From: Murphy, Donald
To: "Geoff West";
Subject: FW: Bull Hill Wind Project Review
Date: Thursday, March 10, 2011 3:11:56 PM
Attachments: Arnet_Frnt Eco_10_trbin spd bat mort.pdf
Baerwald_et_al_jwm_2009.pdf
Curtailment_2008_Final_Report.pdf

Geoff: Well here it is it just came in. I haven't read over it yet. Don

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From: Bard, Richard
Sent: Thursday, March 10, 2011 2:35 PM
To: Timpano, Steve; Murphy, Donald
Cc: Schaeffer, Thomas; Burr, Gregory; Hodgman, Tom; DePue, John
Subject: RE: Bull Hill Wind Project Review

I apologize for the string of emails, but I wanted to be sure the consultant had access to our comments ASAP as requested by LURC. I think this will be the last, for now.

The bat radar studies in Exhibit 13C of the application acknowledge that bat activity peaks when wind speeds are below 5.0 meters per second. Recent studies (Arnett et al. 2009 & 2010, Baerwald et al. 2008) at operating wind facilities have indicated that increasing the cut-in speed (the wind speed at wind the turbine is allowed to begin rotating) for operating turbines to 5.0 meters per second has significantly decreased turbine-caused fatalities for bats. Therefore, in order to minimize risk of mortality to bats MDIFW recommends that operational control measures be established for the Blue Sky East project. These measures should be employed from April 20th through October 15th, such that the applicant set the turbine cut-in speed to 5.0 m/s starting at one-half hour before sunset to one-half hour after sunrise. During this time frame when the wind speed is less than the 5.0 m/s threshold, turbine blades are not allowed to rotate thus reducing risk of fatality for bats. If at any point during this time period the wind speed increases to > 5.0 m/s the turbine blades are free to rotate.

I have included full citations for the above references:

Arnett, E. B., M. P. Huso, M. R. Schirmacher, and J. P. Hayes. 2010. Altering turbine speed reduces bat mortality at wind-energy facilities. *Frontiers in Ecology and the Environment*. : 101101071900096 DOI: 10.1890/100103

Arnett, E. B., M. R. Schirmacher, M. P. Huso, and J. P. Hayes. 2009. Effectiveness of changing wind turbine cut-in speed to reduce bat fatalities at wind facilities. An annual report submitted to the Bats and Wind Energy Cooperative. Bat Conservation International. Austin, Texas, USA.

Baerwald, E. F., J. Edworthy, M. Holder, and R. M. R. Barclay. 2009. A Large-scale mitigation experiment to reduce bat fatalities at wind energy facilities. Journal of Wildlife Management 73:1077-1081.

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From: Bard, Richard
Sent: Thursday, March 10, 2011 10:39 AM
To: Timpano, Steve; Murphy, Donald
Cc: Schaeffer, Thomas; Burr, Gregory; Hodgman, Tom
Subject: RE: Bull Hill Wind Project Review

On December 13, Tom Schaeffer sent comments drafted by Tom Hodgman to Geoff West of First Wind. The comments address the draft Post-Construction Monitoring Plan. The same day, Geoff West replied that we were too late to have Tom H.'s comments incorporated in the draft LURC application, but that they would be reflected in the final plan. None of Tom's recommendations are addressed in any way in the current application. To save the confusion of attaching multiple email threads to this message, I'm copying the text of Tom Hodgman's recommendations below. We still stand by the need for these changes to the Post-Construction Monitoring Plan. If you need copies of the email threads, I'll be happy to send them along. Thank you very much.
Rich

From Tom Hodgman:
I looked over the Postconstruction monitoring plan and see a few things that may warrant a slight change.

1) Weekly searches - I appreciate the analysis of bird/bat mortality over time and suggest modifying the weekly search plan - dropping a few weeks in early summer in exchange for a more continuous track of searches during spring migration and fall migration. I'd suggest searches be conducted April 15 to June 7 then July 7 to Oct 15. I think that's roughly the same number of weeks as proposed.

2) Daily searches - good idea, no changes to dates but which turbines will be searched??? Do you rotate through all???

3) Carcass removal trials - See paper by Smallwood re scavenger removal trials [JWM 74(5):1089-1097]. Perhaps the number of carcasses used should be scaled back to avoid "flooding" or at least be sure to stagger them well over time.

4) Number of years - Need to see a commitment of at least 2 years of mortality searches with an option for a third depending on results in previous 2 years. Think this has been the norm to date and there has been no discussion on our end of modifying that.

5) Radar - I think we all agree another year of radar work is needed to see if the flight height and passage rate is anomalous or something that we just haven't seen before.

6) I'm intrigued by your discussion of curtailment. How do we get engaged in that discussion?? Is there still time to discuss on this project or perhaps more appropriate for your next project.

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From: Bard, Richard
Sent: Tuesday, March 08, 2011 1:36 PM
To: Timpano, Steve; Murphy, Donald
Cc: Schaeffer, Thomas; Burr, Gregory
Subject: RE: Bull Hill Wind Project Review

Steve, et al,
I am waiting for word back from Tom Hodgman that bird survey protocols are adequate and will let you know ASAP about that.

We need some more information and materials about vernal pools:

- For projects with more than 3 pools, the Reptile, Amphibian & Invertebrate (RAI) Group would like all of the vernal pool survey forms to be sent hardcopy (collated and with accompanying photos for each pool whenever possible) and including a CD with a shapefile of the pool outlines (more important for SVP than others). These materials should be sent to Jason Czapiga, GIS coordinator, MDIFW, 650 State Street, Bangor, ME 04401
    - Review and verification of vernal pool significance can take up to several weeks after the materials are received. This step is important for all parties because the RAI Group often detects errors that may remove some presumed Significant Vernal Pools, or upgrade some to Significance that the consultant missed.
- To determine impacts to vernal pool habitat, for each presumed SVP, we'd like to know the percentage of non-forested habitat within the 250 foot boundary, both before and after construction. This data can be sent directly to me, preferably by email.

I don't foresee any emerging issues or questions for discussion at the pre-hearing conference.

Thanks,

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From: Burr, Gregory
Sent: Monday, March 07, 2011 3:45 PM
To: Timpano, Steve; Schaeffer, Thomas
Cc: Bard, Richard; Murphy, Donald
Subject: RE: Bull Hill Wind Project Review

Steve,

I have no other comments on this project.

Greg

Gregory Burr
Regional Fisheries Biologist

Grand Lakes Region
Maine Dept. of Inland Fisheries & Wildlife
317 Whitneyville Road
Jonesboro, Maine 04648
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From: Timpano, Steve
Sent: Monday, March 07, 2011 8:35 AM
To: Schaeffer, Thomas; Burr, Gregory
Cc: Bard, Richard; Murphy, Donald
Subject: FW: Bull Hill Wind Project Review
Importance: High

Can you give Don and me an up-date for progress on review? Don advises he needs to wrap up agency review this week...

Do you anticipate needs for additional information? If yes, we should provide an information request to Don as soon as possible.

Do you anticipate need (unresolved issues / questions?) for participation at the 3/22/11 pre-hearing conference?

Thanks, Steve T.

From: Murphy, Donald
Sent: Friday, March 04, 2011 4:04 PM
To: Timpano, Steve
Subject: Bull Hill Wind Project Review

Hi Steve;

No problem on today's deadline for review of Bull Hill Wind Project as I am also still waiting on DEP. I do need to pull it together next week though. Especially if you and your regional biologists have substantial review comments that I need to get to the applicant to maintain our expedited permitting mandate. Just give me an idea Monday what's up. An FYI is there is a pre-hearing conference scheduled over here 3/22/11 at 9AM on in case as an agency you want to participate. I'll send around a notification to all agency reviewers next week.

Don Murphy

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Frontiers in Ecology and the Environment

Altering turbine speed reduces bat mortality at wind-energy facilities

Edward B Arnett, Manuela MP Huso, Michael R Schirmacher, and John P Hayes

Front Ecol Environ **2010; doi:10.1890/100103**

Altering turbine speed reduces bat mortality at wind-energy facilities

Edward B Arnett[1*], Manuela MP Huso[2], Michael R Schirmacher[1], and John P Hayes[3]

Wind-turbine operations are associated with bat mortality worldwide; minimizing these fatalities is critically important to both bat conservation and public acceptance of wind-energy development. We tested the effectiveness of raising wind turbine cut-in speed – defined as the lowest wind speed at which turbines generate power to the utility system, thereby reducing turbine operation during periods of low wind speeds – to decrease bat mortality at the Casselman Wind Project in Somerset County, Pennsylvania, over a 2-year period. Observed bat mortality at fully operational turbines was, on average, 5.4 and 3.6 times greater than mortality associated with curtailed (ie non-operating) turbines in 2008 and 2009, respectively. Relatively small changes to wind-turbine operation resulted in nightly reductions in bat mortality, ranging from 44% to 93%, with marginal annual power loss ($\leq$ 1% of total annual output). Our findings suggest that increasing turbine cut-in speeds at wind facilities in areas of conservation concern during times when active bats may be at particular risk from turbines could mitigate this detrimental aspect of wind-energy generation.

Front Ecol Environ 2010; doi:10.1890/100103

Wind-energy development is rapidly increasing worldwide, owing to concerns about climate change and the increasing financial costs of and long-term environmental impacts from fossil-fuel use (Pasqualetti *et al.* 2004; Arnett *et al.* 2007). Although wind-generated electricity is renewable and generally considered environmentally "clean", extensive fatalities of bats have been recorded at wind facilities worldwide (Dürr and Bach 2004; Kunz *et al.* 2007; Arnett *et al.* 2008; Figure 1). Because of the distinctive life-history traits of bats, their populations are sensitive to changes in mortality rates and tend to make slow recoveries following declines (Barclay and Harder 2003).

Turbine-related fatalities raise concern about potential impacts on bat populations at a time when many species of bats are known – or suspected – to be in decline (Racey and Entwistle 2003; Winhold *et al.* 2008) and continued development of wind energy is planned (Kunz *et al.* 2007; EIA 2010).

Previous research suggests that more bat fatalities occur during relatively low-wind periods in summer and fall months (Arnett *et al.* 2008). Bats restrict their flight activity during periods of rain, low temperatures, and strong winds (Eckert 1982; Erickson and West 2002). Studies at proposed and operating wind facilities have also documented lower bat activity during high (usually > 6.0 m s^{-1}) wind speeds (Reynolds 2006, Horn *et al.* 2008). Non-spinning turbine blades and turbine towers do not kill bats (Horn *et al.* 2008) and shutting down turbines during low-wind (usually < 6.0 m s^{-1}) periods in summer and fall has been hypothesized as a means for reducing bat fatalities (Kunz *et al.* 2007; Arnett *et al.* 2008). Raising turbine cut-in speed (ie the lowest wind speed at which turbines generate power to the utility system) above the manufactured cut-in speed (usually 3.5–4.0 m s^{-1} on modern turbines) renders turbines non-operational until the higher cut-in speed is reached and turbines then begin to spin and produce power. Thus, raising turbine cut-in speed during low-wind periods should reduce bat kills. Indeed, results from the only published study on the subject indicate that increasing turbine cut-in speed to 5.5 m s^{-1} reduced bat mortality by nearly 60% as compared with normally operating turbines (Baerwald *et al.* 2009).

We studied how increasing turbine cut-in speed affects bat fatalities at wind turbines. Our objectives were (1) to determine if rates of bat fatality differed between fully operational turbines and turbines with cut-in speeds of 5.0 m s^{-1} and 6.5 m s^{-1}, and (2) to quantify the economic costs of different curtailment programs and timeframes. We predicted that bat fatalities would be (1) significantly higher at fully operational turbines as compared with observed mortality associated with both cut-in speed treatments and (2) significantly lower at turbines with a cut-in speed of 6.5 m s^{-1} as compared with that at turbines with 5.0 m s^{-1}, because increasing cut-in speed reduces operating time to generate power.

Study area

The study was conducted at the Casselman Wind Project (39° 51' 22.41" N, 79° 08' 32.22" W to 39° 51' 08.58" N, 79° 06' 18.60" W) in Somerset County near Rockwood, Pennsylvania. This facility lies within the Appalachian mixed mesophytic forest ecoregion that encompasses moist broadleaf forests of the Appalachian Mountains (Brown and Brown 1972; Strausbaugh and Core 1978). Elevations

[1]*Bat Conservation International, Austin, TX* [*]*(earnett@batcon.org);* [2]*College of Forestry, Oregon State University, Corvallis, OR;* [3]*Department of Wildlife Ecology and Conservation, University of Florida, Gainesville, FL*

Figure 1. *Wind facilities on forested ridges in the eastern US are associated with large numbers of bat deaths, especially migratory foliage-roosting species like the hoary bat (*Lasiurus cinereus*).*

range from 732–854 m. Twenty-three General Electric SLE 1.5-megawatt (MW) turbines – each with a rotor diameter of 77 m, rotor-swept-area of 4657 m^2, hub height of 80 m, variable rotor speeds from 12–20 revolutions per minute, and a cut-in speed of 3.5 m s^{-1} – are situated at the facility in two "strings"; the western string consists of 15 turbines, sited on land predominated by forest, whereas the eastern string comprises eight turbines in open grassland that was reclaimed after strip mining. In a study conducted simultaneously at this site, searches for bat carcasses indicated no difference in bat fatality rates between the two strings of turbines (Arnett *et al.* 2009). Migratory foliage-roosting bats – including hoary bats (*Lasiurus cinereus*), silver-haired bats (*Lasionycteris noctivagans*), and eastern red bats (*Lasiurus borealis*) – were the species killed most frequently at this site, representing 75% of all bat fatalities recorded (Arnett *et al.* 2009). Tri-colored bat (*Perimyotis subflavus*), big brown bat (*Eptesicus fuscus*), and little brown bat (*Myotis lucifugus*) fatalities also occurred, but in smaller numbers (Arnett *et al.* 2009).

Methods

We included 12 of the 23 turbines at the Casselman site – eight on the western string and four on the eastern string – and defined three turbine treatments: (1) fully operational, (2) cut-in speed at 5.0 m s^{-1} (C5), and (3) cut-in speed at 6.5 m s^{-1} (C6). We used a randomized block design (Hurlbert 1984) with "turbine" as the blocking factor and "night within turbine" as the sampling unit for treatment. Randomization was constrained so that on each night of sampling, each of the three treatments was assigned to four turbines, at least one of which was on the eastern string. Full balance of the design (ie each turbine assigned each treatment for an equal number of nights) was therefore achieved after 15 nights. The entire randomization process was repeated five times, for a total of 75 nights annually, resulting in each treatment occurring on 25 nights within each block (turbine) each year.

We found little nightly variation in wind speed among turbines and assumed wind speeds were similar at all turbines at any given time. The turbines used in our study generally do not rotate at wind speeds < 3.5 m s^{-1} and "feather" (ie turbine blades are pitched parallel with the wind direction and only spin at very low rotation rates if at all; Figure 2). Thus, application of treatments was dependent on ambient wind speed and treatments could have changed throughout the night. When wind speeds were < 3.5 or > 6.5 m s^{-1}, all turbines were in the same operational condition and no curtailment treatments were in effect for those times; treatments were in effect only when wind speeds were between 3.5 and 6.5 m s^{-1}. Evidence of bat mortality (presence of bat carcasses) was observed the day after treatments had been implemented, but it was impossible to determine the precise time of night and under exactly what wind speed fatalities occurred. Our design accounted for this effect by maintaining balance (four replicates of each treatment on each night) and reassigning treatments randomly to turbines each night. Treatment-related mortality was measured as the sum of all individual carcasses of bats estimated to have been killed during the previous night (referred to here as "fresh" carcasses) observed along transects near a given turbine (see below) after a particular treatment assignment, thereby evenly distributing the effect of varying wind speed within a night and among nights across all turbines and treatments in the study.

We delineated rectangular plots 126 m east–west by 120 m north–south (60 m from the turbine mast in each cardinal direction; 15 120 m^2 total area) centered on each turbine sampled; this area represented the maximum possible search area (Arnett *et al.* 2009, 2010). We established transects at 6-m spacing within each plot, and observers searched 3 m on each side of the transect line; thus, the maximum plot in the east–west direction could be up to 126 m wide. We did not attempt to locate fatalities in low visibility habitats (eg forest, dense grass); also, because the area cleared of forest within plots and the amount of dense vegetation in cleared areas varied among turbines, we did not search the entire maximum possible area surrounding most turbines. We used Global Positioning System (GPS) technology to estimate total area searched and area of each habitat within each turbine plot (Arnett *et al.* 2009, 2010).

Daily searches were conducted at turbines from 27 July to 9 October 2008, and from 26 July to 8 October 2009, coinciding with when most (usually > 80% of) bats are killed at wind facilities (Arnett *et al.* 2008). The study was intentionally established as a "blind" test, and searchers were unaware of turbine treatment assignments throughout the study's duration. On each day, visual searches commenced at sunrise and all study areas were searched within 8 hours (Figure 3). When a dead bat was found, observers placed a flag near the carcass and continued searching. Upon completion of searching, observers returned to each flagged carcass and recorded information on species, sex and age (where possible), turbine number, distance from turbine, azimuth from turbine, surrounding habitat characteristics, and estimated time of death (eg ≤ 1 day, 2 days; Figure 3). Carcasses were then removed from the plot.

The experimental unit was the set of 25 nights that received a particular cut-in treatment for each turbine. The total number of fresh carcasses found after each treatment at each turbine was modeled as a Poisson random variable; we fitted these data to a Generalized Linear Mixed Model using PROC GLIMMIX in SAS v 9.2 (SAS Institute 2008), and used the amount of searchable area as a means of standardizing predictions to reflect expected values when 100% of the area was searched (McCullagh and Nelder 1992). The block effect was negligible and results were almost identical when data were fit to a simple log-linear model. We tested whether treatment means differed from one another using an *F* test and tested linear contrasts of means with a single degree-of-freedom chi-square test, corresponding (respectively) to an *F* test and a single degree-of-freedom contrast *t* test in a General Linear Model analysis of variance context.

Figure 2. *A wind turbine shown in a "feathered" position during the curtailment experiment at the Casselman Wind Project in Somerset County, south–central Pennsylvania.*

Results

Between 27 July and 9 October 2008, 32 fresh carcasses of bats were observed near turbines. At least one fresh carcass was found near each turbine, and 10 of the 12 turbines had at least one fatality during a fully operational night. There was no evidence that fatalities occurred disproportionately at some turbines, and fatalities were well distributed among all turbines (Arnett *et al.* 2010). We found three fatalities at turbines curtailed when the preceding night's wind speeds were < 5.0 m s^{-1} (C5), six at turbines curtailed when the preceding night's wind speeds were < 6.5 m s^{-1} (C6), and 23 at fully operational turbines. Mean bat fatalities per turbine over 25 nights was 0.27 (95% confidence interval [CI]: 0.07, 1.05) for those with a 5.0 m s^{-1} cut-in speed, 0.53 (95% CI: 0.20, 1.42) for those with a 6.5 m s^{-1} cut-in speed, and 2.04 (95% CI: 1.19, 3.51) for fully operational turbines (Figure 4a). There was strong evidence that the number of fatalities over 25 nights differed among turbine treatments ($F_{2,33}$ = 7.36, P = 0.004). We found no difference between the number of fatalities for C5 and C6 turbines (χ_1^2 = 0.68, P = 0.41). Mean total fatalities at fully operational turbines were 5.4 times greater than those at curtailed turbines (C5 and C6 combined; χ_1^2 = 14.11, P = 0.0005, 95% CI: 2.08, 14.11). In other words, in 2008, we found that 82% (95% CI: 52–93%) fewer fatalities occurred when turbines were curtailed as compared with when turbines were fully operational.

Likewise, between 26 July and 8 October 2009, 39 fresh carcasses were observed near turbines. Similar to 2008, we found at least one fresh carcass near each turbine each night, and 11 of the 12 turbines had at least one fatality during a fully operational night; again, this indicates that fatalities were well distributed among turbines (Arnett *et al.* 2010). We found eight fatalities at turbines curtailed when the preceding night's wind speeds were < 5.0 m s^{-1} (C5), six at turbines curtailed when the preceding night's wind speeds were < 6.5 m s^{-1} (C6), and 25 at fully operational turbines. Mean bat fatalities per turbine over 25 nights was 0.73 (95% CI: 0.34, 1.56) for those with a 5.0 m s^{-1} cut-in speed, 0.55 (95% CI: 0.23, 1.31) for those with a 6.5 m s^{-1} cut-in speed and 2.29 (95% CI: 1.46, 3.58) for fully operational turbines (Figure 4b). Again, there was strong evidence that the number of fatalities

Figure 3. *A field biologist records data on bat fatalities. (Inset) A little brown bat (*Myotis lucifugus*) carcass found beneath a wind turbine.*

over 25 nights differed among turbine treatments in 2009 ($F_{2,33}$ = 6.94, P = 0.005). There was no difference between the number of fatalities for C5 and C6 turbines (χ_1^2 = 0.24, P = 0.616). Mean total fatalities at fully operational turbines were 3.6 times greater than those at curtailed turbines (C5 and C6 combined; χ_1^2 = 12.93, P = 0.0003, 95% CI: 1.79, 7.26). In other words, in 2009, we found that 72% (95% CI: 44–86%) fewer fatalities occurred when turbines were curtailed in comparison with the number of fatalities when turbines were fully operational.

Financial costs of curtailment

Lost power output – attributable to the treatments applied during the experiment – was equivalent to approximately 2% of the total projected output for the 12 turbines during the 75-days-per-year we studied. Hypothetically, if the treatments had been applied to all 23 turbines at this facility for the duration of the study (one-half hour before sunset to one-half hour after sunrise for 75 days), the 5.0 m s^{-1} curtailment used would have resulted in 3% lost power output during the study period, but only 0.3 % of total annual power output. If the 6.5 m s^{-1} curtailment were applied to all 23 turbines during the study period, lost output would have been 11% of total output for the period and 1% of total annual output. In addition to decreased revenue from lost power, the company also incurred minor costs for staff time to set up processes and controls and to implement curtailment treatments.

Discussion

Our findings were consistent with our prediction that bat fatalities would be significantly reduced by changing turbine cut-in speed and reducing operational hours during low-wind periods, and corroborate the results of a previous study (Baerwald *et al.* 2009). Both studies suggest that bat fatalities may be reduced by at least 44% when turbine cut-in speed is raised to 5.0 m s^{-1}. However, the actual conservation and population-level consequences of reducing fatalities by changing turbine cut-in speed remain unclear, owing to a dearth of information on bat populations – especially for migratory foliage-roosting bats (O'Shea *et al.* 2003; Cryan and Brown 2007). Without a better understanding of population size, demographics, and impacts of fatalities on bat population viability, it is not possible to determine the influences of any single source of mortality or of mitigation strategies on bat populations. It is thought that cumulative impacts of wind-energy development on bat populations can be expected (Kunz *et al.* 2007; Risser *et al.* 2007), in part because bats have low reproductive rates and are slow to recover from population declines (Barclay and Harder 2003). But until adequate demographic information on bat populations is obtained, the context and impact of wind-turbine-related fatalities and reductions in those fatalities remain uncertain.

Increased bat activity (Reynolds 2006; Horn *et al.* 2008) and fatalities (Arnett *et al.* 2008) at wind-power facilities have been related to low wind speed and weather conditions typical of passing storm fronts, but causal mechanisms underlying this relationship remain unclear. Bats may simply be migrating at higher altitudes – ie above turbine rotors – during high-wind periods, when observed fatalities are low. Alternatively, migration may be less efficient for bats in strong wind conditions, decreasing migratory movements by these species during such periods (Baerwald *et al.* 2009). Arrivals of hoary bats on Southeast Farallon Island off the coast of California during the fall migration were related to periods of low wind speed, dark phases of the Moon, and low barometric pressure, supporting the hypothesis that the timing of migration events is predictable (Cryan and Brown 2007). Low barometric pressure can coincide with the passage of cold fronts that may be exploited by migrating birds and bats (Cryan and Brown 2007). Regional climate patterns, as well as local weather conditions, can be used to predict the foraging and migratory activity of bats (Erickson and West 2002). On a local scale, strong winds can influence the abundance and activity of insects, which in turn influence the activity of insectivorous bats; such bats are known to reduce foraging activity during periods of rain, low temperatures, and strong winds (Eckert 1982; Erickson and West 2002). Episodic hatchings of insects that are likely associated with "favorable" weather and flight conditions may periodically increase local bat activity (Hayes 1997; Erickson and West 2002). More studies are needed to elucidate these patterns, as well as migration behavior, across regions to develop robust predictive models of environmental conditions preceding fatality events and for predicting when turbine curtailment will be most effective in reducing bat fatalities.

Our study design differs from that of Baerwald *et al.* (2009) in part because we were able to change allocation of treatments each night. By reassigning our treatments among turbines each night, we minimized the potential influence that turbine location might have had on mortality within the project. Additionally, any differences in searchable area among turbines were contained in the turbine blocking factor. Our comparison among treatments was within turbines, so we were able to use a simple count of fresh carcasses, unadjusted for observation bias, but using searchable area as an offset (McCullagh and Nelder 1992). The almost even distribution of fatalities among turbines indicates that there was no strong distinction in fatality among turbines, so detected effects can be reasonably attributed to the treatments. Our design is powerful, but it assumes correct determination of carcasses as "fresh" by field observers. We do not believe our misclassification rate was high (Arnett *et al.* 2009), nor did we have reason to believe the probability of misclassifying a carcass as fresh was associated with treatments, because observers were unaware of the treatment allocation scheme. Thus, errors in classification of fresh carcasses should be equal among turbines and treatments and should not have influenced results of our study. Moreover, we compared bat fatalities at 12 experimental turbines to those at 10 fully operational turbines at the Casselman facility that were sampled during the same time period for a different study (see Arnett *et al.* 2010). We estimated bat fatalities per turbine (ie all carcasses found and corrected for field bias) to be 1.48–5.09 times greater ($\bar{x}$ = 2.57) in 2008 and 1.23–2.58 times greater ($\bar{x}$ = 1.80) in 2009 at the fully operational turbines than at the experimental turbines (Arnett *et al.* 2010). These findings provide further support for our contention that reducing operational hours during low-wind periods reduces bat fatalities.

Numerous factors influence power loss – and thus financial costs – of raising cut-in speed of wind turbines to reduce bat fatalities. These factors include type and size of wind turbines, market or contract prices of power, electricity purchase agreements and associated fines for violating delivery of power, variation in temporal consistency, and speed and duration of wind across different sites. Estimated power loss during our experiment was considerably different from that reported by Baerwald *et al.* (2009), primarily because they projected estimated losses only for a 30-day period and for just the 15 turbines used in their experiment, whereas we projected power loss for a 75-day period and for all 23 turbines at the site, not just for our treatment turbines. Also, technological limitations of turbines studied by Baerwald *et al.* (2009) forced them to change cut-in speed for the entire duration of the study. Lost power production resulting from our experimental treatments was markedly low when considering total annual productivity, but power loss was three times higher for the 6.5 m s^{-1} change in cut-in speed as compared with the 5.0 m s^{-1} treatment. This difference in power loss reflects the cubic effect of wind speed on power production (Albadi and El-Saadany 2009). Contrary to our prediction, we found no difference in bat fatalities between the 5.0 m s^{-1} and 6.5 m s^{-1} treatments during either year of the study, and curtailment at 5.0 m s^{-1} proved to be far more cost-effective. However, we

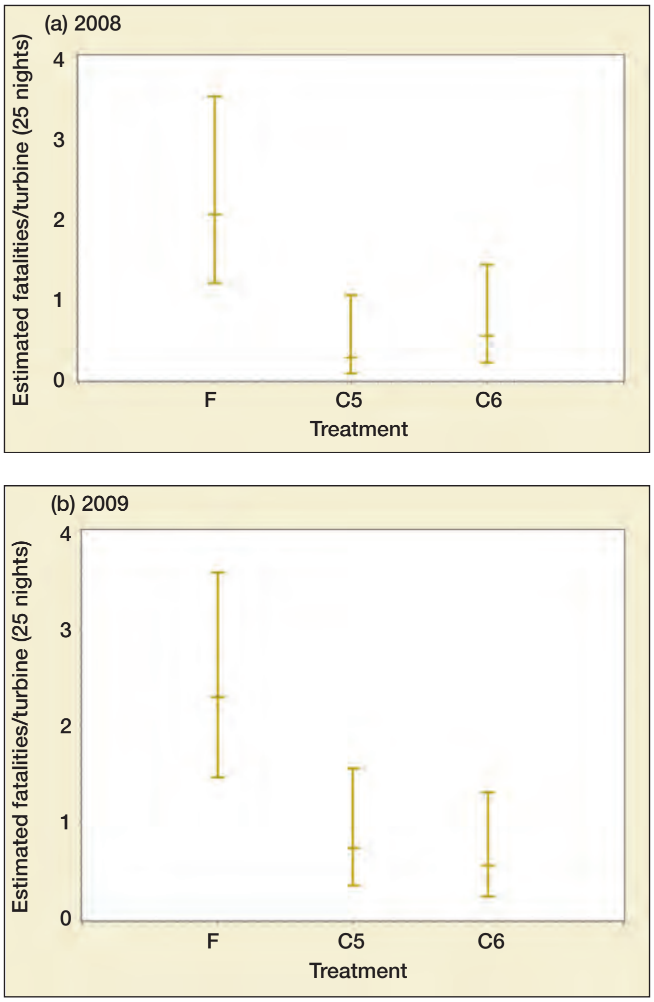

Figure 4. *Estimated number of fresh carcasses of bats per turbine, and 95% confidence intervals, over 25 nights for each of three treatments: cut-in speed at 5.0 m s^{-1}(C5), cut-in speed at 6.5 m s^{-1} (C6) and fully operational (F, no change to cut-in speed) for 12 turbines at the Casselman Wind Project in Somerset County, Pennsylvania; (a) 27 July to 9 October 2008 and (b) 26 July to 8 October 2009.*

found little differentiation in the amount of time different cut-in speed treatments were in effect (WebFigure1), which may explain in part why we found no difference in bat fatalities between the two treatments.

Our study is the first to randomly allocate different cut-in speeds on a nightly basis and to evaluate multiple cut-in speeds. We demonstrated reductions in average nightly bat fatality ranging from 44–93%, with marginal annual power loss. Our findings suggest that increasing cut-in speeds at other wind facilities during summer and fall months will reduce bat fatalities. Additional studies evaluating changes in turbine cut-in speed among different sizes and types of turbines, wind regimes, habitat types, and species of bats (eg Brazilian free-tailed bats, *Tadarida brasiliensis*) would be useful in assessing the general effectiveness of this mitigation strategy. Developing a broader understanding of the demographics and population viability of bats is fundamental in fully evaluating the implications of conservation strategies at wind facilities, but these data are unlikely to be available for most species of bats in the immediate future. We contend that wind operators should implement curtailment measures at turbine sites characterized by high or moderately high numbers of bat fatalities and that such sites warrant mitigation efforts even in the absence of bat population data.

Acknowledgements

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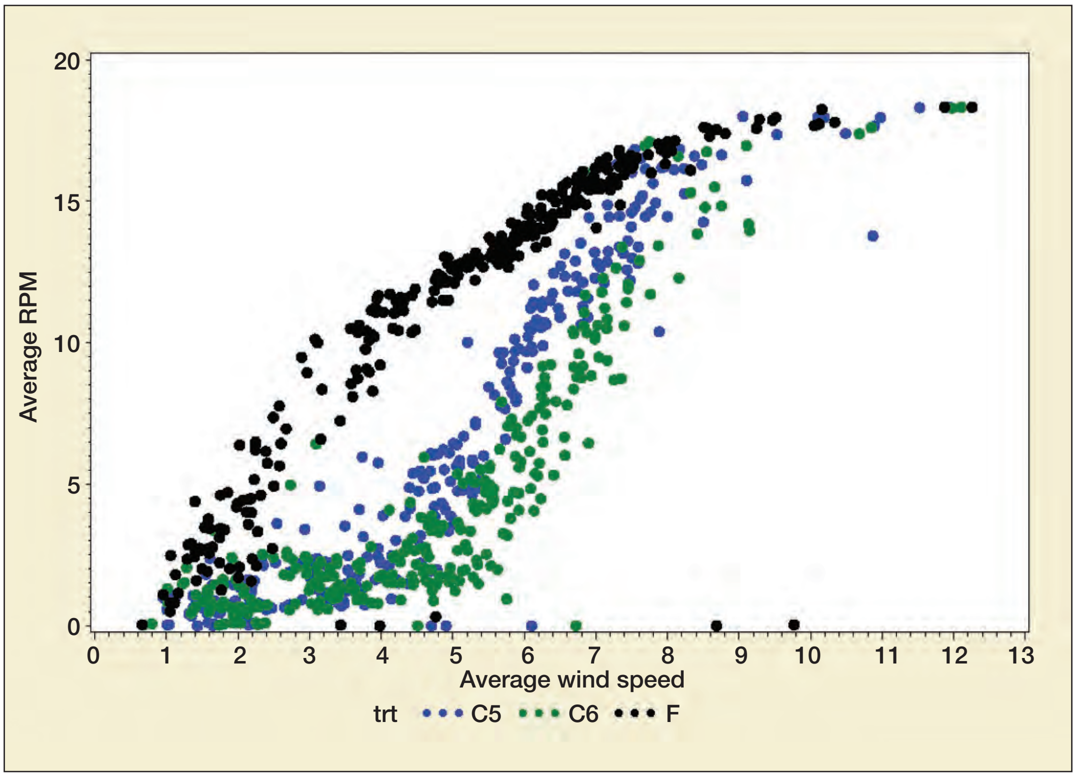

WebFigure 1. *Relationship between average wind speed and average revolutions per minute (RPM) for experimental turbines during each night of study between 27 July and 9 October 2008 at the Casselman Wind Project in Somerset County, Pennsylvania, demonstrating the amount of time treatments were in effect. Average wind speed at the site was between 5 and 6.5 m s-1 only 10% of the study period, wind speeds during which the two curtailment treatments were operationally distinct. This may explain in part why we found no difference in bat fatalities between the two treatments. Further research at other facilities is needed to determine if different changes in cut-in speeds can be detected and the influences on fatality reductions.*

A Large-Scale Mitigation Experiment to Reduce Bat Fatalities at Wind Energy Facilities

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ABSTRACT Until large numbers of bat fatalities began to be reported at certain North American wind energy facilities, wildlife concerns regarding wind energy focused primarily on bird fatalities. Due in part to mitigation to reduce bird fatalities, bat fatalities now outnumber those of birds. To test one mitigation option aimed at reducing bat fatalities at wind energy facilities, we altered the operational parameters of 21 turbines at a site with high bat fatalities in southwestern Alberta, Canada, during the peak fatality period. By altering when turbine rotors begin turning in low winds, either by changing the wind-speed trigger at which the turbine rotors are allowed to begin turning or by altering blade angles to reduce rotor speed, blades were near motionless in low wind speeds, which resulted in a significant reduction in bat fatalities (by 60.0% or 57.5%, respectively). Although these are promising mitigation techniques, further experiments are needed to assess costs and benefits at other locations. (JOURNAL OF WILDLIFE MANAGEMENT 73(7):1077–1081; 2009)

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KEY WORDS Alberta, bat fatality, bats, hoary bat, *Lasionycteris noctivagans*, *Lasiurus cinereus*, mitigation, silver-haired bat, wind energy, wind turbines.

Renewable energy sources, such as wind energy, are seen as environmentally friendly alternatives to burning fossil fuels, and this has led to rapid growth of the wind energy industry. Worldwide, between 1997 and 2006, wind energy increased tenfold in installed capacity, the most dramatic increases occurring in 2005 (41%), 2006 (32%), and 2007 (31%; World Wind Energy Association [WWEA] 2008). Canada more than doubled its installed capacity in 2006 (Canadian Wind Energy Association 2008, WWEA 2008). In 2007, wind generation increased 45% in the United States and 26% in Canada (American Wind Energy Association 2008, Canadian Wind Energy Association 2008, WWEA 2008).

The growth of the wind energy industry has not been without concerns. Although many communities support renewable energy, some express concerns about noise, reduction of landscape beauty, and impacts on wildlife (e.g., Cross Timbers Landowners Conservancy 2008, Save Western NY 2008). Originally, wildlife concerns focused on bird fatalities, but because of many bat fatalities at some facilities, attention has shifted to potential impacts on bats (Kunz et al. 2007, Arnett et al. 2008). Bats are killed by some wind energy facilities in large numbers, especially at facilities with newer, taller turbines (Barclay et al. 2007). Bat fatalities now outnumber bird fatalities in some regions by as much as 10 to 1 (Barclay et al. 2007). The wind energy industry learned from the early incidents of bird collisions and has implemented successful mitigation strategies (but see Smallwood and Thelander 2008). Mitigation to reduce bird fatalities at wind turbines has been primarily by avoiding constructing facilities in environmentally sensitive areas, but other mitigation has included technology and physical changes, such as reducing perching opportunities (e.g., by switching to tubular towers from horizontal lattice towers), increasing turbine blade visibility, and reducing prey sources for raptors (Erickson et al. 2002, Drewitt and Langston 2006, Environment Canada 2007).

High rates of bat fatalities are troubling because bats have slow life-histories (Barclay and Harder 2003); they are relatively long-lived and reproduce slowly for mammals of their size, with most bats having only 1 or 2 young/year, and not every year (Barclay and Harder 2003). These life-history traits make bat populations slow to recover from population declines, thus making them sensitive to changes in mortality rates. Most bats killed at wind energy facilities across North America are migratory tree bats, such as hoary bats (*Lasiurus cinereus*), eastern red bats (*L. borealis*), and silver-haired bats (*Lasionycteris noctivagans*), which are killed during autumn migration (Arnett et al. 2008). These bats migrate from Canada and the northern United States to the southern United States or Mexico (Findley and Jones 1964, Cryan 2003, Cryan et al. 2004) and may encounter several wind-energy facilities along the way.

Previous studies have indicated that bat-fatality rates are not affected by inclement weather (Johnson et al. 2003*b*, Young et al. 2003*a*), aviation warning lights (Johnson et al. 2003*a*), or ultraviolet paint (Young et al. 2003*b*). Bat-fatality rates are affected by turbine height (Barclay et al. 2007), geographic location (Arnett et al. 2008), and wind speed, with more bats killed on low-wind nights (Fiedler 2004, von Hensen 2004, Arnett 2005, Arnett et al. 2008, Horn et al. 2008).

Given that more bat fatalities occur in low wind speeds, the relative ease of manipulating operation of turbines (e.g., compared to turbine location or ht), that turbines produce less electricity in low wind speeds, and that nonmoving turbine blades do not kill bats (Arnett 2005), we examined whether reducing the amount that turbine rotors turn in low wind speeds would reduce bat fatalities.

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STUDY AREA

We conducted a mitigation experiment at a wind energy installation in southwestern Alberta, Canada. The 2,023-ha facility was located approximately 40 km east of the Rocky Mountains (49°35′04″N, 113°47′48″W). The site contained 39 Vestas V80 turbines (Vestas Wind Systems A/S, Randers, Denmark), each with a rated capacity of 1.8 megawatts (MW). The 80-m-diameter rotors were on top of 65-m towers. Turbines were arranged in 8 rows running northwest to southeast. Thirty-one of the turbines were situated in cultivated, mixed agriculture and 8 turbines were in seeded pasture. Height of vegetation, percent ground cover, and time of crop harvest varied among turbines and years, but during the experimental period in 2007, vegetation height varied between 0 m and 0.5 m, percent ground cover varied from 0% to 65%, and all crops were harvested by 7 August.

Bat-fatality rates at this wind energy installation were relatively high, with a corrected fatality rate of 21.70 bats/turbine (12.06 bats/MW) in 2005 and 26.31 bats/turbine (14.62 bats/MW) in 2006 (Brown and Hamilton 2006, Baerwald 2008). Of these fatalities, 54.5% were hoary bats (2005, n = 244; 2006, n = 383) and 42.0% were silver-haired bats (2005, n = 272; 2006, n = 211; Brown and Hamilton 2006, Baerwald 2008).

METHODS

We conducted our study during the peak period of migration by hoary and silver-haired bats, from 15 July to 30 September, 2006 and 2007. Turbine operation was not altered in 2006. We searched 10 randomly chosen turbines every day as part of another study. For the mitigation experiment, we searched the remaining 29 turbines once per week. To locate bat carcasses, one searcher held the end of a 45-m rope attached to the base of a turbine, and another searcher held the end of a 7-m rope attached to the first searcher. Starting with the ropes fully extended (i.e., to 52 m from the turbine base) both searchers walked around the base of the turbine. The rope shortened by 14 m with each rotation thereby creating 2 spiral transects 7 m apart. Given the flat terrain and short vegetation, this proved to be the simplest and most effective search method, with the entire area between transect lines searched. For each carcass found, we recorded species, age, and sex (where possible).

The normal operation of the Vestas V80 turbines involves a cut-in speed of 4 m/second, which means that the turbine begins to generate electricity when wind speed reaches 4 m/second. Below that wind speed, the turbine rotor rotates at a slow rate that increases with wind speed until the rotor is turning at a rate required to trigger the generator rotation (Fig. 1), coinciding with a wind speed of 4 m/second. From 1 August to 7 September 2007, the period with the highest wind-turbine–related bat-fatality rates, the owner of the facility altered operation of 21 randomly chosen turbines in one of 2 ways. For 15 experimental rotor start-up speed turbines, the rotor start-up wind speed was increased to 5.5 m/second, meaning that turbines were idle and motionless during low wind speeds (Fig. 1). We chose the experimental

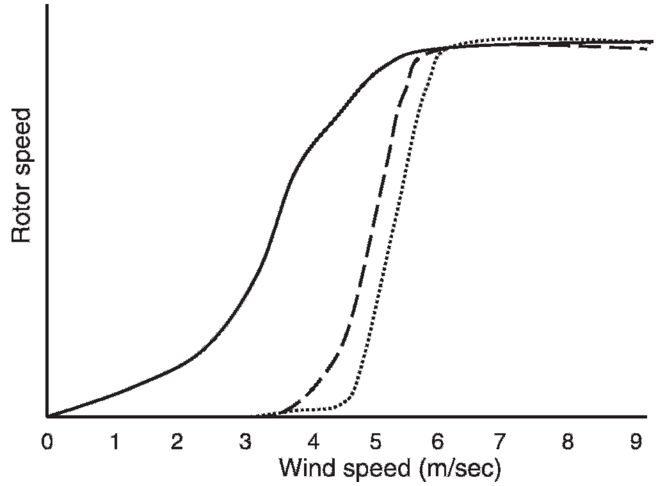

Figure 1. Schematic of the relationship between wind speed (m/sec) and turbine rotor-speed (revolutions/min) for the 3 turbine operations we used to examine whether reducing the amount that turbine rotors turn in low wind speeds would reduce bat fatalities in Alberta, Canada, 2006–2007. Solid line represents operation of control turbines with a 4 m/second cut-in speed and normal idle operation at low wind speeds. Dashed line indicates operation of turbines under the adjusted idle protocol in which blade angles were adjusted to reduce rotor speed in low wind speed. Dotted line indicates operation of turbines with increased rotor start-up speed of 5.5 m/second.

rotor start-up speed based on previous studies relating bat activity or fatality to wind speed (Fiedler 2004, Arnett 2005, Arnett et al. 2008, Horn et al. 2008) and discussions with the wind facility owners and operators. At another 6 experimental idling turbines, using a low-speed idle strategy, operations of the turbines were manipulated to change the pitch angle of the blades and lower the generator speed required to start energy production, which caused turbines to be motionless in low wind speeds, similar to the other experimental treatment (Fig. 1), but with different implications for turbine operations. Both experimental protocols had the effect of reducing the time blades were rotating at low wind speeds.

To select the experimental turbines, we stratified the wind farm into 4 quadrants (NE, NW, SE, and SW) and randomly selected a set number of turbines within each quadrant. We continued to search these turbines once per week and compared fatalities to those at 8 unaltered control turbines, also searched weekly. To ensure that there was no inherent difference in bat-fatality rates between the experimental and control turbines, we compared bat-fatality rates at control versus experimental turbines in 2006 (when no experiment was done) over the same time period as that used for the experiment in 2007.

To determine effectiveness of the mitigation, we compared bat-fatality rates during the experiment at the experimental and control turbines using a one-way analysis of variance (ANOVA) and a Tukey's test. We assessed effectiveness of the mitigation by species using Kruskal–Wallis and Wilcoxon tests because we could not normalize the data. To correct fatality rates per turbine for searcher efficiency and scavenger removal, we conducted searcher efficiency and scavenger removal experiments (details in Baerwald 2008) and corrected fatality rates using the following equation

(Baerwald 2008):

$$F_e = \left[\frac{(C/S_e)}{\left(\sum_I^{i=1} R_i\right)} \right] + \left\{ \left[\frac{C}{S_e} - C \right] - S_e \left[\left(\frac{C}{S_e} - C \right) R_i \right] \right\}$$

where F_e = estimated fatalities, C = number of carcasses found, S_e = searcher efficiency, R_i = percent of carcasses remaining by the ith day following initiation of a scavenger removal trial (Smallwood 2007), and I = search interval (in days). We performed all statistical analyses with JMP 7.0.1 (SAS Institute, Cary, NC) and present means ± standard error.

RESULTS

In 2006, during the same period that the experiment was run in 2007 (i.e., 1 Aug–7 Sep), there was no difference in corrected bat-fatality rates between turbines later selected as experimental or control (control = 24.1 ± 4.8 bats/turbine, experimental rotor start-up speed = 23.4 ± 3.5 bats/turbine, experimental idling = 19.6 ± 5.6 bats/turbine; ANOVA, $F_{2,\,26} = 0.21$, $P = 0.81$). In 2007, during the experimental period, both sets of experimental turbines killed fewer bats than did control turbines (control = 19.0 ± 2.7, experimental rotor start-up speed = 7.6 ± 2.0 bats/turbine, experimental idling 8.1 ± 3.1; ANOVA, $F_{2,\,26}$ = 6.34, $P = 0.006$). There was no difference between the 2 experimental treatments (Tukey's test, $P > 0.05$).

Although corrected fatality rates for each species of migratory bat were reduced by between 50% and 70% at experimental turbines, these were not quite statistically significant when we analyzed the 3 treatments (hoary bat, control = 11.7 ± 2.8 bats/turbine, experimental rotor start-up speed = 4.6 ± 1.3 bats/turbine, experimental idling = 6.1 ± 1.7 bats/turbine; Kruskal–Wallis test, $\chi^2_2 = 5.07$, $P = 0.08$; silver-haired bat, control = 5.6 ± 1.7 bats/turbine, experimental rotor start-up speed = 2.3 ± 0.6 bats/turbine, experimental idling = 1.7 ± 1.0 bats/turbine; Kruskal–Wallis test, $\chi^2_2 = 4.56$, $P = 0.10$). However, when we combined the 2 experimental treatments and compared them to controls, experimental turbines had lower fatality rates for each species (hoary bat, control = 11.7 ± 2.8 bats/turbine, experimental = 5.0 ± 1.0 bats/turbine; Wilcoxon test, $\chi^2_1 = 4.4$, $P < 0.05$; silver-haired bat, control = 5.6 ± 1.7 bats/turbine, experimental = 2.1 ± 0.5 bats/turbine; $\chi^2_1 = 4.2$, $P < 0.05$).

From sunset to sunrise during the experiment, if the operational parameters of the experimental rotor start-up turbines had been unaltered, they would not have produced electricity an average of 29% of the time, based on wind speeds measured at each turbine. However, by changing the rotor start-up speed, these experimental turbines did not produce electricity an average of 59% of the experimental period at night, based on recorded wind speeds, which represents a decrease in operational hours of 42.3% during the experiment. The change in operation of the low-speed idle experimental turbines did not influence the proportion of time they generated electricity.

DISCUSSION

The 2 experimental changes we instituted to the operation of wind turbines had a similar effect on their operation at low wind speeds and, thus, as we predicted, on bat fatalities. However, the effect of changes in operation was different in terms of costs.

By increasing the rotor start-up wind speed at some turbines, we reduced the amount of time these turbines likely produced electricity by an average of 42.3%. However, the cost of this change in terms of electricity and revenue generation was not as great as originally anticipated, due to a combination of market prices at the time and the fact that electricity is generated especially at higher winds speeds, above the experimental rotor start-up speed of 5.5 m/second. It is estimated that over the 1-month experiment, total revenue lost from the 15 turbines with increased rotor start-up speed was between \$3,000 and \$4,000 (Canadian currency). Due to technology limitations of the V80 turbines, rotor start-up speed had to be altered for the entire duration of the study, 24 hours a day, not just at night when bats fly. If operational parameters could have been changed only when bats were active at night, then costs would have been even less. Costs could be further reduced if there are correlations between weather variables (other than wind speed) and fatality risk, and operation can be altered only during high-risk conditions. Conversely, if the market or contract prices were higher during this time, if the wind regime was more influenced by lower wind speeds, or if reduced electricity production violated contract terms, then costs would have been greater.

Typically, wind speeds in southwestern Alberta are lowest in the late summer and early autumn (ABB Electric Systems Consulting 2004), which coincides with the timing of autumn migration of hoary and silver-haired bats and high fatality rates in our study area. Bat migration may not coincide with periods of low wind speeds and electrical generation at sites with high bat-fatality rates in other areas of North America. Thus, altering turbine operation at low wind speeds may be more costly or less beneficial. Additional studies at sites encompassing an array of landscapes, environmental variables, and species need to be performed to determine general effectiveness of this mitigation technique.

The change in wind turbine operation to change the pitch angle of the blades and lower the required generator speed for electricity production had the same effect on bat fatalities as did increasing rotor start-up wind speed. However, there was only a small reduction in electricity and revenue generation compared to normal operation. This change in operation was instituted as a means of reducing wear and tear on the rotor and generator and may, thus, have the dual benefit of reducing bat fatalities and maintenance costs while only marginally affecting electricity and revenue generation.

It is not clear why bat activity and fatalities at wind turbines are lower in high wind speeds. It may be that migration is less efficient in high wind speeds and, thus, migratory movement by these species is reduced. It is also possible that migration continues, but individuals fly at higher altitudes and are thus not detectable and not within the blade-swept area of wind turbines. In either case, if the pattern is consistent across different landscapes and geographic locations, mitigation through the low-speed idle strategy or changing rotor start-up speed may be generally effective.

Management Implications

Although we reduced bat fatalities at a high-fatality site, it was an initial experiment. Further experiments should be performed at other rotor start-up speeds and low-wind idling strategies to determine how these parameter changes influence fatality rate and cost-effectiveness of this form of mitigation. Our experiment reduced hoary and silver-haired bat fatalities, but studies need to be performed at sites where there are high fatality rates of other species, such as eastern red bats, eastern pipistrelles (*Perimyotis subflavus*; Arnett 2005) and Mexican free-tailed bats (*Tadarida brasiliensis*; Piorkowski 2006). Because different makes and models of wind turbines operate differently in terms of rotor start-up speed and idling in low winds, experiments should also be performed using sites with different types of turbines. Compared to relocating turbines with high bat-fatality rates or replacing tall turbines with shorter ones, altering the operational parameters of wind turbines has the potential to be an effective way to reduce bat fatalities. Additional studies at sites encompassing a range of environmental variables, relationships between weather and fatalities, bat species composition, and size and make of turbines, need to be performed to determine the general effectiveness of this mitigation technique.

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Effectiveness of Changing Wind Turbine Cut-in Speed to Reduce Bat Fatalities at Wind Facilities

2008 Annual Report

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BWEC
bats and wind energy cooperative

EXECUTIVE SUMMARY

We implemented the first U.S.-based experiment on the effectiveness of changing turbine cut-in speed on reducing bat fatality at wind turbines at the Casselman Wind Project in Somerset County, Pennsylvania. Our objectives were to 1) determine the difference in bat fatalities at turbines with different cut-in-speeds relative to fully operational turbines, and 2) determine the economic costs of the experiment and estimated costs for the entire project area under different curtailment prescriptions and timeframes.

Twelve turbines of the 23 turbines at the site were randomly selected for the experiment and we employed three treatments at each turbine with four replicates on each night of the experiment: 1) fully operational, 2) cut-in speed at 5.0 m/s (C5 turbines), and 3) cut-in speed at 6.5 m/s (C6 turbines). We used a completely randomized design and treatments were randomly assigned to turbines each night of the experiment, with the night when treatments were applied being the experimental unit. We conducted daily searches at the 12 turbines from 26 July to 10 October 2008. During this same period, we also conducted daily searches at 10 different turbines that were part of a complementary study to determine if activity data collected prior to construction with acoustic detectors can be used to predict post-construction fatalities, and to meet permitting requirements of the Pennsylvania Game Commission's (PGC) voluntary agreement for wind energy (herein referred to as "PGC" turbines). These 10 turbines formed an alternative 'control' to the curtailed turbines. We performed two different analyses to evaluate the effectiveness of changing turbine cut-in speed to reduce bat fatalities; for one we used 12 turbines to determine differences in fatality between curtailment levels and for another using 22 turbines to determine differences in fatalities between curtailment and fully operational turbines. The experimental unit in the first analysis was the turbine-night and turbines were considered a random blocking factor within which all treatments were applied. In our first analysis, the total number of fatalities estimated to have been killed the previous night, herein referred to as "fresh" fatalities, in each treatment at each turbine was modeled as a Poisson random variable with an offset of the number of days a treatment occurred within a turbine (due to the slight imbalance of the design). For our second analysis, the turbine was the experimental unit, with 12 turbines receiving the curtailment treatment, 10 the control (fully operational at all times). We used all carcasses found at a turbine to estimate the total number of bat fatalities that occurred at each turbine between 26 July and 10 October 2008 and compared fatalities using one-way ANOVA.

A total of 32 fresh bat fatalities were found at the 12 treatment turbines between 26 July and 10 October 2008. Each treatment was implemented at each turbine for at least 25 nights, with one treatment at each turbine implemented for 26 nights. At least one fresh fatality was found at each turbine, and 10 of the 12 turbines had at least 1 fatality during a fully operational night, indicating that fatalities did not occur disproportionately at only some turbines, but were well distributed among all turbines. There was strong evidence that the estimated number of fatalities over 25–26 nights differed among turbine treatments ($F_{2,33} = 8.99$, $p = 0.008$). There was no difference between the number of fatalities for C5 and C6 turbines ($\chi_1^2 = 0.83$, $p = 0.3625$, 95% CI: 0.11, 2.22). Total fatalities at fully operational turbines were estimated to be 5.4 times greater on average than at curtailed turbines (C5 and C6 combined; $\chi_1^2 = 14.63$, $p = 0.001$, 95% CI: 2.28, 12.89); in other words, 73% (95% CI: 53–87%) of all fatalities at curtailment turbines likely occurred when the turbines were fully operational.

Estimated total bat fatalities per turbine (i.e., all carcasses found and corrected for field bias) were 1.23–4.68 times greater (mean = 2.34) at PGC turbines relative to curtailed turbines, further supporting the contention that reducing operational hours during low wind periods reduces bat fatalities. This is a conservative estimate of the difference because treatment turbines were fully operational one-third of the time during the study.

The lost power output resulting from the experiment amounted to approximately 2% of total project output during the 76-day study period for the 12 turbines. Hypothetically, if the experimental changes in cut-in speed had been applied to all 23 turbines at the Casselman site for the study period (0.5 hour before sunset to 0.5 hour after sunrise for the 76 days we studied), the 5.0 m/s curtailment used would have resulted in lost output equaling 3% of output during the study period and only 0.3 % of total annual output. If the 6.5 m/s curtailment were applied to all 23 turbines during the study period, the lost output would have amounted to 11% of total output for the period and 1% of total annual output. In addition to the lost power revenues, the company also incurred costs for staff time to set up the processes and controls and to implement the curtailment from the company's offsite 24-hour operations center.

Our study is the first U.S.-based experiment of changing cut-in speed to reduce bat fatalities, and only the third we are aware of anywhere in the world. We demonstrated nightly reductions in bat fatality ranging from 53–87% with marginal annual power loss. Given the magnitude and extent of bat fatalities worldwide, the conservation implications of our findings are critically important. However, more studies are needed to test changes in turbine cut-in speed among different sizes and types of turbines, wind regimes, and habitat conditions to fully evaluate the general effectiveness of this mitigation strategy. We plan to initiate a second year of post-construction fatality searches at the PGC turbines beginning 1 April and continuing through 15 November 2009 and will initiate searches for the curtailment study beginning in mid- late July and continuing through the second week of October in 2009 at the Casselman facility.

Photo by: E. B. Arnett, Bat Conservation International.

INTRODUCTION

Although wind-generated electricity is renewable and generally considered environmentally clean, fatalities of bats and birds have been recorded at wind facilities worldwide (Erickson et al. 2002, Durr and Bach 2004, Kunz et al. 2007, Arnett et al. 2008, Baerwald 2008). Bat fatalities at wind energy facilities generally received little attention in North America until 2003 when 1,400–4,000 bats were estimated to have been killed at the Mountaineer Wind Energy Center in West Virginia (Kerns and Kerlinger 2004). High bat fatalities continued at the Mountaineer facility in 2004 (Arnett 2005) and large kills also have been reported at facilities in Pennsylvania (Arnett 2005) and Tennessee (Fiedler 2004, Fiedler et al. 2007). These fatalities raise concerns about potential impacts on bat populations at a time when many species of bats are known or suspected to be in decline (Racey and Entwistle 2003, Winhold et al. 2008) and extensive planning and development of both onshore and offshore wind energy development is increasing worldwide (EIA 2008, Arnett et al. 2007a, Kunz et al. 2007).

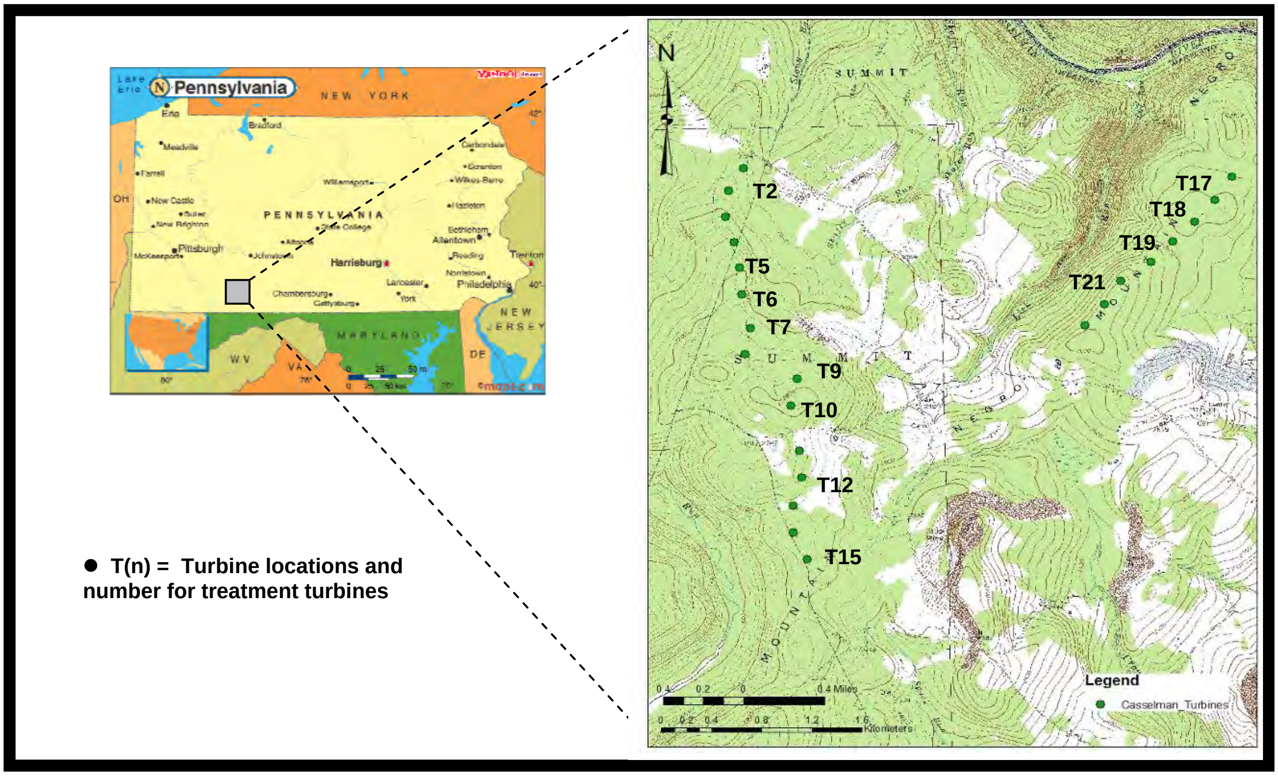
Data previously collected at operating wind energy facilities indicate that a substantial portion of the bat fatalities occurs during relatively low-wind conditions over a relatively short period of time during the summer-fall bat migration period (Arnett et al. 2008). Some curtailment of turbine operations during these conditions and during this period of time has been proposed as a possible means of reducing impacts to bats (Kunz et al. 2007, Arnett et al. 2008). Indeed, recent results from studies in Canada (Baerwald et al. 2009) and in Germany (O. Behr, University of Erlangen, unpublished data) indicate that changing turbine "cut-in speed" (i.e., wind speed at which wind generated electricity enters the power grid) from the normal (usually 3.5–4.0 m/s on modern turbines) to 5.5 m/s resulted in at least a 50% reduction in bat fatalities compared to normally operating turbines. Altering turbine operations even on a partial, limited-term basis potentially poses operational and financial difficulties for project operators, but this mitigation may ultimately prove sufficiently feasible and effective at reducing impacts to bats at minimal costs to companies that operate wind energy facilities.

We implemented the first U.S.-based experiment on the effectiveness of operational curtailment on reducing bat fatality at wind turbines. Our objectives were to: 1) determine the difference in bat fatality at turbines with different changes in the cut-in-speed relative to fully operational turbines, and 2) determine the economic costs of the experiment and estimated costs for the entire project area under different curtailment prescriptions and timeframes. This report presents our experimental design, methods, and first year results of the study.

STUDY AREA

The Casselman Wind Project is located near the town of Rockwood in Somerset County, Pennsylvania (Figure 1). The facility lies within the Appalachian mixed mesophytic forests ecoregion that encompasses the moist broadleaf forests that cover the plateaus and rolling hills west of the Appalachian Mountains (Brown and Brown 1972, Strausbaugh and Core 1978). Turbines at the Casselman facility are GE SLE 1.5 MW turbines with a 77 m rotor diameter, 4,657 m^2 rotor-swept area, 80 m hub height, variable rotor speeds from 12–20 RPMs, and cut-in speed of 3.5 m/s

Figure 1. Location of the Casselman Wind Project study area in Somerset County in south-central Pennsylvania, and locations of 23 turbines at the facility. Curtailment treatment turbines have numbers next to them and no searches were performed at turbine number 22.



(http://www.gepower.com/prod_serv/products/wind_turbines/en/downloads/ge_15_brochure.pdf). There are two "strings" of turbines at the Casselman site. The western string has 15 turbines and is mostly forested (herein referred to as the "forested ridge"; Figure 1). Eleven of the 15 turbines in this string occur in relatively dense, second-growth deciduous hardwood forest with a canopy height generally ranging from 15–20 m; 3 of the 15 turbines in this string occur in open hay pasture near second-growth forest and one occurs in a stand of young (<10 years old) regenerating forest. The eastern string has 8 turbines (herein referred to as "mine ridge"; Figure 1). All turbines in this string occur in open grassland reclaimed after strip mining for coal.

EXPERIMENTAL DESIGN and HYPOTHESES

Twelve turbines were used for the operational curtailment experiment and we employed three turbine treatments with four replicates of each treatment on each night of the experiment: 1) fully operational, 2) cut-in speed at 5.0 m/s, and 3) cut-in speed at 6.5 m/s. We used a randomized block design (Hurlbert 1984) and treatments were randomly assigned to turbines each night of the experiment, with the night when treatments were applied being the experimental unit. Randomization was constrained so that on each night, each treatment was assigned to 4 turbines and over the course of 15 nights, each treatment occurred 5 times at each turbine, in random order. Randomization was further constrained so that each of the three treatments was assigned to at least one turbine on the mine side of the site. There was a slight imbalance in the design because the study was run for 76 rather than 75 nights. Each treatment was assigned to each turbine for 25 nights, with each turbine receiving one additional treatment for one night.

On any given night, there was little variation in the wind speed among turbines (M. Huso, unpublished data), so we assumed that wind speeds were the same at all turbines on any night. The GE 1.5 MW turbines used in this experiment generally do not rotate at low wind speeds and "feather" when winds are <3.5 m/s (i.e., turbine blades are pitched parallel with the wind and free-wheel at very low rotation rates). Thus, the actual application of the curtailment treatment was dependent on the ambient wind speed on each night. There were 4 possible levels of ambient wind speed: <3.5 m/s, 3.5–5.0 m/s, 5.0–6.5 m/s, >6.5 m/s. Table 1 presents conditions of turbines under each of these treatments and wind speeds. When wind speeds were <3.5 or >6.5 m/s, all turbines were in the same operational condition and no curtailment treatments were in effect for those times; only when wind speeds were between 3.5 and 6.5 m/s were any treatments actually effective. When wind speeds were low, bat activity was expected to be high (Table 2; e.g., Arnett et al. 2006, 2007b), and when winds were <3.5 m/s none of the turbines were expected to rotate so we expected no fatalities during these periods at any of the treated turbines because all turbines were feathered below the cut-in speed (Table 2). When wind speeds were >6.5 m/s, bat activity was expected to be low (e.g., Arnett et al. 2006, 2007b) and all turbines were rotating so we expected few fatalities during these nights as well, and hypothesized there would be no differences among treatments (Table 2). When wind speeds were 3.5–5.0 m/s, bat activity was expected to be moderate to high and turbines with two different feathering treatments were not rotating, so we expected no fatalities at these turbines, but potentially high fatalities at the unfeathered, fully operational turbines under these wind conditions. Finally, when wind speeds were 5–6.5 m/s, we expected bat activity to be moderate to low, turbines assigned the 6.5 m/s treatment were not rotating, and we expected no fatalities at these turbines and moderate to low fatalities at the unfeathered turbines. However, wind speed varied throughout the night changing the effective treatment application throughout the night. In addition, fatalities were only observed at the end of the night and it was impossible to determine when and under exactly what conditions of wind speed when a fatality occurred. Our design actively accounted for this effect by maintaining balance (4 replicates of each treatment on each night), and reassigning treatment to turbines each night. Also, the measure of fatality for a treatment was the sum of all fatalities found at a given turbine following a particular treatment assignment, thereby evenly distributing the effect of varying wind speed within a night and among nights across all turbines and treatments in the study.

FIELD METHODS

Delineation of Carcass Search Plots and Habitat Mapping

We attempted to delineate a rectangular plot that is 126 m east-west by 120 m north-south (60 m radius from the turbine mast in any direction; 15,120 m^2 total area) centered on each turbine

Table 1. Possible turbine conditions ("feathered" or "rotating") under different treatments and wind conditions at the Casselman Wind Project in Somerset County, Pennsylvania. Under the treatment condition when wind is <3.5 m/s, we expected all turbines to be feathered with no rotation.

Treatment	**Wind Speed (m/s)**			
	< 3.5	**3.5–5.0**	**5.1–6.5**	**> 6.5**
5.0 m/s	Feathered/ No rotation	Feathered/ No rotation	No feathering/ Full rotation	No feathering/ Full rotation
6.5 m/s	Feathered/ No rotation	Feathered/ No rotation	Feathered/ No rotation	No feathering/ Full rotation
Fully Operational	Feathered/ No rotation	No feathering/ Full rotation	No feathering/ Full rotation	No feathering/ Full rotation

Table 2. Predicted bat activity levels under different treatments and wind conditions (based on analyses in Arnett et al. 2006, 2007b) and predicted fatality levels at the Casselman Wind Project in Somerset County, Pennsylvania.

Treatment		Wind Speed (m/s)			
		< 3.5	**3.5–5.0**	**5.1–6.5**	**> 6.5**
5.0 m/s	Activity	High	Moderate	Moderate	Low
	Fatality	None	None	Moderate	Low
6.5 m/s	Activity	High	Moderate	Moderate	Low
	Fatality	None	None	None	Low
Fully Operational					
	Activity	High	Moderate	Moderate	Low
	Fatality	None	High	Moderate	Low

sampled; this area represents the maximum possible search area for this study [see Figure 2 for an example]). Transects were set 6 m apart within each plot and observers searched 3 m on each side of the transect line; thus, the maximum plot in the east-west direction could be up to 126 m wide. However, dense vegetation and the area cleared of forest at this facility was highly varied and, thus, we eliminated unsearchable habitat (e.g., forest, tall and dense grassland) and usually did not search the entire possible maximum area. We used a global positioning system (GPS) to map the actual area searched at each turbine (see Figure 2 for an example, and Appendix 1 for plot maps). The density-weighted proportion of area searched was used to standardize results and adjust fatality estimates (see methods below). The number of transect lines and length of each line was recorded for each plot and habitat in each plot mapped with a GPS unit. We recorded the percent ground cover, height of ground cover (low [<10 cm], medium [11–50 cm], high [>50 cm]), type of habitat (vegetation, brush pile, boulder, etc), and the presence of extreme slope and collapsed these habitat characteristics into visibility classes that reflect their combined influence on carcass detectability (Table 3; following PGC 2007).

Fatality Searches

We conducted daily searches at 12 of the 23 turbines (2, 5, 6, 7, 9, 10, 12, 15, 17, 18, 19, 21; Figure 1) from 26 July to 10 October 2008. During this same period, we also conducted daily searches at 10 different turbines (1, 3, 4, 8, 11, 13, 14, 16, 20, 23; Figure 1) as part of a different study effort to determine if activity data collected prior to construction with acoustic detectors can predict post-construction fatalities (Arnett et al. 2006, 2009), and to meet permitting requirements of the Pennsylvania Game Commission's (PGC) voluntary agreement for wind energy (PGC 2007). These 10 turbines, herein referred to as "PGC" turbines, were selected because they had multiple years of acoustic data previously collected from 2005–2007 to be correlated with turbine-specific fatality data in the future (Arnett et al. 2006). We then randomly selected the 12 turbines listed above (of the remaining 13 turbines) for the curtailment study; no searches were conducted at turbine 22.

Searchers walked at a rate of approximately 10–20 m/min. along each transect searching both sides out to 3 m on each side for casualties. Searches were abandoned only if severe or otherwise unsafe weather (e.g., heavy rain, lightning) conditions were present and searches were resumed that day if weather conditions permitted. Searches commenced at sunrise and all turbines were searched within 8 hr after sunrise. We recorded date, start time, end time, observer, and weather data for each search at turbines. When a dead bat or bird was found, the searcher placed a flag near the carcass and continued the search. After searching the entire plot, the searcher returned to each carcass and recorded information on date, time found, species, sex and age (where possible), observer name, identification number of carcass, turbine number, perpendicular distance from the transect line to the carcass, distance from turbine, azimuth from turbine, habitat surrounding carcass, condition of carcass (entire, partial, scavenged), and estimated time of death (e.g., ≤1 day, 2 days, etc.). The field crew leader (M. Schirmacher) confirmed all species identifications at the end of each day. Disposable nitrile surgical gloves or inverted plastic bags were used to handle all carcasses to reduce possible human scent bias for carcasses later used in scavenger removal trials. Carcasses were placed in a plastic bag and labeled. Fresh carcasses, those determined to have been killed the night immediately before a

Figure 2. Sample carcass search plot at a wind turbine depicting the maximum plot size of 126 m east-west and 120 m north-south, 6 m wide transect lines (searched 3 m on each side), unsearchable area (black), and area encompassed by easy (white), moderate (light tan), difficult (dark tan), and very difficult (brown) visibility habitat.

Table 3. Habitat visibility classes used during this study (following PGC 2007). Data for Classes 3 and 4 were combined during our final analyses.

% Vegetative Cover	Vegetation Height	Visibility Class
≥90% bare ground	≤15 cm tall	Class 1 (Easy)
≥25% bare ground	≤15 cm tall	Class 2 (Moderate)
≤25% bare ground	≤25% > 30 cm tall	Class 3 (Difficult)
Little or no bare ground	≥25% > 30 cm tall	Class 4 (Very Difficult)

search, were redistributed at random points on the same day for searcher efficiency and scavenging trials.

Field Bias Trials

Searcher efficiency and removal of carcasses by scavengers was quantified to adjust the estimate of total bat fatalities for detection bias. We conducted bias trials throughout the entire study period and searchers were never aware which turbines were used or the number of carcasses placed beneath those turbines during trials. Prior to the study's inception, we used EXCEL to generate a list of random turbine numbers and random azimuths and distances (m) from turbines for placement of each bat used in bias trials.

We used only fresh killed bats for searcher efficiency and carcass removal trials during this study. At the end of each day's search, the field crew leader gathered all bats and then redistributed only fresh bats at predetermined random points within any given turbine's searchable area. Data recorded for each trial carcass prior to placement included date of placement, species, turbine number, distance and direction from turbine, and visibility class surrounding the carcass. We attempted to distribute trial bats equally among the different visibility classes throughout the study period, and succeeded in distributing roughly one-third of all trial bats in each visibility class (easy, moderate, and difficult [difficult and very difficult were combined]). We attempted to avoid "over-seeding" any one turbine with carcasses by placing no more than 4 carcasses at any one time at a given turbine.

Because we used fresh bats for searcher efficiency trials and carcass removal trials simultaneously, we did not mark bats with tape or some other previously used methods (see Kerns et al. 2005) that could impart human or other scents on trial bat carcasses. Rather, we removed an upper canine tooth from each trial bat so as to distinguish them from other fatalities landing nearby or if scavengers pulled the trial bat away from its original random location. Each trial bat was left in place and checked daily by the field crew leader or a searcher not involved with the bias trials; thus, trial bats were available and could be found by searchers on consecutive days during daily searches unless that were previously removed by a scavenger. We recorded the day that each bat was found by a searcher, at which time the carcass remained in the scavenger removal trial. If, however, a carcass was removed by a scavenger before detection by a searcher, it was removed from the searcher efficiency trial and used only in the removal data set. When a bat carcass was found, the searcher inspected the canine teeth to determine if a bias trial carcass had been found. If so, the searcher contacted the field crew leader and the bat was left in place for the carcass removal trial. Carcasses were left in place until removed by a scavenger or they decomposed to a point beyond recognition, at which time the number of days after placement was recorded.

ANALYTICAL METHODS

Comparison of Treatments

The experimental unit in the first analysis was the turbine-night and turbines were considered a random blocking factor. The total number of fatalities estimated to have been killed the previous night, herein referred to as "fresh" fatalities, in each treatment at each turbine was modeled as a Poisson random variable with an offset of the number of days a treatment occurred within a turbine (due to the slight imbalance of the design). These data were fit to a Generalized Linear Mixed Model using PROC GLIMMIX in SAS v9.1 (SAS Institute 2007) with turbine as the blocking factor. The block effect was found to be negligible and results were almost identical when the data were fit to a simple log-linear model.

Comparison of PGC and Curtailment Turbine Bat Fatalities

For our second analysis, the turbine was the experimental unit, with 12 turbines receiving the curtailment treatment, 10 the control (fully operational at all times). We used all carcasses found at a turbine to estimate the total number of bat fatalities that occurred at each turbine between 26 July and 10 October 2008. We compared fatalities at PGC with curtailment turbines using one-way analysis of variance with each turbine as the experimental unit and $\log_e$ (estimated total fatalities) as the response (SAS Institute 2007).

Carcass persistence/removal. Estimates of the probability that a carcass was not removed in the interval between searches were used to adjust carcass counts for removal bias. Removal includes removal by predation, scavenging, wind or water, or decomposition beyond recognition. In most fatality monitoring efforts, it is assumed that carcass removal occurs at a constant rate that is not dependent on the time since death; this simplifying assumption allows us to estimate fatality when search intervals exceed one day. The length of time a carcass remains on the study area before it is removed is typically modeled as an exponentially distributed random variable. The probability that a carcass is not removed during an interval of length *I* can be approximated as $r_j = \hat{\bar{t}}_j (1 - \exp(-I_{ij} / \hat{\bar{t}}_j)) / I_{ij}$, the average probability of persisting given its death might have occurred at any time during the interval. Data from 114 bat carcasses used in removal trials were fit to an interval-censored parametric failure time model, with carcass persistence time modeled as a function of visibility class. We used an alpha of 0.05 to determine if there was a statistically significant effect among visibility classes.

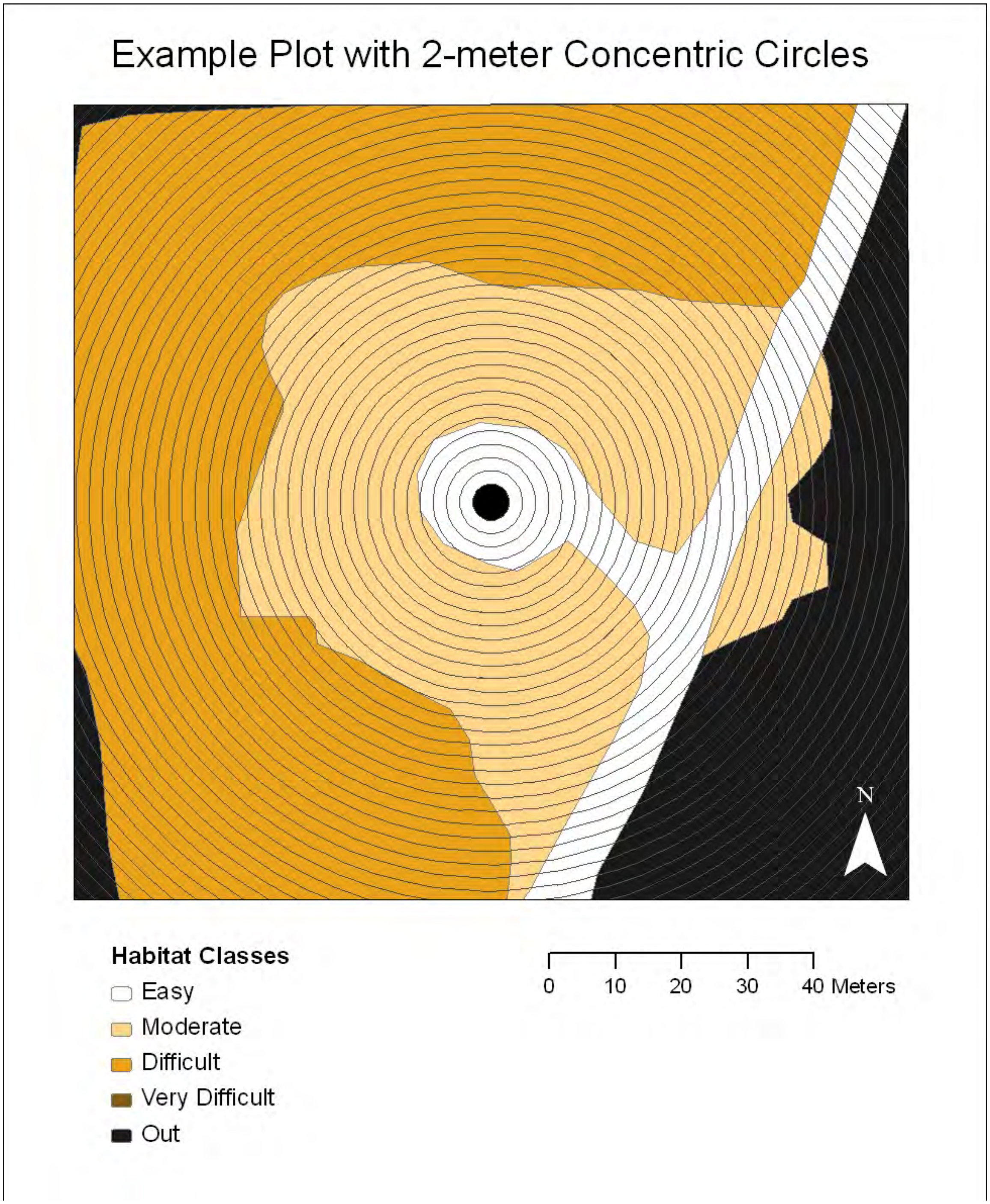
Searcher efficiency. Estimates of the probability that a carcass will be detected by an observer during a search (searcher efficiency) were used to adjust carcass counts for observer bias. Failure of an observer to detect a carcass on a search plot may be due to its size, color, or time since death, as well as conditions in its immediate vicinity (e.g., vegetation density, shade). In most fatality monitoring efforts, because we cannot measure time since death, it is assumed that a carcass' observability was constant over the period of the search interval. In this study, searches were conducted daily and carcass persistence times were long, giving a substantial opportunity for a searcher to detect a carcass that was missed on a previous search. Carcasses used in searcher efficiency trials were placed on search plots and monitored for 20 days. The day on which the carcass was either observed or removed by a scavenger was noted. Of the 100 carcasses placed in multi-day searcher efficiency trials, 4 had no visibility class recorded (2 of these had no species ID so could not be identified as bird or bat), leaving 96, 83 of which were bats, 13 were birds. Of the 83 bats, 4 were removed by scavengers before the searches took place, leaving 79. Of these, 70 were either seen or persisted beyond 7 days and were included in estimates of searcher efficiency rates. We fit searcher efficiency trial carcass data to a logistic regression model with odds of observing a carcass throughout the study period, given that it persisted, modeled as a function of visibility class. We used an alpha of 0.10 to determine if there was a statistically significant effect among visibility classes.

Density of carcasses and proportion of area surveyed. The density of carcasses was modeled as a function of distance from the turbine. Only carcasses found in 'easy' visibility areas were used for this analysis, and data from all turbines were used, yielding a total of 144 bat carcasses. The searcher efficiency in the 'easy' class was estimated to be 100% (see below in results) and we assumed that the carcass persistence time would be equal for all carcasses within this class and would not change as a function of distance, so that any carcasses removed before detection would be equally distributed among all distances, creating no bias. Carcasses from other visibility classes were not used because their probability of detection would be different from those in the easy class, and while we can adjust total fatality for detection probability less than 1, we cannot assume that the adjustment applies to a particular distance. Carcasses were "binned" into 2 m rings (Figure 3) extending from the turbine edge out to the theoretical maximum plot distance. We determined the total area among all search plots that was in the easy visibility class (m^2) and calculated carcass density from this. We combined data from all turbines to calculate carcass density (number of carcasses/m^2) in each ring. These data were modeled as a conditional cubic polynomial with the following estimated function:

$$\text{If distance} \leq 81\text{m, then density} = \exp(-2.8573 + 0.0849*\text{dist} - 0.0028*\text{dist}^2 + 0.00001858*\text{dist}^3) - 0.01; \text{ otherwise, density} = 0.00137*\exp(-0.05*(\text{distance}-81))$$

The actual, unweighted, area surveyed within plots ranged from 41.8 to 95.6% of the delineated theoretical maximum. Density of bat carcasses is known to diminish with increasing distance from the turbine (e.g., Kerns et al. 2005), so a simple adjustment to fatality based on area surveyed would likely lead to over estimates, because unsearched areas tend to be farthest from turbines. The calculated function (see above) relating density to distance from a turbine

Figure 3. Hypothetical carcass search plot for a wind turbine illustrating 2 m rings extending from the turbine edge out to the theoretical maximum plot distance and the depicted "easy" searchable area (shaded area within line drawing) of the plot, used to develop weights for adjusting fatalities.



was used to weight each square meter in the plot. The density-weighted fraction of each plot that was actually searched (60.9–99.6%, mean = 82.9%) was used as an area adjustment to per-turbine fatality estimates rather than using a simple proportion. In addition, using this density weight, we estimated that the search plots represented 94.7% of the total density weighted area of the entire site, rather than only 83% of the actual surveyed area.

Fatality estimates. We adjusted the number of fatalities found by searchers by estimates of searcher efficiency and of the proportion of carcasses expected to persist unscavenged during each interval using the following equation:

$$\frac{c_{ijk}}{\hat{a}_i * \hat{p}_{jk} * \hat{r}_j * \hat{e}_j} = \hat{f}_{ijk}$$

Where:

$\hat{f}_{ijk}$ is the estimated fatality in the k^{th} visibility class that occurred at the i^{th} turbine during the j^{th} search;

c_{ijk} is the observed number of carcasses in the k^{th} visibility class at the i^{th} turbine during the j^{th} search;

$\hat{a}_i$ is the estimated density-weighted proportion of the area of the i^{th} turbine that was searched;

$\hat{p}_{jk}$ is the estimated probability that a carcass in the k^{th} visibility class that is on the ground during the j^{th} search will actually be seen by the observer;

$\hat{r}_j$ is the probability than an individual bird or bat that died during the interval preceding the j^{th} search will not be removed by scavengers; and

$\hat{e}_j$ is the effective interval (i.e., the ratio of the length of time before 99% of carcasses can be expected to be removed, to the search interval).

The value for $\hat{p}_{jk}$ was estimated through searcher efficiency trials and assumed not to differ among turbines, but differ with search interval (*j*) and visibility class (*k*); $\hat{r}_j$ is a function of the average carcass persistence rate and the length of the interval preceding the j^{th} search; and $\hat{r}_j$ and $\hat{e}_j$ are assumed not to differ among turbines, but differ with search interval (*j*).

The estimated annual per turbine fatality was calculated for PGC and curtailed turbines using two different estimators: a modified version of an estimator presented by Johnson et al. (2003) (P. Shoenfeld, unpublished data) used by Kerns and Kerlinger (2004) and Kerns et al.

(2005) (herein referred to as the modified estimator, which is the current estimator required by PGC 2007) but which has been shown to be biased under certain conditions (Huso in press), and an estimator newly derived by M. Huso, Oregon State University (Huso in press; herein referred to as the MH estimator). The equation for the MH estimator in this study is:

$$\hat{f} = \frac{\sum_{i=1}^{u}\sum_{j=1}^{n_i}\sum_{k=1}^{3}\hat{f}_{ijk}}{u}$$

where n_i is the number of searches carried out at turbine *i*, 1= 1, …, u, and u = 10 or 12 for PGC and curtailment turbines, respectively. The per turbine estimate and confidence limits were divided by 0.947 to adjust for actual density-weighted area searched and multiplied by 23 to give total annual fatality estimates (Cochran 1977). No closed form solution is yet available for the variance of this estimator, so 95% confidence intervals of this estimate were calculated by bootstrapping (Manly 1997). Searcher efficiency was estimated from a bootstrap sample (with replacement) of searcher efficiency data, carcass persistence estimated from a bootstrap sample of carcass persistence data, and these values were applied to the carcass data from a bootstrap sample of turbines to estimate average fatality per turbine. This process was repeated 1000 times. The 2.5^{th} and 97.5^{th} quantiles from the 1000 bootstrapped estimates formed the 95% confidence limits of the estimated fatality.

RESULTS

Comparison of Treatments

A total of 32 fresh bat fatalities were found at the 12 curtailment study turbines between 26 July and 10 October 2008. At least one fresh fatality was found at each turbine, and 10 of the 12 turbines had at least 1 fatality during a fully operational night, indicating that fatalities did not occur disproportionately at only some turbines, but were well distributed among all turbines (Figure 4). We found 3 fresh fatalities at turbines that were curtailed when wind speeds were <5.0 m/s (C5) the preceding night, 6 at turbines curtailed when wind speeds were <6.5 m/s (C6), and 23 at turbines that were fully operational.

There was strong evidence that the estimated number of fatalities over 25–26 nights differed among turbines ($F_{2,33}$ = 8.99, p = 0.008, Figure 5). There was no difference between the number of fatalities at C5 and C6 turbines (χ_1^2 = 0.83, p = 0.3625, 95% CI: 0.11–2.22; Table 4, Figure 5). Total fatalities at fully operational turbines were estimated to be 5.4 times greater on average than at curtailed turbines, C5 and C6 combined (χ_1^2 = 14.63, p = 0.001, 95% CI: 2.28–12.89; Table 4, Figure 5). In other words, 73% (95% CI: 53–87%) of all fatalities at curtailment turbines likely occurred when the turbines were fully operational.

Figure 4. Number of fresh bat fatalities (n = 32 total) found at each turbine for each of three operational treatments (cut-in speed changed to 5.0 m/s [C5], cut-in at 6.5 m/s [C6], and fully operational [F]) for 12 turbines at the Casselman Wind Project in Somerset County, Pennsylvania, 26 July to 10 October 2008.

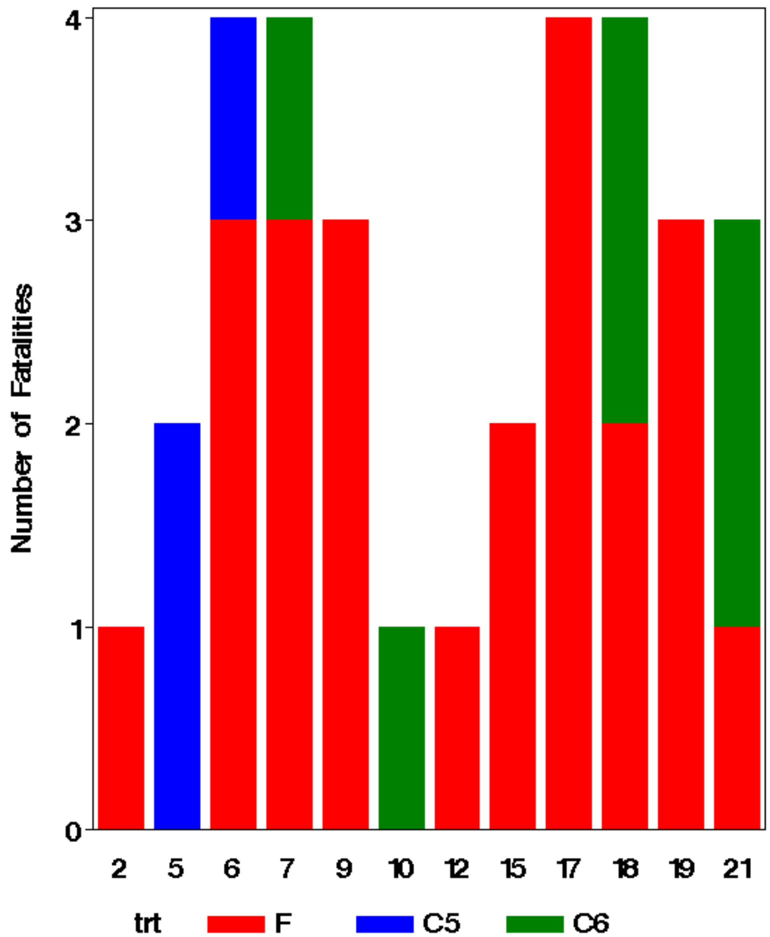


Figure 5. Estimated number of fresh bat fatalities per turbine, and 95% confidence intervals, over 25 nights for each of three treatments (cut-in speed changed to 5.0 m/s, cut-in at 6.5 m/s, and fully operational [none]) for 12 turbines at the Casselman Wind Project in Somerset County, Pennsylvania, 26 July to 10 October 2008.

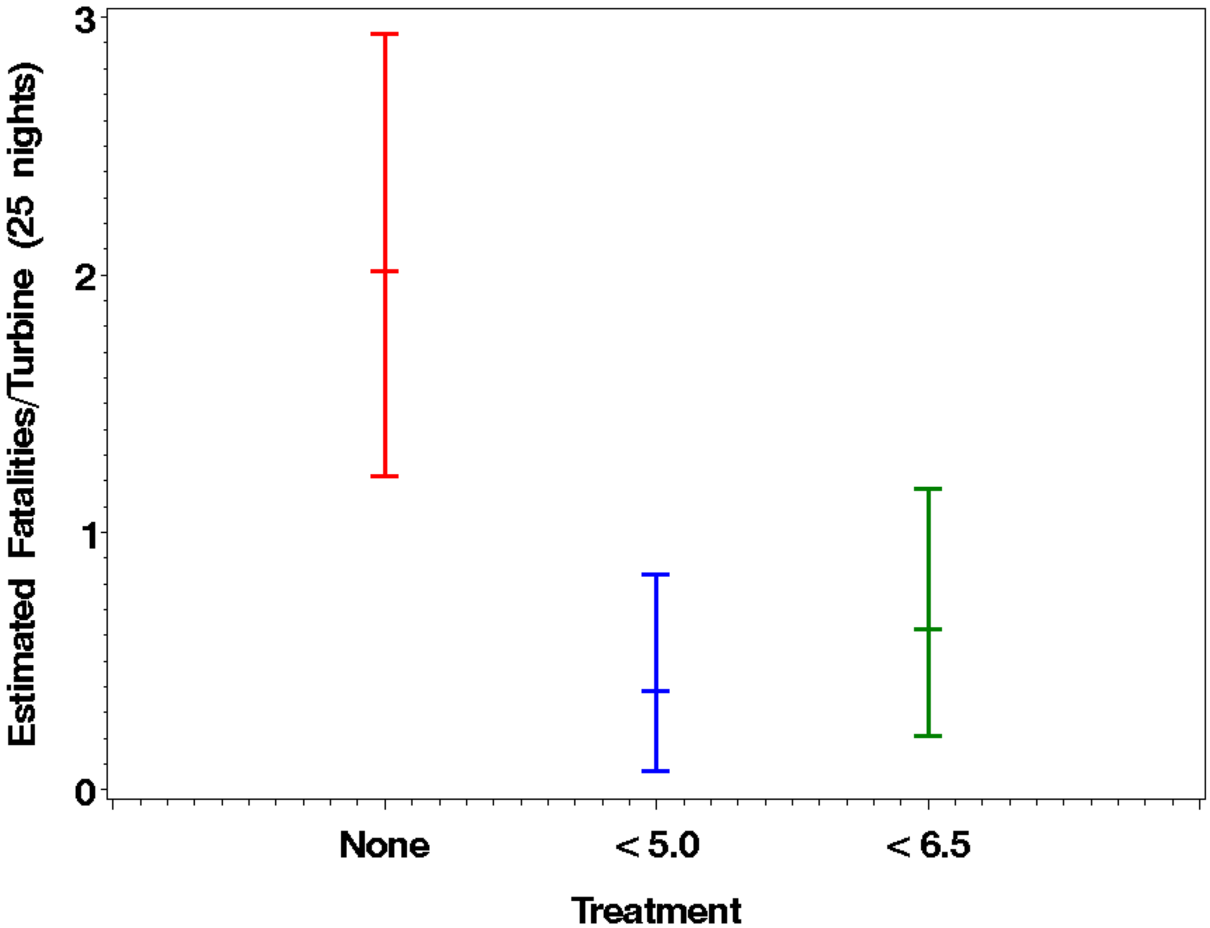


Table 4. Estimated ratio of the number of fresh bat fatalities per turbine, and 95% confidence interval, over 25 nights for each of three curtailment treatments (cut-in speed changed to 5.0 m/s, cut-in at 6.5 m/s, and fully operational) for 12 turbines at the Casselman Wind Project in Somerset County, Pennsylvania, 26 July to 10 October 2008.

Comparison	Estimated Ratio	95% Confidence Interval	
Cut-in at 5.0 vs 6.5 m/s	0.50	0.11	2.22
Fully operational vs average of 5.0 and 6.5 m/s treatments	5.42	2.28	12.89

Comparison of PGC and Curtailment Turbine Bat Fatalities

The average temperature (Figure 6), average wind speed (Figure 7), and percent of night when wind speed was <6.5 m/s (Figure 8) were similar between the PGC and curtailed turbines, suggesting no inherent environmental differences between the two groups of turbines that might have influenced our comparison of bat fatalities. However, while the average proportion of density weighted area in the easy visibility class was not statistically significantly different between the two turbine groups (Satterthwaite t-test with unequal variances, $t_{10.9} = -1.64$, $p = 0.129$), one PGC turbine had about 40% in the easy class when all others in the PGC and the curtailment group were ~20% or less (Figure 9). This turbine (PGC #20) could bias fatality numbers for the PGC group because carcasses at this turbine would be easier to find than at other turbines. When this turbine was omitted from the analysis, the average percent of the density weighted area in the easy visibility class was 16.7% (95% CI: 13.9, 19.5) for PGC turbines and 14.5% (95% CI: 12.5, 16.4) for curtailed turbines. Without turbine 20, there was no evidence that the average fraction of the density weighted area actually searched differed between the two groups ($t_{19} = 0.48$, $p = 0.640$). Thus, we concluded that comparison of the two groups was warranted, as it seemed unlikely to be strongly influenced by differences in detectability of the carcasses among the turbines.

Field Bias Trials. Data from 70 searcher efficiency trials for randomly placed carcasses were fit to a logistic regression model and searcher efficiency differed significantly among the visibility classes ($\chi^2_2 = 25.8$, $p = 0.0001$). All 30 carcasses in the ‘easy’ class that persisted long enough to be observed were found by searchers, while 17 of the 24 carcasses in the ‘moderate’ class that persisted long enough to be observed were found (Table 5). Only 2 of 16 carcasses that persisted more than 1 week in the ‘difficult’ class were found. Data from 114 scavenger removal trial for carcasses were fit to an interval-censored parametric failure time model. Using alpha = 0.10, average carcass persistence time was not found to differ among visibility classes ($\chi^2_2 = 1.778$, $p = 0.411$). Average persistence time was estimated to be 28.19 (95% CI: 16.87, 50.15) days (Table 5).

Figure 6. Histograms of the percent of survey nights and average temperature (C) for 10 turbines surveyed as part of the Pennsylvania Game Commission Cooperative Agreement (PGC; n = 10) and experimentally curtailed turbines (CURT; n = 12) from 26 July to 10 October 2008 at the Casselman Wind Project facility in Somerset County, Pennsylvania.

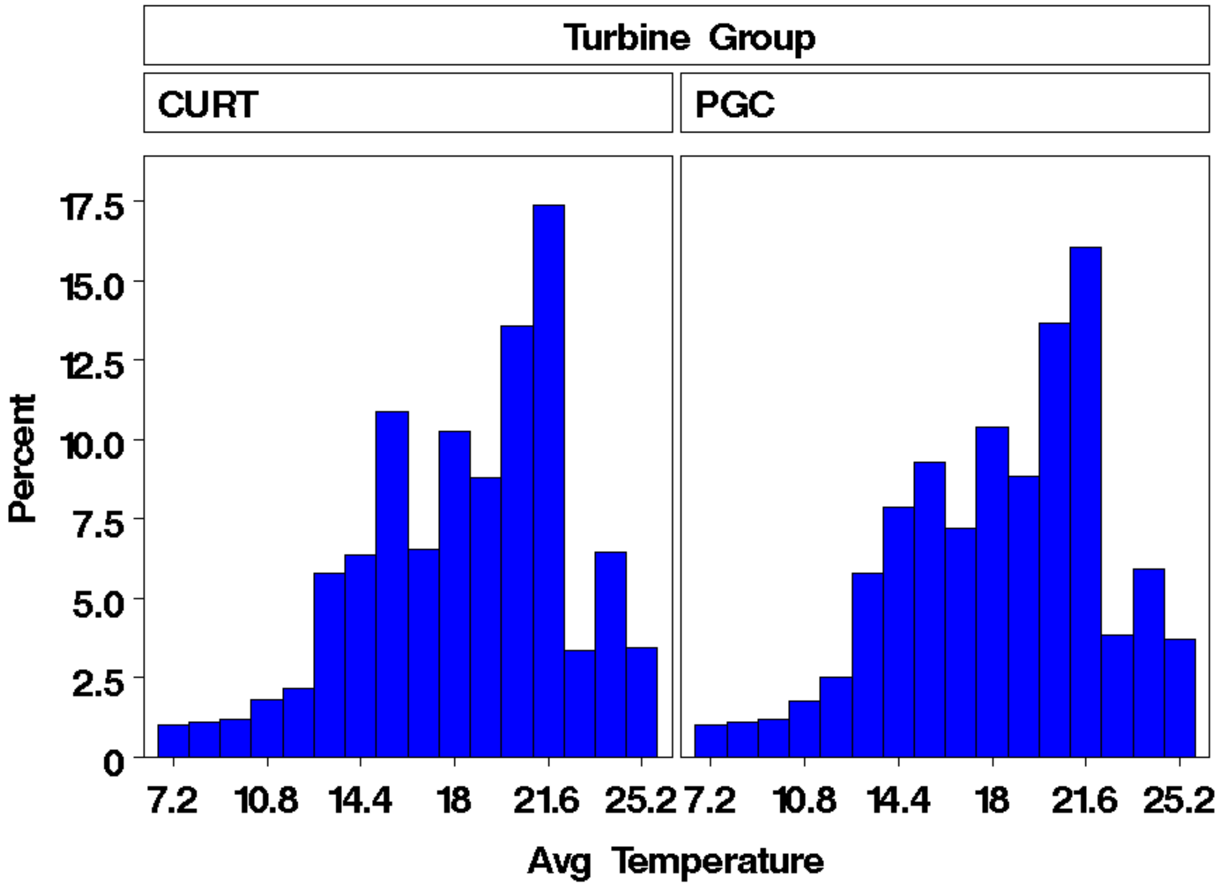


Figure 7. Histograms of the percent of survey nights and average wind speed (m/s) for 10 turbines surveyed as part of the Pennsylvania Game Commission Cooperative Agreement (PGC; n = 10) and experimentally curtailed turbines (CURT; n = 12) from 26 July to 10 October 2008 at the Casselman Wind Project facility in Somerset County, Pennsylvania.

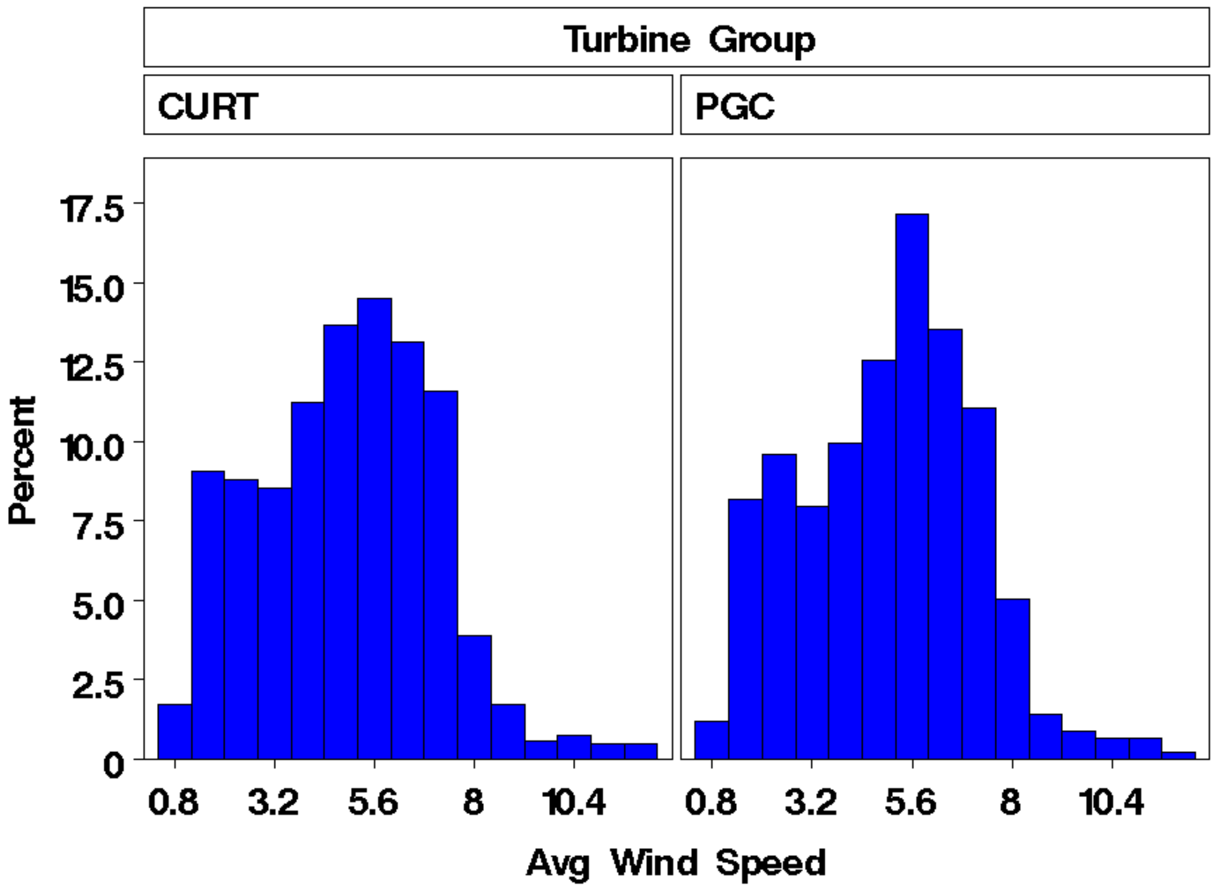


Figure 8. Histograms of the percent of survey nights and percent of night when wind speed was < 6.5 m/s for 10 turbines surveyed as part of the Pennsylvania Game Commission Cooperative Agreement (PGC; n = 10) and experimentally curtailed turbines (CURT; n = 12) from 26 July to 10 October 2008 at the Casselman Wind Project facility in Somerset County, Pennsylvania.

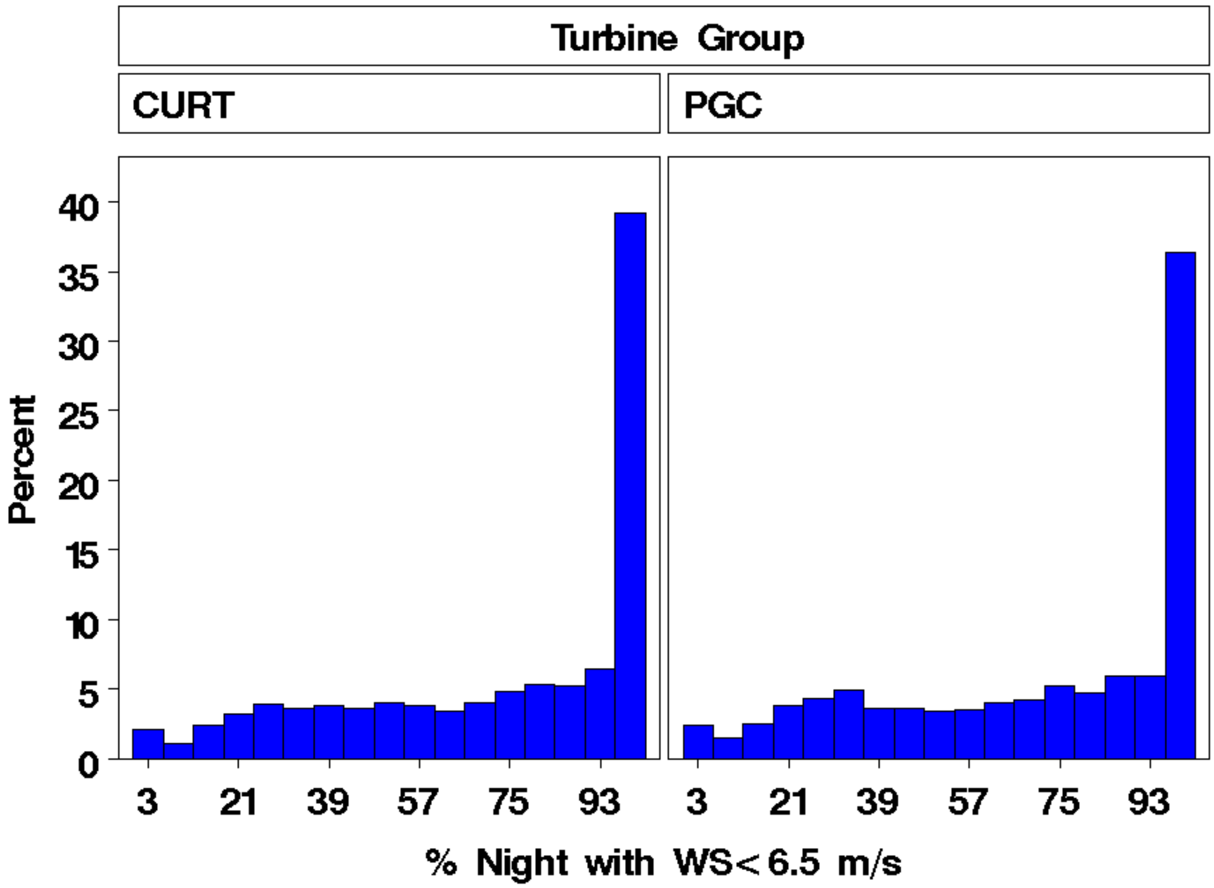


Figure 9. Histograms of the density weighted percent of plots in easy visibility habitat for 10 turbines surveyed as part of the Pennsylvania Game Commission Cooperative Agreement (PGC; n = 10) and experimentally curtailed turbines (CURT; n = 12) from 26 July to 10 October 2008 at the Casselman Wind Project facility in Somerset County, Pennsylvania.

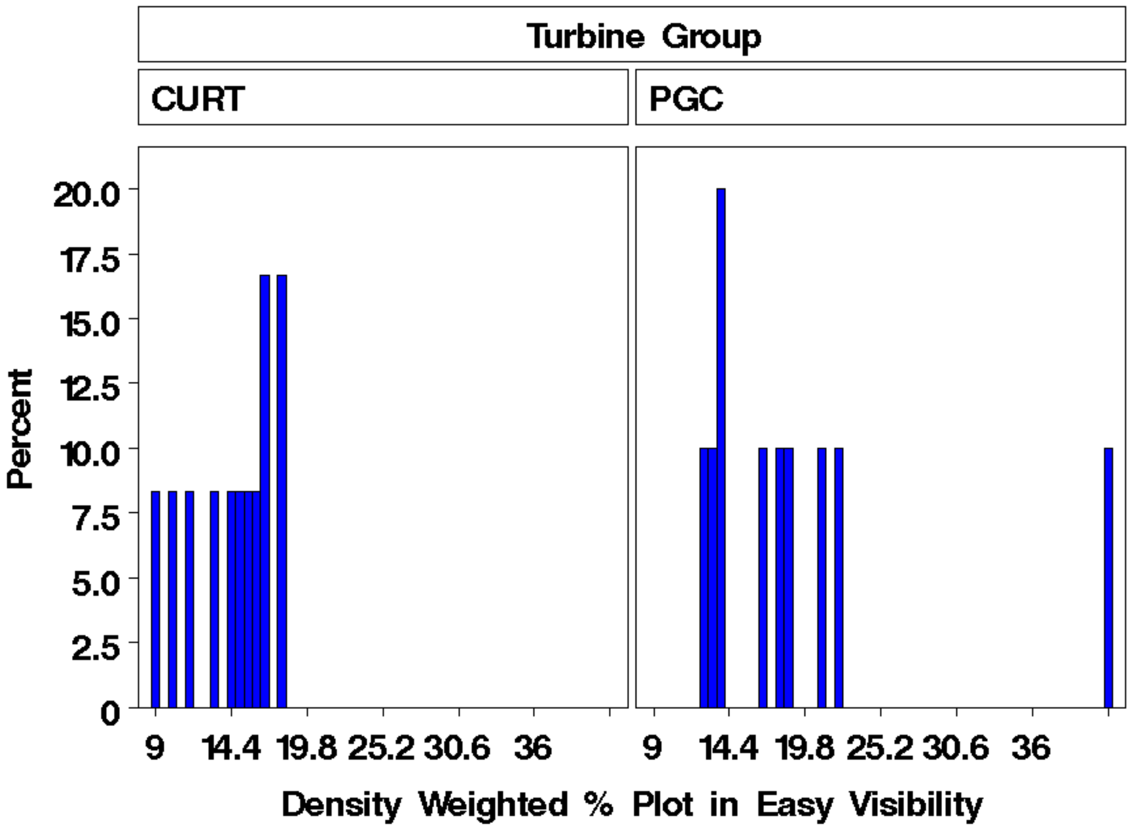


Table 5. Mean and 95% confidence intervals (CI) for searcher efficiency (proportion of available carcasses a searcher was likely to detect) and carcass persistence (average number of days a carcass was estimated to persist unscavenged or detectable by a searcher) in each habitat visibility class from the Casselman Wind Project facility in Somerset County, Pennsylvania in 2008. Difficult and very difficult classes (classes 3 and 4) were combined for the final analysis.

	Searcher Efficiency			Carcass Persistence		
Visibility Class	**Mean**	**Lower CI**	**Upper CI**	**Mean**	**Lower CI**	**Upper CI**
easy	1.000	1.000	1.000	28.192	16.866	50.153
moderate	0.708	0.542	0.875	28.192	16.866	50.153
difficult	0.125	0.031	0.313	28.192	16.866	50.153

Fatality Estimates. The estimated number of bat fatalities per turbine from 26 July through 11 October was 23.49 (95% CI: 16.14, 68.93) for the PGC turbines and 10.05 (95% CI: 6.76, 32.49) for the curtailed turbines using the MH estimator (Table 6). Using the modified estimator, the estimated number of bat fatalities per turbine was 14.86 (95% CI: 11.53, 32.91) for the PGC turbines and 6.60 (95% CI: 5.54, 14.56) for the curtailed turbines. The average bat fatality estimate per turbine using the MH estimator was 1.5 times greater than that of the modified estimator. Estimated bat fatalities per turbines were 1.23 to 4.68 times greater (mean = 2.34) at PGC turbines relative to curtailed turbines, using the MH estimator, and 1.61 to 2.87 times greater (mean = 2.25) using the modified estimator. This analysis provides further support for the contention that reducing operational hours during low wind periods reduces bat fatalities, but is a conservative estimate of the actual difference because treatment turbines were fully operational one-third of the time during the study.

Financial Costs of Curtailment

At the end of the experiment, Iberdrola Renewables evaluated how much power loss had occurred by comparing daily output of the curtailed turbines with the output of turbines that were not curtailed. The lost power output resulting from the experiment amounted to approximately 2% of total project output during the 76-day study period (12 turbines, 26 July to 10 October). Hypothetically, if the experiment had been applied to all 23 turbines at the Casselman site for the study period (½ hour before sunset to ½ hour after sunrise for the 76 days we studied), the 5.0 m/s curtailment used would have resulted in lost output equaling 3% of output during the period and only 0.3 % of total annual output. If the 6.5 m/s curtailment were applied to all 23 turbines during the study period, the lost output would have amounted to 11% of total output for the

Table 6. Estimated fatalities (mean and 95% confidence intervals [CI]) per turbine and for the site total, adjusted for searcher efficiency, carcass removal, and area, for PGC (fully operational) and curtailed (CURT; curtailed one-third of study period) from 26 July through October 11 for the Casselman Wind Project in Somerset County, Pennsylvania, using two different estimators (MH estimator (M.Huso, Oregon State University, unpublished data [manuscript in press] and the Modified estimator (from P. Shoenfeld, unpublished data, and Erickson et al. 2004; e.g., Kerns and Kerlinger 2004, Kerns et al. 2005; estimator currently required by PGC 2007). We also present the estimated ratio of per turbine fatality at PGC versus Curtailment turbines for the same period.

		MH Estimates			Modified Estimates		
	N turbines	Mean	Lower 95% CL	Upper 95% CL	Mean	Lower 95% CL	Upper 95% CL
Per Turbine							
CURT	12	10.05	6.76	32.49	6.60	5.54	14.56
PGC	10	23.49	16.14	68.93	14.86	11.53	32.91
Site total							
CURT	23	243.9	164.2	789.0	160.3	134.4	353.5
PGC	23	570.4	392.0	1673.7	360.9	279.9	799.1
Ratio of PGC:CURT		2.34	1.23	4.68	2.25	1.61	2.87

study period and 1% of total annual output. In addition to the lost power revenues, the company also incurred costs for staff time to set up the processes and controls and to implement the curtailment from the company's offsite 24-hour operations center based in Portland, Oregon.

DISCUSSION

Our findings were consistent with our predictions that bat fatalities would be significantly reduced by changing turbine cut-in speed and reducing the operational hours during low wind periods, and corroborate the only other studies of operational curtailment (Baerwald et al. 2009, O. Behr, University of Erlangen, unpublished data). All three studies of operational curtailment conducted to date indicate that bat fatalities can be reduced by at least 50%.

In the first analysis, our study design differed from other studies in part because we were able to change treatments easily on each night of the study from a centralized, off-site command center, thus allowing the night to be the experimental unit in our analysis. Because we used the turbine as a blocking factor, any differences in searchable area among turbines were contained in the blocking factor. The almost even distribution of fatalities among turbines indicates that there was no strong distinction in fatality among turbines, so detected effects can be reasonably attributed to the treatments. This design is very powerful, but also is very dependent on the correct determination of fresh carcasses. If a two day old carcass was discovered, it could have been inaccurately attributed to the treatment of the previous night, rather than the night before that. Appendix 2 presents data from turbines where the potential existed for misclassification of fresh carcasses. For all but one of the fatalities attributed to a curtailment treatment, the previous treatment was a fully operational treatment. In slightly over half (12/23) of the fatalities attributed to fully operational treatments, the previous treatment was also a fully operational treatment. Thus, even if our accuracy in determining fresh carcasses was off by a day and all carcasses that were found were in fact 2 days old and hence killed during the prior treatment, the majority of fatalities would still have been associated with fully operational turbines (12 curtailed vs 20 fully operational, Appendix 2). We do not believe that our misclassification rate was that high, nor do we have reason to believe that the probability of misclassifying a carcass as fresh is in any way associated with the treatment. Thus, we assume that any error in our classification of fresh bats was equal among turbines and treatments and that it did not greatly influence the results of this study. Our second analysis demonstrated that estimated fatalities were higher at PGC compared to curtailed turbines and further supports our contention that reducing operational hours during low wind periods reduces bat fatalities. These fatality differences likely represent a conservative estimate of the effect of curtailment because the curtailed turbines were fully operational 1/3 of the time during the study.

Numerous factors influence the power loss and, thus financial costs of changing the cut-in speed of wind turbines reduce bat fatalities. These include, but are not limited to, the type and size of wind turbines and computer hardware used, market or contract prices of power, power purchase agreements and associated fines for violating delivery of power, and variation in temporal consistency, speed and duration of wind across different sites. Wind speeds in the Mid-Atlantic Highlands region are typically lowest in late summer and early fall (S. McDonald, Iberdrola Renewables, unpublished data). The loss in power production resulting from our experimental treatments was surprisingly low when considering the full annual productivity lost, but power loss was 3 times higher for the 6.5 m/s change in cut-in speed compared to the 5.0 m/s treatment. Our data indicated no significant difference in fatalities between these two changes in cut-in speed, albeit with low statistical power to detect such a difference, and thus further research at the Casselman site and other sites is needed to determine whether lower changes in cut-in speed may provide the same biological effects as higher cut-in speeds with less financial cost. Power loss during our experiment was considerably different from that reported by Baerwald et al. (2009) primarily because we curtailed turbines only at night when bats are flying and because of different market pricing for electricity between the two study sites. Technological limitations of the Vestas V80 turbines studied by Baerwald et al. (2009) forced them to change the cut-in speed for the entire duration of the study, 24 hours a day. Baerwald et al. (2009) noted that if the operational parameters could have been changed only when bats were active at night, then costs would have been even less for their study.

Higher bat activity (e.g., Arnett et al. 2006, 2007b, Redell et al. 2006, Reynolds 2006, Weller 2007) and fatalities (Arnett et al. 2008) have been consistently related to periods of low wind speed and weather conditions typical of the passage of storm fronts. The casual mechanism underlying this relationship remains unclear, but perhaps migration is less efficient for bats in high wind speeds and thus migratory movement by these species is reduced (Baerwald et al. 2009). Cryan and Brown (2007) reported that fall arrivals of hoary bats on Southeast Farallon Island were related to periods of low wind speed, dark phases of the moon, and low barometric pressure, supporting the view that migration events may be predictable. Low barometric pressure can coincide with passage of cold fronts that may be exploited by migrating birds and bats (Cryan and Brown 2007). Erickson and West (2002) reported that regional climate patterns as well as local weather conditions can predict foraging and migratory activity of bats. On a local scale, strong winds can influence abundance and activity of insects, which in turn influence bat activity. Bats are known to reduce their foraging activity during periods of rain, low temperatures, and strong winds (Erkert 1982, Erickson et al. 2002). Episodic hatches of insects that are likely associated with favorable weather and flight conditions may periodically increase local bat activity (Erickson and West 2002). More studies incorporating daily fatality searches are needed so that patterns such as those described above can be determined at multiple sites across regions. These data will be critical for developing robust predictive models of environmental conditions preceding fatality events, and for predicting when operational curtailment will be most effective to reduce bat fatalities.

Our study is the first U.S.-based experiment of changing cut-in speed to reduce bat fatalities, and only the third we are aware of anywhere in the world. We demonstrated reductions in average nightly bat fatality ranging from 56 to 92% with minimal annual power loss. Given the magnitude and extent of bat fatalities worldwide, the conservation implications of our findings and those of Baerwald et al. (2009) are critically important. However, additional studies are needed to test changes in turbine cut-in speed among different sizes and types of turbines, wind regimes, and habitat conditions to fully evaluate the general effectiveness of this mitigation strategy.

NEXT STEPS

We are preparing a scope of work for a second year of testing operational curtailment at the Casselman facility in summer and fall 2009. We will initiate a second year of post-construction fatality searches at the PGC turbines beginning 1 April and continuing through 15 November 2009 and will initiate searches for the curtailment study beginning in mid- late July and continuing through the second week of October at the Casselman facility. A final report on the 2-years of curtailment data gathered at Casselman will be prepared in December 2009 and distributed in February 2010, with a journal manuscript submission to follow shortly afterward.

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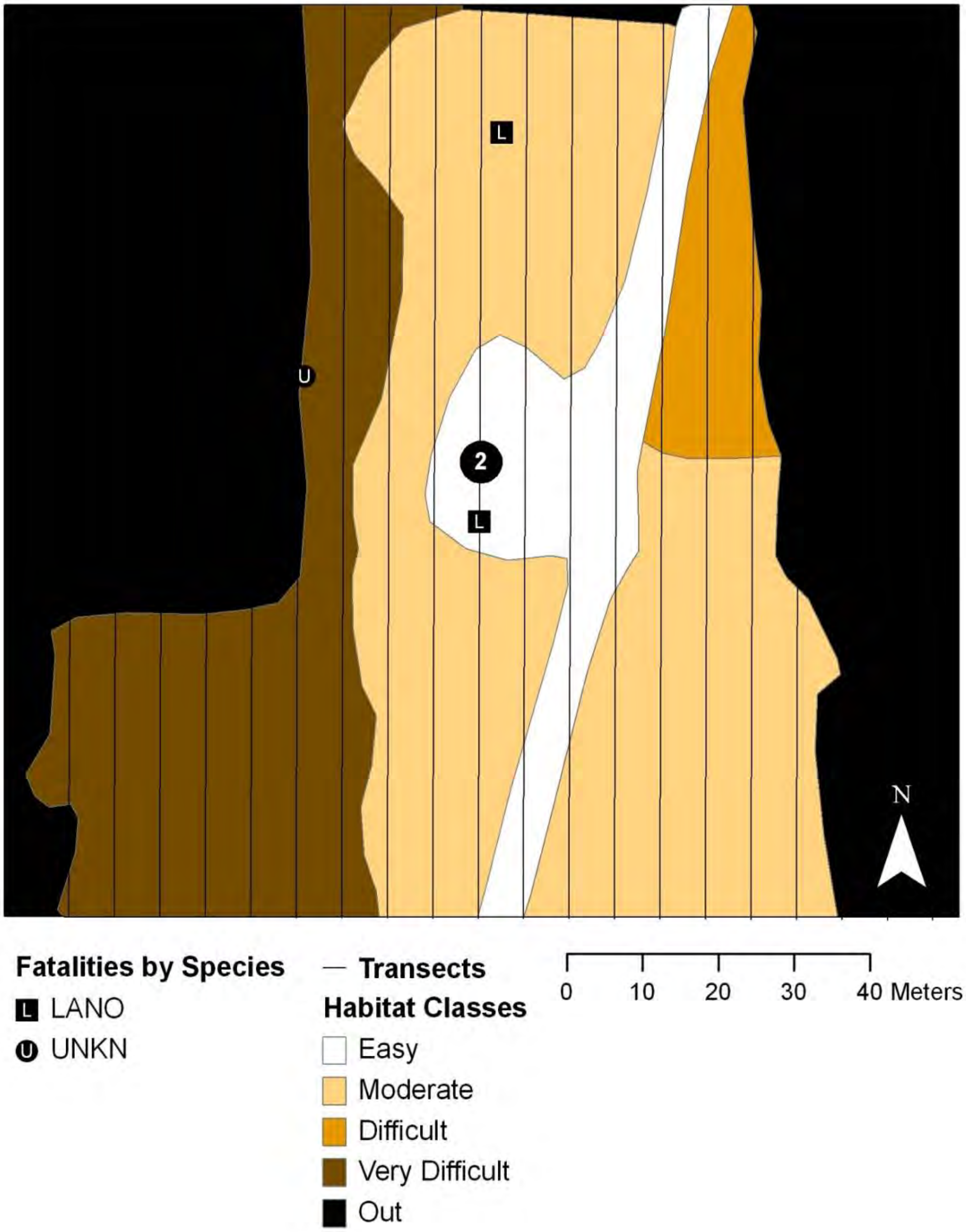
APPENDIX 1
(Turbine Plot Maps)

Turbine 2



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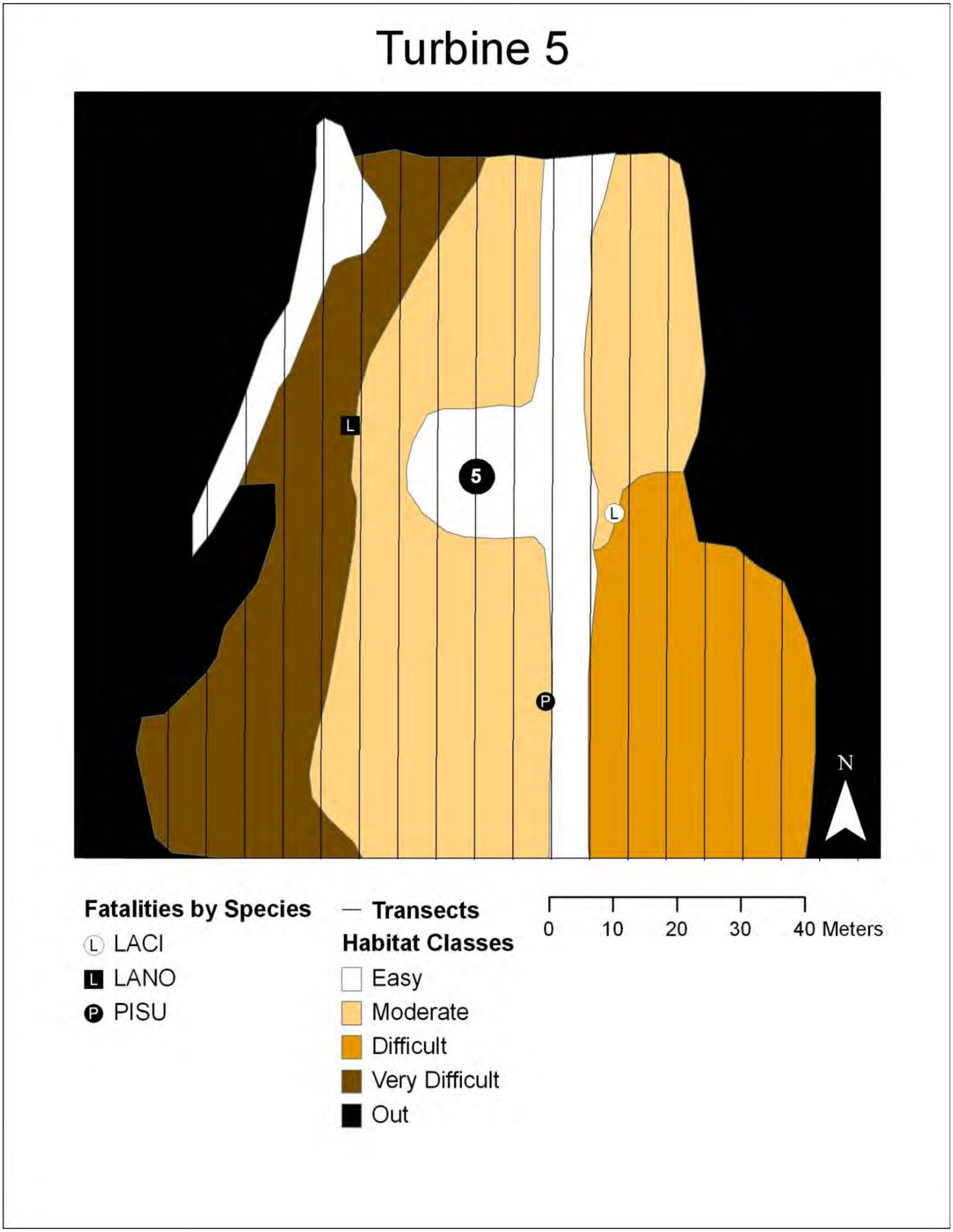
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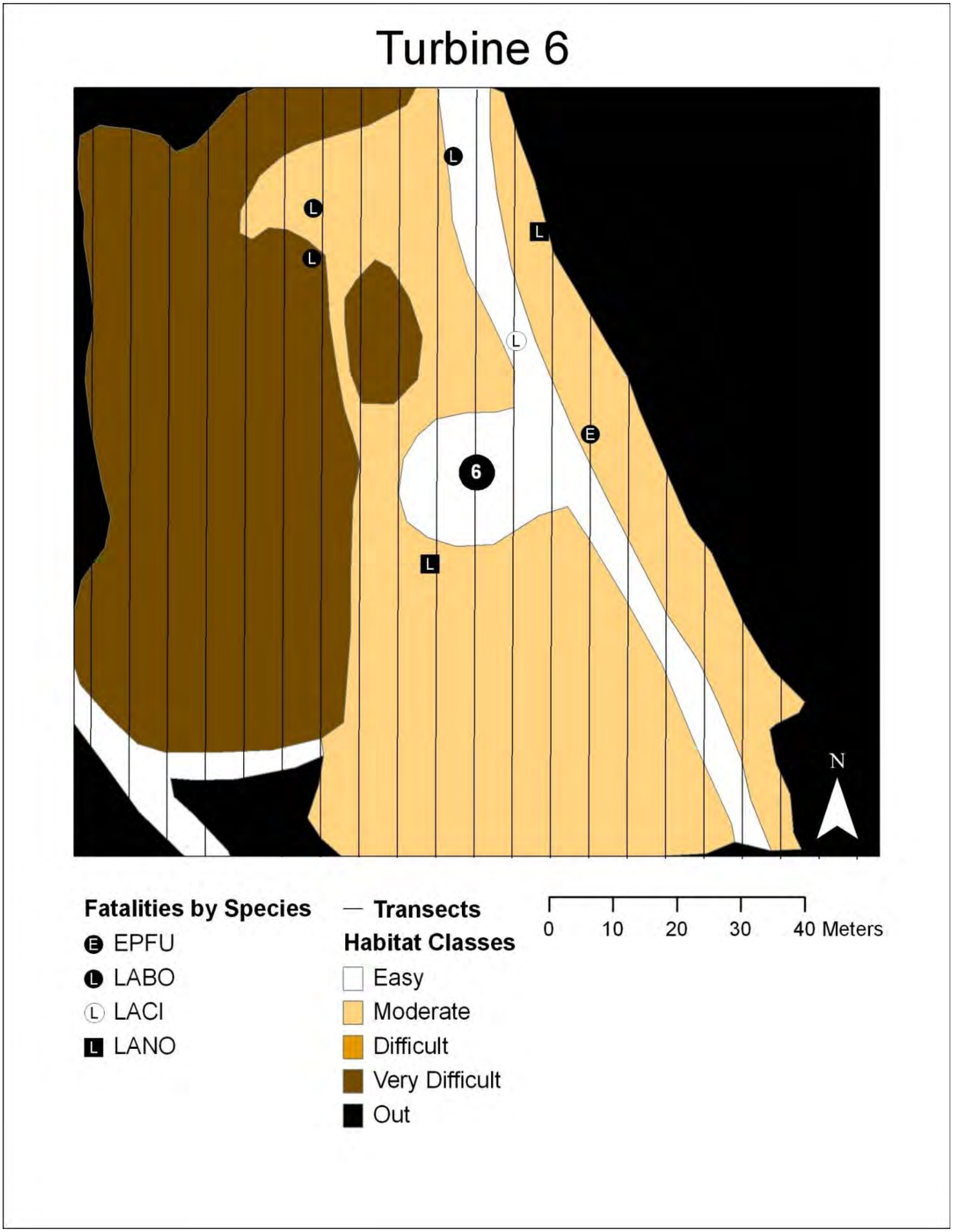
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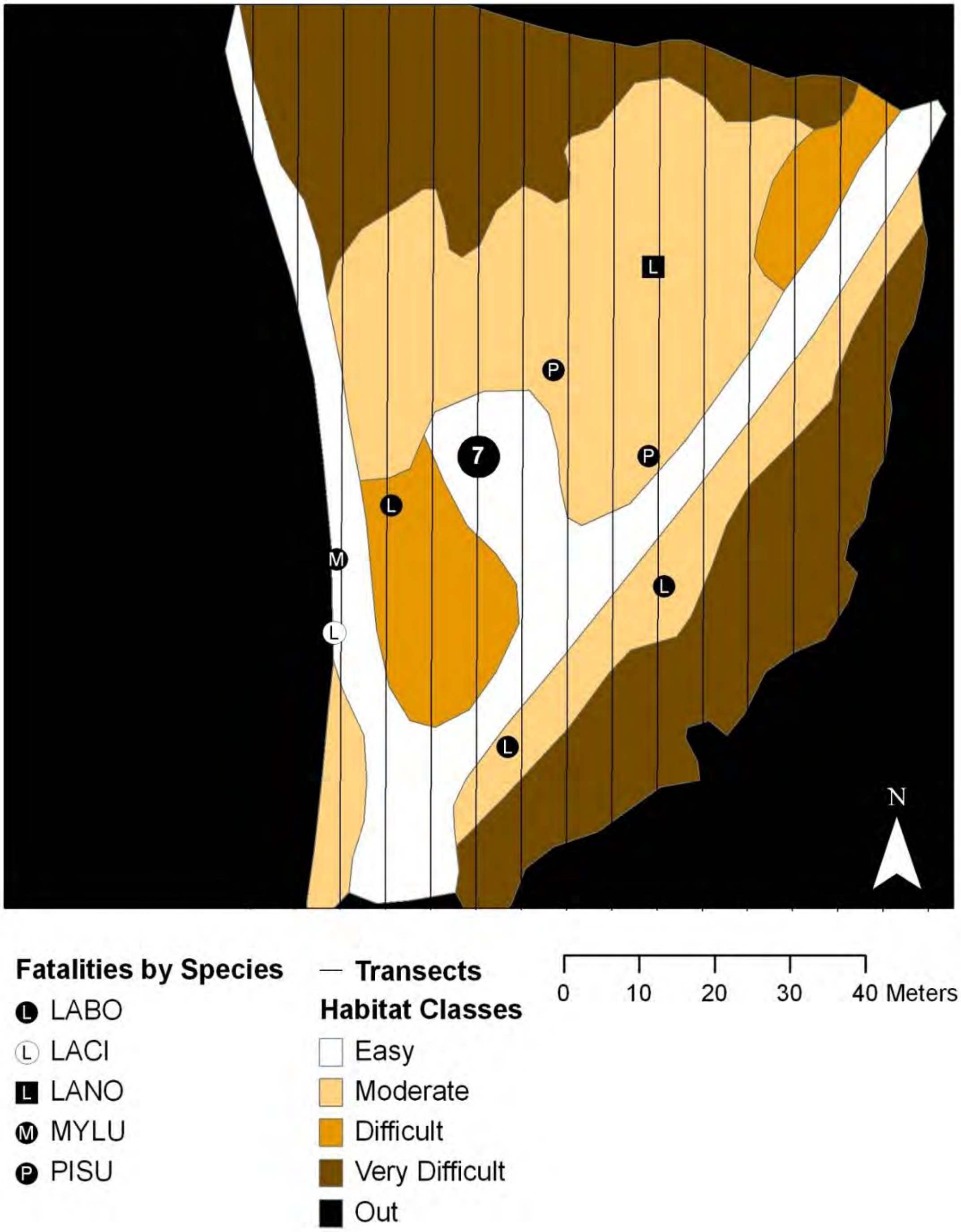
Turbine 7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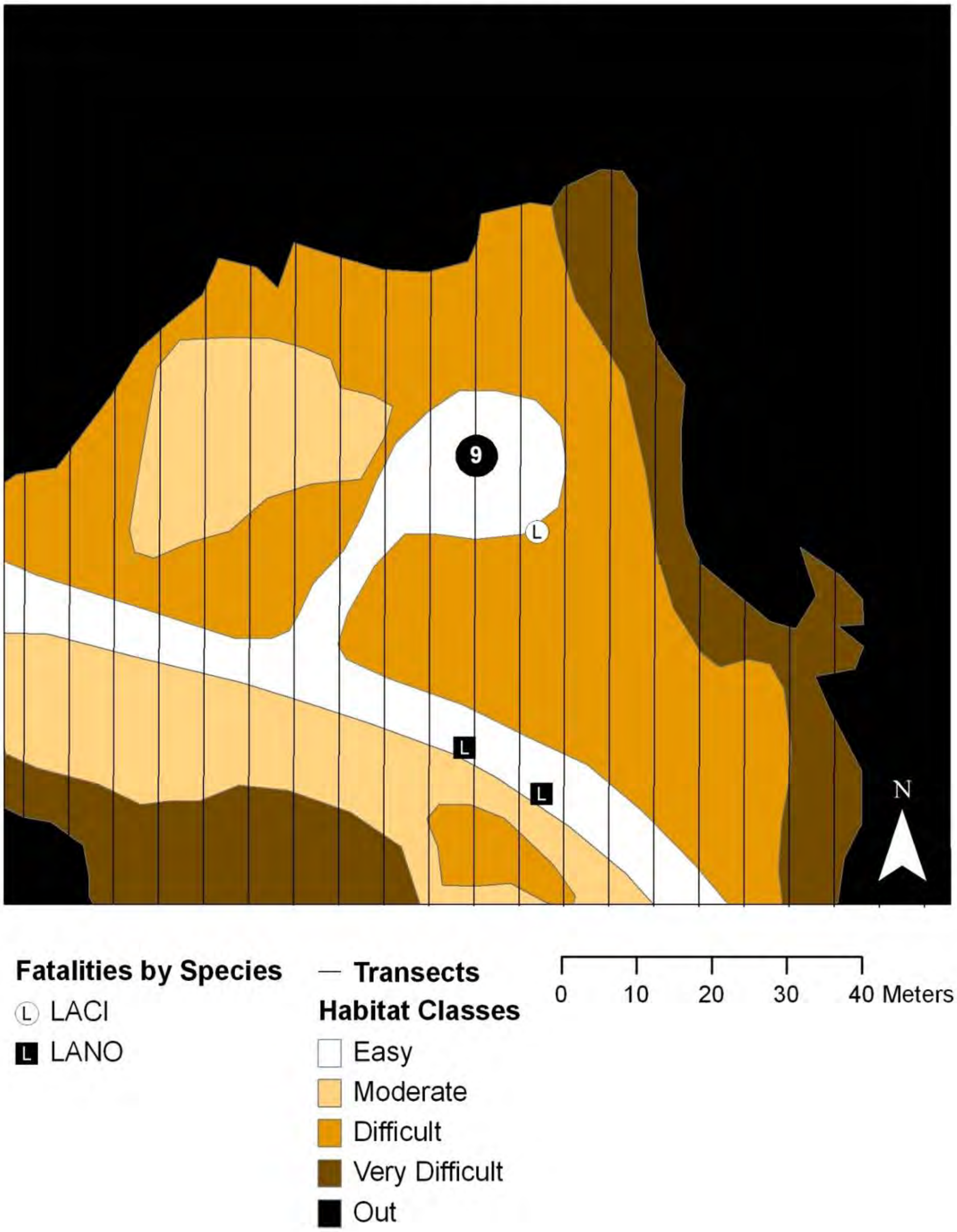
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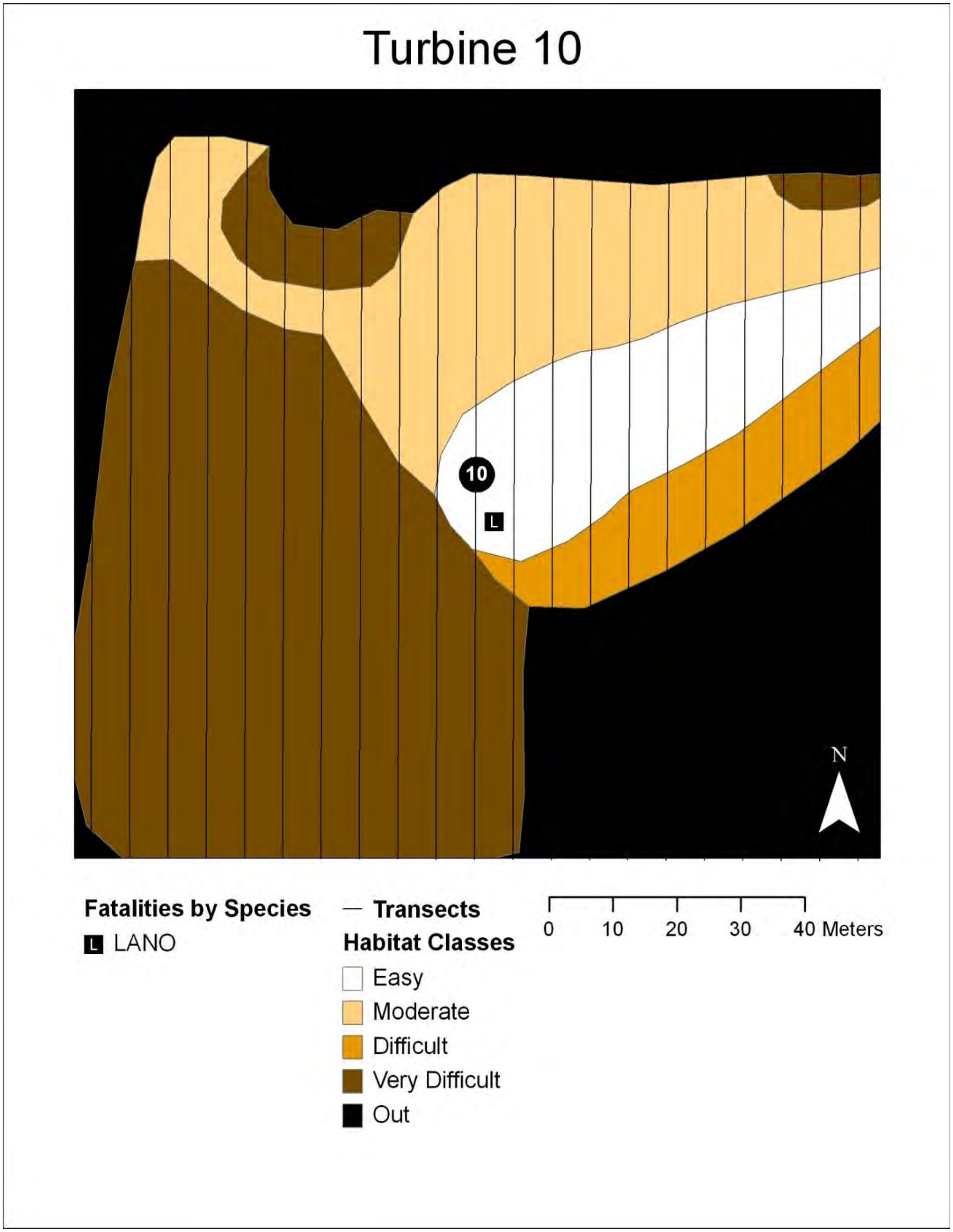
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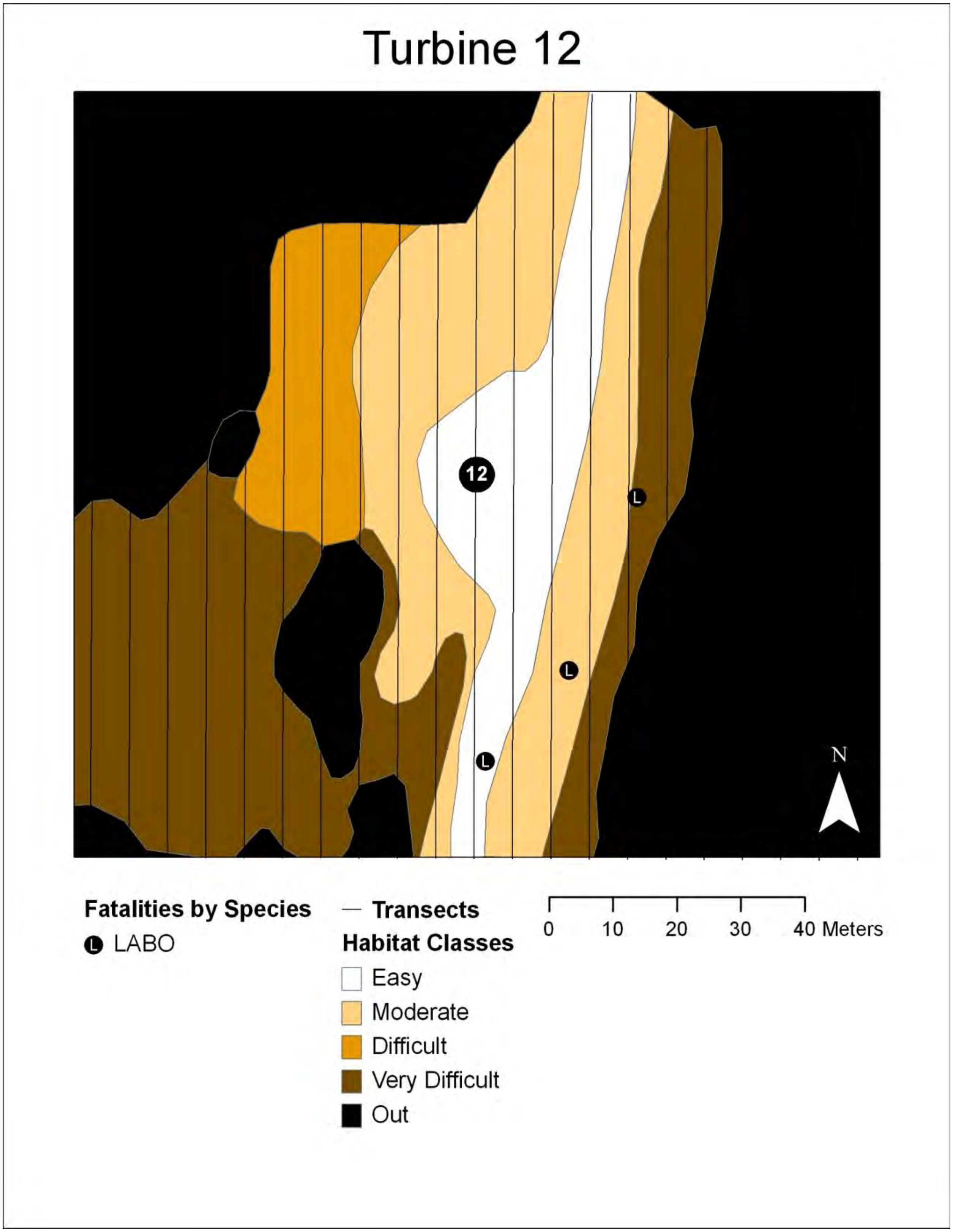
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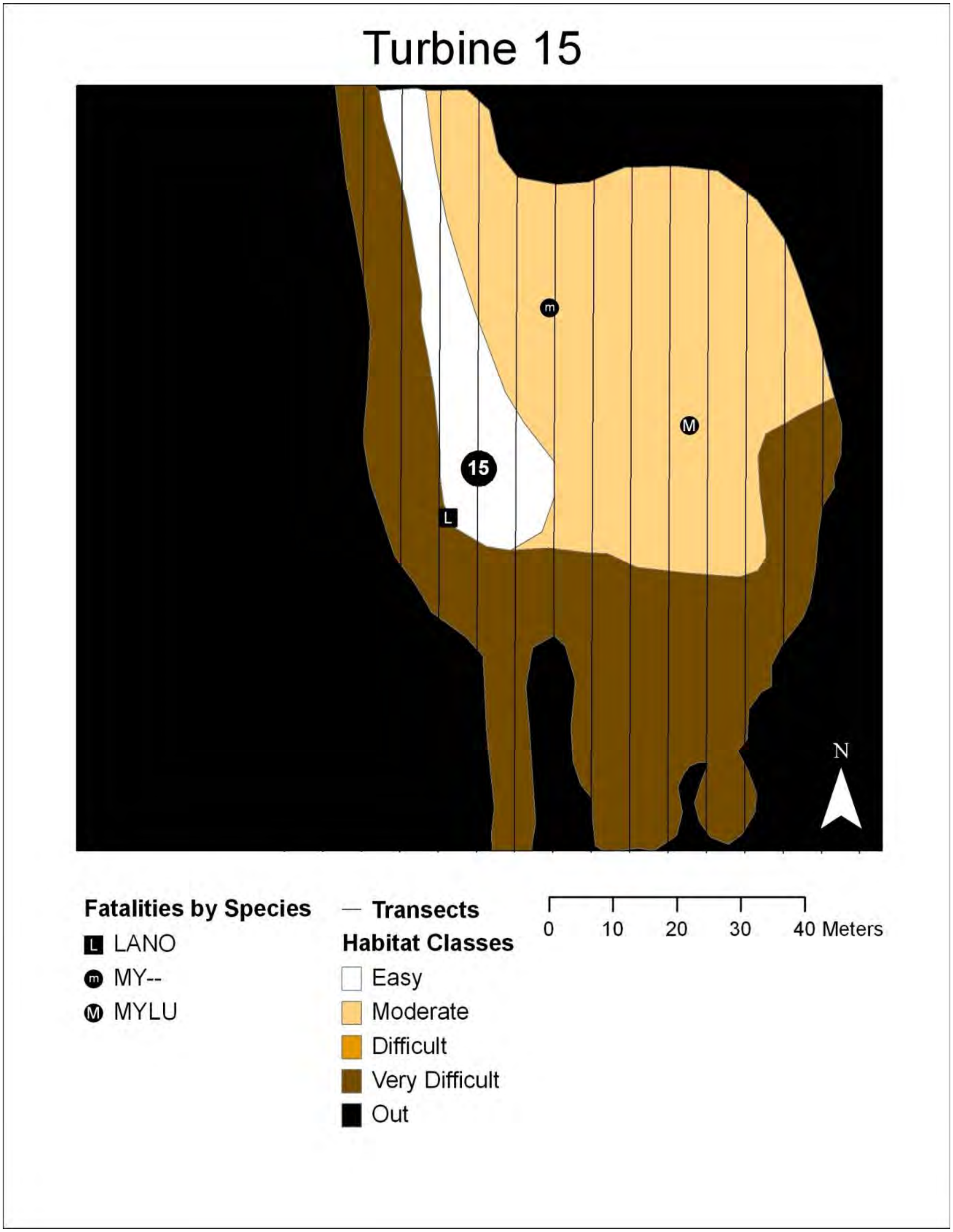

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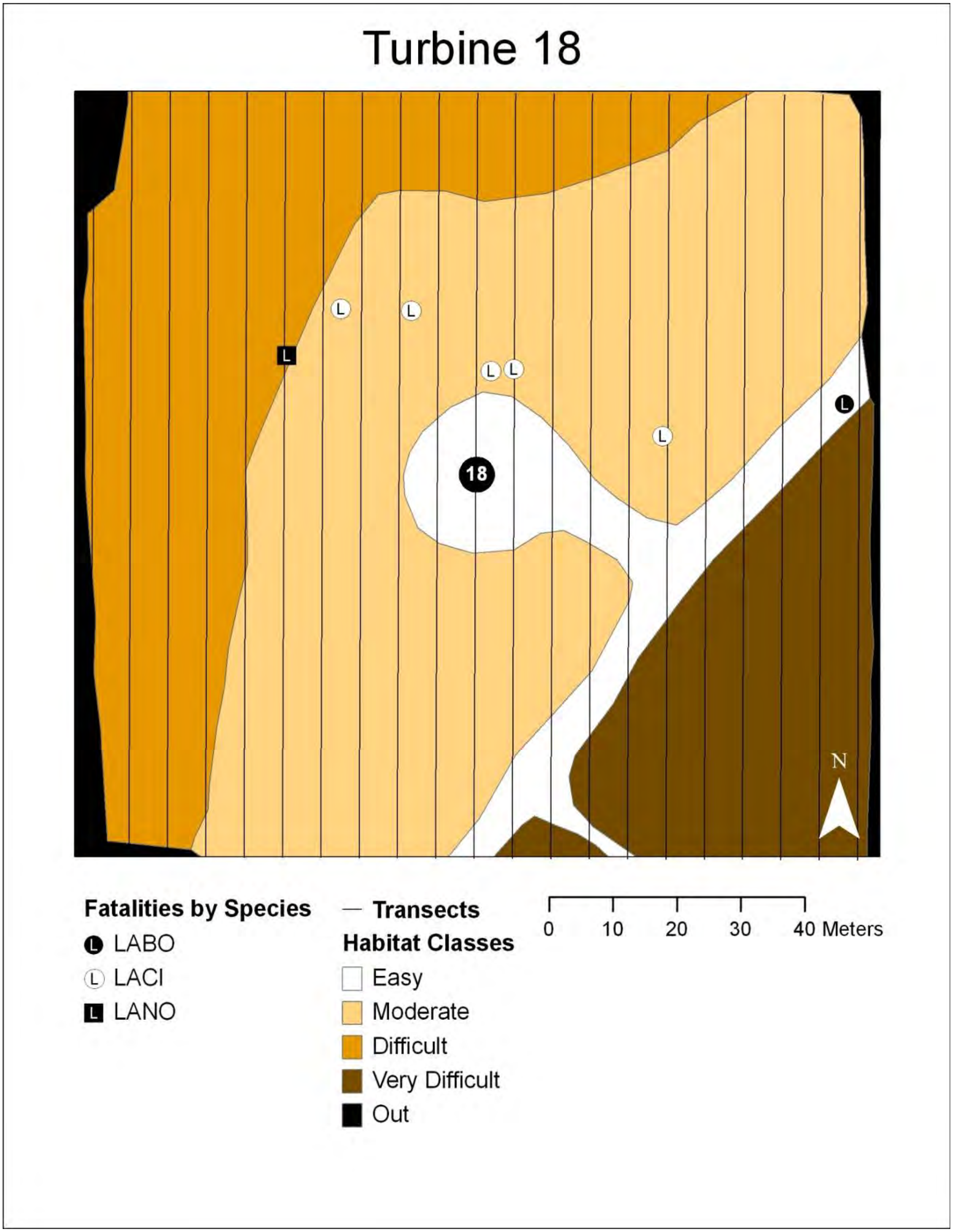
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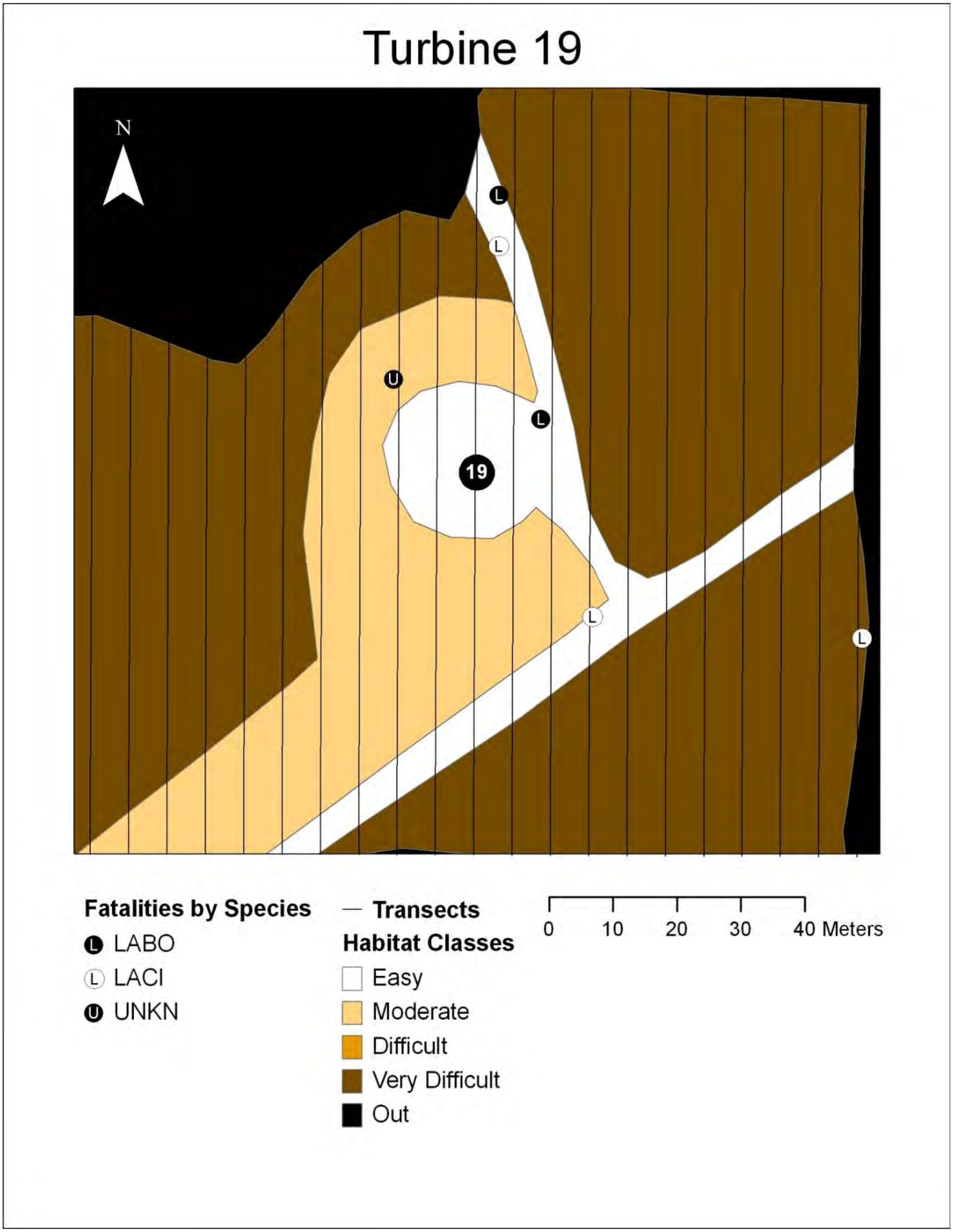
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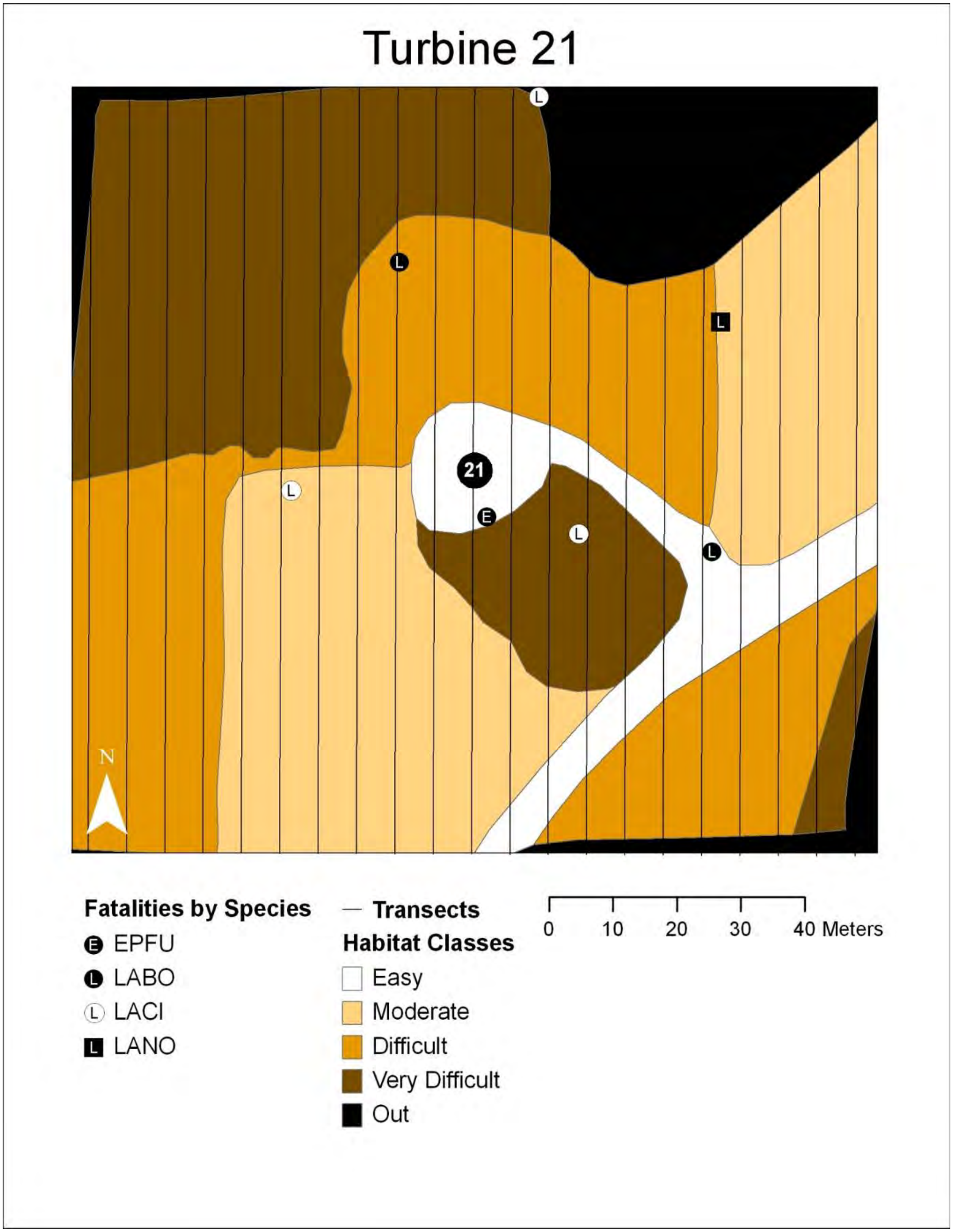
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Appendix 2. Turbines, fatality count, and treatments that could have yielded potential for misclassification of fresh bat fatalities to treatments at the Casselman Wind Project in Somerset County, Pennsylvania.

Turbine	Fatality count	Treatment	Prior Treatment
6	1	C5	C5
5	1	C5	NF
5	1	C5	NF
7	1	C6	NF
10	1	C6	NF
18	1	C6	NF
18	1	C6	NF
21	1	C6	NF
21	1	C6	NF
6	1	NF	C5
6	1	NF	C5
9	1	NF	C5
17	1	NF	C5
2	1	NF	C6
6	1	NF	C6
7	1	NF	C6
15	1	NF	C6
17	1	NF	C6
18	1	NF	C6
19	1	NF	C6
7	2	NF	NF
9	1	NF	NF
9	1	NF	NF
12	1	NF	NF
15	1	NF	NF
17	2	NF	NF
18	1	NF	NF
19	1	NF	NF
19	1	NF	NF
21	1	NF	NF

From:	Murphy, Donald
To:	"Geoff West";
Subject:	FW: Bull Hill Wind Project Review
Date:	Friday, March 11, 2011 11:17:57 AM

From: Bard, Richard
Sent: Friday, March 11, 2011 11:17 AM
To: Bard, Richard; Timpano, Steve; Murphy, Donald
Cc: Schaeffer, Thomas; Todd, Charlie
Subject: RE: Bull Hill Wind Project Review

One last word for the applicant:
USFWS is in the process of changing their guidelines for review of wind energy projects. I don't know whether this project would be reviewed under the revised guidelines or the old ones, but it is worth advising them of potential changes. Draft guidelines are available at:

- Land bird guidelines = see http://www.fws.gov/windenergy/docs/Wind_Energy_Guidelines_2_15_2011FINAL.pdf
- Eagle conservation plan guidance = see http://www.fws.gov/windenergy/docs/ECP_draft_guidance_2_10_final_clean_omb.pdf

Rich

From: Bard, Richard
Sent: Thursday, March 10, 2011 2:35 PM
To: Timpano, Steve; Murphy, Donald
Cc: Schaeffer, Thomas; Burr, Gregory; Hodgman, Tom; DePue, John
Subject: RE: Bull Hill Wind Project Review

I apologize for the string of emails, but I wanted to be sure the consultant had access to our comments ASAP as requested by LURC. I think this will be the last, for now.

The bat radar studies in Exhibit 13C of the application acknowledge that bat activity peaks when wind speeds are below 5.0 meters per second. Recent studies (Arnett et al. 2009 & 2010, Baerwald et al. 2008) at operating wind facilities have indicated that increasing the cut-in speed (the wind speed at wind the turbine is allowed to begin rotating) for operating turbines to 5.0 meters per second has significantly decreased turbine-caused fatalities for bats. Therefore, in order to minimize risk of mortality to bats MDIFW recommends that operational control measures be established for the Blue Sky East project. These measures should be employed from April 20th through October 15th, such that the applicant set the turbine cut-in speed to 5.0 m/s starting at one-half hour before sunset to one-half hour after sunrise. During this time frame when the wind speed is less than the 5.0 m/s threshold, turbine blades are not allowed to rotate thus reducing risk of fatality for bats. If at any point during this time period the wind speed increases to > 5.0 m/s the turbine blades are free to rotate.

I have included full citations for the above references:

Arnett, E. B., M. P. Huso, M. R. Schirmacher, and J. P. Hayes. 2010. Altering turbine speed reduces bat mortality at wind-energy facilities. *Frontiers in Ecology and the Environment*. : 101101071900096 DOI: 10.1890/100103

Arnett, E. B., M. R. Schirmacher, M. P. Huso, and J. P. Hayes. 2009. Effectiveness of changing wind turbine cut-in speed to reduce bat fatalities at wind facilities. An annual report submitted to the Bats and Wind Energy Cooperative. Bat Conservation International. Austin, Texas, USA.

Baerwald, E. F., J. Edworthy, M. Holder, and R. M. R. Barclay. 2009. A Large-scale mitigation experiment to reduce bat fatalities at wind energy facilities. Journal of Wildlife Management 73:1077-1081.

Richard Bard
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Jonesboro, ME 04648
207-434-5927 (office)
207-592-0109 (cell)
www.mefishwildlife.com

From: Bard, Richard
Sent: Thursday, March 10, 2011 10:39 AM
To: Timpano, Steve; Murphy, Donald
Cc: Schaeffer, Thomas; Burr, Gregory; Hodgman, Tom
Subject: RE: Bull Hill Wind Project Review

On December 13, Tom Schaeffer sent comments drafted by Tom Hodgman to Geoff West of First Wind. The comments address the draft Post-Construction Monitoring Plan. The same day, Geoff West replied that we were too late to have Tom H.'s comments incorporated in the draft LURC application, but that they would be reflected in the final plan. None of Tom's recommendations are addressed in any way in the current application. To save the confusion of attaching multiple email threads to this message, I'm copying the text of Tom Hodgman's recommendations below. We still stand by the need

for these changes to the Post-Construction Monitoring Plan. If you need copies of the email threads, I'll be happy to send them along. Thank you very much.
Rich

From Tom Hodgman:
I looked over the Postconstruction monitoring plan and see a few things that may warrant a slight change.

1) Weekly searches - I appreciate the analysis of bird/bat mortality over time and suggest modifying the weekly search plan - dropping a few weeks in early summer in exchange for a more continuous track of searches during spring migration and fall migration. I'd suggest searches be conducted April 15 to June 7 then July 7 to Oct 15. I think that's roughly the same number of weeks as proposed.

2) Daily searches - good idea, no changes to dates but which turbines will be searched??? Do you rotate through all???

3) Carcass removal trials - See paper by Smallwood re scavenger removal trials [JWM 74(5):1089-1097]. Perhaps the number of carcasses used should be scaled back to avoid "flooding" or at least be sure to stagger them well over time.

4) Number of years - Need to see a commitment of at least 2 years of mortality searches with an option for a third depending on results in previous 2 years. Think this has been the norm to date and there has been no discussion on our end of modifying that.

5) Radar - I think we all agree another year of radar work is needed to see if the flight height and passage rate is anomalous or something that we just haven't seen before.

6) I'm intrigued by your discussion of curtailment. How do we get engaged in that discussion?? Is there still time to discuss on this project or perhaps more appropriate for your next project.

Richard Bard
Assistant Regional Wildlife Biologist
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207-434-5927 (office)
207-592-0109 (cell)