noise on the foraging efficiency and foraging success of the greater mouse-eared bat, a model selected because it represents an especially vulnerable group of gleaning bats that rely on their capability to listen for prey rustling sounds to locate food. Their study clearly found that traffic noise, and other sources of intense, broadband noise deterred bats from foraging in areas where these noise were present presumably because these sounds masked relevant sounds or echos the bats use to locate food.

Although there are few studies specifically focused on the noise effects of wind energy facilities on birds, bats and other wildlife, scientific evidence regarding the effects of other noise sources is widely documented. The results show, as documented in various examples above, that varying sources and levels noise can affect both the sending and receiving of important acoustic signaling and sounds. This also can cause behavioral modifications in certain species of birds and bats such as decreased foraging and mating success and overall avoidance of noisy areas. The inaudible frequencies of sound may also have negative impacts to wildlife. Given the mounting evidence regarding the negative impacts of noise – specifically low frequency levels of noise such as those created by wind turbines on birds, bats and other wildlife, it is important to take precautionary measures to ensure that noise impacts at wind facilities are thoroughly investigated prior to development. Noise impacts to wildlife must be considered during the landscape site evaluation and construction processes. As research specific to noise effects from wind turbines further evolves these findings should be utilized to develop technologies and measures to further minimize noise impacts to wildlife.

---

[3] The alerting distance is the maximum distance at which a signal can be heard by an animal and is particularly important for detecting threats (Barber et al. 2010).

REFERENCES:

Barber, J.R., K.R. Crooks, and K. Fristrup. 2010. The costs of chronic noise exposure for terrestrial organisms. Trends Ecology and Evolution 25(3): 180–189. Available at: http://www.sciencedirect.com/

Bayne, E.M., L. Habib and S. Boutin. 2008. Impacts of Chronic Anthropogenic Noise from Energy-Sector Activity on Abundance of Songbirds in the Boreal Forest. Conservation Biology 22(5) 1186-1193. Available at: http://oz.biology.ualberta.ca/faculty/stan_boutin/uploads/pdfs/Bayne%20etal%202008 %20ConBio.pdf

California Department of Transportation, Technical Noise Supplemental, A Technical Supplement to the Traffic Noise Analysis Protocol, October 1998. Available at: http://www.dot.ca.gov/hq/env/noise/pub/Technical%20Noise%20Supplement.pdf

Dooling, R. 2002. *Avian Hearing and the Avoidance of Wind Turbines*. National Renewable Energy Laboratory, NREL/TP-500-30844. 83 p. Available at: http://www.nrel.gov/wind/pdfs/30844.pdf

Dooling R. J., and A. N. Popper. 2007. The effects of highway noise on birds**.** Report to the California. Department of Transportation, contract 43AO139. California Department of Transportation, Division of Environmental Analysis, Sacramento, California, USA. Available at: http://www.dot.ca.gov/hq/env/bio/files/caltrans_birds_10-7-2007b.pdf

Foreman, Richard T.T. and L.E. Alexander. 1998. Roads and their major ecological effects. Annual Review of Ecological Systems 29: 207-231. Available at: http://pracownia.org.pl/pliki/roads_and_their_major_ecological_effects.pdf

Francis, C.D., C.P. Ortega and A. Cruz. 2009. Noise Pollution Changes Avian Communities and Species Interactions. Current Biology, in press, doi: 10.1016/j.cub.2009.06.052. Available at: http://www.sciencedirect.com/

Habib, L, E.M. Bayne and S. Boutin. 2007. Chronic industrial noise affects pairing success and age structure of ovenbirds *Seiurus aurocapilla.* Journal of Applied Ecology 44: 176-184. Available at: http://oz.biology.ualberta.ca/faculty/stan_boutin/ilm/uploads/pdfs/Habib%20etal%202 007%20JAE.pdf

Kaliski, K. 2009. Calibrating Sound Propagation Models for Wind Power Projects, State of the Art in Wind Siting Seminar, October. National Wind Coordinating Collaborative.

Lengagne, T. 2008. Traffic noise affects communication behaviour in a breeding anuran, *Hyla arborea.* Biological conservation 141: 2023-2031. Available at: http://www.sciencedirect.com/

Lohr, B., T.F. Wright and R.J. Dooling. 2003. Detection and discrimination of natural calls in masking noise by birds: estimating the active space of a signal. Animal Behavior 65:763- 777. Available at: http://biology-web.nmsu.edu/twright/publications/LohretalAnimBehav2003.pdf

Physclips. n.d. UNSW School of Physics, Sydney, Australia. dB: What is a Decibel? Web. 28 January 2011. http://www.animations.physics.unsw.edu.au/jw/dB.htm

Quinn, J.L., M.J. Whittingham, S.J. Butler, and W. Cresswell. 2006. Noise, predation risk compensation and vigilance in the chaffinch Fringilla coelebs. Journal of Avian Biology 37: 601-608**.** Available at: http://www.ncl.ac.uk/biology/assets/MWhitt_pdf/06quinnJAB.PDF

Rabin, L.A., R.G. Coss, D.H. Owings. 2006. The effects of wind turbines on antipredator behavior in California ground squirrels (Spermophilus beecheyi). Biological Conservation 131: 410-420. Available at: http://www.sciencedirect.com/

RenewableEnergyWorld Editors. 2010. Measuring wind turbine noise. Are decibel levels the most important metric for determining impact? Renewable Energy News, November 22. Available at: http://www.renewableenergyworld.com/rea/news/article/2010/11/measuring-wind- turbine-noise

Salt, A.N. and T.E. Hullar. 2010. Responses of the ear to low frequency sounds, infrasound and wind turbines. Hearing Research 268: 12-21. Available at: http://www.sciencedirect.com/

Schaub, A, J. Ostwald and B.M. Siemers. 2008. Foraging bats avoid noise. The Journal of Experimental Biology 211: 3174-3180. Available at: http://jeb.biologists.org/cgi/content/full/211/19/3174

Swaddle, J.P. and L.C. Page. 2007. High levels of environmental noise erode pair preferences in zebra finches: implications for noise pollution. Animal Behaviour 74: 363-368.

Van den Berg, G.P. 2004. Effects of the wind profile at night on wind turbine sound. Journal of Sound and Vibration 277: 955-970. Available at: http://www.nowap.co.uk/docs/windnoise.pdf

Vanderheiden, G. Ph.D. n.d. About Decibels (Db). Web. 28 January 2001. http://trace.wisc.edu/docs/2004-About-dB/

Exhibit SM4

Photographs © Susan Morse

This scrape was found early on our walk. It was created by a resident bobcat which was posting a scent message to others of its species. Interdigital glands between the toes leave secretions within the scratched and piled materials. Looking at this photograph, my colleague's hand is at the back of the scrape where the bobcat's hind feet have piled the materials upon which the interdigital gland secretions are sometimes combined with feces and urine to create the scent mark. Individual bobcats announce their social and sexual status through these marks and also post their whereabouts within their habitat.

This power pole exhibits fresh scent marking performed by a black bear. At the top of the picture I have placed small sticks into the oblique pairing of two holes which were created by upper and lower incisor teeth. The sticks demonstrate that the two incisors which performed the bite were opposite from one another. Resident bears regularly scent-mark throughout their habitat to minimize unwanted contact and conflicts with each another. At other times scent marking is utilized to facilitate contact with potential mates.

A close-up of the power pole described above shows a bear hair which became attached to the pole within the splintered wood created by the bitten and clawed surface. This hair is white because it is undoubtedly from a white chest blaze which many black bears have. Rubbing of the marked surface is a common behavior of black bears, probably because unique body scents associated with sebaceous oils add to the desired olfactory communication.

This picture depicts a heavily browsed tree which over time became “broomed” and ultimately killed. Too many moose can certainly compromise the food- making plants within their habitat.   We saw an tremendous amount of moose sign on Tuttle-Willard Mountain, particularly along the ridgeline.

These fresh scars are caused by the lower incisors of a feeding moose that removed the bark with its teeth in order to eat the contents of the inner bark and sap flow. We found a tremendous amount of barking sign like this throughout the Tuttle-Willard Ridgeline habitat.

To prove that there has been a long-term presence of residential moose within the Tuttle-Willard Ridgeline environment we also looked for older evidence of moose “barking” trees and browsing. This old scar which had completely healed over was created by a moose roughly four or five years ago.

New Hampshire Audubon’s Francie von Mertens and neighbor and naturalist Nathan Schaefer discuss extensive moose feeding sign which we found in this area. These pin cherries have been killed as a consequence of excessive moose browsing. Abundant sign like this throughout the habitat convinced me that moose numbers are perhaps too great for this region, however, these impacts are self-limiting. Moose populations eventually decline as a consequence of declining opportunities for adequate nutrition.

Throughout the entire day we found considerable evidence of bear feeding sign. Here young naturalist, Nathan Schaefer, is posing beside an American beech tree which, top-to-bottom, has been scarred by the claws of a bear which climbed the tree in order to access and eat beech nuts. I found numerous trees exhibiting this kind of sign—new and old alike. In addition, the quality habitat that exists along the ridgeline and adjacent slopes also provides a highly supportive diversity of mast-producing trees and shrubs. This is great bear habitat!

Highly skilled tracker, Scott Semmens investigates a day bed site that I found beneath a large old growth hemlock. The few old growth trees we examined there will be destroyed by the installation of the proposed wind power facility. This is most unfortunate because the trees are few in number and highly important to female bears with young cubs. Biologists throughout the range of black bear recognize that large coniferous "refuge trees" are critical to the well-being of infant cubs, especially in spring and early summer. A female bear uses these trees to hide and protect her cubs while she forages nearby. Potential enemies typically cannot access the cubs high within the crown of a refuge tree like this hemlock. When the mother bear returns from feeding she will often rest beneath the tree and call her infant cubs down to her in order to nurse them.

The large hemlock tree described above was "scent marked" by the bear that used the day bed site. Note the claw marks which are reddish-looking because they are relatively fresh and were made this spring or early summer.

Many of us found bear feces throughout the day. This segment of one feces pile is from a spring feeding bear and shows that the bear was feeding on ants and wild strawberries, to name just two of the dietary choices that this bear enjoyed earlier this summer.

Years ago I discovered that one could better visualize exactly how bear scent-marking wounds were created by simply using a bear skull to re-enact the bite. Photo 1113 is a picture I took at Wolfrun, my study area in northern Vermont, and the photo shows that the upper canine has inserted into the wood and held fast while the long scar is created by the lower jaw which actually performs the bite. Thirty eight years of research at Wolfrun and throughout the northeast has helped me appreciate that looking for bear scent-marking sign is easily found if one concentrates on looking for conspicuous white birches along ridgelines. Throughout the day I found multiple examples, both new and old, of bears scent-marking on birches along the Tuttle-Willard Ridgeline. These pictures depict some of the trees we studied.

Old rotten stumps and logs are often clawed open by black bears in order to access and eat colonial insects, especially the eggs and larvae of carpenter ants and other species. This is but one of the many examples of “grubbing” that I discovered throughout the day. In years of limited soft mast, bears will eagerly seek out even more of this kind of foraging opportunity so as to benefit from the protein-rich insects that can be found there.

Exhibit SM5

New Hampshire Wildlife Habitat
Land Cover 2010 — Antrim

NEW HAMPSHIRE WILDLIFE HABITAT LAND COVER 2010

Locations of known and potential critical wildlife habitat in the state.

- Coastal Island
- Dune
- Salt marsh
- Peatland
- Wet meadow/Shrub wetland
- Forest Floodplain
- Grassland
- Pine barren
- Cliff
- Rocky ridge or Talus slope
- Alpine
- High-elevation Spruce-fir
- Lowland Spruce-fir
- Northern hardwood-conifer
- Appalachian oak-pine
- Hemlock-hardwood-pine

- Developed or Disturbed

NEW HAMPSHIRE Wildlife Action Plan

FISH GAME

0 1 2 Miles

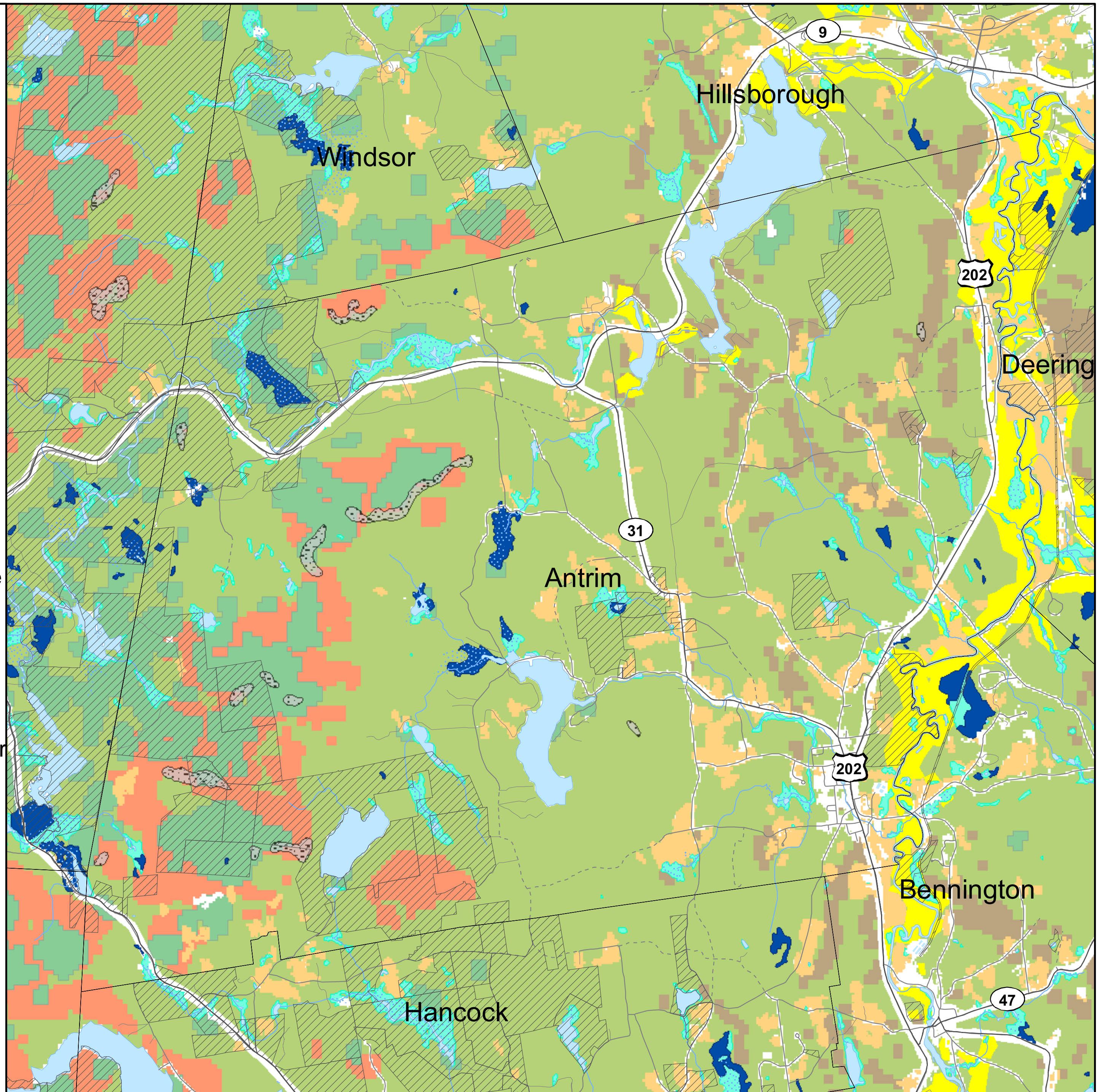


Exhibit SM6

Observation report
by Geoffrey T. Jones

Memo

To: Sue Morse & Richard Block
From: Geoffrey T. Jones, licensed NH forester # 151
Reason: Summary of observations made on Tuttle Hill Traverse
Date: July 15, 2012

On Tuesday, July 10, 2012, I traversed the Tuttle Hill ridge with several other folks, the purpose of which was to make a collective assessment of the natural resource values that exist and what values might be impacted by the wind tower project being proposed by Antrim Wind, LLC (Eolian Renewable Energy). The following are my passing observations:

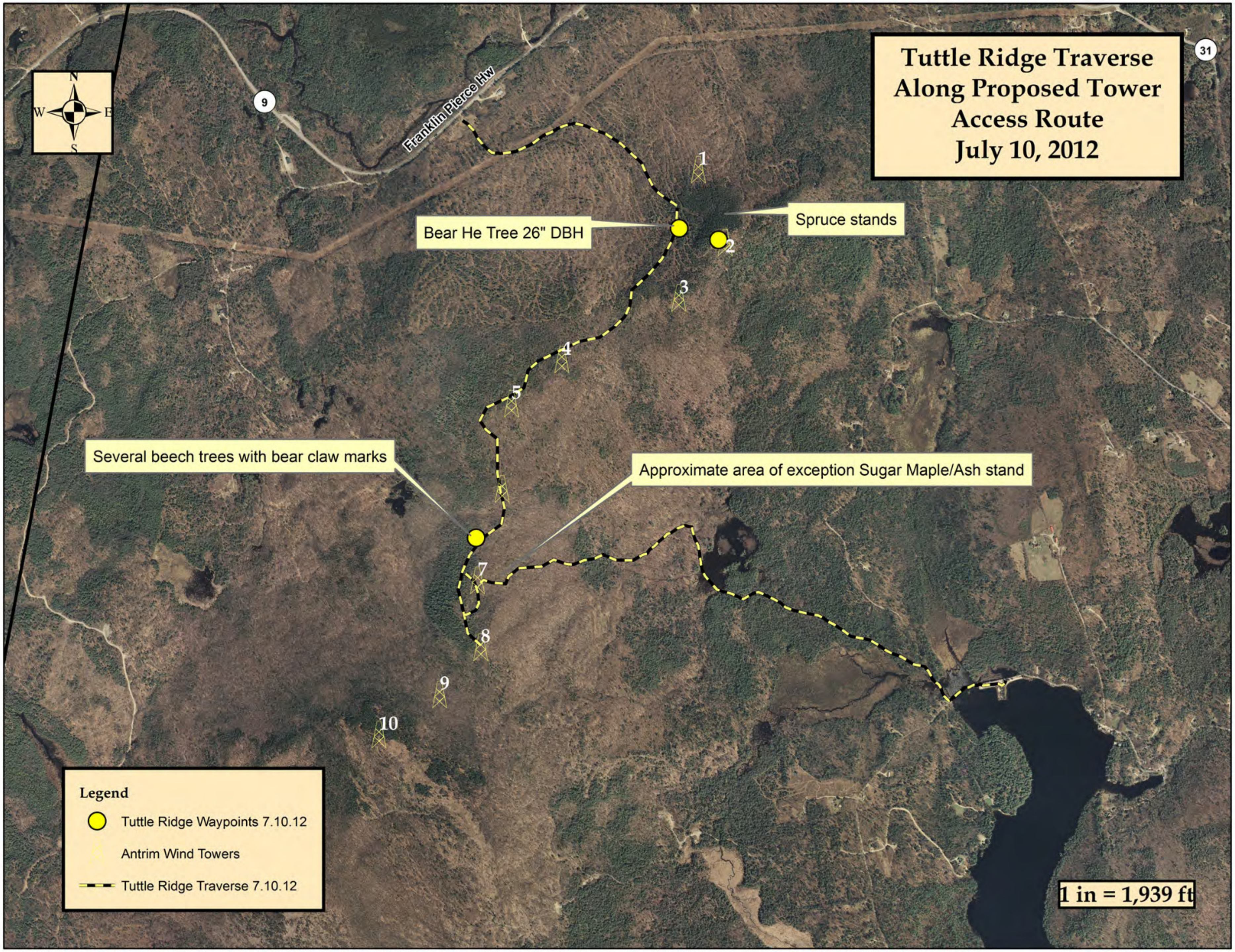
1. We approached the mountain from the northwest side off Rte. 9 and bushwhacked to the MET tower access road and followed a GPS route of the proposed access route north to south. This "virtual route" appeared to be fairly accurate, as we picked up flagging along most of the route. We also found most of the proposed tower sites (2-8).
2. Tuttle Hill lies in a 12,994 acres unfragmented forest block (roadless area), of which 3,582 acres of protected lands lies (nearly 1/3 of the unfragmented forest block).
3. Recent logging operations have been conducted along approximately 1 mile of the ridge (between tower sites 2 and close to 8), including clear-cuts at several of the proposed tower sites. Evidence of past logging was noted in the vicinity of tower site 8.
4. There are several natural communities that have been identified and mapped by TRC on a 1/23/12, to which I concur.
5. Prior to visit, it was my suspicion, that because of the lack of development, this area contained some important ecological features. This was confirmed in the field, which included the following:
    a. Pockets of large, very old hemlock trees;
    b. Stands of old, high elevation red spruce (the largest of which had recently been cut);
    c. Softwood stands providing high-quality cover (spruce-fir, spruce-hemlock, white pine). Some of the stands had mast

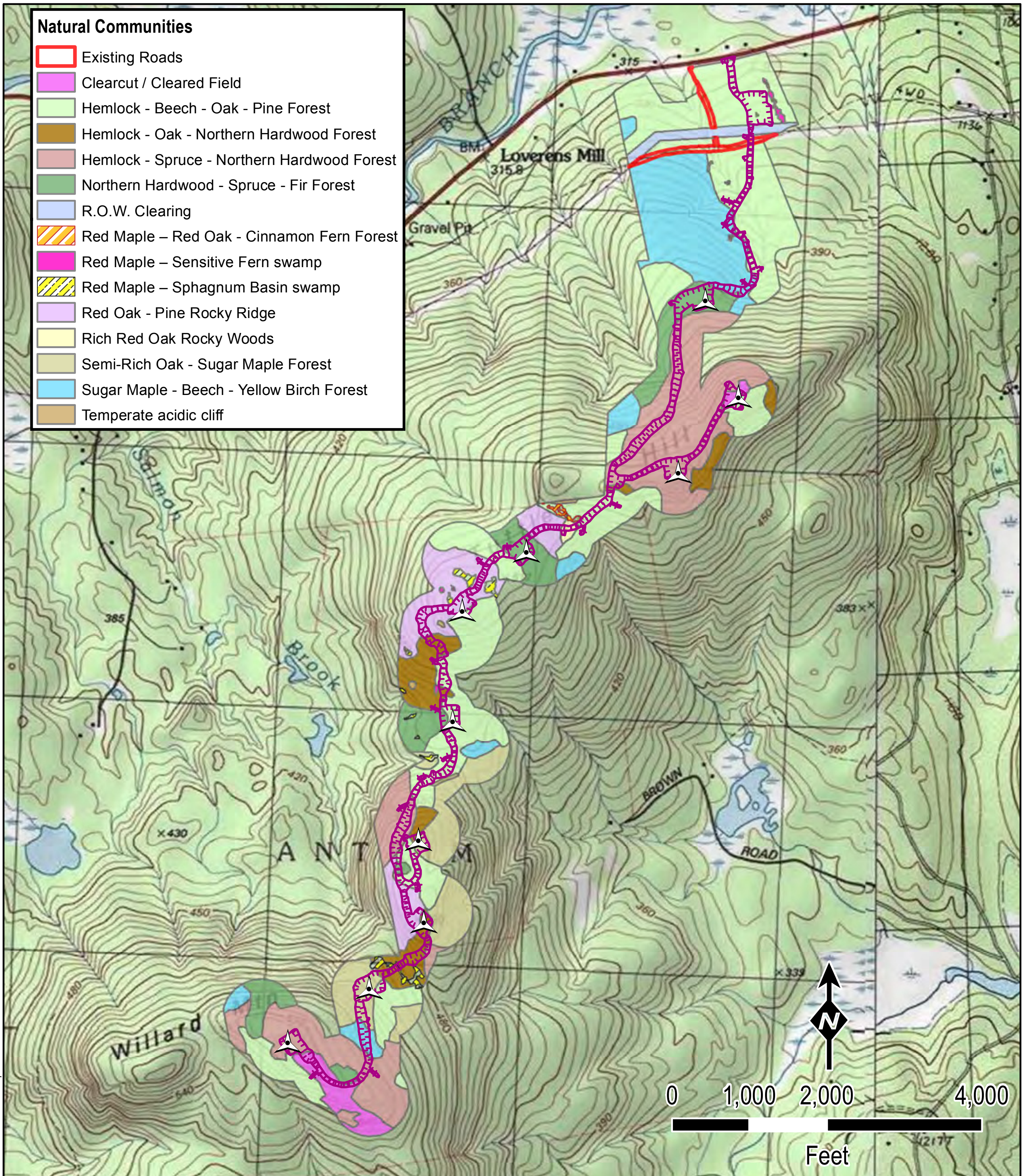
producing trees interspersed, increasing their value as winter cover;

d. Some exceptional stands of sugar maple and white ash;
e. A variety of forest types including trees that produce important mast (beech, oak, cherry, horse chestnut, hickory)
f. A variety of wildlife sign including moose, deer, bobcat, coyote, and bear. The bear sign was prominent throughout the area, underscoring the fact that this is core bear habitat. This is significant, because bears are indicators of ecosystem health.
g. Night hawks were observed in flight and voices clearly recorded on the lower eastern slopes of Tuttle Hill.

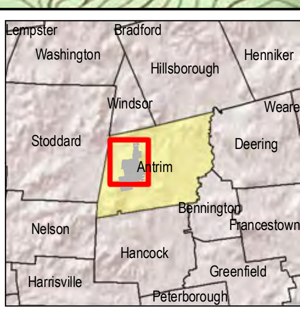
One important factor I keep in mind when assessing unfragmented forestland that is being slated for a land use change is the following: According to internationally renowned biologist and Pulitzer Prize author, Dr. E. O. Wilson (Harvard University professor for over 5 decades and author of more than twenty books), the greatest threat to life on planet earth comes from habitat fragmentation and invasive species invasions through human development. I believe that this undeveloped area of northwestern Antrim contains important ecological and habitat values that contribute to and are interconnected with the adjacent conservation lands in Antrim, Stoddard, and Hancock.

The proposed wind energy development of Tuttle and Willard Hills will result in both habitat loss and make the area ripe for invasion by a host of invasive plants and pests, as forest land is cleared for access roads and tower sites. Alternative sites should be sought.


Tuttle Ridge Traverse
Along Proposed Tower
Access Route
July 10, 2012
Spruce stands
Bear He Tree 26" DBH
Several beech trees with bear claw marks
Approximate area of exception Sugar Maple/Ash stand
Franklin Pierce Hw
9
31
N
S
E
W
1
2
3
4
5
7
8
9
10
Legend
Tuttle Ridge Waypoints 7.10.12
Antrim Wind Towers
Tuttle Ridge Traverse 7.10.12
1 in = 1,939 ft



S:\Projects\TRCAugusta\182878-Antrim Windpark\Att 1 Natural Communities Map 8x11.mxd



Legend

Proposed WTG

Proposed Disturbance Area

Hillsboro and Stoddard 7.5-Minute USGS Topographic Quadrangles

EOLIAN RENEWABLE ENERGY

ANTRIM WIND ENERGY PROJECT

ANTRIM, NH

Attachment 1

Natural Communities Map

Produced by: TRC | 1/23/2012

Geoffrey T. Jones
PO Box 336
Stoddard, NH 03464
Tel. # 603-446-3439
E-mail: geoffreytjones@gmail.com

Education

1979 University of New Hampshire, Durham, NH (9/77-5/79). Associate in Applied Science Degree. Major: **Forest Technology**. GPA: 3.36

1977 Keene State College, Keene, NH (KSC 2/74-5/77, UNH 9/66-1/69). B.A. Degree. Major: **Biology**, Cum Laude. Major concentration in ecology and plant sciences.

1973 American Tractor-Trailer Training School, Foxboro, MA (4/73-5/73). **Licensed Commercial TT.**

1971 Marine Science Technician School: United States Coast Guard Training Center, Governor's Island, NY, NY (11/70-4/71). Obtained the rank of **Marine Science Technician Petty Officer, 3rd Class.**

Work Experience

June 2010 Founded Loveland Forestry, sole proprietor: offering full spectrum of affordable, award winning land management and tree care services to appreciative landowners in the Monadnock Region. NRCS/TSP Provider, Certified Professional Logger; NHTF Inspector, Licensed Forester, NH Class A commercial license.

1979-2009 Society for the Protection of New Hampshire Forests: Associate Forester 1979-84; Forester Manager 1984-89; **Director of Land Management** 1989 to 2009. Responsible for supervising dept. of 4 FTE personnel, coordinating, and/or performing work associated with owning and managing 45,000 + acres of land on 160+ separate woodlots, including, but not limited to: timber inventories, forest management plans, timber harvesting, boundary maintenance, road construction/maintenance, property records, maps, annual work plans and budgets, contracts, volunteer activities, and various educational presentations. Guided SPNHF to 1st in NH FSC certification status.

1974-78 Summers, Cheshire County YMCA, Richmond, NH. Staff/Top Staff duties included **director** of leadership and training program; **director** of hiking and canoeing programs; constructed a Project Adventure ropes course; conducted a 2 year biological and chemical analysis on an associated lake in conjunction with academic and camp interests.

1976-77 **Biology Laboratory Assistant**, Keene State College. Assisted professor in preparing and organizing materials for laboratory lessons and exams.

1973-74 March-May: **professional tree climber**, Chase's Tree Service, Keene, NH; May to July, **professional commercial tractor-trailer driver**, Upper Cape Leasing, Middletown, Mass. Hauled goods throughout northeast and mid-Atlantic states; September 1973-January 1974, **dump truck driver, snowplow operator**, Keene Highway Dept.

1969-73	United States Coast Guard, Boston MA and Portland, ME. Assigned to USCGC Hamilton, WHEC-715. **Seaman** 2 years: included 4-months of underway training at North Atlantic Fleet Training Group Center, (GITMO), Cuba; 10-month tour of duty in Vietnam (1969-70); 3-month cadet training cruise to Europe. **Marine Science Technician** 2 years: conducted surface meteorological observations and various oceanographic casts, including: Nansen, STD, and BT casts; plankton and tarball tows; Carbon 14 tests. Observations conducted in the North Atlantic on 5 ocean stations. Weathered storms with 50+ foot seas.
1966-67	Summers: **Laborer/Foreman** on TSI crew, John C. Calhoun Forestry Services, Gilsum, NH. Treated hundreds of acres.

Professional Membership & Affiliations

1964-present	Member, **National Wildlife Federation**.
1967	Brother, **Alpha Gamma Rho** Fraternity, Omega Chapter UNH
1980-88	Board of Directors, **NH Wildlife Federation**. Chairman and co-founder of committee responsible for producing bi-monthly publication *New Hampshire Wildlife* (original circulation 6,000+).
1984-2009	Member of **Thompson School Advisory Committee**-Forestry. (Chair, 1988-91).
1986-present	Member of national, NE, and state chapter of **Society of American Foresters**.
1988	Member of a **national review panel** for UNH-TSAS evaluation of SAF creditation.
1988-2009	SPNHF representative to **Monadnock Advisory Commission**.
1993-2009	SPNHF representative to **New Hampshire Timber Harvesting Council**. (founding member)
1995-97	Member of New Hampshire **Forest Sustainability Standards Work Team** that produced the guide "Good Forestry in the Granite State". (NOTE: member of 2008-10 revision team)
1997	SPNHF representative to **New Hampshire Forest Liquidation Study Committee**.
2009-present	**Harris Center for Outdoor Education**, land management committee member.
2009-present	**New Hampshire Association of Conservation Commissions**, Board Member.
2010-present	**New Hampshire Forest Pest Advisory Committee**, member

Awards

1965	Keene High School Football Coaches Defensive Player of the Year Award
1977	Keene State College Biological Honor Society, Beta Beta Beta.
1979	UNH-TSAS "Bull-O-The-Woods" Award.
1982	New Hampshire Wildlife Federation Distinguished Service Award.
1988	New Hampshire Wildlife Federation Distinguished Service Award.
1993	GSD/SAF New Hampshire Forester of the Year Award.
1993	American Society of Agricultural Engineers Blue Ribbon Award for *A Guide to Logging Aesthetics*
1994	Northeastern Loggers Association Outstanding Contributions to Forest Industry Education Award.
1997	The Council of Eastern Forestry Technician Schools Graduate Forestry Technician Achievement Award No. 10 (for significant contributions to the field of forestry and technician education).

2006	The New England Society of American Foresters Austin Cary Practicing Professional Award.
2006	Northeastern Loggers Association Outstanding Management of Resources Award.
2008	Annette and Kingsbury Browne Conservation Volunteer of the Year Nominee (for work associated with Robb Reservoir—Trust or Public Lands Award).
2011	NH Audubon Tudor Richards Award (designee to be awarded 10/11for "working tirelessly and effectively on behalf of conservation in New Hampshire").

Civic Involvement

1980-83	**Scoutmaster**, Troop 87, Concord
1993-2005	Cheshire County YMCA, Camp Takodah **property committee** (1999-02 chair)
1996-present	Stoddard **Conservation Commission** (Chair since 1999)
1999-2004	Concerned Cheshire Citizens (seeking use of low impact alternatives to expensive bypass around Keene, NH. Successfully challenged a $66 million dollar project on sound environmental reasoning, 2 roundabouts installed at major intersections, more in the works)

Special Skills & Interests

- Licensed Professional Forester # 151
- NRCS/TSP #10-6525 (2010)
- NHTHC Certified Logger (2010)
- 1999 Completed 4-day course on chainsaw safety: “Train the Trainer” program offered by the National Park Service and the Appalachian Trail Conference. Certified as chainsaw safety instructor
- Skilled timber feller/instructor
- 1999 Completed 38 hour US Army Corp. of Engineers Wetland Delineation, course offered by UNH
- 1997 SmartWood Green Certified Assessor
- 1994 Qualified as expert witness in fields of forestry and logging operations by the Keene District Court in <u>Wixon v. Buschbaum; #92-CV-411</u>
- Photography and power point proficient productions and presentations
- Own & operate 40-HP 4WD tractor with numerous implements
- Capable with MS Word, MS Excel, GPS, ArcGIS/ArcMap 10.1
- 1988 hiked 270+ miles along Appalachian Trail (from Mt. Katahdin to foothills of Mt. Washington).
- 1966-2007 hiked 48-4,000 “footers” in NH White Mtns., completed 48th peak 8/12/07
- Enjoy skiing, sailing, canoeing/kayaking, hiking/camping, and ice hockey.
- Carpentry skills—renovating 200-year old cape

Background

October 1948	Born in Keene, NH. Educated in New Hampshire schools; traveled extensively in the military; have had a wide variety of practical and educational experiences that collectively reinforce my professional objectives.

Exhibit SM7

Observed Bird Species List from Bruce Hedin

These are the results of birdlife either seen or heard on the property of the proposed Wind Farm in Antrim, NH on July 10, 2012.

The walk followed the intended route of the access road to the footprints of the various towers and also visited the existing Meteorological Tower. The walk represents a one-time snapshot of avian residents at a time of year when birdsong has diminished and many species are trying not to divulge the locations of their nests.

(H = Heard V = Visual sighting)

Red-Tailed Hawk (V)

Broad Winged Hawk (immature) (H,V)

Turkey (several dust-bath locations, stray feathers)

Mourning Dove (V)

Pileated Woodpecker (H)

Hairy Woodpecker (V)

Eastern Phoebe (Seen at MET tower)

Eastern Wood Peewee (H)

Blue Jay (H,V)

American Crow (V)

Red Breasted Nuthatch (H)

White Breasted Nuthatch (H)

Hermit Thrush (H)

Wood Thrush (H)

Red-Eyed Vireo (Located nest w/four young)

Black Throated Green Warbler (H)

Blackburnian Warbler (H x4, V)

Pine Warbler (H x3)

Ovenbird (H) (Active nest found)

Rufous Sided Towhee (H,V) (at MET tower. Good sighting, Species has see sharp decline in State)

Song Sparrow (H)

American Goldfinch (H,V)

Common Nighthawk (H,V) Sighting off Wind Tower grid, but notable because of drastic decline in the numbers of this specie within the State.

On July 19, 2012, a follow-up walk was made to visit the southern-most part of the proposed turbine project, specifically the summit of Willard Mountain and the sites for proposed turbines number 9 and 10.

The following additional species were identified on this date:

Winter Wren (H)

Golden-Crowned Kinglet (H)

Brown Creeper (H)

Total species count: 26

Additionally, it is known that Ravens nest on nearby Bald Mountain and Crows and Tanagers should be expected to be observed on the ridge, but were not on these days.

One or two walk-throughs cannot reveal all, but this seems to be a pretty good sample.

Bruce Hedin

Hancock, New Hampshire

July, 2012

Exhibit SM8

Photographs by Richard Block

Met tower from site of Turbine #3

Clearing for road

Approaching clearing for site of Turbine #3

Clearing for Turbine #5

Clearing for Turbine #3

Location of Turbine #3

Location of Turbine #6

Location of Turbine #8

Location of Turbine #9

Location of Turbine #10A

120-year old red oak stump

Wetland delineation

Wetland violation

Wetland violation

Wetland violation

Large boulders along proposed road

Large boulders along proposed road

Large boulders along proposed road

Large boulders along proposed road

Large boulders along proposed road

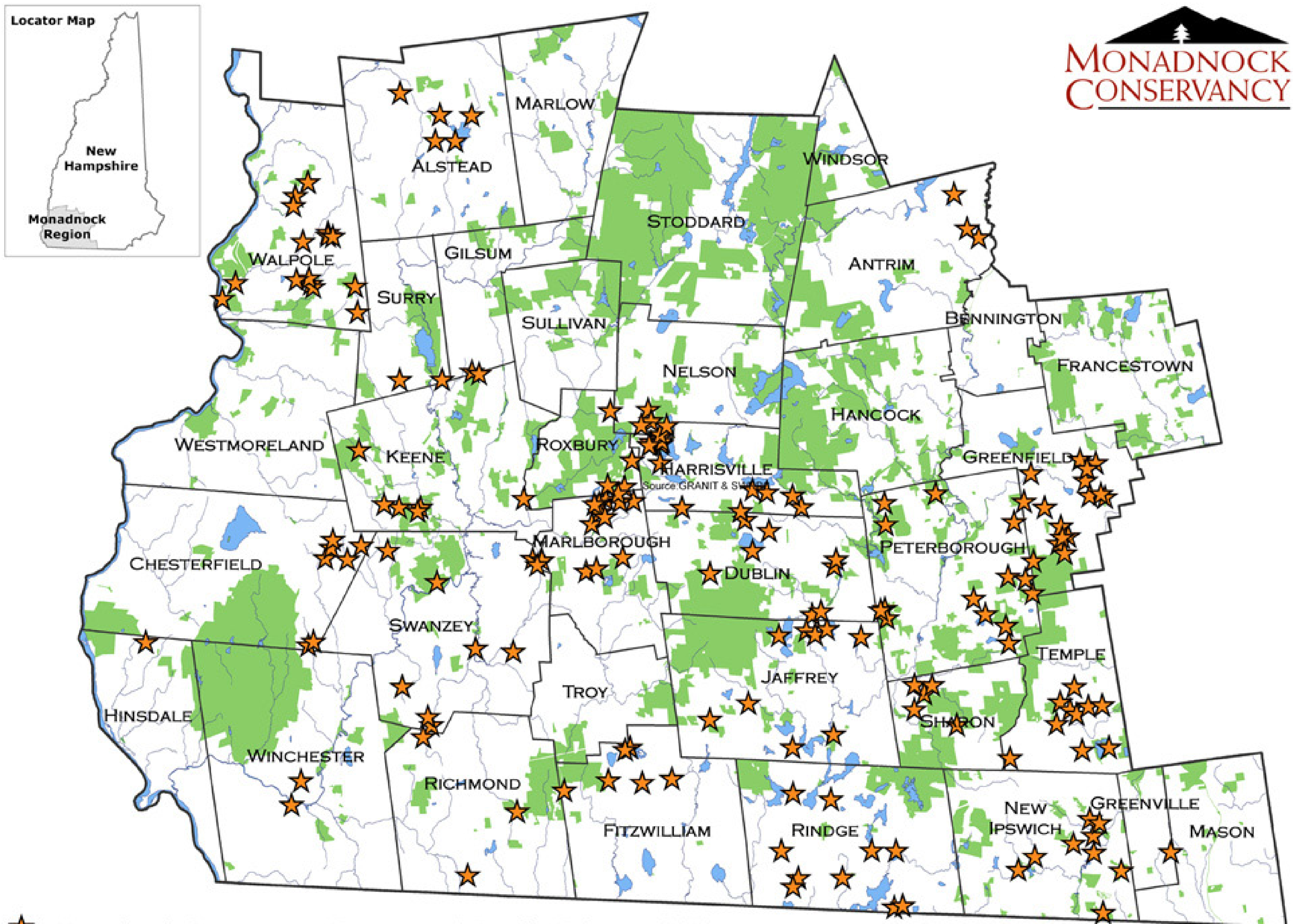
Large boulder on summit of Willard Mountain, 50 yards from turbine site

Vernal Pool next to turbine clearing

Red-eyed vireo nest along proposed road

Exhibit SM9

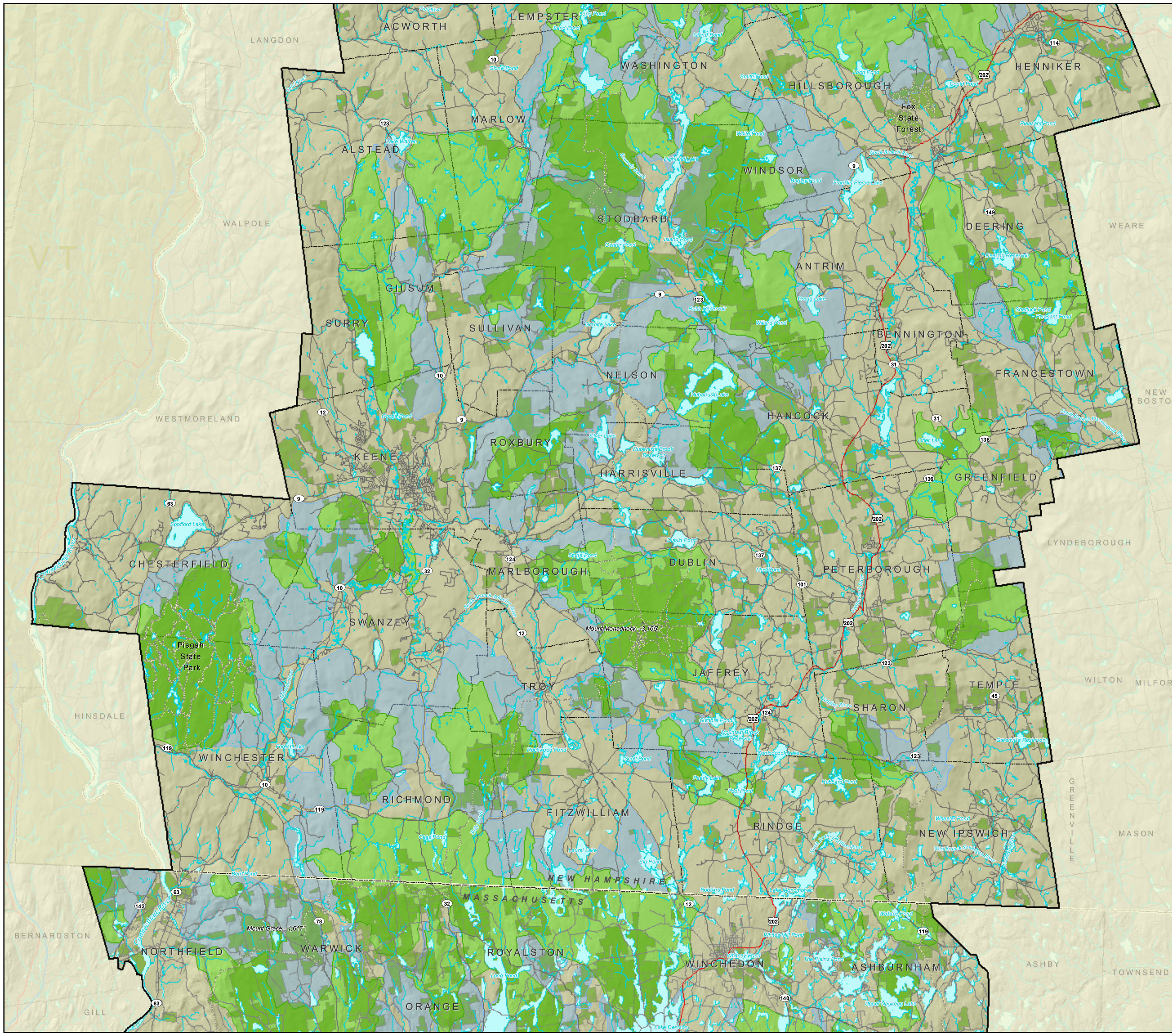
Maps of conservation land



Monadnock Conservancy Easements & Lands, February 2010

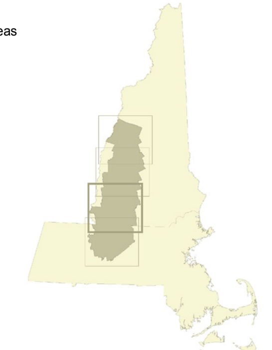
Conserved, Public, or Institutional Lands

All data obtained from NH GRANIT and The Monadnock Conservancy.



Quabbin to Cardigan Partnership

New Hampshire - South



- Core Conservation Focus Areas
- Supporting Landscapes
- Conserved Lands
- Recreational Trails
- Lakes & Reservoirs
- Rivers & Streams
- Town Boundaries
- Interstate Highway
- US Route
- Primary State Route
- Local Road

ABOUT

Launched in 2003, the Quabbin to Cardigan Initiative (Q2C) is a collaborative, landscape-scale effort to conserve the Monadnock Highlands of north-central Massachusetts and western New Hampshire. The two-state region spans one hundred miles from the Quabbin Reservoir northward to Mount Cardigan and the White Mountain National Forest, and is bounded to the east and west by the Merrimack and Connecticut River Valleys. Encompassing approximately two million acres, the Quabbin to Cardigan region is one of the largest remaining areas of intact, interconnected, ecologically significant forest in central New England, and is a key headwater of the Merrimack and Connecticut rivers.
The Quabbin to Cardigan Initiative is a collaborative effort of twenty seven private organizations and public agencies working on land conservation in the two Q2C states. The Q2C Initiative does not protect land directly, its member organizations do. Land is conserved strictly on a willing-seller basis through a combination of conservation easements and land acquisitions, managed by private owners, conservation organizations and public agencies. The Quabbin to Cardigan partners share a vision of consolidating the permanent protection of the region's most ecologically significant forest blocks, and key connections between them for wildlife passage and human recreation. Q2C partners worked for more than three years to develop the Quabbin to Cardigan conservation plan, which combines state-of-the-art natural resource science and the consensus vision of the Q2C partner organizations. Completed in 2007, the Q2C plan has identified approximately 600,000 acres of core conservation focus areas that represent the region's most ecologically significant forests. These conservation focus areas represent about 30% of the two million-acre region. An additional 400,000 acres, or another 21% of the region, have been identified as "supporting landscapes" that buffer and link the core areas.

For more information: www.q2cpartnership.org

DATA SOURCES

Most of the data displayed here is stock digital data from the Office of Geographic and Environmental Information (MassGIS), Commonwealth of Massachusetts Executive Office of Environmental Affairs, Vermont Center for Geographic Information, Inc (VCGI) or from the NH GRANIT database maintained by Complex Systems Research Center (CSRC) at the University of New Hampshire. NH GRANIT, CSRC, VCGI and MassGIS maintain a continuing program to identify and correct errors in these data. CSRC, NH Office of State Planning, MassGIS, VCGI and the cooperating agencies and organizations make no claims as to the validity or reliability or to any implied uses of these data.

SCALE (1:115,000)

0 1.25 2.5 5 Kilometers

0 1.25 2.5 5 Miles

Map prepared by the Society for the Protection of NH Forests Research Department

JANUARY 2009