BEFORE THE PUBLIC SERVICE COMMISSION
OF THE STATE OF MISSOURI

In the Matter of the Application of Ameren Transmission Company of Illinois for Other Relief or, in the Alternative, a Certificate of Public Convenience and Necessity Authorizing it to Construct, Install, Own, Operate, Maintain and Otherwise Control and Manage a 345,000-volt Electric Transmission Line from Palmyra, Missouri, to the Iowa Border and Associated Substation Near Kirksville, Missouri.[1]	)	File No. EA-2015-0146

Motion to Strike or Deny Admission of Certain Exhibits

Ameren Transmission Company of Illinois ("ATXI") hereby files its objections[2] to certain inadmissible exhibits that were offered at local public hearings and moves the Public Service Commission ("PSC") to strike those exhibits or otherwise deny their admission.

While it is true this Commission is not bound by the technical rules of evidence, it is still bound by the fundamental rules of evidence:

> Cases brought before administrative agencies generally are less formal and structured than are civil proceedings in the circuit courts. That does not mean that evidentiary rules developed in civil cases have no application to administrative actions, however. To the contrary, the legislature has specifically directed that many evidentiary principles developed in civil actions be applied in administrative ones, including those regarding privilege, judicial notice, admission of writings and documents, depositions and so forth.

[1] The project for which the CCN is sought in this case also includes a 161,000-volt line connecting to the associated substation to allow interconnection with the existing transmission system in the area.

[2] At the first local public hearing, held in Shelbyville, Missouri, on October 19, 2015, Administrative Law Judge Pridgin agreed that objections to any exhibits offered at the local public hearings did not need to be made at the hearing itself but could be made following the receipt of hearing transcripts. *Transcript - Volume 2 (Local Public Hearing - Shelbyville 10-19-15)* at 21:4-15 [EFIS Item No. 74].

State Bd. of Registration for Healing Arts v. McDonagh, 123 S.W.3d 146, 154 (Mo. 2003). In fact, the Commission's own regulation at 4 C.S.R. 240-2.130(1) adopts particular rules of evidence found at Mo. Rev. Stat. § 536.070. Because exhibits offered by lay witnesses at the local public hearings become part of the record, they are subject to the same evidentiary rules as are those offered at hearing.

A. Fundamental Rules of Evidence Govern the Admissibility of Exhibits Offered at the Public Hearings.

1. Relevance

One of these fundamental rules of evidence is the exclusion of irrelevant evidence. Mo. Rev. Stat. § 536.070(8) ("Irrelevant and unduly repetitious evidence shall be excluded."). To be relevant, the proffered evidence must tend to either prove or disprove any fact in issue or corroborate other relevant evidence bearing on the principal issues before the Commission. *In the Matter of the Joint Application of Great Plains Energy Inc., et al., for Approval of the Merger of Aquila, Inc.*, 2008 Mo. PSC LEXIS 820 at *6 (Order Denying Motions for Rehearing, Clarifying Report and Order, and Denying Motion to Stay as Being Moot) (Case No. EM-2007-0374, August 5, 2008). In deciding whether to grant a CCN, the "principal issues" before the Commission pertain to economic feasibility, the need for the transmission line and financing; protection from EMF, wildlife or bat populations are not, however, principal concerns of the Commission. *See State ex rel. Util. Consumers Council of Mo., Inc. v. Pub. Serv. Comm'n*, 562 S.W.2d 688, 698-99 (Mo. App. E.D. 1978) (upon review of grant of CCN for construction of the Callaway nuclear plant, court affirming finding by Commission

that the issue of safety was not an issue to be decided by the Commission: "[t]he considerations of the Commission do not attempt to protect the citizens of Missouri against radiation hazards." To the contrary, the "Commission must determine whether it will issue its certificate of convenience and necessity. To arrive at its determination, the Commission must find that the nuclear facility is adequate to meet the needs of the public and is economical when compared with alternative sources of energy.").

The same is true here. Other federal and state agencies—U.S. Fish & Wildlife and the Missouri Department of Conservation, to name two—have certain authority over aspects of the transmission line. These concerns are not the principal considerations of the Commission.

2. Proper Foundation

Another fundamental rule of evidence applicable before the Commission is the necessity of laying a proper foundation for the admissibility of writings, documents and records. *See, e.g, Smith et al. v. Morton et al.,* 890 S.W.2d 403, 406 (Mo. App. E.D. 1995) (confirming that in an administrative proceeding a proper foundation is required even though the technical rules of evidence do not apply); *McDonagh*, 123 S.W.3d at 153 (while recognizing that technical rules of evidence do not apply in administrative proceedings, the Supreme Court also stated that experts could only testify if a proper foundation were laid and that Section 490.065 applied in an administrative proceeding). Proper foundation requires authentication of the document sought to be admitted. *Collins v. West Plains Mem. Hosp.*, 735 S.W.2d 404, 407 (Mo. App. S.D. 1987). In terms of receiving expert testimony, including admission to the record of hearsay as the basis of

the expert's opinion, proper foundation also requires compliance with all of the foundational elements of section 490.065.

The Commission, as required by the fundamental rule of evidence requiring a proper foundation, has frequently rejected the admission into evidence of documents for which the proper foundation had not been laid. *See, e.g., In the Matter of the Application by Aquila, Inc., for Authority to Assign, Transfer, Mortgage or Encumber Its Franchise, Works or System,* 2003 Mo. PSC LEXIS 1558 at *2 (Order Denying Staff's Motion to File Exhibits Late) (Case NO. EF-2003-0465, December 4, 2003) (rejecting Staff request to admit SEC10-Q filing and documents evidencing sale of collateral where no foundation could be laid for exhibits); *In the Matter of Union Electric Co. of St. Louis, Mo., for Authority to File Tariffs Increasing Rates for Electric Service,* 1983 Mo. PSC LEXIS 19 at *10 (Report and Order) (Case No. ER-1983-0163, October 21, 1983) (rejecting utility's request to admit Proposition I campaign literature where no foundation laid to identify authors or to describe their connection with Proposition I); *In the Matter of Missouri Gas Energy's Tariff Sheets Designed to Increase Rates for Gas Service*, 2000 Mo. PSC LEXIS 1186 at *3 (Order Sustaining Objections to Late-Filed Exhibit No. 241) (Case No. GR-1998-0140, August 10, 2000) (denying admission of IRS letter ruling because, among other grounds, no foundation had been laid for its admission).

The requirement that proper foundation be laid before a document is admitted into evidence equally applies to scientific studies and reports. The requirement that a witness be able to lay the proper foundation for scientific studies or surveys is reflected in Section 536.070(11):

> The results of statistical examinations or studies, or of audits, compilations of figures, or surveys, involving interviews with many persons, or examination of many records, or of long or complicated accounts, or of a large number of figures, or involving the ascertainment of many related facts, shall be admissible as evidence of such results, if it shall appear that such examination, study, audit, compilation of figures, or survey was made by or under the supervision of a witness, who is present at the hearing, who testifies to the accuracy of such results, and who is subject to cross-examination, and if it shall further appear by evidence adduced that the witness making or under whose supervision such examination, study, audit, compilation of figures, or survey was made was basically qualified to make it. All the circumstances relating to the making of such an examination, study, audit, compilation of figures or survey, including the nature and extent of the qualifications of the maker, may be shown to affect the weight of such evidence but such showing shall not affect its admissibility.

Mo. Rev. Stat. § 536.070(11). Within § 536.070(11), the witness must testify as to the accuracy of the statistical examination, study, audit, compilation of figures or survey before it can be admitted into evidence. *State ex rel. Hotel Continental v. Burton*, 334 S.W.2d 75, 87-88 (Mo. 1960); *In the matter of the Application of Ill. Central Gulf R.R. Co.*, 1982 Mo. PSC LEXIS 51 at *35 (Report and Order) (Case No. RS-80-321, January 22, 1982). None of the lay witnesses who offered the exhibits addressed below have the ability to meet these foundational requirements.

3. Bar Against Hearsay

The bar against the admission of hearsay evidence over objection is also a fundamental rule of evidence before the Commission. *Lee v. Missouri Am. Water Co*., 2009 Mo. PSC LEXIS 430 at *2-*3 (Order Denying Evidentiary Motions Without Prejudice) (Case No. WC-2009-0277, May 19, 2009). This is because the value of hearsay evidence depends on the *declarant's* credibility evaluated under cross-examination; where there is no opportunity for the declarant to be cross-examined, that

determination cannot be made. *Id.; see also In the Matter of the Application of Union Electric Co., d/b/a Ameren Missouri for Permission and Approval and a Certificate of Public Convenience and Necessity Authorizing it to Construct, Install, Own, Operate, Maintain, and Otherwise Control and Manage a Utility Waste Landfill and Related Facilities at its Labadie Energy Center*, 2013 Mo. PSC LEXIS 896 at *2-*3 (Order Regarding Objections and Motion to Strike) (Case No. EA-2012-0281, August 28, 2013). Because the right to cross-examination of opposing witnesses is a fundamental due process right, hearsay evidence must be excluded upon objection to its admission. *In the Matter of the Application of Keith Mallory for a Certificate of Convenience and Necessity to Haul Mobile Homes*, 1982 Mo. PSC LEXIS 20 at *7 (Report and Order) (Case No. T-48,374, September 20, 1982). Where there is an objection made, hearsay evidence does not rise to the level of "competent and substantial evidence" upon which the Commission can base its decision. *State ex rel. Marco Sales, Inc. v. Pub. Serv. Comm'n*, 685 S.W.2d 216, 220 (Mo. App. W.D. 1984); *State ex rel. DeWeese v. Morris*, 221 S.W.2d 206, 209 (Mo. 1949). Reliance on such information would therefore constitute error by the Commission.

Application of this fundamental rule of evidence by the Commission has resulted in the exclusion of an affidavit that merely relayed what the affiant learned from another person (*McFarlin v. KCPL&L Greater Mo. Operations Co.*, 2013 Mo. PSC LEXIS 311 at *5-*6 (Order Regarding Motion for Summary Determination) (Case No. EC-2013-0024, March 21, 2013)); exclusion of website pages, as well as testimony from an unrelated public hearing (*Lee*, 2009 Mo. PSC LEXIS 430 at *2-*3); exclusion of anonymous letters

(*In the Matter of the Joint Application of Great Plains Energy Inc., KCP&L Co., and Aquila, Inc., for Approval of the Merger of Aquila, Inc.*, 2008 Mo. PSC LEXIS 693 at *26 (Report and Order) (Case No. EM-2007-0374, July 1, 2008); exclusion of letters from various witnesses who were not present to testify at hearing (*In the Matter of the Application of Keith Mallory*, 1982 Mo. PSC LEXIS at *6-*7), and studies prepared and published by non-governmental entities or individuals (*Labadie*, 2013 Mo. PSC LEXIS 896 at *10). It is equally true that where the information in them is offered for the truth of the matter asserted, newspaper articles or clippings also constitute inadmissible hearsay. *Wessel v. Wessel*, 953 S.W.2d 630, 631 (Mo. App. S.D. 1997) *citing Thoroughbred Ford, Inc. v. Ford Motor Co.*, 908 S.W.2d 719, 736 (Mo. App. W.D. 1995); *McDowell v. LaFayette Co. Comm'n*, 802 S.W.2d 162, 166 (Mo. App. W.D. 1990); *see also Labadie*, 2013 Mo. PSC LEXIS 896 at *10.

4. Standards for Expert Testimony

Finally, as noted earlier, the standards for admission of expert testimony constitute a fundamental rule of evidence in administrative proceedings such that expert testimony must meet the standards for admissibility set out in Mo. Rev. Stat. § 490.065. *McDonagh*, 123 S.W.3d at 154-155. This statute expressly allows opinion testimony only from experts in the relevant area established as such by proper foundation, and requires a showing that facts and data are of a type reasonably relied on by experts in the field in forming opinions or inferences upon the subject of the expert's testimony. 123 S.W.3d at 156, *citing* Mo. Rev. Stat. § 490.065.3. That foundation must be laid—even at a local public hearing—in order for a witness to be qualified as an expert under section 490.065.

Labadie, 2013 Mo. PSC LEXIS 896 at *6. Where an expert merely acts as a conduit for another expert's opinion by testifying as to opinions contained in documents he or she has reviewed, however, such testimony is hearsay and inadmissible. *Bruflat v. Mister Guy, Inc*., 933 S.W.2d 829, 833 (Mo. App. W.D. 1996); *State ex rel. Missouri Hwy. & Transp. Comm'n v. Modern Tractor & Supply Co.*, 839 S.W.2d 642, 655 (Mo. App. S.D. 1992).

It is equally important to note that even where an expert relies upon documents containing facts and data of a type reasonably relied on by experts in the field in forming his or her opinions, the underlying documents are not admissible absent proper foundation. *Wilson v. ANR Freight Sys., Inc.*, 892 S.W.2d 658, 664-665 (Mo. App. W.D. 1994). This is because the books or publications are often hearsay evidence of matters concerning which living witnesses could be called to testify. *Longshore v. City of St. Louis*, 699 S.W.2d 16, 18 (Mo. App. E.D. 1985).

B. Certain Exhibits Offered at the Public Hearings Do Not Meet These Fundamental Rules of Evidence.

Some of the exhibits offered by those testifying at the two public hearings fail to meet the fundamental rules of evidence and, therefore, are not admissible as evidence in this proceeding.

1. Exhibit 1 – Shelbyville Local Public Hearing

Exhibit 1 (attached as Exhibit 1-S), introduced by witness Dale Goers, consists of a three-page printout from a website for American Farmland Trust and contains numbers purportedly reflecting the number of acres of farmland lost from production. Mr. Goers

relied on the article as support for his statement that "we lose fifty acres of crop land every hour in the United States." *Transcript - Volume 2 (Local Public Hearing - Shelbyville 10-19-15)* at 17:2-6 [EFIS Item No. 74]. Mr. Goers did not explain the source of the article, although it is apparent from the web address printed at the bottom of the article that it was likely downloaded from the internet. This article, offered for the truth of the matter asserted (to prove the rate of loss of farmland), lacks appropriate foundation and is inadmissible hearsay; moreover, it is irrelevant to any issue in this proceeding. ATXI objects to this exhibit on these bases, and it should be stricken from the record.

2. Exhibit 4 – Queen City Local Public Hearing

Exhibit 4 (attached as Exhibit 4-QC), introduced by witness Tandy Hawkins, consists of a study titled "Valuation Guidelines for Properties with Electric Transmission Lines." Mr. Hawkins testified that his son had obtained this study and that it supported his opinion that the presence of a transmission line would affect valuation of the entire parcel. *Transcript - Volume 3 (Local Public Hearing - Queen City 10-26-15)* at 64:24-65:6 [EFIS Item No. 72]. No other foundation was laid for the study, and Mr. Hawkins provided no qualifications from which one could conclude that he had any particular expertise on the subject or that the study was of a transmission line or parcels the same or similar to the ones here. This study, offered for the truth of the matter asserted (to prove that the presence of a transmission line impairs the value of the entire parcel), lacks appropriate foundation and is inadmissible hearsay; moreover, it is irrelevant to any issue in this proceeding in that the value of an easement is not an issue with which the PSC is

directly concerned. ATXI objects to this exhibit on these bases, and it should be stricken from the record.

3. Exhibit 6 – Kirksville Local Public Hearing

Exhibit 6 (attached as Exhibit 6-K), introduced by witness Clifford Hollenbeck, is comprised of a one-page research abstract and a research article about the alleged effect of magnetic fields on honey bees. Mr. Hollenbeck, a commercial beekeeper, submitted the studies for the purpose of proving that EMF has an effect on honeybees. *Transcript - Volume 4 (Local Public Hearing - Kirksville 10-27-15)* at 77:15-24, 79:3-7 [EFIS Item No. 73]. Mr. Hollenbeck, however, did not provide any foundation for the study and abstract, nor did he provide any information as to why the study and abstract were reliable; further, Mr. Hollenbeck did not offer testimony to suggest any reason why the study and abstract were not barred from admission into evidence on the grounds that they are hearsay. In addition, the abstract and the study is irrelevant to the issues before the PSC in that, much like the potential effects of radiation, it is not the PSC's duty to protect bees from the alleged effects of EMF. Therefore, Exhibit 6 from the Kirksville Local Public Hearing should not be admitted into evidence in this matter.

4. Exhibit 7 – Kirksville Local Public Hearing

Exhibit 7 (attached as Exhibit 7-K), introduced by witness Michael Kelrick, consists of

- an email from an official at U.S. Fish and Wildlife Service to Kenneth Lynn, an Ameren employee, about the need to conduct bat surveys in the proposed project area,

- a December 5, 2014 letter from the U.S. Fish and Wildlife Service to Mr. Lynn about bat surveys and the restriction of removal of trees during periods to minimize impacts on bats and migratory birds,
- an October 16, 2014 comment letter from the Missouri Department of Conservation to Burns and McDonnell, the organization charged with developing potential transmission line routes, enclosing a Natural Heritage Review Report for the project, identifying spawning stream seasonal construction restrictions and two conservation easements,
- a November 21, 2014 supplemental comment letter from the Missouri Department of Conservation to Burns and McDonnell regarding the segmentation of forest blocks and conservation easements,
- a research article regarding white-nose syndrome and its impact on the Indiana bat, and
- a research article regarding the effect of forest fragmentation on bat species in southeastern Missouri.

Mr. Kelrick is a biology and ecology professor at Truman State University whose primary area of research involves various plant species. *Transcript - Volume 4 (Local Public Hearing - Kirksville 10-27-15)* at 102:13-103:14 [EFIS Item No. 73].

With regard to the communications between ATXI and U.S. Fish and Wildlife and ATXI and the Missouri Department of Conservation, Mr. Kelrick summarized or read from the communications to demonstrate that additional field work needed to be done for the project:

> So it seems very clear that there's a substantial amount of field work that would be required to even ascertain whether there are concerns to be pursued, and then furthermore that the plans for addressing whatever the consequences of those field studies would be would remain to be worked out with those agencies. And those agencies, indeed, would have to approve those plans prior to the project going forward.

Id. at 107:10-17. Regarding the research articles offered by Mr. Kelrick—one discussing the effect on bats of disruption in bat habitat in southeast Missouri and the other about white-nose syndrome in bats (although Mr. Kelrick admits he does not know whether the

syndrome is present in northeastern Missouri)—Mr. Kelrick offered these documents as support for his point that additional field work will need to be completed by other relevant agencies with regard to these issues. *Id.* at 110:14-111:10.

These out-of-court documents are offered to prove the truth of the matter asserted that there exist concerns related to the bat habitat and the need to conduct studies; they constitute, therefore, inadmissible hearsay. Although Mr. Kelrick is a biology and ecology professor, he did not testify as to particular expertise in bat or bat habitats; instead, his primary area of research deals with plants. Moreover, the research studies lack proper foundation in that Mr. Kelrick admits that he doesn't know if white-nose disease (the subject of one of the research papers) is in Missouri; further, the other research study relates to habitats in southeast Missouri. Most importantly, Mr. Kelrick admits that these concerns are those which are addressed by other agencies—not the PSC; as such, these documents are irrelevant to this proceeding. This exhibit should not be admitted into evidence.

5. Exhibit 9 – Kirksville Local Public Hearing

Exhibit 9 (attached as Exhibit 9-K), introduced by witness Stephen Hadwiger, is comprised of two pages: the first is a diagram of Mr. Hadwiger's house and its proximity to the proposed transmission line, and the second is a narrative summarizing epidemiological studies regarding childhood leukemia; it is the second page to which ATXI objects. The only testimony offered by Mr. Hadwiger regarding the second page of Exhibit 9 is the following: "[t]he studies that compare – of the studies I've got on the back page there has a nice diagram that shows what the electromatic—magnetic radiation

differences are between microwaves and power lines and things like that." *Transcript - Volume 4 (Local Public Hearing - Kirksville 10-27-15)* at 161:12-16 [EFIS Item No. 73]. Although the second page of Exhibit 9 states that Mr. Hadwiger is a professor of nursing, no foundation was laid through testimony that Mr. Hadwiger has any special expertise in the relationship between EMF and childhood leukemia. Similarly, there was no foundation laid for the admissibility of the summary itself. Furthermore, this issue is not an issue to be addressed by the PSC; as such, the information is irrelevant. Finally, as a summary of research, it contains nothing more than hearsay within hearsay—something which an expert is not even entitled to rely upon under Missouri law. Exhibit 9 should be stricken for these reasons.

6. Exhibit 11 – Kirksville Local Public Hearing

Exhibit 11 (attached as Exhibit 11-K), introduced by witness John Leunen, contains a two-page copy of a pamphlet purportedly dealing with the Mid-American Energy Project in Iowa, followed by a series of aerial maps showing the proposed transmission route in relation to certain properties; ATXI objects to the admission of the two-page pamphlet. Mr. Leunen testified that he obtained Mid-American Energy's brochure online and relied on the brochure to testify as to a transmission line project in Iowa. *Transcript - Volume 4 (Local Public Hearing - Kirksville 10-27-15)* at 195:2-8 [EFIS Item No. 73]. The copy of the pamphlet is hearsay, and no hearsay exception authorizes its admission. In addition, no foundation was provided for the pamphlet, and it is irrelevant to the Mark Twain transmission line project. For these reasons, Exhibit 11 should be stricken from evidence.

7. Exhibit 12 – Kirksville Local Public Hearing

Exhibit 12 (attached as Exhibit 12-K), introduced by witness David Sidwell, contains a one-page letter from Mr. Sidwell to the PSC and a copy of a newspaper article about the Mark Twain project printed in the local newspaper. ATXI objects to the admission into evidence of the newspaper article. Mr. Sidwell provided no testimony at the hearing that was related in any way to the news article. *Transcript - Volume 4 (Local Public Hearing - Kirksville 10-27-15)* at 206:6-20 [EFIS Item No. 73]. Mr. Sidwell's letter makes reference to the news article to support his opinion regarding ATXI's treatment of those who attended the open houses. News articles are classic examples of hearsay, and this article provides no exception as Mr. Sidwell relies on it for the truth of the matters therein asserted. Furthermore, the fact that it may have been included with a letter to the PSC does not make it any more admissible; in fact, it constitutes triple hearsay. Because the news article is hearsay and no exception justifies its admission, it should be stricken from Exhibit 12.

Relief Sought

Because these exhibits lack foundation, constitute inadmissible hearsay and are irrelevant to the issues in this case, the PSC should strike from the record Exhibit 1 from the Shelbyville Local Public Hearing, Exhibit 4 from the Queen City Local Public Hearing, and all or a portion of Exhibit Nos. 6, 7, 9, 11 and 12 from the Kirksville Local Public Hearing.

Respectfully submitted,

/s/ James B. Lowery

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CERTIFICATE OF SERVICE

I do hereby certify that a true and correct copy of the public version of the foregoing Motion to Compel Discovery has been e-mailed, this 20th day of January, 2016, to counsel for all parties of record.

/s/ James B. Lowery

An Attorney for Ameren Transmission Company of Illinois

AMERICAN FARMLAND TRUST

FARMLAND

America's farm and ranch land supplies us with bountiful food and a clean environment. But we're losing farm and ranch land at a dangerous rate.

EXHIBIT NO. 1
FOR IDENTIFICATION
DATE: 11/5 RPTR:

EXHIBIT 1-S

In America, we're blessed with some of the most productive farmland in the world – from the fruit groves of the West Coast to the Midwest's amber waves of grain.

Our fertile farmland gave our nation the foundation to grow and prosper over centuries. But its abundance also allowed us to waste it.

We lose nearly 50 acres of farmland every hour – and once farms are bulldozed and paved over, that land is gone forever.

Working together, we can stop the loss of this irreplaceable natural resource and save the land that sustains us.

50

ACRES OF FARM AND RANCH LAND

developed every hour in the U.S.

24

MILLION ACRES

of agricultural land developed since 1982

37%

OF AMERICA'S DEVELOPED LAND

converted in the last three decades

5+

MILLION ACRES

of farm and ranch land permanently protected since AFT's start

Why is farm and ranch land so important?

EXHIBIT 1-S

EXHIBIT
4
SAP 16-26-15

Valuation Guidelines for Properties with Electric Transmission Lines

By: Kurt C. Kielisch, ASA, IFAS, SR/WA, R/W-AC

Before a discussion can be entered about the perception of electric transmission lines and their effect on property value, it is important to understand what a transmission line is and how it differs from a distribution line.

An electric *transmission* line is an electric line that transports electrical power from one substation to another. These lines are typically 100kV (kilovolts) or larger exceeding one mile in length[1], have large wood or steel support towers over 45ft in height, and often have more than one set of wires (3 wires per circuit plus the static wire). Electric transmission lines do not directly serve electric utility customers: their power is distributed from distribution point to distribution point. Transmission line wires are not insulated and are "bare". Typically, they constructed to have at least 20ft of clearance between the ground elevation and wire at low sag.

An electric *distribution* line is a power line that transports electricity from the substation to the electric utility customers. These lines are of less voltage, typically under 65kV, carried on wood poles of 45ft in height or less and hold one pair of wires. The voltages of these lines are downgraded before the electricity is brought to the customer's residence or commercial building. The focus of this report is on "transmission" lines, not "distribution" lines

Perception = Value

The valuation of properties that have an electric transmission line requires an understanding of the basic principles of Market Value. Market Value is defined, in layman's terms, as the value a property would sell for at a given date considering an open market. (A complete definition of this term is included in the body of the appraisal report.) An open market assumes that the property is available for purchase by the public, being properly marketed for maximum exposure, and that the buyer is well informed, fully knowledgeable and acting in their best interest. Included in this definition is that the buyer has full knowledge of the pros and cons of the property, and then acts with that knowledge in a way that will benefit them. In other words, the value of the property is based on the perception of the buyer. Understanding that perception drives value is the foundation in analyzing the effect that electric transmission lines have on property value.

The key point of the Market Value definition, which gives guidance to answer the "impact" question, is the "willing buyer" part of the equation. In appraising a property the appraiser attempts to reflect the potential buyer of the subject property and estimate their action as to the subject property with all its advantages and disadvantages (knowledgeable buyer). To accurately reflect this buyer, the appraiser must determine the typical profile of such a buyer of the property in question. An example of this

1 Wis. Stat. 196.491(1)(f)

EXHIBIT 4-QC

would be a one bedroom condominium along a lake may indicate a typical buyer to be a retired couple who is looking for a recreational retreat for themselves and their guests. Another example would be a parcel with the best use being a dairy farm; the typical buyer would be a person either currently engaged in dairy farming looking to expand or relocate, or one who desires to enter into this field -- in either case a "dairy farmer." Such an analysis should be obvious, yet often overlooked when appraising properties.

For rural properties that are utilized for agricultural purposes, the most likely buyer would be one who: (1) prefers the rural lifestyle over the urban lifestyle; (2) typically generates their income from working in the agricultural field; (3) would be sensitive to environmental issues that affect the uses of the land and the view shed of the land; and (4) would be sensitive to health and safety issues relating to the land and its use.

It is most likely that such a person, when confronted with an electric transmission line traversing the property, would view such an improvement as aesthetically "ugly," potentially hazardous to their health, disruptive to rural lifestyle and potentially harmful to the use of the land for agricultural purposes.

Research Format

Our research into the impact of electric transmission lines followed several stages. The first was a "literature" study. This study involved investigating, collecting, indexing and reading many of the published articles, news stories and published transcripts relating to the topics of EMFs and stray voltage. Stray voltage was included in this research due to the concern dairy farmers have relating to its presence from high voltage power lines. This research resulted in over 2,500 pages of information collected and analyzed. The purpose of this study was to discover "what is the public's perception of high voltage transmission lines." Overall, the majority of the articles indicated a "fear" of these power lines, citing health concerns as the primary factor. Other concerns included stray voltage issues (mainly with rural publications) and aesthetics. It was clear that most of the information the public receives about these matters is negative. The literature study will follow these "guidelines."

The second part of our study involved researching studies completed on the effects on property value due to the presence of electric transmission lines. This included collecting many of the published research studies on this topic found in the public domain. Additionally, the study reviewed trade journals not available to the public, but available only to real estate professionals. Again, to be fair, some of the studies indicated that there was no measurable effect. However, there were a number of studies (mostly recent) that indicated there was a measurable effect and that effect ranged from a loss of 10% to over 30% of the overall property value. These studies included both improved and vacant land.

Empirical Studies

Below is a sampling of some studies we have reviewed regarding the impact that electric transmission lines have on land value and were utilized to formulate our opinion of value when a property is impacted by a high voltage transmission line.

- *Study of the Impact of a 345kV Electric Transmission Line in Clark County, Town of Hendren.*

EXHIBIT 4-QC

(Appraisal Group One, Kurt C. Kielisch, 2006, revised 2009) This study was limited to Hendren Township, Clark County, and covered a five year time period from January 1st, 2002 to June 1st, 2006. This study included 22 land sales of agricultural and recreation land, of which 4 were encumbered with a 345kV electric transmission line having wood H-pole design, 60ft height and 150ft wide easement. The other 18 land sales were considered comparable to the power line encumbered sales. The conclusion of this study was that: (a) the land sales with an electric transmission line sold for 23% less than comparable land sales without a transmission line; and, (b) the more severe the location of the power line the greater was the loss of value.

- *An Impact Study of a 345kV Electric Transmission Line on Rural Property Value in Marathon County - Wisconsin.* (Appraisal Group One, Kurt C. Kielisch, 2006) This study focused on the impact a 345kV line, known as the Arrowhead-Weston line, had on property value. This power line was a 345kV electric transmission line, having steel single poles ranging in height from 110ft to 150ft, single and double circuit lines, having a 120ft wide easement. The study compared sales within a 2 year time period (January 1st, 2004 to December 31st, 2005) in Marathon County, Wisconsin, focusing the area to the Townships of Cassel and Mosinee. This study used 14 land sales, of which 5 were encumbered with the power line and 9 were not. A simple regression technique and matched pair analysis was used to extract the value impact. The study concluded with a finding that when the power line traversed the property along the edge, such as a back fence line, the loss was as low as -15%, and when it bisected a large parcel the loss was as high as -34%. The properties were all raw land sales with either agricultural or residential land use.

- *Transmission Lines and Property Values State of the Science* (Electric Power Research Institute [EPRI}, 2003). This study completed by EPRI for the benefit of its electric utility clients reviewed the issue of property values being impacted by electric transmission lines by summarizing research they had on the subject. Essentially they concluded that the results are mixed, some cases showing a loss in value ranging from 7-15% with appraisers who had experience with valuing such properties, to having no effect. Interestingly, it appeared in their survey that appraisers who did not have experience valuing such properties tended to overrate the negative effects.

- *American Transmission Company, Zone 4, Northeast Wisconsin - High Voltage Transmission Line Sales Study* (Rolling & Company, 2005). This study researched the impact that high voltage electrical transmission lines have on property value in the northeast Wisconsin area. They collected information on 682 land sales of which 78 involved lots near a transmission line corridor, but not directly encumbered by the transmission line. Their conclusions were: (a) easement lots sold at about 12% less than lots located over 200ft from the transmission lines; and (b) no clear impact on "proximity" lots those that lie within 200ft from the easement area but are not directly subject to the easement.

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- *Properties Near Power Lines and Valuation Issues: Condemnation or Inverse Condemnation* (David Bolton, MAI. Southwestern Legal Foundation. 1993). This study cites a number of studies that prove a loss of property value due to proximity to an electric transmission line and then cites his own study. His own study found that in the Houston area assessed values of properties that adjoined a power line easement had a 12.8% to 30.7% lower assessment than the average homes not on the line, but in the same area. He also found that: (1) many buyers refused to even look at such properties; (2) such properties took at least twice as long to sell; (3) some brokers said such properties can take three times longer and finally sell at a 25% loss of value; and (4) overall homes adjoining transmission line easements took six times longer to sell and experienced a 10% to 30% loss in value.

- *Power Line Perceptions: Their Impact on Value and Market Time* (Cheryl Mitteness and Dr Steve Mooney. ARES Annual Meeting paper. 1998) The authors interviewed homeowners on or near electric transmission lines and found: (1) that in relation to the average impact of overall property value, 33% said 2-3% loss and 50% said a 5% loss or greater; (2) nearly 66% said the power line negatively affected their property value; (3) 83% of real estate appraisers surveyed said the presence of the power lines negatively affected the property values, most saying the loss was 5% or greater.

- *Analysis of Severance Damages (James Sanders, SRA, 2007)* This study completed an analysis of the impact of a transmission line through the middle of the Continental Ranch subdivision outside of the Tucson, Arizona area. This subdivision had a wood H-pole high voltage electric transmission line running through a portion of the subdivision. The author compared the residential lots abutting the easement to ones that were not. All lots abutting the easement were much bigger than the non-easement abutting lots. The author used improved properties for his study and by the use of regression analysis isolated many variables of value for an improved property to remove them from the analysis. In conclusion, through extensive use of the regression technique, the author finds an overall loss to the improved properties abutting the power line easement at -12%. This loss is attributed to both the land and improvements. However, the author notes that the lots are typically twice the size of the non-easement lots. When the size of lots was factored the overall loss to the land only was factored at -40%. It should be noted that the residences were at a distance from the power line.

- *The Peggy Tierney property: A Comparative Study of the Impact of a 69kV Transmission Line v. 345kV/69kV Transmission Line (Kurt C. Kielisch).* This was a brief study on the impact difference, if any, between an existing 69kV transmission line and a new proposed 345kV and 69kV transmission line on the same property. The property was a 3.70 acre residential lake front improved property that had an existing 69kV transmission line crossing the west half of the parcel along the road and required the property owner to cross under the power line to enter the parcel. The 69kV line had an easement width of approximately 100ft, wood H-poles at 50-60ft in height. The new 345kV line was to be placed within the existing easement, more or less, would have 140ft monopoles and carries both a 345kV and 69kV line. The seller attempted to sell the property at its full list price after an experienced lake front home Realtor established the list price from a comparative sales analysis. The home eventually sold for 27% less than the list price and took longer to sell in a relatively strong lake front home market. The buyer cited the pending 345kV line as the principle reason for their low offer.

- A comparative sales analysis to isolate the percentage of loss a residential and/or agricultural

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land use property suffers due to the presence of a high voltage electric transmission line (HVTL). This study was found in an appraisal completed by Aari K. Roberts for American Transmission Corporation (ATC) on the Herbert Bolz property located in the Town of Rubicon, Dodge County, Wisconsin. Mr. Roberts compared the sale of a rural agricultural 24 acre land parcel that had an HVTL crossing the property, to three comparable agricultural land sales of comparability that did not have a HVTL. His sales comparison study concluded that the property with a HVTL suffered a 29% loss of value due to the presence of the HVTL. This study was completed in September 2007.

- A sales analysis of the property located at: N8602 CTH D, Town of Deer Creek, Outagamie County, Wisconsin. This is a single family home located on 3.19 acres in the rural area of Outagamie County. The home was a ranch style residence with 1,500sf GLA, attached 2-car garage, 8/3/2 room count, full basement and was in average condition overall. The property also had a 104ft x 52ft pole barn and two other outbuildings. There were two appraisals completed on this property, one by the condemnor (ATC) and one by the property owner. The average Before taking value of the two appraisals was $221,000. The property was then improved with a 345kV & 138kV electric transmission line having 126ft pole height and was placed along the roadside reaching 68ft into the property. The edge of the easement was in less than 20ft to the residence, however the placement of the pole was as close to the roadway right-of-way as possible. The condemnor American Transmission Company (ATC) purchased the property and installed the transmission line. Then they upgraded the property with new paint, doors, sinks, dishwasher and flooring, plus cleaned the premises and outbuildings. ATC put the property on the market asking $179,900 a number established by the appraiser for ATC as the After value. It was sold for $128,500 10 months after ATC purchased it.

  The Before taking average value was $221,000. The property was then improved and upgraded at an expense estimated to be $8,000-$10,000, then resold 10 months later with the transmission lines in place for $92,500 less or 42% less. The only differences between the Before taking market value and After taking sale price were the transmission line and time. A review of the Outagamie County market between November 2008 and September 2009 shows only a small downward trend in rural residential property value, therefore the biggest part of the loss is attributed to the presence and near proximity of the transmission line that being 38%-40%.

- *The Gene Laajala property: A Comparative Study of the Impact of a 161kV Transmission Line v. 345kV/161kV Transmission Line (Kurt C. Kielisch).* This was a brief sales study on the impact difference, between an existing 161kV transmission line and a new 345kV/161kV transmission line on the same property. The property was a 20 acre rural agricultural and residential property that had an existing 161kV transmission line bisecting the parcel along the east side. The 161kV line had an easement width of approximately 120ft, wood H-poles at 50ft± in height. This line was replaced with an upgraded easement comprised of 345kV/161kV line which was to be placed within the existing easement, more or less, and had (2) 110ft and (3) 120ft steel H-poles. The property was appraised in January 2007 with a Before condition value of $204,500 using the Cost approach and $185,500 using the Comparable Sale approach, by Ted Morgan, MAI. (The whole property appraised was 40 acres and the 20 acre parcel was portion out of this whole). The ATC appraiser did not appraise the home in the Before condition, but did conclude the Before taking land value was $44,000 for 20 acres (using his $2,200/acre conclusion for 40 acres) and the assessed value of the improvements were $107,600, indicating a $151,600 Before

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value. The property sold and closed in October 2007 for $120,000. The seller attributes the loss to the new power line, it being larger and more lines. The loss indicated was $65,500 (using Morgan's Comparable Sales value) or $31,600 (using ATC's land plus assessed improvement value), indicating a loss range of 35% to 21%.

- *An Impact Study of the Effect of High Voltage Power Lines on Rural Property Value in Southwestern Indiana (Kurt C. Kielisch, Appraisal Group One, 2010).* This study was based in southwest Indiana in Gibson County. It was focused on large agricultural land and the impact of a high voltage transmission lines (HVTL) varying in size from monopole to large steel lattice towers. The study included 32 land sales of which10 were HVTL sales. The time period was January 1st, 2006 to December 31st, 2009. Adjustments were made for time, location and other utility easements (if any) and the results were graphed to compare the non-HVTL land sales to the HVTL land sales. The study concluded that the power lines negatively impacted the property with an impact range from -5% to -36% with the average impact being -20%.

Other Value Issues

Another issue relating to the presence of the transmission line is potential for the creation of an "utility" corridor. Such a corridor is a where several utility transmission lines are placed, such as gas transmission pipelines and communication lines. Indeed, the State of Wisconsin made it a legislative rule that future placement of such utilities are to be given preference to "existing utility corridors."[2] An electric transmission line meets the definition in this statute as an existing corridor. This "corridor" concept continues to grow in the perception of the public as such rules become more commonly known. The reality of such an event happening is the placement of the Arrowhead-Weston Power line, which was often placed within an existing utility corridor such as an oil transmission pipeline, smaller electrical transmission lines or abandoned electric transmission line easements. The very power line that is the focus of this analysis is further proof of the corridor effect for it has been expanded, enlarged and added circuits within the existing easement.

Other factors to consider regarding the valuation of HVTL impacted rural properties are agricultural equipment concerns operating under and near the line, health issues of workers in close proximity of the lines, health concerns of farm animals in close proximity of the lines, stray voltage, the concerns of public in relation to electro-magnetic fields, safety issues regarding bare wires of the transmission line and other concerns addressed in the literature study to follow.

In conclusion, it can be stated with a high degree of certainty that there is a significant negative effect ranging from -10% to -30% of property value due to the presence of the high voltage electric transmission line. The actual loss depends on factors of land use, location of the power line and its size.

2 Wis. Stats 1.12(6)(a).

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Literature Study

HVTL Impacts on Rural and Agricultural Properties

Throughout the nation's rural communities, literature research suggests that the presence of an HVTL easement can have a noticeable impact on both the use and appeal of rural properties and farms. Common concerns include stray voltage, health risks to livestock and cattle, diminished livelihoods and heritage, limited land use, and lessened aesthetic appeal. As the following literature survey will show, many different issues play a role in shaping one's perception of the impact of HVTLs on rural property values.

Stray Voltage

To understand the potential impact of HVTLs on rural land, it's important to discuss a key component in many farmers' apprehension about HVTLs: stray voltage.

Stray voltage is the rural equivalent of the high-profile residential Electromagnetic Field (EMF) factor, but instead of fearing leukemia or brain cancer, farmers fear their animals will become unproductive, ill, and even die.

Whenever energy is transferred, some is lost along the way. If metal buildings are near leaking energy, they can act as a conduit for voltage to find its way to feeding systems, milking systems and stalls.

In their 1995 presentation, "Stray Voltage: The Wisconsin Experience," a team of researchers led by Mark Cook and Daniel Dascho stated that farmers most worry that stray voltage will increase somatic cell count in their animals, make cows nervous, reduce milk production, and increase clinical mastitis.[3]

"Few issues are more upsetting to dairymen than fighting case after case of clinical mastitis with more and more cows in the sick pen," writes Dr. Winston Ingalls. "It represents extra time to properly handle such cows, lost production, vet calls, treatment products, concern about contaminated milk and an occasional dead or culled cow."[4]

In Cook & Dascho's presentation, they discuss their findings from a non-random sampling study of farms with stray voltage complaints stemming from a nearby substation. Their research team found no significant relationship between cow contact current and distance from the substation or contact currents. However, they also noted that cow contact current depends on many physical factors from on-farm and off-farm electrical power systems. They say, "There are many confounding factors that may outweigh the impacts of stray voltage which makes it difficult to draw conclusions from field studies about its effects on production and animal health."[5]

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3 **Stray Voltage: The Wisconsin Experience.** Written for presentation at the 1995 International Meeting by Mark A Cook, Daniel M Dascho, Richard Reines and Dr. Douglas J Reinemann.

4 **Clinical Mastitis.** Winston Ingalls, Ph.D. GoatConnection.com. August 2, 2003. http://goatconnection.com/articles/publish/article_173.shtml

5 **Stray Voltage: The Wisconsin Experience.** Written for presentation at the 1995 International Meeting by Mark A Cook, Daniel M Dascho, Richard Reines and Dr. Douglas J Reinemann.

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In a 2003 study prepared for the NRAES Stray Voltage and Dairy Farms Conference, a research team conducted by the University of Wisconsin-Madison and led by Dr. Douglas J Reinemann studied the effects of stray voltage on cows at four dairy farms over a two-week time period. He and his team found that after the first few days of exposure, cows quickly acclimated to the presence of stray voltage. They also found that stray voltage of 1mA had little effect on the immune system of a cow.[6]

Concerning EMF levels, they noted that "even though man-made signals were larger than the naturally occurring currents, levels are significantly lower than what is considered sufficient earth current strength to develop step potential anywhere near the Public Service Commission 'level of concern.'"[7]

Stray voltage is usually undetectable by humans, and some researchers believe it occurs when electricity escapes a power line or wiring system and emits a secondary current. The problem intensifies with older barns that add automated electrical equipment, "raising ambient levels of current. Soon the cumulative effect of these secondary currents becomes harmful to cows." Though stray voltage can be measured, experts don't know how and why it happens or what conclusive effect (if any) it has on animals.[8]

Despite little concrete evidence, courts have compensated farmers for their losses due to stray voltage when all other factors are eliminated. In 1999 a jury awarded Peterson Bros. Dairy $700,000 after deciding that stray voltage from an automated feeding system from Maddalena's Dairy Equipment of Petaluma, California slashed the herd's milk output and increased the cow's death rate.[9]

The company's defense attorney called stray voltage "junk science," the Petersons' claim of stray voltage in the milk barn a "harebrained theory" unsupported by electrical engineers, and blamed the herd's health problems on the Petersons' own mismanagement.[10]

In a similar case in Wisconsin in 2004, a dairy operation owned by George and Kathy Muth successfully sued Wisconsin Electric Power Co. (now We Energies) for negligence in the maintenance and operation of a distribution system on their farm. They claimed that the system led to stray voltage that injured and killed several of their dairy cows and damaged their milk production. The utility said that the levels of stray voltage were "extremely low" and were levels you could find anywhere.[11]

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6 **Dairy Cow Response to the Electrical Environment: A Summary of Research conducted at the University of Wisconsin-Madison.** Paper presented at the NRAES Stray Voltage and Dairy Farms Conference. Dr. Douglas J. Reinemann. April 2003.

7 **Results of the University of Wisconsin Stray Voltage Earth-Current Measurement Experiment.** A revised version of a report submitted to the State of Wisconsin Legislature on June 25, 2003. Written by David L Alumbaugh and Dr. Louise Pellerin.

8 **Jury gives $700,000 to dairy farmers for losses blamed on "stray voltage."** Author Unknown. The Associated Press. April 21, 1999.

9 **Ibid.**

10 **Ibid.**

11 **Power company negligent in dairy suit; Jury awards $850,000 to couple over effect of stray voltage on cows.** Lauria Lynch-German. Milwaukee Journal Sentinel. February 27, 2004.

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The farmers said that shortly after moving to their new location, they faced low milk production, excessive illnesses, and deaths of cows. [12] The cows didn't walk right or act normal. They didn't want to go into the barn, inside, or into the stalls. The Muths examined everything from the animals' food to their bedding until consultants told them it could be stray voltage. In one year, they lost 15-18 cows and calves. Autopsies were inconclusive.[13]

After reviewing herd management and nutrition, they hired a consultant who detected stray voltage. Later that year the utility found no stray voltage problems. The farmers further consulted with veterinarians and tested and ruled out all the other factors except for stray voltage.[14]

The farmers hired an electrician to upgrade the farm's wiring, but it didn't decrease the stray voltage. After being asked, the utility made some other changes, but this also had no effect. Further consultants still found stray voltage from a conductor on the utility's distribution lines. A couple years later the utility removed a piece of underground electrical equipment and the herd immediately recovered...though the level of stray voltage remained the same.[15]

The utility's attorney stated that being able to measure something doesn't make it harmful. He cited several federal and state studies that say the current must be 2 milliamps or higher to adversely affect cattle and said no reading on their farm reached that level.[16]

The jury awarded the dairy farm $850,000 in damages.[17]

Stray voltage fears aren't limited to dairy or cattle operations. Max Hempt, a horse farm owner in Pennsylvania, tried to oppose a proposed 9-mile 138kV HVTL because he feared that the line's EMFs caused by stray voltage could cause sterility and death among his horses.[18]

Though it's difficult to prove a significant presence of stray voltage, and even more difficult to prove a direct correlation between stray voltage and poor health, courts have awarded farmers sizable judgments to compensate them for damaging stray voltage from nearby power lines.

In 2002, one such case in Iowa made it to the state supreme court where the court upheld a $700,000 judgment to a dairy farmer who argued that stray voltage from nearby power lines injured his herd. A substation sits less than a quarter mile from his farm. He said he often got electric shocks from the metal buildings on the farm. Also, he said his herd acted oddly, appearing frightened and refusing to enter barns. Milk production also suffered.[19]

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12 **Jury must decide in voltage complaint; Farm family says stray power harmed dairy herd.** Lauria Lynch-German. Milwaukee Journal Sentinel. February 5, 2004.
13 **Dairy farm owner testifies that stray voltage killed cows in his herd.** Lauria Lynch-German. Milwaukee Journal Sentinel. February 10, 2004.
14 **Jury must decide in voltage complaint; Farm family says stray power harmed dairy herd.** Lauria Lynch-German. Milwaukee Journal Sentinel. February 5, 2004.
15 **Ibid.**
16 **Ibid.**
17 **Power company negligent in dairy suit; Jury awards $850,000 to couple over effect of stray voltage on cows.** Lauria Lynch-German. Milwaukee Journal Sentinel. February 27, 2004.
18 **Farmer Fears Stray Voltage From PP&L 138 kV Line Could Harm His Horses.** Author Unknown. Northeast Power Report. June 24, 1994.
19 **Court upholds stray voltage judgment.** Mike Glover. The Associated Press. October 10, 2002.

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The defendant, Interstate Power Co., said that "there's an inherent risk to transmitting electricity" and it shouldn't be vulnerable to such lawsuits unless they were negligent. The court ruled in favor of the dairy farmer, citing the lack of a statute exempting electric utilities from nuisance claims.[20]

One year later the Wisconsin Supreme Court similarly found "that a utility can be held responsible for harming the health of a dairy herd with stray voltage even though state-recommended voltage tests did not find potentially damaging levels where the animals congregated."[21]

As the preceding case studies show, courts have acknowledged stray voltage and its possible effects. However, to fully understand the apprehension surrounding power lines, one must examine the EMF debate and its fear factor.

EMFs and Fear

In 1990, the EMF debate was so prevalent that members of Congress passed a bill that would limit the public's exposure to EMFs.[22] A couple years later, in response to public concern about EMFs, Congress established the EMF-RAPID program in 1992. Its purpose was to coordinate and execute a limited research program to fill information gaps concerning the potential health effects of exposure to EMFs, to achieve credibility with the public that previous research has not earned, and to coordinate and unify federal agencies' public messages about possible EMF effects.[23] The program originally was to receive $65 million in funding, but total funding is expected to be $46 million.[24]

Several years later in 1999, the National Institute of Environmental Health Sciences studied the health effects of EMF exposure and found conflicting results. Though they concluded that the evidence is weak linking EMFs to health risks, they also found that the most common health risk was leukemia (mostly appearing in children). They also found a fairly consistent pattern of a small, increased risk of childhood leukemia with increasing exposure. The majority of the panel's voting members voted to acknowledge EMFs as a possible human carcinogen. They concluded that ELF-EMF exposure cannot be recognized as entirely safe because of weak scientific evidence.[25]

In 2005, UK scientists conducted a case-control study on childhood cancer in relation to distance from high voltage power lines in England and Wales. They found an association between childhood leukemia and proximity of home address at birth to HVTLs. "The apparent risk extends to a greater distance than

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20 **Ibid.**
21 **Utility liable for stray voltage, high court says.** Don Behm. Milwaukee Journal-Sentinel. June 26, 2003.
22 **Electric Powerlines: Health and Public Policy Implications** – Oversight Hearing before the Subcommittee on General Oversight and Investigations of the Committee on Interior and Insular Affairs House of Representatives, 101st Congress, second session on electric powerlines: health and public policy implications. March 8, 1990.
23 **Electric and Magnetic Fields Research Program** by Mr. Mukowski from the Committee on Energy and Natural Resources. 105th Congress, first session. June 12, 1997.
24 **Ibid.**
25 **NIEHS Report on Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields.** Released by the National Institute of Environmental Health Sciences on May 4, 1999.

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would have been expected from previous studies" although they have yet to discover an "accepted biological mechanism" to explain their results.[26]

Though an accepted biological mechanism remains elusive, an early nineties case made it possible to link loss of property value to a fear of EMFs. In the 1993 case, *Criscuola v. Power Authority of the State of New York*, the court found that, "there should be no requirement that the claimant must establish the reasonableness of a fear or perception of danger or of health risks from exposure to high voltage power lines" and "Whether the danger is a scientifically genuine or verifiable fact should be irrelevant to the central issue of its market value impact."[27]

Utilities say that landowners should not be able to recover damages or injunctive relief "based on myth, superstition or fear about an alleged health risk that is not supported by substantial scientific or medical evidence."[28]

With the EMF debate unresolved, and evidence for both sides of the argument, some communities are reluctant to approve new HVTLs...and may even legally oppose them.

In an effort to preempt public opposition, Public Service Enterprise Group offered hundreds of thousands of dollars to New Jersey towns opposing its proposed HVTL project if the towns dropped all opposition and didn't comment on the payments. Opponents called them "bribes." The utility called them "settlements" to help minimize impacts of the project on towns and residents.[29]

Some towns accepted payment, but the majority did not. Either they said they didn't have enough time to respond to the offer, or they rejected them as payoffs. One of the opposing mayors, Mayor James Sandham of Montville, said it's not about the money; "It's about safety and property values."[30]

HVTLs and Property Values

Fear can impact the public's buying habits. Residential homeowners' resistance to abutting HVTLs is well documented. Though homeowners may fear negative effects on their community and environment,[31] their first point of opposition is usually safety, especially if there are many children in the neighborhood. Though the 1979 Wertheimer study linking EMFs to childhood leukemia has long been contested, supported, and contested again, the very existence of a debate about the safety of EMFs sows enough doubt in residents' minds to justify the fear.[32] And that fear can influence the values of nearby homes.[33] [34] [35] [36]

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26 **Childhood cancer in relation to distance from high voltage power lines in England and Wales: a case-control study.** Gerald Draper, Tim Vincent, Mary E Kroll, John Swanson. British Medical Journal (bmj.com). June 3, 2005.
27 **'Criscuola' – The Sparks Are Still Flying.** Michael Rikon. New York Law Journal. April 24, 1996.
28 **High Court Hears Arguments Today on EMF Claims.** Todd Woody. The Recorder. June 6, 1996.
29 **Opponents of $750M N.J. power line project argue towns were paid to drop opposition.** Lawrence Ragonese. The Star-Ledger. January 31, 2010.
30 **Ibid.**
31 **NY Power Line Opponents Win Court Fight.** Associated Press. New York Post. February 20, 2009.
32 **Lines in Sand and Sky.** B.Z. Khasru. Fairfield County Business Journal. September 3, 2001. Vol. 40 Issue 36, p3, 2p.
33 **Power line plan concerns metro residents.** Melissa Maynarich. News 9 (Oklahoma). July 22, 2008.

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When given the choice to purchase two identical homes, one with such health concerns and the other without, most buyers will choose the home without the concern,[37] forcing the homeowner to lower their price. Aesthetic impact can also influence a property's value. Many residents don't want to look at HVTLs,[38] something they consider to be an "eyesore."[39]

One of the hardest properties to sell can be one encumbered by an HVTL. Unlike roadway proximity, its effect isn't readily noticeable or measurable. Though homes near HVTLs typically have larger lots (and that can be a benefit), the biggest disadvantage is the fear factor surrounding EMFs.[40]

In the early nineties, when EMFs were just entering the public consciousness, it was difficult to find a measurable price difference between homes close to an HVTL and those that were not.[41] However, two researchers (Hsiang-te Kung & Charles F Seagle) conducted a case study on the impact of power transmission lines on property values and found that such negligible results depended almost entirely on the public's ignorance of EMFs and their related issues. They also found that the amount of potential property loss increased dramatically the more homeowners were aware of the potential health impacts of EMFs.[42]

The effect of HVTLs on property values has long been a matter of contention with many studies either proving a diminutive effect or none at all. Methodologies differ and different areas of the country register different results. Some markets (ex. high-end homes) are very sensitive to HVTLs whereas others (ex. low-end homes) hardly notice them. The size of the line and the pylons are also a factor. A 69kV power line will have less effect than will a 1,200kV power line. Distance from the easement also matters. Some studies combine homes thousands of feet from HVTLs with those directly encumbered. Research sponsors also may play a factor with many being funded by the utilities themselves.

For example, in a 2007 study funded by a utility, researchers Jennifer Pitts and Thomas Jackson conducted market interviews, literature research and empirical research and reported little (if any) impact of power lines on property values. However, they did note that there is an increasing recent opinion that proximity to power lines has a slight negative effect on property values.[43]

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34 **Power Line Worries Landowners.** Ben Fischer. The Wisconsin State Journal. June 3, 2006.
35 **Lines in Sand and Sky.** B.Z. Khasru. Fairfield County Business Journal. September 3, 2001. Vol. 40 Issue 36, p3, 2p.
36 **Commissioners voice opposition to transmission lines.** David Rupkalvis. The Graham Leader. February 9, 2010.
37 **Real Estate Agents on Property Value Declines.** 4 Realtor opinion letters submitted to residents in the Sunfish, MN area whose properties are being affected by an HVTL.
38 **Ibid.**
39 **Power line plan concerns metro residents.** Melissa Maynarich. News 9 (Oklahoma). July 22, 2008.
40 **High Voltage Transmission Lines, Electric and Magnetic Fields (EMF's) And How They Affect Real Estate Prices.** David Blockhus. January 3rd, 2008. http://siliconvalleyrealestateinfo.com/electric-and-magnetic-fields-emfs-and-how-they-effect-real-estate-prices.html
41 **Impact of power transmission lines on property values: A case study.** Hsiang-te Kung & Charles F Seagle. Appraisal Journal. Vol. 60, Issue 3, p.413, 6p. July 1992.
42 **Ibid.**
43 **Power lines and property values revisited.** Jennifer M. Pitts & Thomas O. Jackson. Appraisal Journal. Fall, 2007.

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Two California appraisers, David Harding and Arthur Gimmy, published a rebuttal to the Pitts-Jackson study that disagreed with their methodology, took issue with their sponsor, addressed omitted information, and failure to conduct before-and-after cost comparisons.[44]

Pitts and Jackson responded to the rebuttal and defended their methodology, saying they purposely limited their literature research to only include empirical, peer-reviewed articles from The Appraisal Journal and the American Real Estate Society journals. They acknowledged they conducted the research for "a litigation matter" but did not elaborate on their sponsor.[45]

In a similar case, researchers James A Chalmers and Frank A Voorvaart published a large study spanning nearly 10 years and over 1,200 properties in which they found that an encumbering HVTL had only a small negative effect on the sale price of a residential home. In half of their samples they found consistent negative property values mostly limited to less than 10%, with most between 3%-6%.[46]

They summarized their findings as showing "no evidence of systematic effects of either proximity or visibility of 345-kV (kilovolt) transmission lines on residential real estate values."[47]

They did, however, say that "An opinion supporting HVTLs effects would have to be based on market data particular to the situation in question and could not be presumed or based on casual, anecdotal observation. It is fair to presume that the direction of the effect would in most circumstances be negative, but the existence of a measureable effect and the magnitude of such an effect can only be determined by empirical analysis of actual market transactions."[48]

Appraiser Kerry M. Jorgensen disagreed with the authors' views that paired data analysis and retroactive appraisal were "too unrefined and too subjective to be of much value," and that only through objective statistics could the effect of HVTLs on property value be truly understood. He argued that relying too much on statistics can be dangerous as there could be problems with how the data is compiled and interpreted. For example, he points out that out of their set of 1,286 qualifying sales, only 78 (6%) are directly encumbered by a power line easement, and only 33 (2.6%) more are within 246 feet of a power line easement.[49]

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44 **Comments on "Property Lines and Property Values Revisited."(Letter to the editor)** David M. Harding & Arthur E. Gimmy & Thomas O. Jackson & Jennifer M. Pitts. Appraisal Journal. Winter, 2008. http://www.entrepreneur.com/tradejournals/article/176131510.html

45 **Ibid.**

46 High-Voltage Transmission Lines: Proximity, Visibility, and Encumbrance Effects. James A Chalmers and Frank A Voorvaart. The Appraisal Journal via the Appraisal Institute website. Volume 77, Issue 3; Summer, 2009; pages 227-246. Reposted by CostBenefit of the Environmental Valuation and Cost-Benefit News blog - http://www.envirovaluation.org/index.php/2009/11/09/high-voltage-transmission-lines-proximity-visibility-and-encumbrance-effects

47 **Power Lines Don't Affect Property Values. The Appraisal Journal**. July 30, 2009. http://www.appraisalinstitute.org/about/news/2009/073009_TAJ.aspx

48 **High-Voltage Transmission Lines: Proximity, Visibility, and Encumbrance Effects.** James A. Chalmers, PhD and Frank A. Voorvaart, PhD. The Appraisal Journal. Summer 2009. Pgs. 227-245.

49 **Letters to the Editor.** Kerry M. Jorgensen. Appraisal Journal. January 1, 2010. http://www.thefreelibrary.com/Comments+on+"high-voltage+transmission+lines:+proximity,+visibility,...-a0220765052

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The Chalmers-Voorvaart study also attracted the interest of Washington Post Real Estate writer Elizabeth Razzi who wrote that the study was paid for by Northeast Utilities and completed before they proposed a high-voltage transmission grid in New England. She also wrote that both Chalmers and Voorvaart are appraisers and expert witnesses for the power industry.[50]

Several studies have found that, over time, property value damages from nearby HVTLs diminish though properties near the pylons stay permanently damaged no matter the elapsed time.[51] In the first case, though the property owner may grow accustomed to HVTLs and thus think less of them, new potential buyers aren't as sensitized and the diminutive impact is fresh to them.

Realtors usually oppose HVTLs. Nearly all surveyed realtors and appraisers in the Roanoke and New River valleys of Virginia said that close proximity to HVTLs would diminish property values by as much as $25,000, but mostly for high-end homes. Lower-end homes see little impact.[52]

Diminished property values can also impact communities. In one case, Delaware residents were worried that a proposed 1,200 megawatt HVTL would depress local property values, thus weakening the local tax base and leading to higher taxes to offset the losses. Kent Sick, author of a 1999 paper on power lines and property values, projects losses from a few percentage points to 53%.[53]

In Atlanta, a local realty group named Bankston Realty ranked power lines as the number one item that damages resale value, followed closely by busy roads and inferior lot topography. They advise buyers to pay 15% less of the asking price if power lines are present, and they advise sellers to accept it as a logical perception of value.[54]

Evidence suggests that HVTLs affect the health of residents in close proximity to lines 345kV and higher. Evidence also suggests that the power lines have little to no impact on property values because encumbered lots are often larger and more private than unencumbered lots, resulting in no diminution of purchase price. However, most studies did observe longer time on the market for encumbered properties.[55]

Rural Impact

Now that the reader is aware of stray voltage, EMFs, and property values, the reader will have a deeper understanding of the potential effects of HVTLs on rural land throughout the United States.

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50 **Do High-Voltage Lines Zap Property Values?** Elizabeth Rassi. Local Address. August 4, 2009. http://voices.washingtonpost.com/local-address/2009/08/do_high-voltage_lines_zap_prop.html

51 **The Effect of Public Perception on Residential Property Values in Close Proximity to Electricity Distribution Equipment.** Sally Sims, B.Sc. Paper presented to the Ph.D. Forum at the Pacific Rim Real Estate Society Conference. January 2002. This is the first part to the study.

52 A Question of Power: Part III – Realtors: High voltage lines lower property values. Leslie Brown. Roanoke Times. 1998. http://www.vapropertyrights.org/articles/98lineslowervalues.html

53 **Expert: Power lines hurt property value, market research shows sellers lose up to 53 percent.** Elizabeth Cooper. Gannett News Service. May 20th, 2006.

54 **Atlanta Homes and Resale Value... Power lines are a definite NO.** The Bankston Group. July 17, 2008. http://atlantaintheknow.com/2008/07/17/atlanta-homes-and-resale-value-power-lines-are-a-definite-no/

55 **High Voltage Power Lines Impact On Nearby Property Values.** Ben Beasley. Right of Way Magazine. February 1991.

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In Goodhue County, Minnesota, an area locally known for protecting agriculture, CapX2020 (a utility consortium) is proposing to build a 345kV HVTL through the county that may be doubled to 690kV. Local landowner Linda Grovender voiced her concern in a 2010 letter to the editor of the Cannon Falls Beacon. She worries that the line, proposed to traverse residential and agricultural lands instead of following existing utility right-of-way, will have an adverse effect on her family's health (due to EMFs), jeopardize agricultural interests, result in lost agricultural productivity, and damage property values.[56] She wrote that if the proposed 345kV HVTL is doubled to 690kV (as it legally could be) it could have an adverse effect on her family's health, jeopardize agricultural interests, result in lost agricultural productivity, and damage property values.[57]

Elsewhere n Minnesota, Dairyland Power Cooperative (one of the chief members of CapX2020) surveyed rural landowners for their opinion regarding the proposed HVTL in their area. Whether they were crop or dairy farmers, each had several reasons why the proposed line would impact their business. The unnamed respondents shared Grovender's views and said they prefer to use highway corridors and woodlands to avoid impacts to productive agricultural land; protect livestock; avoid interference with large farm equipment, GPS, and navigation systems used in farm machinery; preserve open channels for crop-dusting; protect farm buildings; protect pasture land, tree farms, and timber production.[58]

The Dairyland survey also found that livestock operations are concerned that the HVTL will generate stray voltage, impacting livestock and feedlots. Cattle, horses, and other livestock will not go near transmission lines due to stray voltage. And stray voltage can impact the health of beef cattle and hogs. Farmers also fear potential impacts on dairy operations, poultry, livestock mortality, horse boarding facilities, and herd reproduction. [59]

HVTLs also pose potential technological obstacles. For example, The GPS equipment used in the farm equipment may not be able to steer around transmission poles, potentially making farming around the towers extremely difficult. [60]

One major concern was the routing the HVTLs through the middle of properties or fields. The surveyed farmers quoted many repercussions for bisecting a property. They include: Interrupted irrigation and tile drainage equipment and practices; decreased food production; fragmented existing cropland and dairy operations; diminished lease value: the addition of transmission lines would make it difficult to lease farm land for the top rental price; compacted soil from construction of the HVTLs and access roads: it would take 3–5 years to restore.[61]

Across the border in Wisconsin, the state's Department of Agriculture validated many of the Minnesota respondents' concerns when it found that HVTL construction could compact soil, making it difficult to

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56 **No CAPX2020.** Letter to the Editor by Linda Grovender. The Cannon Falls Beacon. March 23, 2010.
57 **Ibid.**
58 **SE Twin Cities-Rochester-La Crosse Transmission System Improvement Project Macro-Corridor Study, Appendix A: Summary of Public Comments regarding a proposed HVTL.** Dairyland Farm Cooperative. September 2007.
59 **SE Twin Cities-Rochester-La Crosse Transmission System Improvement Project Macro-Corridor Study, Appendix A: Summary of Public Comments regarding a proposed HVTL.** Dairyland Farm Cooperative. September 2007.
60 **Ibid.**
61 **Ibid.**

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plow and plant those areas, naturally resulting in reduced crop yields. The HVTLs force farmers to change planting patterns to avoid support structures. Since farm land is only as valuable as its ability to yield good crops, rural property values suffer from the limitations and effects of HVTLs on their land.[62]

Potential compaction, forced building changes, and lower property values equally threaten dairy operations as much as agricultural farmers. Susan and Robert Herckendorf, dairy farmers in the path of the proposed A-W HVTL, are worried that the line could put local dairies out of business.[63]

In researching the possible negative factors of the then-proposed Arrowhead-Weston HVTL in Wisconsin in 2000, the state's Public Service Commission found that rural property values may decrease from "concern or fear of possible health effects from electric or magnetic fields; The potential noise and visual unattractiveness of the transmission line; Potential interference with farming operations or foreclosure of present or future land uses."[64] They also found that the value of agricultural property will likely decrease if the pylons inhibit farm operations."[65] However, they also found that adverse effects appear to diminish over time.[66]

The impact report further states that, on farmland, HVTL installation can remove land from production, interfere with operation of equipment, create safety hazards, and deprive landowners the opportunity to consolidate farmlands or develop the land for another use. The greatest impact on farm property values is likely to occur on intensively managed agricultural lands.[67]

Nearly a decade later in 2009, the Wisconsin Public Service Commission conducted another study on the environmental impacts of transmission lines and found that "in agricultural areas, the number of poles crossing a field may be the most significant measure of impact," and "agricultural values are likely to decrease if the transmission line poles are in a location that inhibits farm operations."[68] Beyond the impact of pole placement, the PSC found that "the overall aesthetic effect of a transmission line is likely to be negative to most people, especially where proposed lines would cross natural landscapes. The tall steel or wide 'H-frame' structures may seem out of proportion and not compatible with agricultural landscapes or wetlands."[69] They further explained that "Transmission lines can affect farm operations and increase costs for the farm operator. Potential impacts depend on the transmission line design and the type of farming. Transmission lines can affect field operations, irrigation, aerial spraying, wind breaks, and future land development."[70]

The study further examines how rural HVTL pole placements can affect agricultural land values: They can create problems for turning field machinery and maintaining efficient fieldwork patterns; expose

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62 **Line could affect farms, property values.** Author Unknown. Oshkosh Northwestern. June 26, 2000.
63 **Ibid.**
64 **Property Values (pages 212-215) from Final Environmental Impact Statement, Arrowhead-Weston Electric Transmission Line Project, Volume 1.** Public Service Commission of Wisconsin. Docket 05-CE-113. Date issued, October 2000.
65 **Ibid..**
66 **Ibid.**
67 **Property Values (pages 212-215) from Final Environmental Impact Statement, Arrowhead-Weston Electric Transmission Line Project, Volume 1.** Public Service Commission of Wisconsin. Docket 05-CE-113. Date issued, October 2000.
68 **Environmental Impacts of Transmission Lines.** Public Service Commission of Wisconsin. March 2009.
69 **Ibid.**
70 **Ibid.**

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properties to weed encroachment; compact soils and damage drain tiles; result in safety hazards due to pole and guy wire placement; hinder or prevent aerial activities by planes or helicopters; interfere with moving irrigation equipment; hinder future consolidation of farm fields or subdividing land for residential development.[71]

To oppose these potentially diminutive effects on their land, landowners sometimes organize against them. In Ohio, a group of concerned citizens formed the group, Citizens Advocating Responsible Energy (CARE), to oppose FirstEnergy's proposed Geauga County power line. On their website they state the reasons for their opposition. They fear the HVTL will devalue the properties it crosses, force affected property owners to continue paying taxes on damaged property, damage natural beauty and local ecology, lessen agricultural productivity of impacted land, thus reducing farm income and local purchasing power, and create a thorough-fare for snowmobiles and off-road vehicles.[72]

Other times, concerned landowners are united in voice, but not in form. In 2010, Idaho property owners in Bonneville County are nervously following the progress of Idaho Falls Power's proposed 161kV HVTL that would pass close to their homes.[73]

Lynn Pack, a Bonneville County dairy farmer, has educated himself on HVTLs and said he's most concerned with stray voltage. "It causes so many problems with cow's production. They won't feed, they won't drink water, they dry up and when they dry up they just don't give any milk." [74] Another property owner, Sharon Nixon, fears the HVTL could harm her husband's health after his recent victory over bone cancer. She also fears the value of her home will fall. "It is not something we want in our backyard. We worked all our lives. This is our dream home." [75]

Idaho Falls Power General Manager Jackie Flowers said the HVTL is a necessary step to meet new federal energy reliability standards and that the utility is open to the public's input. [76]

A year earlier in Idaho, a coalition of Rockland County farmers tried to convince Idaho Power Company to avoid routing a new HVTL through their land, citing environmental and development concerns.[77] Doug Dokter, Idaho Power project leader, said the new lines are required because the existing lines are at their capacity.[78] Because of their concerns, utility representatives say they're looking at other options and hope for a compromise to avoid invoking eminent domain to take the land. [79]

Sometimes opposition to a proposed HVTL route can alter its course. In 1994, Public Service Company of New Mexico abandoned plans to take new right-of-way through the Jemez Mountains for a 50-mile long HVTL extension that Indian groups and environmentalists argued would cut through several miles

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71 **Ibid.**
72 **We oppose FirstEnergy's proposed Geauga County power line.** Website posting by Citizens Advocating Responsible Energy (CARE). Date unknown but website copyright suggests sometime from 2008-2009.
73 **Transmission Lines Worry Property Owners.** Brett Crandall. Local News 8. March 5, 2010.
74 **Ibid.**
75 **Ibid.**
76 **Ibid.**
77 **Headway being made on proposed route for power transmission line.** Author Unknown. The Power County Press and Aberdeen Times. April 8, 2009.
78 Ibid.
79 Ibid.

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of pristine vistas and Native American ruins.[80] The utility instead re-routed the extension to follow an existing utility corridor, bringing the decade-long dispute to a close.[81]

In 2008, California farmers and ranchers found themselves in a similar situation. San Diego Gas & Electric proposed a 150-mile long, 500kV HVTL (in conjunction with several 230kV HVTLs) across San Diego and surrounding counties to meet increasing energy needs and transport required renewable energy.[82]

Affected landowners are worried the line will have "huge" impacts on their properties. Katie Moretti, an affected cattle rancher, and other farmers worry that building construction access roads across untouched land will limit their land's future use. She also worries that the utility won't compensate her for the loss of use.[83]

Another rancher, Glen Drown, also worries about the impact the line will have on land-use and property values since the proposed route bisects several of his parcels subdivided for future development.[84]

Local dairy producer, Richard Van Leeuwen, is worried that stray voltage from the line would damage the health of his calves and milking cows. To protect his herd's health he said he would have to relocate the calf farm to another part of his property, costing millions.[85]

San Diego County Farm Bureau Executive Director Eric Larson acknowledges that the farming community won't be able to stop the project, but he's trying to make it compatible with the area's farming interests by recommending burying the line underground in some areas, going around some areas, and utilizing existing right-of-way.[86]

Elsewhere in the state, the City of Brentwood researched the potential impact of HVTLs on agricultural land values by interviewing several of their local and experienced Real Estate brokers. All the brokers said that "Agricultural land with power lines above ground is worth less than properties with below-ground utilities."[87]

However, in a 2007 report, the California Department of Conservation's Farmland Mapping and Monitoring Program reported that HVTLs installed on agricultural land for a wind farm will result in a temporary disturbance of 10 acres of farmland and permanently affect 1 acre. Since the affected areas are mainly grazing land, the report concluded that the HVTL would not significantly impair productivity. Though the impact to agricultural productivity during construction would be negative, they claimed it would be mostly insignificant.[88]

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80 **PNM Scraps Jemez Power Line Plan.** Keith Easthouse. Sante Fe New Mexican. December 16, 1994.
81 **Ibid.**
82 **Proposed power line would impact farms.** Christine Souza. California Farm Bureau Federation. May 28, 2008.
83 **Proposed power line would impact farms.** Christine Souza. California Farm Bureau Federation. May 28, 2008.
84 **Ibid.**
85 **Ibid.**
86 **Ibid.**
87 **City of Brentwood, California.** Website page explaining their approaches to valuing agricultural land. Date and author unknown.
88 **3.3 Agricultural Resources.** Part of the public draft by The California Department of Conservation's Farmland Mapping and Monitoring Program. July 2007.

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Across the country in Leesburg, Virginia, 26 landowners opposed Dominion Energy's proposed 230kV HVTL, saying it will damage their property values, thus decreasing their tax base and thus affect the county as a whole. They also fear its impact on Blue Ridge tourism.[89]

Bill Hatch, owner of a 400-acre farm was upset to learn the line would run through his farm. He said the proposed line would so affect his farm that he could only afford to keep it by direct marketing or agro-tourism, but he admitted that few people would want to visit a farm with power lines.[90]

Landowners want the utility to bury the lines, but the utility says it will cost 10 times more than traditional overhead lines. However, Harry Orton, an underground power line expert, testified that while the initial costs of burying the lines are higher, the lower cost of maintenance over the years evens the cost along the lines' lifecycle.[91]

A year later in 2006, Dominion proposed an additional 500kV HVTL to meet growing demand and routed it through northern Virginia because it was the most efficient route. However, the area is also one of the state's most pristine, and the proposal met with fierce resistance from landowners, environmentalists, Congressman Frank Wolf, and actor Robert Duvall.[92]

In the path of the HVTL are landowners of some of the most valuable land in Virginia, and they were bothered that the utility plans to erect the 40-mile, 15-story HVTL in their back yards.[93]

One landowner, Cameron Eaton, fears the line will bring financial ruin and "sink" her investment into her 100-acre Fauquier County property and horse business. "No one will buy that land if some ugly power line could run right over their house. I'm broken off at the knees."[94]

Real estate agents consider the area's picturesque countryside to be its most valuable quality. Matt Sheedy, a land developer and president of Virginians for Sensible Energy Policy, said that the very proposal that the line will soon dominate the countryside has already "sent land values plummeting." Brokers confirmed that the market froze. People backed out of real estate contracts, unwilling to live anywhere under the line. Sheedy's groups estimated that land immediately affected could lose as much as 75% of its value.[95]

"When you're out in the country and you're selling property, what you're selling is the open space and the bucolic views and the history," Sheedy said. "Running power lines through an area like this is just devastating." To landowners Gene and Deborah Bedell, who were trying to sell their 223-acre farm to pay for their retirement, it was a hard blow. Their agent old them no one would buy their property if they knew "that it could have a power line looming over it."[96]

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89 **Committee Hears Debate Over Underground, Overhead Power Lines.** Megan Kuhn. Leesburg Today. May 20, 2005.
90 **Ibid.**
91 **Committee Hears Debate Over Underground, Overhead Power Lines.** Megan Kuhn. Leesburg Today. May 20, 2005.
92 **Landowners Fear Ruin from Power Line Route.** Sandhya Somashekhar. Washington Post Staff Writer. December 11, 2006.
93 **Ibid.**
94 **Ibid.**
95 **Ibid.**
96 **Ibid.**

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Further north in New York, over 50 landowners and local officials spoke before the state's Public Service Commission in opposition to Upstate NY Power Corp's proposed construction of a 230kV HVTL in their community.[97]

Sharon B. Rossiter, co-owner of Doubledale Farms in Ellisburg, said the HVTL will damage their crop cycle, remove 100 acres from use, and make planting difficult by having to navigate around the poles. Also worried is Roberta F. French, owner of Farnham Farms in Sandy Creek. The proposed line will bisect her blueberry farm, eliminating two-thirds of it.[98]

Jay M. Matteson, Jefferson County agricultural coordinator, advocated routing the HVTL through public land to avoid damaging productive, private land. "The burden should be on New York state and the developer to prove to local landowners why their land is less valuable than public land," he said.[99]

The Town of Henderson opposed it because the town's foundation is tourism and agriculture, and the community is "very concerned about the visual impacts of this project."[100]

Robert E. Ashodian, chairman of the Henderson Harbor Area Chamber of Commerce's Economic Development Committee, agreed. "The scenic resources of the community and the natural resources are at the heart of the value of the community."[101]

In an effort to appease worried or angry landowners, agricultural property owners in Montana with HVTLs encumbering their land will be exempt from paying taxes on land within 600 feet on either side of the HVTL Right-of-Way.[102]

In the 2002 study, "The Impact of Transmission Lines on Property Values: Coming to Terms with Stigma," authors Peter Elliott and David Wadley cite a 1978 Canadian study that, according to one commentary, found "the per acre values from more than 1,000 agricultural property sales in Eastern Canada were 16-29% lower for properties with easements for transmission lines than for similar properties without easements." The impact was greater on smaller properties. The 1978 study found little difference in impact from 230kV or 500kV HVTLs. The study also found that the impacts didn't seem influenced by time.[103]

Three more Canadian studies on the impact of HVTLs on agricultural land values found different results.[104] Brown 1976 studied the effect of low-voltage power lines on agricultural land in Saskatchewan and found no measurable impact on property values. The Woods Gordon 1981 study focused on the effects of 230kV to 500kV HVTLs on Ontario farmland and found some areas had an average of a 16.9% negative impact, two areas had a positive effect, and others showed no statistically

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97 **Transmission line gets no support.** Nancy Madsen. Watertown Daily Times. November 17, 2009.
98 **Transmission line gets no support.** Nancy Madsen. Watertown Daily Times. November 17, 2009.
99 **Ibid.**
100 **Ibid.**
101 **Ibid.**
102 **Tax facts on proposed power line.** The Montana Standard Staff. The Montana Standard. July 11, 2009.
103 **The Impact of Transmission Lines on Property Values: Coming to Terms with Stigma.** Peter Elliott & David Wadley. Property Management, pgs.137-152. 2002.
104 **The Effects of Overhead Transmission Lines On Property Values: A Review And Analysis Of The Literature.** Edison Electric Institute Siting & Environmental Planning Task Force. 1992.

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significant effect. The third study, a master's thesis referred to as Thompson 1982 found sales prices lower for properties crossed by HVTLs but only where the land has potential for irrigation.(pgs. 56-57)[105]

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105 Ibid.

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PubMed

Display Settings: Abstract

Bioelectromagnetics. 1988;9(3):285-301.

Mechanism of biological effects observed in honey bees (Apis mellifera, L.) hived under extra-high-voltage transmission lines: implications derived from bee exposure to simulated intense electric fields and shocks.

Bindokas VP[1], Gauger JR, Greenberg B.

Author information

Abstract

This work explores mechanisms for disturbance of honey bee colonies under a 765 kV, 60-Hz transmission line [electric (E) field = 7 kV/m] observed in previous studies. Proposed mechanisms fell into two categories: direct bee perception of enhanced in-hive E fields and perception of shock from induced currents. The adverse biological effects could be reproduced in simulations where only the worker bees were exposed to shock or to E field in elongated hive entranceways (= tunnels). We now report the results of full-scale experiments using the tunnel exposure scheme, which assesses the contribution of shock and intense E field to colony disturbance. Exposure of worker bees (1,400 ı) to 60-Hz E fields including 100 kV/m under moisture-free conditions within a nonconductive tunnel causes no deleterious affect on colony behavior. Exposure of bees in conductive (e.g., wet) tunnels produces bee disturbance, increased mortality, abnormal propolization, and possible impairment of colony growth. We propose that this substrate dependence of bee disturbance is the result of perception of shock from coupled body currents and enhanced current densities postulated to exist in the legs and thorax of bees on conductors. Similarly, disturbance occurs when bees are exposed to step-potential-induced currents. At 275-350 nA single bees are disturbed; at 600 nA bees begin abnormal propolization behavior; and stinging occurs at 900 nA. We conclude that biological effects seen in bee colonies under a transmission line are primarily the result of electric shock from induced hive currents. This evaluation is based on the limited effects of E-field exposure in tunnels, the observed disturbance thresholds caused by shocks in tunnels, and the ability of hives exposed under a transmission line to source currents 100-1,000 times the shock thresholds.

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ORIGINAL RESEARCH ARTICLE

Magnets, magnetic field fluctuations and geomagnetic disturbances impair the homing ability of honey bees (*Apis mellifera*)

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Summary

Adult honey bees possess a magnetoreception sense similar to other animals such as birds, fish, whales, dolphins, insects, and microbes. Organisms use this sense for orientation purposes during migrations and traveling long distances. The sudden loss and disappearance of honey bees from a hive or apiary has been plaguing beekeepers for more than a century. This age-old disorder predates virtually all herbicides and pesticides, many diseases or pests and honey bee management protocols. To investigate possible involvement of a magnetoreception disorder (MRD) with loss of forager homing abilities: A. magnetized wires were glued to their abdomens; B. foragers were exposed to artificially induced fluctuating magnetic fields; and C. untreated foragers' return rates were monitored during naturally occurring disturbances to Earth's magnetosphere. Treated and untreated foragers were released at varying distances from their hives and their return rates were monitored. Significant differences in their return rates indicated that interactions existed between forager losses and exposure to both static and oscillating magnetic fields, as well as during fluctuations in the Earth's magnetosphere. In addition, D. decreases in untreated forager return rates also correlated with increasing intensity of extraterrestrial protons that entered Earth's atmosphere. Finally, winter colony losses in the northeast USA also correlated with annual geomagnetic storm occurrences. Collectively, these five observations indicate that coronal eruptions on the Sun are involved with interference of a forager's magnetoreception sense here on Earth. How abnormal magnetic fields and fluctuations relate to the epidemiology of honey bee losses is consistent with their behaviour and development.

Los imanes, las fluctuaciones de campos magnéticos y las perturbaciones geomagnéticas afectan la habilidad para volver a la colmena de las abejas melíferas (*Apis mellifera*)

Resumen

ALas abejas melíferas adultas poseen un sentido de magnetorrecepción similar al de otros animales como las aves, los peces, las ballenas, los delfines, otros insectos y ciertos microbios. Los organismos utilizan este sentido con fines de orientación durante las migraciones y viajes de larga distancia. La repentina pérdida y desaparición de abejas melíferas de sus colmenas o colmenares ha estado afectando a los apicultores desde hace más de un siglo. Este viejo problema es virtualmente anterior a la utilización de herbicidas y pesticidas, a muchas enfermedades o plagas y a los protocolos de manejo de abejas melíferas. Con el fin de investigar la posible implicación del desorden de la magnetorrecepción (MRD) en el fenómeno de la pérdida de habilidad para volver a la colmena de las abejas pecoreadoras: A. redes magnéticas fueron pegadas a los abdómenes de las abejas; B. abejas pecoreadoras fueron expuestas a fluctuaciones inducidas en campos magnéticos; y C. pecoreadoras no tratadas fueron monitorizadas para medir su tasa de retorno a la colmena durante la perturbación natural de la magnetosfera en la Tierra. Las pecoreadoras tratadas y no tratadas fueron puestas en libertad a diversas distancias de sus colmenas, y sus tasas de retorno fueron monitorizadas. Las diferencias significativas en sus tasas de retorno indicaron que existen interacciones entre las pérdidas de pecoreadoras y la exposición tanto a campos magnéticos estáticos como a los oscilantes, así como a las fluctuaciones de la magnetosfera terrestre. Asimismo, D. se encontró una correlación entre la disminución en las tasas de retorno de las pecoreadoras y el incremento de la intensidad de los protones extraterrestres que se introdujeron en la atmósfera de la Tierra. Finalmente E. se encontró una correlación entre las pérdidas de

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colonias durante el invierno en el noreste de EE.UU. y la aparición de las tormentas geomagnéticas anuales. Colectivamente, estas cinco observaciones indicaron que las erupciones en la corona solar interfieren en el sentido de magnetorrecepción de las pecoreadoras en la Tierra. La relación entre las fluctuaciones y anormalidades que se dan en los campos magnéticos y la epidemiología de las pérdidas de abejas melíferas es congruente con su comportamiento y desarrollo.

Keywords: Honey bees, orientation, magnetoreception, homing

Introduction

In 1891, R C Aikin observed a sudden and complete loss of adult honey bees (*Apis mellifera* L.) from colonies in an apiary he managed in Colorado, USA (Aikin, 1897). The hives still contained laying queens, healthy brood and young nurse bees caring for them. Since the adult bees seemed to him to evaporate and were nowhere to be found, he named the syndrome "evaporation." Notably, he reported: "The weather was so warm that there was no loss of brood; and as they had from four to seven combs well filled, the hives were soon very populous again." His observations and the ability of colonies to recover are inconsistent with a contagious disease or pest as causal agents for the sudden "evaporation" of only adult bees.

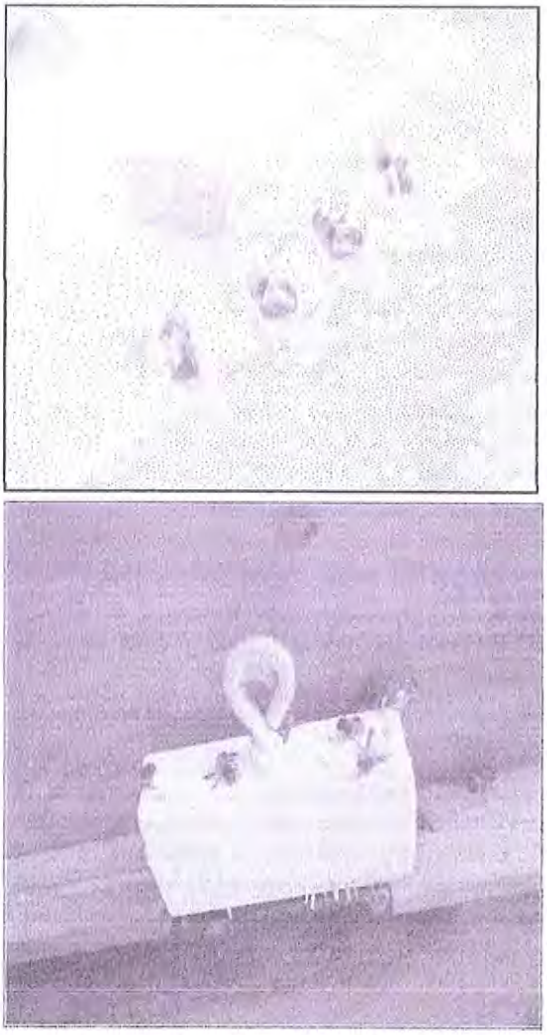


Fig. 1. A. Anesthetized bees with colour-coded wire magnets on abdomens. ***B.*** Magnet over hive entrance and removal of wires from returning foragers.

"Evaporation," "Disappearance Disease," "Dwindling Disease," "Autumn Collapse," "May Disease" and "Colony Collapse Disorder" (CCD) are various names used throughout history to describe similar observations: an unexpected, abrupt and severe loss of adult honey bees from a colony and apiary. Similar phenomena have been re-discovered and re-documented periodically around the world for more than a hundred years (Aikin, 1897; Oertel, 1965; Foote, 1966; Wilson and Menapace, 1979; Finley *et al.*, 1996; Underwood and vanEnglesdorp, 2007; Oldroyd, 2010).

It is important to recognize that honey bee colonies can "collapse," "fail" or "die-off" due to many maladies caused by viruses, fungi, bacteria, microsporidia, mites, pesticides and starvation (Neuman and Carreck, 2010; Ratnieks and Carreck, 2010; Van der Zee *et al.*, 2012; vanEnglesdorp *et al.*, 2012; Spleen *et al.*, 2013). But, what is unique concerning the "evaporation" disorder is the absence of victims: adult bees leave the hive and cannot be found. Therefore, autopsies cannot be performed. This key symptom sets the "disappearance" disorder apart from virtually all other maladies that are not only contagious, but also leave evidence of dead, sick or afflicted bees in or near the hive.

Seven symptoms identify the "dwindling" phenomenon: 1. a sudden, inexplicable loss of adult workers; 2. an absence of sick or dead bees; 3. presence of healthy brood; 4. existence of an egg-laying queen; 5. presence of fit, young adults; 6. an undersized cluster of bees; and 7. the condition is not contagious.

The seventh symptom is significant in that colonies afflicted with the "collapse" disorder can recover or be merged with other colonies without harm; moreover, equipment from affected hives can be used with healthy colonies without severe consequences (Aikin, 1897; Oertel, 1965; Foote, 1966; Wilson and Menapace, 1979; vanEnglesdorp *et al.*, 2008). Despite exhaustive studies, no single and demonstrable cause of CCD symptoms has yet been demonstrated (Cox-Foster *et al.*, 2007; vanEnglesdorp *et al.*, 2009). A study by Bromenshenk *et al.* (2010) linking invertebrate iridescent virus (Family Iridoviridae) with afflicted colonies was not reproducible (Tokarz *et al.*, 2011). Linking iridovirus and *Nosema* with the disorder is

inconsistent with true "disappearance disease" because those infectious agents leave symptoms of their presence: dead or deformed bees in or near the hive; bees acting in an erratic crawling behaviour; faecal matter on hive bodies; and, moreover, both are contagious. Not so with the "collapse" disorder: healthy colonies are left behind and no adult bees can be found.

Repeatedly, studies have shown the "evaporation" disorder to be non-transmissible and not due to pathogens or parasites (Foote, 1966; Wilson and Menapace, 1979; Johnson, 2010). For example, extracts of bees from afflicted colonies have been mixed with live bees in small cages, and in no case was there an abnormal death rate (Ortel, 1965). "Combs containing honey and pollen, taken from dead colonies, were given to nuclei. No abnormal death rate was noted;

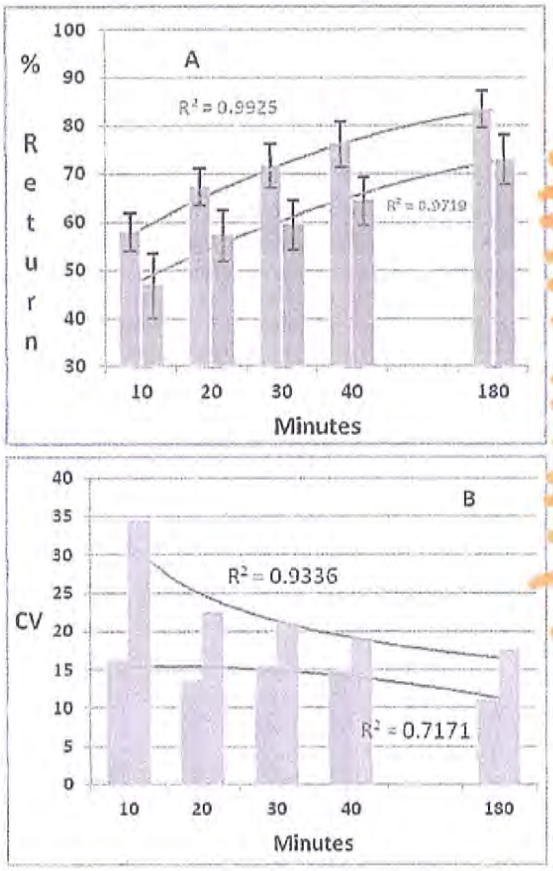


Fig. 2. A. Cumulative return rates at different time intervals for foragers returning with non-magnetized (blue) and magnetized wires (red) on their abdomens. Bees were released 80 m from their hives. Results represent the average of 15 experiments. Error bars are 90% confidence intervals. *B.* Coefficient of variation (CV) for returning bees at increasing 10-min. time intervals.

development proceeded normally." (Ortel, 1965). "Colonies that survive the winter quickly build their adult populations. Beekeepers can then split these colonies by removing half of the immature and adult bee population, introducing them into the equipment of a dead colony, and adding a new queen. This practice permits beekeepers to build their colony numbers back up by mid-summer..." (vanEnglesdorp *et al.*, 2008). Also, a seldom recognized detail in many studies involving the "collapse" problem in the USA, is that it predates the introduction of many pesticides (Frazier *et al.*, 2011), diseases and pests which have been a focus of research in recent years, including neonicotinoids (Thany, 2010), *Nosema ceranae* (Williams *et al.*, 2008) and *Varroa destructor* (Wenner and Bushing, 1996), to name a few. A nagging problem with all research to date involving the "collapse" disorder is that only surviving bees were sampled for examination, because missing bees could not be found, resulting in an extraordinary and unavoidable statistical bias in experimental methods (e.g. Bromenshenk *et al.*, 2010; vanEnglesdorp *et al.*, 2009).

Behavioural scientists have accumulated decades of experimental evidence about honey bees' ability to perceive and orient themselves in magnetic fields. Their findings provide a novel theory as to a cause for the sudden, non-infectious loss of adult bees: it involves a sixth sense, termed "magnetoreception." Numerous organisms, including honey bees, extract directional information from Earth's ambient magnetic field (Lindauer and Martin, 1972; Gould *et al.*, 1978; Kirschvink *et al.*, 1985; Collett and Baron, 1994; Frier *et al.*, 1996; Kirschvink *et al.*, 1997; Gould, 1998; Golland and Pazur, 2005; Johnson and Lohmann, 2008; Frankel, 2009; Wajnberg *et al.*, 2010). A magnetoreceptive sense allows many organisms to use Earth's magnetic "lines" to migrate and travel long distances without using visual landmarks (for example, whales, dolphins, butterflies, salmon, geese, ducks, zebra and turtles). Indeed, experiments indicate that honey bees can be trained to respond to changes in local magnetic fields (Gould *et al.*, 1980; Tomlinsin *et al.*, 1981; Hsu *et al.*, 2010), and their sixth sense can be altered by exposure to abnormal magnetic fields (Lindauer and Martin, 1972; Towne and Gould, 1985; Walker and Bitterman, 1985, 1986, 1989). A magnetoreceptive sense opens the possibility that an environmental stress factor, involving severe fluctuations in Earth's magnetosphere following major coronal eruptions on the Sun, can interfere with a forager's homing ability and thereby lead to bee losses.

Experiments described herein provide evidence that experimentally induced changes in magnetic fields and solar-induced geomagnetic storms produces a "magnetoreception disorder" (MRD) in foragers, which causes them to get lost when returning to their colony. A review of past research indicates that bees use Earth's magnetosphere for orientation and that geomagnetic disturbances were likely to have contributed to, or caused the mysterious bee losses that have been documented in the past.

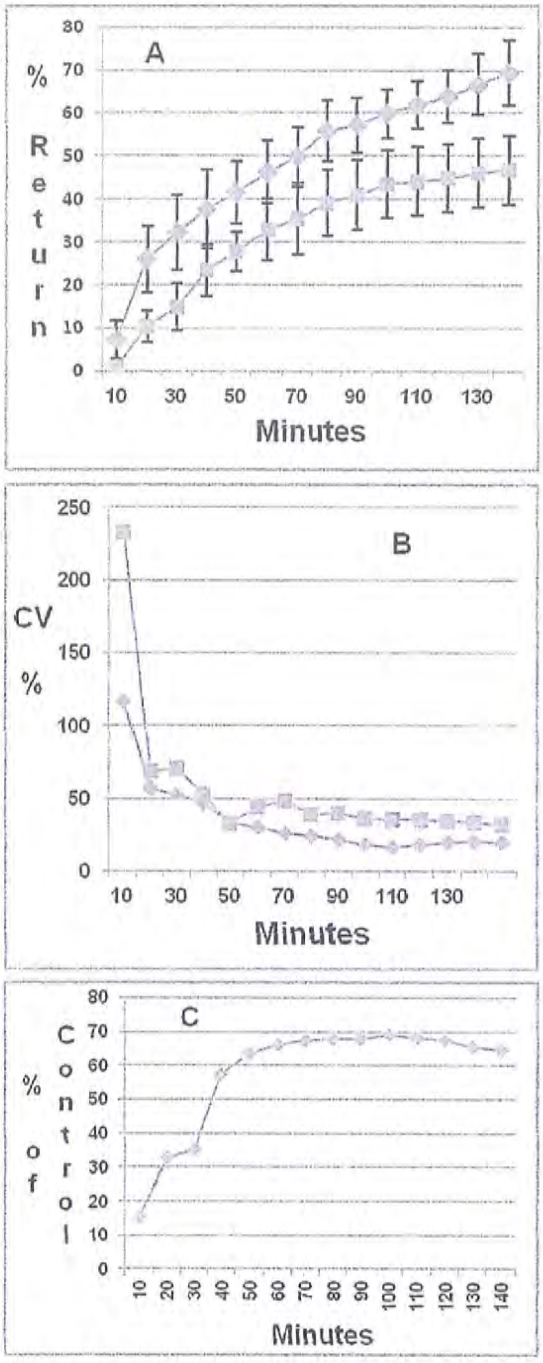


Fig. 3. A. Cumulative return rates of foragers bearing magnetized (red) or non-magnetized (blue) wires when released 800 m from their hives. Error bars are 90% confidence intervals. Each point represents an average of 11 experiments. *B.* Coefficient of variation (CV) for return rates. *C.* Inhibition of forager homing ability when bearing magnetized wires compared to controls.

Material and methods

Apis mellifera

Homing ability of honey bees was evaluated in the presence and absence of experimentally induced magnetic fields and during uncontrolled, natural fluctuations in Earth's magnetosphere. Colonies were feral swarms collected from suburban areas and maintained in Bakersfield, California, USA. After smoking the entrances of colonies to force guard bees and other non-foragers into hives, entrances were blocked. A few minutes later returning bees were collected by placing clear, plastic specimen cups (120 cc, 5-6 cm diameter) over them as they accumulated above the entrance. Cups were perforated to allow for air circulation. The cups were then slid onto a thin but firm plastic sheet to prevent bees from escaping. Captured bees were anesthetized by cooling them to 3-6°C for approximately 15 min. Bees with pollen on their legs were considered to be pollen gatherers. In one experiment, bees were separated based on colour of pollen pellets to associate them with different foraging sites. Nectar gatherers amongst the remaining bees were identified by gently pressing remaining bees on their abdomens and observing if they exuded a liquid from their mouth. Approximately 15 % to 20 % of them released a fluid that tested positive for glucose using a diabetic glucometer: they were considered to be nectar foragers.

Wire attachment

After nectar and pollen foragers were selected, magnetized and non-magnetized wires were attached to the mid-to-anterior dorsal region of their abdomens with the aid of handmade plastic forceps (Fig. 1A). A thin, flexible plastic strip (2 x 10 cm) with a v-shaped notch (4 x 4 mm) cut into a corner was placed between the thorax and abdomen to hold the bee's wings back while glue (circa 1.5 µl) was applied.

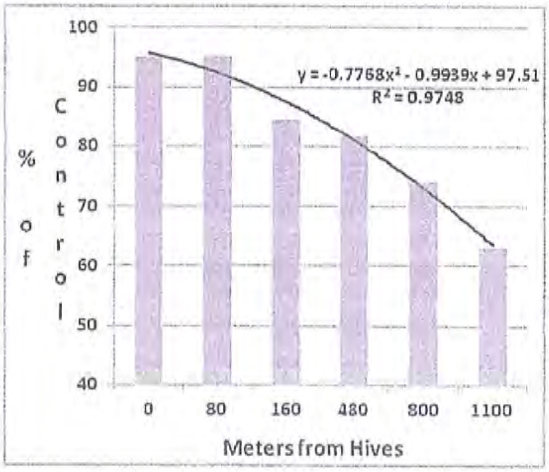


Fig. 4. Static magnetic fields increasingly inhibit return of foragers released at progressively longer distances from their hives.

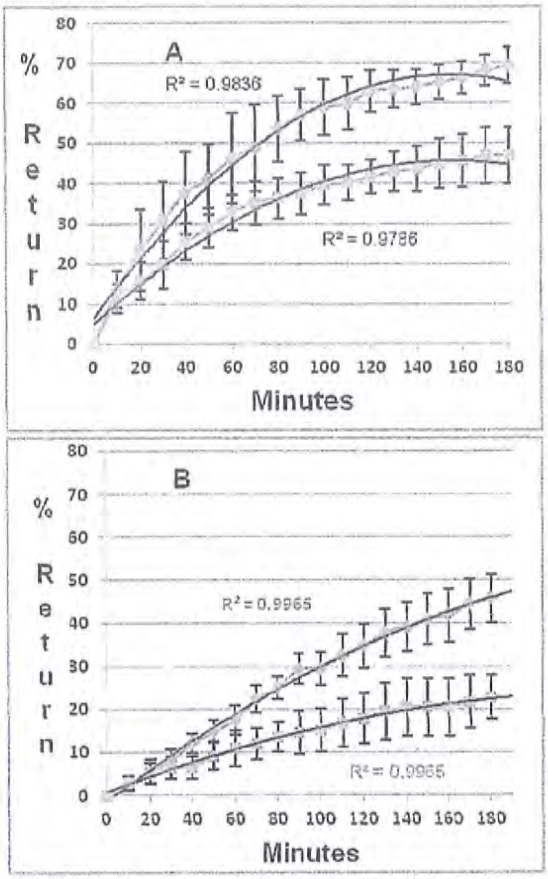


Fig. 5. Inhibition of foragers' homing ability after exposure to an oscillating magnetic field (red markers). Controls were not exposed (blue markers). ***A.*** Bees were released 480 m (9 experiments) or ***B.*** 800 m (12 experiments) from their hives.

Wires were then attached parallel to the bee's abdomen. Next, a clear plastic vial (25 cm^3) was placed over each bee at room temperature to allow glue to dry and allow for bee recovery (usually 1-5 min.). In all experiments, 15 to 21 (*n*) bees were used per treatment and release point. The procedure was minimally harmful based on return rates (90-100 %) when bees were released 1 m in front of their hives, or 80 m from their hive. Experiments involved 10 different colonies over a two-year period (2011, 2012, from June to November).

Wire preparation

Steel wires (www.forneyind.com) (30 cm x 0.89 mm dia.) were painted and colour-coded using acrylic paint. After drying, wires were cut to 4.0 - 4.5 mm lengths and each weighed approximately 15 mg (pollen pellets possess a similar weight). Magnetization was induced for a minimum of 15 mins by placing the cut wires onto neodymium-iron-boride ($Nd_2Fe_{14}B$) rare earth axially polarized rod magnets (5 cm x 2.5 cm dia.) (www.amazingmagnets.com). Magnetic field intensity at their poles for magnetized and non-magnetized wires was measured using a triple fluxgate magnetometer (Alpha lab Inc.; Salt Lake City, Utah, USA). Flux density values represent the Z-vector component of the wire's magnetic field when placed perpendicular to the instrument's sensor. Intensity averaged $\leq 0.2 \times 10^{-6}$ Tesla (T) and $\geq 2.0 \times 10^{-6}$ T, respectively, for control and magnetized wires. Wires with intermediate values were discarded. Repeat measurements indicated the intensity of magnetized wires did not become weaker within 48 hours.

Geomagnetic storms

Instability in Earth's geomagnetic field occurs constantly, and is logged by NOAA/SWPC daily at three hour intervals. Called the K-index, it ranges from 0 to 9. As a consequence, forager return experiments comparing different treatments were often subject to a varying background "geomagnetic noise." Disturbances of a K-index ≥5 are considered major storms (http:maar.us/geomagnetic_storm_scale.html). When geomagnetic "contamination" occurred during experiments, comparisons of return rates between controls and treatments were not reproducible, therefore they were not included in data analysis. Experimental treatments were only compared and evaluated when K-indices of magnitude ≤4 occurred (considered minor fluctuations).

Treatment protocols

The homing ability of honey bees was evaluated in four ways: A. during the presence of a wire magnet on their body that induced a

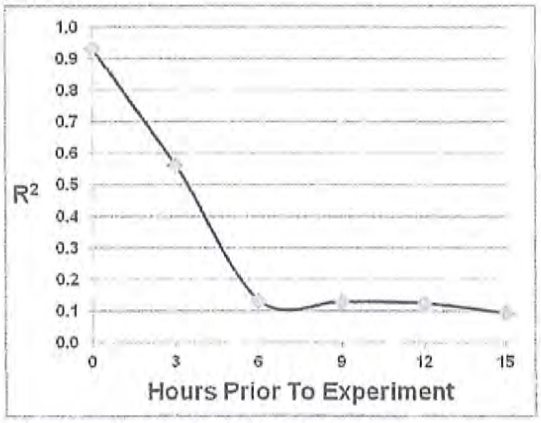
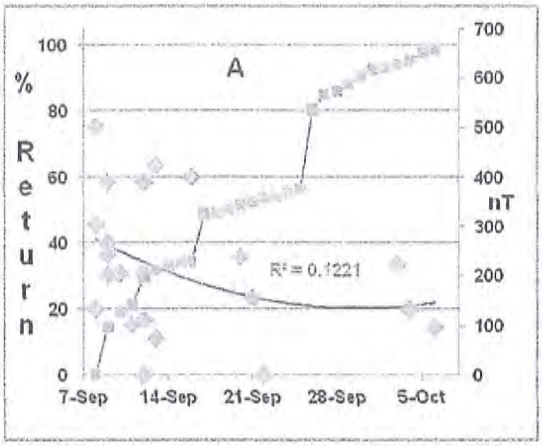


Fig. 6. Correlation coefficients for forager return rates during geomagnetic disturbances (in nT) for 6 different time periods: 0 = *during* the 3 hour experiment; 3 = *during expt.* + prior 3 hrs; *during expt.* + prior 6 hrs; etc. Foragers were released 480 m and 800 m from their hives. Trendline is the average for both distances.

EXHIBIT 6-K

static magnetic field; B. after their exposure to an induced oscillating magnetic field; and C. during uncontrolled, natural fluctuations in Earth's magnetosphere. In addition, D. an independent survey of winter colony losses from 2000 to 2006 was compared to the record of geomagnetic disturbances in Earth's magnetosphere.

A. After bees were anesthetized, a nontoxic, fast-drying "Tacky" glue (www.duncancrafts.com) was used to attach wires onto their abdomens (n=15-21 per treatment). Each treatment took approximately 20-30 min. After they recovered, bees bearing magnetized and non-magnetized wires were transferred into separate clear plastic containers (32 x 19 x 11 cm) through a 3 cm hole in the lid. They were then taken to different locations and distances to be released: 15 to 21 bees were released per treatment per location. Hives bodies were not visible from all release sites. Bees that did not fly from containers were excluded from data analysis. Release distances were approximately 80 m, 100 m, 380 m, 800 m and 1,100 m from their hives. When released either at 380 m or at 800 m in easterly or westerly directions, or at 1,100 m in north or south directions, there was no statistically significant difference in forager return rates, indicating alignment of wire magnets with Earth's magnetic field made no difference. Therefore, data were pooled at equal release distances regardless of direction. Ambient temperatures ranged from 27 to 41°C.



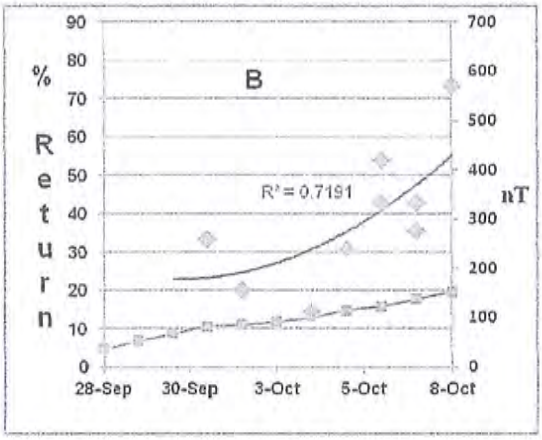


Fig. 7. A. Loss of returning foragers bearing non-magnetized wires (blue markers) in 2011 over a 29-day period. ***B.*** Subsequent recovery of returning foragers during 11 days of relatively minor (K-index ≤4) geomagnetic disturbances (green markers). Green markers are the cumulative intensities of geomagnetic activity in nT from 18 to 21 hours GMT (9 AM to 12 AM pacific time). Four major disturbances to Earth's magnetosphere are indicated by red markers. Bees were released 800 m from their hives. Geomagnetic activity is represented by the cumulative sum of K-indices (nT) preceding (3 hrs.) and during (3 hrs.) each experiment.

Wires on returning foragers were removed automatically (Fig. 1B) from their abdomens by rectangular magnets (10 x 2.5 x 4.5 cm) placed 1.5 cm above hive entrances (9 cm wide). Wires were removed and counted at 10 min time intervals. Recovery of the colour coded wires from bees was 90 to 100 % when released 1 m in front of their entrances. Retrieval magnets were left on hive entrances for 24 hours to determine if additional bees returned after 3 h. Of 1,008 returning bees released at 80 m, 96.8 % returned within 3 h. Nearby hives were also fitted with retrieval magnets at entrances to determine if returning foragers drifted to neighbouring hives: only 2 bees in 1,000 did so.

B. Foragers were also exposed to a fluctuating magnetic field in a laboratory environment. Stationary cups containing freshly collected bees were placed 3 to 5 mm from the perimeter of a rotating circular wooden disk 35 cm in diameter. Two Neodymium magnets (the same as those used to magnetize wires) were attached on opposite sides of the disk's perimeter, with positive ends pointed in the same direction. The disk was rotated by hand 360°, 10 times in one direction, then

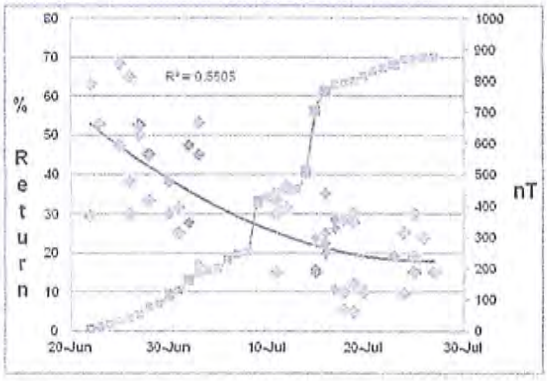


Fig. 8. Loss of returning foragers (blue markers) bearing non-magnetized wires during minor (green markers) and major (red markers) disturbances to Earth's magnetosphere in 2012. Foragers were released 800 m from their hives. Geomagnetic storms are represented by the cumulative sum of K-indices (in nT) preceding (3hrs) and during (3 hr) each experiment.

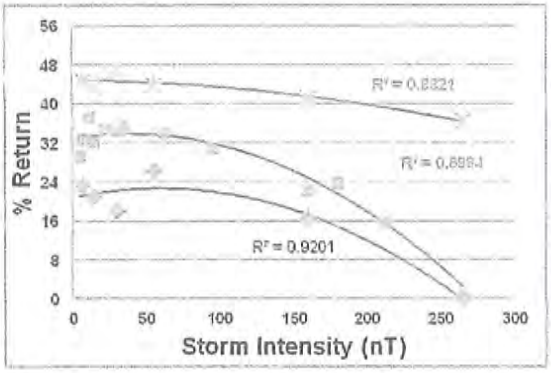


Fig. 9. Return of foragers during natural disturbances to Earth's magnetosphere. Release sites from hives were 380 m (green, triangles), 800 m (red, squares) or 1100 m (blue, diamonds). Magnetic disturbances are expressed in nT (Boulder, Colorado, USA, observatory).

10 times in the opposite direction, for a total of 4 cycles. The procedure lasted 80 seconds and created an alternating magnetic field (+/-, $2x10^{-4}$ T) positive to negative 20 times in one 10-cycle rotation, then negative to positive 20 times in the opposite direction (0.5 Hz). No wires were attached to bees during treatment. Bees were at room temperature and active during exposure to the oscillating magnetic field. During treatment, extra care was taken to not expose control bees, also in stationary cups and at a different location, to magnets, electromagnetic fields or batteries (including cell phones) in the lab environment. A magnetometer placed near control bees did not detect any magnetic field oscillations. After anesthetization, colour-coded, non-magnetized wires were attached to treated and non-treated foragers to monitor when they returned. Bees were then released at 480 m or 800 m distances from their hives and their return rates monitored at 10-minute intervals.

C. During each experiment, disturbances in Earth's magnetosphere were noted: K-index values reported herein were from the NOAA/SWPC observatory located in College Alaska, USA (N65°, W102°) (http.www.swpc.noaa.gov/ftpdir/indices/old_indices/2011_DGD.txt). Compared to other observatory locations in the world, it has the most comprehensive data and is most sensitive to fluctuations in Earth's magnetic field caused by solar flares. The K-index represents the sum of the maximum positive and negative horizontal fluctuation values recorded during each of 8, 3-hour periods. Because K-indices represent a semi-logarithmic scale, midpoints at each K-index range were converted to nT in tables and figures (www.swpc.noaa.gov/info/Kindex.html). For example, a magnitude 5 K-index fluctuates from 70 to 120 nT, for which the midpoint 95 nT was used in data analysis (Boulder Colorado, USA, observatory).

Extraterrestrial proton flux values were obtained from NOAA's geostationary operational environmental orbiting satellite (GOES-13). (http.www.swpc.noaa/ftpdir/indices/old_indices/2012Q2_DPD.txt). The satellite monitors the proton flux arriving at Earth's outer atmosphere as a result of coronal eruptions on the Sun.

D. Six years of winter colony losses were surveyed by Burdick and Caron in northeast, USA (MAAREC Beekeeper Survey, 2006). States included New York, Pennsylvania, New Jersey, Maryland and Delaware. Averaged losses for each winter from 2000/2001 through 2005/2006 were, respectively: 41.7 %, 13.3 %, 30.0 %, 41.0 %, 33.7 % and 23.1 %. During those six winters, from the beginning of August to February (2001 to 2006), major geomagnetic storms that occurred during daylight hours (Eastern Time) were totalled for each of four different K-index ranges (≥5, ≥6, ≥7, ≥8). Then, bee losses per hour for each year were plotted versus each range's total hours (see Fig. 11, for example). Correlation coefficients were determined for each of the 4 graphs.

Data analysis

In appraising whether or not statistically significant differences occur between return rates for magnetically and non-magnetically treated foragers, it must be recognized that uncontrollable fluctuations in wind velocity, temperature and Earth's geomagnetic field occur on a daily basis; those variables can influence bee return rates. Moreover, it is important to recognize that "control" foragers are invalid controls when major geomagnetic disturbances occur during experiments, because their homing abilities are interfered with when K-indices ≥5 take place. In an uncontrollable geomagnetic environment, even minor fluctuations in the K-index probably affect reproducibility

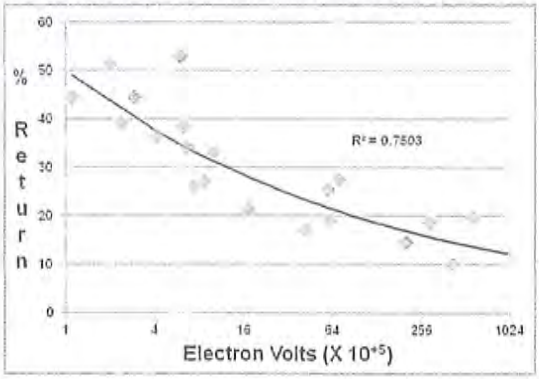


Fig. 10. Forager return rates as a function of the proton flux intensity reaching Earth's outer atmosphere as measured by the NOAA/SWPC Geosynchronous Operational Environmental Satellite (GOES-13). Measurements were from 26 June to 27 July, 2012, a 32 day period that included 8 days when geomagnetic storms of 5 and greater occurred during and 3 hours prior to experiments. Each point represents an average of multiple observations (total=58 observations). The proton flux is proportional to intensity of the sun's solar flares. (www.swpc.noaa.gov/fptdir/indices/old_indices.html).

between experiments. Hence, a relatively lenient 90 % confidence level was selected for use in data analysis. Statistical information involving return times involves the Pearson correlation coefficient (R^2). Histograms indicated return frequencies were skewed for both treatments, so a nonparametric Mann-Whitney test was used to evaluate statistical significance. Most bees returned within a 3-hour period. A similarity in forager return patterns consistently occurred at all release distances tested, usually within 3 hours, and studies involved over 300 experiments conducted over a 2-year period (from June to November). Considering the relevance of honey bees as pollinators and their value to agriculture and food production, null-hypothesis tests and significance levels should be assessed in light of such environmentally uncontrollable sources of variation. This is especially true when evaluating the theory that geomagnetic storms can cause a magnetoreceptive disorder (MRD) in foragers, and thereby lead to a disappearance of adult bees returning to a colony or apiary.

Results

Forager return rates represent the cumulative number of bees that came back to their hives at successive 10-minute time intervals after being released at sites 80 m, 480 m and 800 m from their hives in both easterly and westerly directions. At 1,100 m, bees were released in north and south directions.

A. When foragers bearing non-magnetized wires were released 80 m from their hives, 76.2 % returned within 40 minutes after release, compared to 64.4 % for bees bearing magnetized wires (Fig. 2A). In both cases, respectively, that represented 91.4 % and 88.3 % of all bees that returned after 180 minutes. No additional bees returned after 180 min. Ten minutes after release, the coefficient of variation (CV) was 2.1 times greater for "magnetized" foragers compared to control bees, but the difference gradually declined with time (Fig. 2B).

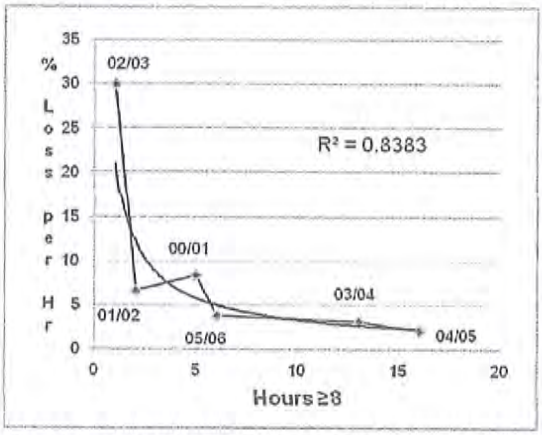


Fig. 11. Correlation of honey bee losses with total hours of K-indices ≥8 from August thru February. Winter bee losses were surveyed by Burdick and Caron (2006) from 2000/2001 to 2005/2006. K-indices ≥8 were from SWPC/NOAA.

When foragers bearing non-magnetized or magnetized wires, respectively, were released at 800 m, 69.0 % and 47.3 % returned 140 minutes after release (Fig. 3A). As occurred at the 80 m location, there was a 2.0-fold increase in the CV at the 10 min time interval; thereafter, it declined (Fig. 3B). Nevertheless, there were greater variations in return rates for 13 of the later 14 observations. Compared to controls, the decrease in return rates for foragers bearing magnetized wires was strong for the first 30 minutes (Fig. 3C) but, thereafter, differences between treated and non-treated bees remained relatively constant and ranged from 27.7 % to 33.5 %. The difference between total return percentages for foragers bearing non-magnetized and magnetized wires was significantly different ($P<0.01$, two-tailed test). As release distances increased, there were progressively greater losses for bees bearing magnetized wires than those with non-magnetized wires (Fig. 4).

Return of untreated foragers during natural disturbances to Earth's magnetosphere were plotted at increasing geomagnetic fluctuation intensities (Fig. 9). As release distances and storm intensities increased, forager losses increased.

B. As with bees carrying magnetized wires, fewer foragers experimentally exposed to an oscillating magnetic field also returned than non-treated foragers. From a 480 m release distance, return rates at 180 minutes for treated foragers were 68.5 % of controls (Fig. 5A), and at the 800 m release distance, 49.9 % of controls (Fig. 5B).

C. When a three hour period (06.00 - 09.00, pacific coast time) was included prior to each experiment (beginning daylight hours), the correlation coefficient declined from 0.931 to 0.560; and when periods included prior 9, 12 and 15 hour periods (night time), correlations of return rates with K-indices declined, respectively, to 0.133, 0.129, 0.124 and 0.091 (Fig. 6).

D. From 7 September to 6 October, 2011, there were four major geomagnetic storms of magnitude 5 or 6 during experiments, and forager return rates declined (Fig. 7A). Thereafter, there were 13 days when the K-index was ≤ 4, and forager return rates gradually improved from approximately 20 % to 80 % (Fig. 7B). Note that variation in return rates between experiments was considerable when the four major geomagnetic storms occurred ($R^2=0.122$), compared to the recovery period ($R^2=0.719$) when major storms were absent, representing a 5.9-fold improvement in correlation coefficients. Geomagnetic intensities, expressed in nT, were expressed cumulatively (Figs 7 and 8) to graphically accentuate the increase in magnetosphere disturbances versus the gradual decline (%) in bee return rates.

From 22 June to 28 July 2012, seven major geomagnetic storms occurred of magnitude 5 or 6 during experiments (Fig. 8). During that 36 day period, return of foragers also gradually declined, ranging from 30 % to 70 % at the beginning of the period, to 5 % to 30 % at the end of the period.

As geomagnetic storm intensities and release distances increased,

the number of foragers that returned decreased (Fig. 9). A similar decline in forager homing ability also occurred as proton flux intensity at Earth's outer atmosphere increased during that same period (Fig. 10).

E. Bee losses reported by Burdick and Caron (2006) for the winters from 2000/2001 through 2005/2006 were progressively more correlated as geomagnetic storm intensities increased from 5 to 8 (expressed as % loss each year vs. total number of hours each year, at K-index ranges ≥5, ≥6, ≥7 and ≥8). The resulting 4 correlation coefficients of bee losses per hour for each progressively increasing K -index range were, respectively, R^2=0.115, R^2=0.311, R^2=0.582 and R^2=0.838 (see Fig. 11, K ≥8, R^2=0.838 for example). When correlation coefficients for each K-index range were plotted as dependently derived variables (y axis) versus increasingly intense independent storm ranges (x axis), a nearly perfect linear relationship of correlation coefficients resulted (R^2=0.998) (Fig. 12).

Discussion

Foragers selected for our experiments included nectar and pollen gatherers. When released at various distances from their hives, statistically significant decreases in numbers of returning bees occurred for those bearing magnetized wires compared to bees with non-magnetized wires. Losses occurred when bees were released in either north - south (1,100 m) or east - west directions (380 m, 800 m). It is noteworthy that variation in return rates for bees bearing magnetized wires were greater than controls in 18 of 19 cases (C/s, Figs 2B, 80 m; and 3B, 800 m). As release distances increased, progressively fewer bees with attached magnets returned to their hives compared to those without magnets (Fig. 4). At the longest distance (1,100 m) evaluated, 64.7 % of "magnetized" foragers returned relative to controls. When bees were exposed to a brief (80 sec) oscillating magnetic field, their return rates also decreased as release distances increased from 380 m to 800 m. Again, it appears a forager's magnetoreception sense is more involved with homing as distances increase. Of importance is that the colonies used in tests were examined during each experiment and exhibited no disease symptoms. Therefore, during these studies, which included multiple geomagnetic storm episodes in 2011 and 2012, failures of foragers to return were not due to a pathogen or pest: losses were more likely to have been due to an induced magnetoreception disorder (MRD).

It should be noted that initially, a 2.1 fold increase in variation of return rates occurred when magnetized bees were released at 80 m from their hives (Fig. 1B), a relatively short distance, which was close enough to their hives that visual or celestial orientation mechanisms would have been expected to be dominant (von Frisch, 1967). Since 95 % of bees eventually returned to their colony after 180 minutes at the 80 m release site (Fig. 1A), it appears that other homing cues eventually became overriding at short distances. In addition, a 2.0-fold increase in the coefficient of variation was initially obtained at the 800 M release site (Fig. 3B), also suggesting bees bearing magnets became confused or disoriented and that their magnetoreceptive sense was probably involved, at first, in their homing ability. The data supports a conclusion that orientation can rely on multiple senses, which is consistent with research reported by Dovey *et al.* (2013).

Foragers freed at north - south release sites (1,100 m) had magnets aligned with Earth's magnetic field. They too exhibited a MRD. Therefore, it was unlikely magnets were exerting a torque that may have interfered with homing capability when foragers were released in east - west directions. Because missing bees rarely returned 24 hours after release (at distances greater than 80 m), a beekeeper may well conclude, as in the past, that they had "evaporated", "disappeared" or "dwindled." Single bees from experimental colonies that were kept in cups either in a lab environment or outdoors on their hive lids did not survive longer than 10-12 hours.

Foragers used in these studies were healthy and from strong colonies, which were monitored regularly and showed no disease symptoms or pest problems (except for an occasional mite) and they continued to thrive after each experiment; so, a pathogen, parasite, pest or a combination of them was not the cause for their failure to return. These observations indicate a contagion was not involved (symptom #7). Moreover, bees were maintained and released in a suburban environment, so an agricultural pesticide was not likely the problem either. A reasonable conclusion is that induced magnetic fields caused their magnetoreception sense to malfunction. Thereafter, they became disoriented and eventually lost, an outcome that is consistent with symptom #1: a loss of adult foragers. These

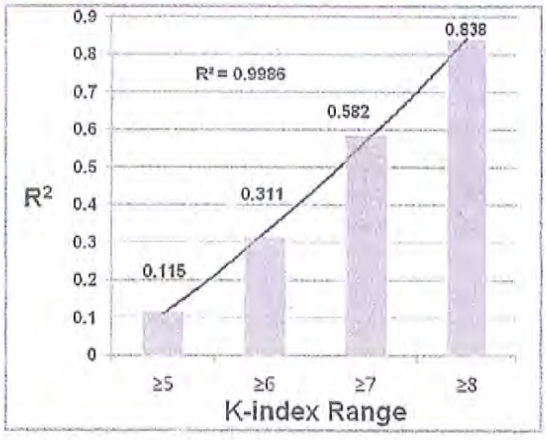


Fig. 12. Correlation of 4 geomagnetic storm ranges with independently derived correlation coefficients. The correlation coefficient indicated for each K-index range represents the value obtained when % colony losses per hour were plotted versus hours of storms for each of 4 K-indice ranges over 6 winter periods. (See Fig. 11, K ≥8, for example.) Graphs of the other K-index ranges (≥5, ≥6, ≥7) are not included: only their correlation coefficients are indicated.

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Table 1. Colour of pollen pellets removed from foragers' corbiculae. Values represent percent of total.

SITE	POLLEN	Hive #1	Hive #2	Hive #3	Hive #4	Hive #5
1	Orange	0.0	3.7	0.0	39.5	4.5
2	Cream	80.0	14.8	17.1	13.2	68.2
3	Yellow	0.0	25.9	14.3	0.0	4.5
4	Brown	6.7	25.9	51.4	31.6	4.5
5	Green	6.7	18.5	8.6	2.6	13.6
6	Red	6.7	11.1	8.6	13.2	4.5

observations support the hypothesis that at long distances, an organism's magnetoreception sense becomes increasingly important for orientation and homing.

Lindauer and Martin (1972) also demonstrated direct evidence that a magnetic sense was involved in orientation of adult bees. They reported foragers' dance orientation changed when comb was placed in the presence of a compensated (weakened) magnetic field. Further proof of orientation using a magnetic sense in honey bees was also provided by Collett and Baron (1994). They reported a magnetic sense was involved in orientation in the rain under a completely overcast sky, and even when the sun's light was depolarized and its ultra violet radiation eliminated.

During the course of these studies, two series of major geomagnetic storms occurred (K-index 5 and 6) which altered Earth's magnetic field and untreated forager return rates declined progressively. This happened during fall 2011 (four storms, Fig. 7) and summer 2012 (seven storms, Fig. 8) when queens were actively laying eggs and building up the colonies population. One possible explanation for the gradual "dwindling" of return rates for bees on days when there were no storms is that immature bees had replaced adult foragers who had gone astray on days when storms occurred. Without a fully developed magnetoreception sense, immature bees that replaced adult foragers would be vulnerable to becoming disoriented and then lost, especially when released at long distances from their hive. This explanation is consistent with a 9 to 15 day period involved with development of their magnetoreceptive sense (Kuterbach and Walcott, 1986; Manning, 2009).

Consistent with this interpretation was the subjective observation that foragers collected after geomagnetic storms occurred were smaller and hairier in appearance, crude indicators used by beekeepers and entomologists to identify younger bees from older bees. This scenario too is consistent with symptom #2: an absence of sick or dead bees in or near the hive. Thus, one important side effect of geomagnetic storms is that foraging responsibly probably shifted onto a progressively younger work force whose magnetoreception sense was under developed. These observations are consistent with symptom #5: afflicted colonies contain fit, young adults. Under these circumstances, a colony can recover, unlike presence of a severe disease. However, in the fall when queens cease egg-laying responsibilities, a loss of foragers ("autumn collapse") would result in an undersized cluster of over-wintering bees, rendering a colony highly susceptible to die-off, especially in northern latitudes, which is consistent with symptom #6.

On 6 November 2001, Esquvel *et al.* (2007) were measuring the flight behaviour of the stingless bee Guirucu (*Scwarziana quadripunctata*) as it exited its earthen hive. A statistically significant difference occurred in the angle of departure when a spontaneous geomagnetic storm occurred (229 nT maximum fluctuation, K-index = 7): the departure angle decreased from 39° to 16°, a 23° difference. When seeking foraging sites, honey bees can fly about 30 km / h (20 mph). Theoretically, they would be nearly 90 km (60 miles) off course three hours after departing their entrance, which is well beyond their usual foraging range. At such long distances, it is unlikely foragers would have enough energy or be able to find their way back to their colony using visual, celestial, odour or magnetoreceptive senses, and is consistent with symptom #2 - no dead bodies in or near hives. Of equal importance is being 23° off-course when foragers return from a long foraging trip and unable to use other cues, thereby causing them to be substantially off course and, consequently, unable to locate their hive.

Data indicates, fortunately, that losses in homing ability during geomagnetic storms are not permanent. Most experiments reported herein began about three hours after sunrise. When major geomagnetic storm intensities were compared to forager losses during the course of experiments, a significant correlation resulted (R^2=0.93, Fig. 6). However, when major storm activity was considered at progressively earlier 3 hour time intervals extending back 15 hours, the correlations declined sharply, to approximately R^2=0.11. Apparently, adult foragers can "reset" their internal compass and regain their homing ability after storms occurred at night while they were clustered at the entrance or inside the hive body, which is nevertheless pervious to magnetic fluctuations. This appears not to be the case for captured foragers who were exposed to an oscillating magnetic field, taken to a distant site and then released. It appears, therefore, foragers need to put their hive's location in perspective while they are present in the hive's local

magnetic field.

Iron in the form of super paramagnetic magnetite (Fe_3O_4) is a proposed magnetic field receptor molecule in adult honey bees (Hsu and Li, 1993). Iron accumulates gradually in bees after eclosion (Manning, 2009; Kuterbach and Walcott, 1986) and maximum levels peak at the time when honey bee workers commence foraging behaviour (Kuterbach and Walcott, 1986). It is important to recognize that homing ability is not an either / or condition, but develops gradually as bees develop.

During maturation, young bees must still leave the hive to defecate and in doing so visually familiarize themselves with surrounding areas. (Capaldi and Dyer, 1999; Collett and Baron, 1994). Therefore, before maturation, bees must rely on visual, celestial or odour cues for orientation when near their hives, but they would be at risk to becoming lost when released at longer distances. The recovery of homing ability after 13 days (Fig. 9B) is consistent with a 9 to 15 day period involved with their accumulation of iron and development of their magnetoreceptive sense (Kuterbach and Walcott, 1986). It is likely that the number of young workers remaining with the queen will vary depending on the reproductive proficiency of a queen. It is likely that after adult foragers suffer a MRD episode, younger workers can forage nearby food sources and use visual cues for homing. Consistent with these observations is the finding (Menzel *et al.*, 2005) that captured, displaced bees either exhibited a slow search flight with frequent changes of direction in which they attempt to "get their bearings" (those possessing an immature magnetoreception sense); or, they exhibit a direct path to their hive or feeding station (those possessing a mature magnetoreception sense). This difference likely resulted because researchers did not differentiate immature bees from mature foragers when they were captured.

Intracellular organelles involved with magnetoreception contain magnetite and are termed magnetosomes (Frankel, 2009; Galland and Pazur, 2005; Winklhofer, 2010). It has been hypothesized that the receptor molecule contains a pair of radicals that are involved in detection of the geomagnetic field (Lau *et al.*, 2010). The positive correlation of intense proton flux intensities detected by the GOES-13 satellite with forager losses provides another mechanism as to why adult foragers become lost, in addition to major fluctuations in Earth's magnetosphere caused by solar storms. Following a coronal eruption and after protons enter Earth's atmosphere those subatomic particles have potential to interfere with the separation, orientation and 3-dimentional rotation of the dual electron fields in the proposed magnetoreceptor molecule (Lau *et al.*, 2010). Interactions between protons and electrons would likely annihilate the molecule's anisotropy, and thereby result in reduced directional sensitivity.

Magnetic fields induced by magnetized wires were static, relatively weak and ranged from 2 to 2.5 nT, about 5 % of Earth's magnetosphere at 50° latitude, and more than 10 times greater than control wires. Induced magnetic fields were to some extent comparable to a geomagnetic K-index of 3 (20 to 40 nT), which fluctuates (non static), and is considered a minor perturbance to Earth's magnetosphere. Though magnetized wires attached to foragers were relatively weak, an interference of homing ability was detected, indicating bees are more sensitive than previously estimated (4.3 nT) (Kirschvink *et al.*, 1997).

It seems reasonable that as storm intensities increase beyond magnitudes 5 and 6 - the most intense encountered during these studies - a forager's ability to return would diminish proportionately. Indeed, this appears to be the case. Losses that occurred during the six year survey reported by Burdick and Caron (2006) were plotted against four different ranges of geomagnetic disturbances: K-indices ≥5, ≥6, ≥7 and ≥8 (Fig. 11). Each of the four independently derived correlation coefficients of bee losses, for each individual range, were positively and linearly correlated with storm intensities which extended from magnitudes 5 to 8 (Fig. 12). Such extensive bee loss surveys are rare and geomagnetic records only date back to 1995; nevertheless, the correlations support research described herein involving loss of returning foragers as fluctuations in Earth's geomagnetic field increase. Interestingly, colony losses per hour declined rapidly with time (Fig. 11). A simple explanation for this pattern is that a rapid loss of foragers occurs at first. Then, a colony's subsequent exposure to additional geomagnetic activity has less of an effect because most foragers have already become "lost."

The MAAREC survey is unique in that it included colony loss data near a peak in a sunspot cycle (2000-2003) as well as a trough (2004 -2006). Honey bee losses, like sunspot cycles, seem to occur in cycles as well (Wilson and Menapace, 1979). Information from the northeast correlated extraordinarily well (R^2=0.998) with geomagnetic storm intensities. More recent national surveys contain an unacceptable amount of anchoring bias in that they were conducted only during a lull in the sunspot cycle (2007-2011) (vanEnglesdorp *et al.*, 2012). Obviously, to be unbiased and statistically legitimate for comparative purposes, honey bee loss surveys need to occur during a peak in a sunspot cycle as well.

A MRD is consistent with the sudden loss of adult bees observed by beekeepers and entomologists involving CCD. Two of their common observations are that some apiaries with CCD symptoms have been identified near neighbouring apiaries with no CCD symptoms; and, colonies within an apiary often exhibit symptoms but others do not. Apiculturists should recognize that foragers from different colonies do not forage at the same sites or in equal numbers (Table 1). Moreover, they should be aware that beekeepers often use different genetic strains of queens (Carnolian, Italian, Russian, etc.) in different apiaries. These conditions explain why specific apiaries and / or colonies exhibit MRD symptoms and others do not, for the following reasons.

Firstly, evidence presented indicates honey bee losses due to

aberrant magnetic fields grow more severe as foraging distances increase. Therefore, colonies foraging at long distances would be affected more than those foraging nearby sites, where visual cues would predominant. Thus, not all colonies would be affected equally. Nor would subtle differences in return rates be noticed unless precise measurements of returning bees were made. For example, five colonies were examined regarding what colour pollen their returning foragers had on their legs (Table 1). Evidence clearly demonstrates the diversity of pollens that different colonies were foraging and the relative numbers (%) of foragers doing so. Assuming the cream-coloured pollen that colonies # 1 and # 5 collected came from a site 5,100 m (3 miles) from their hives, then they would be extremely affected by a geomagnetic storm when returning, and suffer CCD like symptoms – adult bee losses of 80.0 % and 68.2 %, respectively. Colonies #2, #3 and #4 would be relatively unaffected (losses of 14.8 %, 17.1 % and 13.2 %): this hypothetical example assumes the other three foraging sites are closer to hives. The same scenario would occur for colony #3 whose foragers were collecting brown-coloured pollen (51.4 %). The colony would lose nearly half their adult foragers if they were gathering that pollen at a long distance from their hive. The other four colonies would show losses to lesser degrees, ranging from 4 % to 32 %. In both examples, geomagnetic storms would produce the common observation that some hives appear to be affected, others do not.

Secondly, an important consideration of why some colonies and apiaries demonstrate MRD symptoms during a geomagnetic storm and others do not involves genetics. A honey bee's phenotype is the composite of its observable characteristics or traits, such as homing behaviour. Natural selection only acts on phenotypes of organisms. Genes responsible for resistance or susceptibility to extreme geomagnetic fluctuations are the entities that are ultimately reproduced and transmitted over generations. It is likely that no queen breeder has ever selected for resistance to severe geomagnetic disturbances. Nor has natural selection by "Mother Nature" since the last ice age 10,000 years ago, a mere speck in an evolution time-scale. That's when bees migrated northward from the equator where DNA and fossil evidence indicates they evolved (Whitfield *et al.*, 2006), and where Earth's magnetic disturbances are less than half that of the northern hemisphere. It is reasonable to expect, therefore, there is diversity amongst honey bee strains as to their susceptibility. Once more, variation amongst queens regarding genetic vulnerability would account for observations of why some apiaries or colonies are affected by geomagnetic storms and others are not.

Earth's magnetosphere is usually relatively stable, providing a reliable reference for honey bee orientation purposes; but, it is disrupted periodically. Severe coronal mass ejections on the Sun result in solar storms containing sub atomic particles along with their magnetic fields that typically take about 1 to 2 days to reach Earth. Major storms can occur at any time, even during lulls in sunspot cycles. Upon impact with Earth, they disturb its ambient magnetosphere, causing geomagnetic storms and intense proton fluxes that typically last 2 to 4 days. Under severe circumstances, those organisms that rely on Earth's magnetic "lines" for orientation can become disoriented during migrations or foraging at relatively long distances from their nests.

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EXHIBIT 6-K

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Mark Twain 345kV Transmission Line Project

Marquardt, Shauna <shauna_marquardt@fws.gov> Mon, Jun 23, 2014 at 3:28 PM
To: "Lynn, Kenneth W" <KLynn@ameren.com>
Cc: Shauna Marquardt <shauna_marquardt@fws.gov>

Kenny,

I am going to be taking the lead on the Mark Twain 345kV Line project. To obtain your official list of species that could be present in your project area, you can use our new project review website, IPaC. I have attached instructions on how to obtain a species list that serves as official correspondence from us. Based on this species list you will be able to further evaluate potential impacts to species that could be present.

Based on the information you submitted, I do have a few initial thoughts for you consider. Both Indiana and northern long-eared bats will show-up on your species list. This project is basically going right through the part of the state we consider to have the most maternity colonies of Indiana bat. We know a little less about northern long-eared bats here, but we do know they occur and will be concentrated in larger forested blocks.

Although you have not yet selected your alignment, I can tell you that if there will be more than 5 acres of mature forest removed to complete this project, bat surveys will be necessary. It could be prudent to skip the time and expense of a highly detailed habitat assessement and use a more general assessment to guide the level of effort and locations of bat surveys. What is the timeline of this project? Seems like we are a little ways out? I am happy to visit with you about alignment alternatives when you get to that point.

Please feel free to call or email with questions as you move into the next stages of this project.

Shauna

~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
Shauna Marquardt
Fish and Wildlife Biologist
U.S. Fish and Wildlife Service
Missouri Ecological Services Field Office
101 Park De Ville Drive, Suite A
Columbia, MO 65203
573/234-2132 ext. 174 (office)
573/234-2181 (fax)
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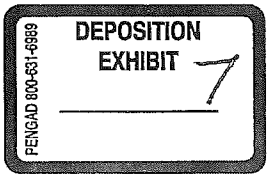
IPaC Instructions.pdf
148K



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United States Department of the Interior

FISH AND WILDLIFE SERVICE
Missouri Ecological Services Field Office
101 Park DeVille Drive, Suite A
Columbia, Missouri 65203-0057
Phone: (573) 234-2132 Fax: (573) 234-2181

December 5, 2014

Mr. Kenny Lynn
Ameren Transmission
1901 Chouteau Ave
PO Box 66149
St. Louis, Missouri 63166-6149

Dear Mr. Lynn:

This letter is in response to the revised route alternatives for the Ameren Mark Twain Transmission Project received in our office on October 6, 2014. The U.S. Fish and Wildlife Service (Service) is providing this response under the authority of the Fish and Wildlife Coordination Act (16 U.S.C. 661 et seq.), National Environmental Policy Act of 1969 (42 U.S.C. 4321-4327), Migratory Bird Treaty Act (16 U.S.C. 703-712), and Endangered Species Act of 1973, as amended (16 U.S.C. 1531-1543).

Federally Listed and Proposed Bat Species

The Mark Twain Transmission Project consists of two major segments, Maywood to Zachary and Zachary to State Line. For each major segment, Ameren has reduced the potential alternatives within each segment to two alternative routes per segment. The two routes for Maywood to Zachary run through Marion, Shelby, Lewis, Knox, and Adair counties. The two routes for Zachary to State Line run through Adair and Schuyler counties. Every county intersected by the proposed alignment is known to be occupied by maternity colonies of the endangered Indiana bat (*Myotis sodalis*). Furthermore, based on past surveys, the routes pass through five known maternity colony home ranges. Many areas along the proposed alignment have suitable habitat but likely have not been surveyed for federally listed bats. These areas of suitable habitat in the aforementioned counties have a high likelihood of occupancy by Indiana bats. The proposed endangered northern long-eared bat (*Myotis septentrionalis*) also occurs in northeast Missouri and has been documented in Lewis County.

Removal of trees during the hibernation season of bats (November 1 to April 1) prevents the direct take of tree-roosting bats. However, there is still potential for indirect take through habitat loss and degradation. In a June 23, 2014 email, Shauna Marquardt of my staff relayed to you the

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need to conduct surveys for federally listed bats along the proposed alignment in order to determine where the species might occur and to identify roost trees or roosting areas. These data are necessary to identify areas that should be avoided and to help develop minimization measures where necessary. Guidelines for conducting summer surveys for Indiana bats are available here: http://www.fws.gov/midwest/Endangered/mammals/inba/inbasummersurveyguidance.html.

Migratory Birds

Restricting woody vegetation clearing to winter months also serves to prevent injury to or mortality of most nesting migratory birds. Raptors and owls, however, breed during late winter and early spring. Because these species are protected under the Migratory Bird Treaty Act, we recommend implementing measures to avoid or minimize impacts to active nests.

While direct take may be avoided by clearing woody vegetation during the winter, the Service is concerned about the effects of permanent loss of habitat from clearing the ROW. According to the proposed alignments you provided, the project will consist of approximately 100 miles of new transmission line and associated ROW through the forest-limited landscape of northeast Missouri. ROW construction for each alternative route will require tree and woody vegetation removal. Should the final alignment require substantial removal of forested habitat, we would like to discuss with you options to replace this habitat elsewhere or to protect other areas containing comparable habitat. We have worked with other companies involving the removal of mature forested habitat associated with ROWs and would be happy to provide examples of mitigation measures which have been implemented to benefit migratory birds.

Finally, when selecting the final alignment, Ameren should minimize overall forest degradation and loss and should avoid fragmentation of existing forest patches to the extent practical to reduce impacts to federally listed bats and migratory birds. At this time, the Service cannot recommend specific routes because each of the four alternatives intersects with known Indiana bat maternity colony home ranges. The Service requests a meeting with Ameren and the Missouri Department of Conservation to coordinate efforts on the Mark Twain Transmission Project before the final alignment is selected. Should proposed route alternatives change, or if you have questions concerning this response, please contact Shauna Marquardt at (573) 234-2132, extension 174.

Sincerely,

Amy Salveter
Field Supervisor

Cc: MDC, Jefferson City, MO (Attn: Jennifer Campbell-Allison, Policy Coordination)

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MISSOURI DEPARTMENT OF CONSERVATION

Headquarters
2901 West Truman Boulevard, P.O. Box 180, Jefferson City, Missouri 65102-0180
Telephone: 573-751-4115 ▲ www.MissouriConservation.org

ROBERT L. ZIEHMER, Director

October 16, 2014

Mark Twain Transmission Project
C/O Burns and McDonnell
Attention: Jennifer Berry
9400 Ward Parkway
Kansas City, MO 64114

RE: MARK TWAIN TRANSMISSION PROJECT - ENVIRONMENTAL COMMENTS

Ms. Berry:

The Missouri Department of Conservation (Department) is in receipt of your request for environmental concerns related to the Mark Twain Transmission Project.

The Department is the state agency responsible for forest, fish and wildlife resources in Missouri. As such, the Department participates in project review when a project might affect those resources. Department comments are for your consideration to avoid, minimize and mitigate project impacts in Missouri.

PROJECT DESCRIPTION

The proposed transmission line would total approximately 100 miles from Palmyra to Kirksville to the Iowa border. Version 10 of the route network (provided by Ameren UE staff) includes the counties of Schuyler, Adair, Knox, Lewis, Shelby and Marion. Transmission line support towers would have dimensions of up to 130 feet in height with a cleared right-of-way of approximately 150 feet.

LISTED AND PROTECTED SPECIES

Enclosed find a Natural Heritage Review Report for the proposed Mark Twain Transmission Line based on Alignment Version 10 provided by Ameren UE to the Department by email on August 15, 2014.

Multiple natural heritage records for Indiana bat (*Myotis sodalis*) exist adjacent to the proposed routes. You or your client may be required to consult with the U.S. Fish and Wildlife Service pursuant to the Endangered Species Act. The U.S. Fish and Wildlife Service may be contacted by phone at 573-234-2132 or by mail at U.S. Fish and Wildlife Service, Ecological Services, 101 Park Deville Drive, Suite A, Columbia, Missouri 65203-0007.

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Bald eagles (*Haliaeetus leucocephalus*), a federally protected species under the Bald and Golden Eagle Protection Act, are known to nest near streams and rivers within the range of this project. Work managers should be alert for nesting areas within 1500 meters of project activities and follow federal guidelines at: http://www.fws.gov/midwest/MidwestBird/EaglePermits/baeatakepermit.html. In addition, you may wish to request assistance from the U.S. Fish and Wildlife Service as described above.

SPAWNING STREAM SEASONAL CONSTRUCTION RESTRICTIONS

The following waterways have seasonal restrictions that could impact construction timing, if work would occur below the ordinary high water mark: South Fabius River and Troublesome Creek (Marion County). The affected locations are described in the enclosed Natural Heritage Review Report and shown in the enclosed map. Any work conducted below the ordinary high water mark in these stream segments should be avoided between March 15 and June 15. Management recommendations for construction projects affecting Missouri streams and rivers are also enclosed for reference.

The South Fabius River watershed supports a diverse aquatic community. Surveys conducted from 1941 to 1999 in the watershed revealed the presence of 58 fish species, four crayfish species, and 19 freshwater mussel species. Three species have been collected in the watershed that are part of the Communities of Conservation Concern Checklist, namely American eel, ghost shiner, and Mississippi silvery minnow. Special designation has been given to the watershed because of these robust aquatic communities. A portion of the watershed was designated an Aquatic Conservation Opportunity Area in 2006, and a Priority Watershed in 2011. Sampling in 2008 showed robust aquatic communities in the South Fabius Aquatic Conservation Opportunity Area near the potential project sites. Many of the aquatic species found in the watershed rely on clean, cool and high-quality habitat. Forested riparian corridors are critical to maintaining these high-quality aquatic systems. Degradation of these high-quality habitats could result in losses of biological diversity.

EXISTING CONSERVATION EASEMENTS

The Department holds interest in two conservation easements that precede proposed route segments A1 and A2.

Proposed segment A2 crosses the Bringer Stream Stewardship Trust Fund Easement (Marion County, T59N, R07W, Section 15 and 16) as seen in Figure 1. This easement is part of an In-lieu-Fee Mitigation (ILF) instrument originally purchased by the Missouri Conservation Heritage Foundation in 2006. This perpetual easement compensated landowners to maintain the existing condition of a wooded riparian corridor along the

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watercourse for the purpose of sustaining fish, wildlife, forest and riparian values, as described in the enclosed Stream Stewardship Trust Fund Conservation Easement. A change of condition, such as removal of riparian vegetation, would violate the terms of the Bringer Conservation Easement and the In-lieu-Fee instrument. At a minimum, a change of condition of this parcel would require an amendment to the agreement and repayment of the purchase price plus interest to the Missouri Conservation Heritage Foundation for the affected portion of the easement parcel.

The proposed route A2 would impact two portions of the Bringer easement for an estimated total of 3.95 acres. The proposed route A2 would bisect the easement into two unconnected portions. Short term impacts of the proposed route segment A2 at the Bringer easement would likely include conversion of riparian corridor to shrubs and grasses, and possibly soil compaction. Long term impacts of this conversion would likely result in a diminished riparian function offered by existing trees along the watercourse. Shrubs and grasses provide a lesser level of stream bank protection from erosion than trees because their root networks are more shallow than those of trees. Unlike trees, shrubs and grasses provide no shade for the stream channel. Riparian trees offer stream shading which maintains lower water temperatures and increased dissolved oxygen levels during the warm seasons. Many aquatic wildlife have an upper thermal tolerance for survival, growth and reproduction that is better served by stream shading. In addition, aquatic wildlife require a minimum dissolved oxygen content in river water which cannot be sustained diurnally during the warm season without stream shading.

Pages 12 and 13 of the enclosed ILF mitigation instrument between the U.S. Army Corps of Engineers, Kansas City District and the Missouri Conservation Heritage Foundation Stream Stewardship Trust Fund describe allowed and restricted activities on the parcels for which the perpetual easement applies.

Proposed segment A1 crosses the Bevill Stream Stewardship Agreement Easement (Marion County, T59N, R08W, Section 25), as seen in Figure 2. This perpetual easement was purchased by the Department in 1996 as part of a Stream Stewardship Agreement. The agreement compensated landowners to maintain the existing condition of a wooded riparian corridor along the watercourse for the purpose of sustaining fish, wildlife, forest and riparian values, as described in the enclosed Stream Stewardship Agreement Easement. A change of condition, such as removal of riparian vegetation, would violate the restrictions contained in the easement. At a minimum, a change of condition of this parcel would require repayment of the purchase price plus interest for the affected portion of the easement parcel.

An estimated 0.80 acres of the Bevill easement would be impacted by proposed route segment A1. The proposed route A1 would bisect the easement into two unconnected

portions. Short term impacts could include vegetation conversion from riparian corridor to shrubs and grasses, as well as soil compaction. Similar to the impacts on the Bringer Easement, long term impacts of this conversion on the Bevill easement would likely result in a diminished riparian function.

CONCLUSION

In consideration of the Department's responsibility to manage fish, wildlife, and forest resources held in the public trust, the least environmentally damaging route segment would be a modified form of route A2 that would completely avoid the Bringer Stream Stewardship Trust Fund Conservation Easement.

Thank you for the opportunity to provide comments. Note that this response does not preclude other comments the Department may provide under the Clean Water Act permitting process or the National Environmental Policy Act, if applicable. If you have any questions about these comments, please contact me at (573) 522-4115, Extension 3159 or by email at jennifer.campbell-allison@mdc.mo.gov.

Sincerely,

JENNIFER CAMPBELL-ALLISON
POLICY COORDINATOR

JCA/ak

Enclosures

c: Chris Wood, Burns & McDonnell
Peggy Ladd, Ameren UE
Kenny Lynn, Ameren UE
Brian Holderness, Ameren UE
Shauna Marquart, U.S. Fish and Wildlife Service
Marvin and Loretta Bringer, Bringer Stream Stewardship Trust Fund landowner
Edward and Betty Bevill, Bevill Stream Stewardship Agreement landowner
Chris Vitello, Missouri Conservation Heritage Foundation

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MISSOURI DEPARTMENT OF CONSERVATION

Headquarters
2901 West Truman Boulevard, P.O. Box 180, Jefferson City, Missouri 65102-0180
Telephone: 573-751-4115 ▲ www.MissouriConservation.org

ROBERT L. ZIEHMER, Director

November 21, 2014

Mark Twain Transmission Project
C/O Burns and McDonnell
Attention: Jennifer Berry
9400 Ward Parkway
Kansas City, MO 64114

RE: MARK TWAIN TRANSMISSION PROJECT - ENVIRONMENTAL COMMENTS

Ms. Berry:

This letter provides a supplemental response to Ameren's request for environmental concerns related to the Mark Twain Transmission Project and is a part of the Department of Conservation (Department) response provided in a letter to you dated October 16, 2014.

As indicated previously, the Department is the state agency responsible for forest, fish and wildlife resources in Missouri. As such, the Department participates in project review when a project might affect those resources. Department comments are for your consideration to avoid, minimize and mitigate project impacts in Missouri.

PROJECT DESCRIPTION

The proposed transmission line would total approximately 100 miles from Palmyra to Kirksville to the Iowa border. Version 10 of the route network (provided by Ameren UE staff) includes the counties of Schuyler, Adair, Knox, Lewis, Shelby and Marion. Transmission line support towers would have dimensions of up to 130 feet in height with a cleared right-of-way of approximately 150 feet.

CONTIGUOUS FOREST BLOCKS

A number of the alignments proposed as of the October 2014 Open House will result in fragmentation of woodland habitat, including forest blocks greater than 150 acres. The northerly route from Maywood to Zachary (comprised of segments A2, A6, A9, A14) fragments the fewest forest blocks.

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Large forest blocks provide important habitat for wildlife. These habitat types are rare in present day northern Missouri and are utilized by neotropical migrant birds, currently in decline, as well as both game and non-game wildlife. Some neotropical migrant bird species are forest interior species and fragmentation of timber blocks leaves them vulnerable to brood parasitism from the brown-headed cowbird and predation. While edge habitat benefits habitat generalist species of birds, specialized species that require forest/woodland interiors are vulnerable to fragmentation caused by forest/woodland disturbances and would likely decline from a transmission line transecting the forest/woodland block.

Large forest blocks are associated with diverse wildlife species. For example, Henry Sever Lake Conservation Area is approximately 300 acres of forest and woodland habitat that supports 29 neotropical migrant bird species. Large timber blocks on the proposed routes range from 173 to 1,222 acres and likely include the same bird species, as well as additional species.

Forest blocks that would be impacted by the remaining proposed route segments on the Maywood to Zachary route are as follows:

- A2 would fragment a forest block approximately 300 acres in size at T60N, R8W Section 36 and T60N, R7W, Sections 31 and 32.
  - Two *Myotis sodalis* (Indiana bat) records are located within six (6) miles of where the A2 route segment and the subject forest block intersect.
- A3 would fragment the following forest blocks:
  - Approximately 1,222 acres: T59N, R9W, Sections 9, 10, 11, 14, 15, 22, and 23;
    - One (1) *Myotis sodalis* record within five (5) miles.
  - Approximately 181 acres: T60N, R12W, Sections 23-24;
  - Approximately 206 acres: T59N, R11W, Section 13 and T59N, R10W, Section 18;
  - Approximately 440 acres: T60N, R13W, Sections 1 and 2; and T61N, R13W, Section 36; and T61N, R12W, Section 31.
- The eastern portion of A7 includes a large forest block. According to Department records, this area includes a known Blue Heron rookery. The landowner reports that this rookery is still active.
- A13 would fragment the following forest blocks:
  - Approximately 293 acres: T61N, R14W, Sections 22 and 23;
  - Approximately 223 acres: T61N, R14W, Section 24.

Forest blocks that would be impacted by the remaining proposed route segments on the Zachary to State Line route are as follows:

- B9 would fragment a forest block (approximately 652 acres) at T65N, 15W, Section 12 and T65N, 14W, Sections 7,8 and 18.
  - Eight (8) *Myotis sodalis and* one (1) *Lasionycteris noctivagans (*silver-haired bat) records are known within four (4) miles of this forest block.

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- B13 would fragment a forest block (approximately 270 acres) at T66N, R15W, Sections 31 and 32.
  - Five (5) *Myotis sodalis* and one (1) *Lasionycteris noctivagans* (silver-haired bat) records are known within 3 miles of this forest block.
  - Two known roosting sites are located 1.4 miles from this forest block, and are located within 0.17 miles of the proposed B13 route segment.
  - This block is adjacent to another 204 acre block at T66N, 15W, Section 31, separated by a farm road. These two blocks effectively form a 474 acre block, and it is located within four (4) miles of several other large timber blocks.

You or your client may need to consult with the U.S. Fish and Wildlife Service (573-234-2132) regarding Endangered Species Act and Migratory Bird Treaty Act compliance.

EXISTING EASEMENTS

Please refer to the earlier letter to you, dated October 16, 2014, regarding impacts to the Bringer and Bevill easements that would be impacted by route segments A2 and A1, respectively.

The South Fabius River is an important river in the northeastern portion of Missouri. Its ecological integrity and diverse aquatic community are reflective of the relatively wide and contiguous riparian woodlands and stable stream channels found in the watershed. As currently proposed, segment A2 would impact 3.95 acres of the Bringer easement, or segment A1 would impact 0.8 acres of the Bevill easement. Impacts of the proposed transmission line route segments on these easements will include riparian woodland fragmentation and an increased risk of stream channel instability.

An alternative to crossing one of these easements should include avoidance of the easement by routing around the parcel. Shapefiles of these easements were provided to Chris Wood by email on October 22, 2014.

If it is not possible to avoid the subject easement, impacts should be minimized by crossing perpendicular to the stream to reduce the area of land disturbed by right-of-way clearing.

As previously stated, a modified form of route segment A2 would appear to be the least environmentally damaging to forest, fish and wildlife resources and the Department's interest in these existing stream easements.

CONCLUSION

As presented in October 2014, the routes from Maywood to Zachary and the routes from Zachary to State Line appear to create potential impacts to forest, fish and wildlife resources in Missouri. The northerly route from Maywood to Zachary comprised of segments A2, A6, A9, A14 appears to create the fewest impacts to these resources. Alternatives and modifications to the remaining proposed route segments could focus on

first avoiding, then minimizing, and finally mitigating impacts to forest, fish and wildlife resources.

Avoidance measures could include upgrade of existing transmission lines rather than clearing a new right of way.

Minimization measures could include paralleling the new line to existing transmission lines to avoid new fragmentation events and minimize the total number of cleared acres for the project. Another minimization measure could consider routing around forest and woodland blocks of greater than 150 acres, rather than bisecting these forest blocks.

Avoidance and minimization of impacts to the Bringer or Bevill easements are strongly encouraged. Avoidance could include routing around the easement. If avoidance were not possible, minimization could include crossing at a different location within the easement or crossing perpendicular to the waterway.

If it would be helpful, the Department would be willing to meet with Ameren, its consultant, and the U.S. Fish and Wildlife Service to discuss Department comments provided for this project.

Thank you for the opportunity to provide comments. Note that this response does not preclude other comments the Department may provide under the Clean Water Act permitting process or the National Environmental Policy Act, if applicable. If you have any questions about these comments, please contact me at (573) 522-4115, Extension 3159 or by email at jennifer.campbell-allison@mdc.mo.gov.

Sincerely,

Jennifer Campbell-Allison

JENNIFER CAMPBELL-ALLISON
POLICY COORDINATOR

JCA/pb

Enclosures

c: Chris Wood, Burns & McDonnell
Peggy Ladd, Ameren UE
Kenny Lynn, Ameren UE
Brian Holderness, Ameren UE
Shauna Marquart, U.S. Fish and Wildlife Service

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Journal of Mammalogy, 93(4):1086–1098, 2012

Population-level impact of white-nose syndrome on the endangered Indiana bat

WAYNE E. THOGMARTIN,* R. ANDREW KING, PATRICK C. MCKANN, JENNIFER A. SZYMANSKI, AND LORI PRUITT

United States Geological Survey, Upper Midwest Environmental Sciences Center, 2630 Fanta Reed Road, La Crosse, WI 54603, USA (WET, PM)
United States Fish and Wildlife Service, Division of Endangered Species, Bloomington Field Office, 620 S. Walker Street, Bloomington, IN 47403, USA (RAK, LP)
United States Fish and Wildlife Service, Division of Endangered Species, United States Fish and Wildlife Resource Center, 555 Lester Avenue, Onalaska, WI 54650, USA (JAS)

* *Correspondent: wthogmartin@usgs.gov*

Establishing status and trend for an endangered species is critical to recovery, especially when it is faced with a nascent extinction agent. We calculated, with hierarchical log-linear change-point models, hibernaculum-level population trends between 1983 and 2009 for the endangered Indiana bat (*Myotis sodalis*) now subjected to the fast-spreading fungal disease white-nose syndrome. We combined trends from 222 wintering populations before and after onset of the disease to determine trend for clusters of interacting wintering populations, recovery units, and the species. Before onset of the disease, a west-to-east gradient in trends existed, with westernmost populations declining and easternmost populations increasing in abundance. The species as a whole, however, was stationary between 1983 and 2005 (–0.5% mean annual change; 95% confidence interval [*CI*] = –2.8, +1.8%). Estimated mean population size in 2009 was 377,124 bats (195,398–957,348), with large variance apparently caused by white-nose syndrome. With the onset of white-nose syndrome (2006–2009), the species exhibited a 10.3% annual decline (95% *CI* = –21.1, +2.0%). White-nose syndrome is having an appreciable influence on the status and trends of Indiana bat populations, stalling and in some cases reversing population gains made in recent years.

Key words: change-point analysis, endangered species, *Geomyces destructans*, *Myotis sodalis*, trend estimation

DOI: 10.1644/11-MAMM-A-355.1

White-nose syndrome has been associated with severe and abrupt declines in bat abundance in eastern North America since the winter of 2006 (Blehert et al. 2009; Frick et al. 2010a; Turner et al. 2011), spreading throughout the eastern United States and Canada. As of spring 2012, white-nose syndrome had been confirmed in hibernacula as far north as Ontario and Quebec, as far south as Alabama, and as far west as eastern Missouri; the fungus causing white-nose syndrome, *Geomyces destructans*, has been observed over a wider range, occurring in Oklahoma, for instance (Blehert et al. 2011; Foley et al. 2011). *G. destructans* has afflicted 6 species of hibernating bats (Blehert et al. 2011; Foley et al. 2011), including the little brown (*Myotis lucifugus*), northern long-eared (*M. septentrionalis*), eastern small-footed myotis (*M. leibii*), big brown (*Eptesicus fuscus*), tricolored (*Perimyotis subflavus*), and Indiana bats (*M. sodalis*). The Indiana bat is a species for which there is particular concern because of its status as endangered under the United States Endangered Species Act of 1973. The Indiana bat is also a red-listed species according to the International Union for the Conservation of Nature (Arroyo-Cabrales and Ticul Alvarez Castaneda 2008). Information regarding the spatial and temporal patterns in species abundance is needed, but not available, for predicting population-level impacts of this disease.

Indiana bats aggregate in winter in subterranean colonies; thus, the most common means for determining population size is periodic direct observation and counting of hibernating individuals in caves and mines (Hayes et al. 2009). Trained surveyors search all sections of a hibernaculum to count and identify to species all bats observed. The fidelity by bats to subterranean roosts allows researchers to focus monitoring on a few discrete locations in winter (Hayes et al. 2009).

Historically, surveys were limited to one per year at each hibernaculum because repeated or prolonged disruption of bats during hibernation can cause increased energy expenditure from arousal and premature depletion of fat reserves (Speakman et al. 1991; Thomas 1995; Thomas et al. 1990).

Indiana bats have been counted at various times and locations since 1929; these early counts were infrequent and prospective in nature. By the mid-20th century, a number of known aggregations of Indiana bats began to be counted on a semiregular basis (Clawson 2002). By 1983, survey methods were largely standardized and all known large aggregations of Indiana bats were regularly estimated by state and federal biologists and academic chiroptologists. Many smaller and moderately sized aggregations, however, continued to be counted less frequently; the most common rotation was surveys conducted biennially (Clawson 2002; Kunz 2003). For populations that exhibit complete fidelity to a hibernaculum, this biennial count would pose no analytical problems, nor would problems occur if the counts were synchronized. However, Hayes et al. (2009:117) noted "Tallies based on direct counts involve a suite of assumptions that are rarely articulated, yet can ultimately impact their utility for inferring population trends... [A]ttempts to infer population trends... are based on the assumptions that availability and quality of roosts are static and that bats exhibit high rates of fidelity to roosts through time." *Myotis*, however, are not entirely faithful to their hibernaculum from one year to the next (Elder and Gunier 1978; Fath 2002), nor are all counts made synchronously. As a consequence, bats counted in 1 year in 1 hibernaculum may move to another nearby hibernaculum the subsequent year and be counted again. This lack of independence, if it were not accounted for, could lead to a biased estimate of the number of bats in a region as well as exert uncertain and potentially misleading effects on estimated trends and variation in trends.

A credible estimate of species population trajectory and accompanying levels of confidence are not possible absent a robust consideration of the dependency among wintering populations and the asynchronous nature of surveys. Our objectives were, therefore, manifold. First, we determined estimates of population trend for each sufficiently surveyed hibernaculum across the species range (Fig. 1). Second, with these trend estimates as the basis for inference, we hierarchically aggregated population trajectories across complexes of interacting populations, United States Fish and Wildlife Service recovery units, and the species, as a means of dampening the unknown extent of site infidelity and uncertain hibernaculum availability and quality. We accommodated many of the uncertainties and difficulties associated with these data with hierarchical Bayesian methods. Third, we tested whether the epizootic white-nose syndrome was evident within the time series of counts we analyzed. Conventional estimates of trend are insufficient for analyzing periods in which substantial shifts in mean population size and trend are expected to occur at some intervening date. Thus, our modeling approach allowed for an estimation of trend before and after the advent of this disease.

Methods

Hibernaculum counts.—The Indiana Bat Recovery Team maintains a database of hibernaculum data for all known (i.e., current and historic) wintering locations of Indiana bats (curated by A. King; Appendix I). This database contains detailed historical counts from hibernacula with 1 or more Indiana bat winter occurrence records. Since 2005, a biennial data request for winter population counts of Indiana bats has been sent to bat biologists across all 27 states of the species range; these data are then used in calculating a range-wide population estimate once every 2 years.

Standardization of hibernaculum surveys occurred by ~1980, so we limited our analyses of trends to those counts collected between 1983 and 2009 (the 2011 biennial survey of results was ongoing as of this analysis). Details of survey protocol are described by Kunz (2003) and Hayes et al. (2009). A mean of 103 Indiana bat hibernacula were surveyed each year (range = 39–181) across 24 states between 1983 and 2009; as Clawson (2002) noted, surveys were more commonly conducted in odd years (128 hibernacula [95% confidence interval {*CI*} = 109,146] in odd years versus 77 hibernacula [67, 86] in even years). Hibernaculum counts were conducted by 1–7 surveyors between January and March, typically within a 2.2-hour period (maximum = 7 hours). Approximately 12% of surveys required vertical caving gear for access to the hibernaculum. Surveyors reported that 86% of hibernaculum counts were derived by individual counting of bats; the remaining 14% of estimates were determined by multiplying the areal estimate of a cluster of hibernating bats by a bat packing density, an expansion factor determined by the surveyors. No animals were handled in the course of this study.

Trend estimation.—We used change-point modeling to estimate trend before and after the intervention of white-nose syndrome (Toms and Lesperance 2003). Change-point models can be formulated either sequentially or retrospectively; with the former, a decision is made regarding the occurrence of a change on the basis of the data, whereas in the latter, the time series of data is examined to determine if a change point has occurred in the sequence and, if so, where this change occurred. In the case of Indiana bat populations subject to white-nose syndrome, this change point is expected to evolve spatially with the spread of the disease (W. E. Thogmartin et al., in litt.). Rather than model an evolving spatiotemporal process given incomplete survey data, we took the former route to change-point modeling and set a priori a change point equivalent to year 2005. This is the year before the first recorded occurrence of *G. destructans* (Blehert et al. 2009).

We modeled the trend for each hibernaculum with the response as log(count+1) and explanatory variables as years (within the range of 1983–2009), and a constructed variable named yr0609. Yr0609 took on the value of 0 for years between 1983 and 2005, and then the value for year-2005 for

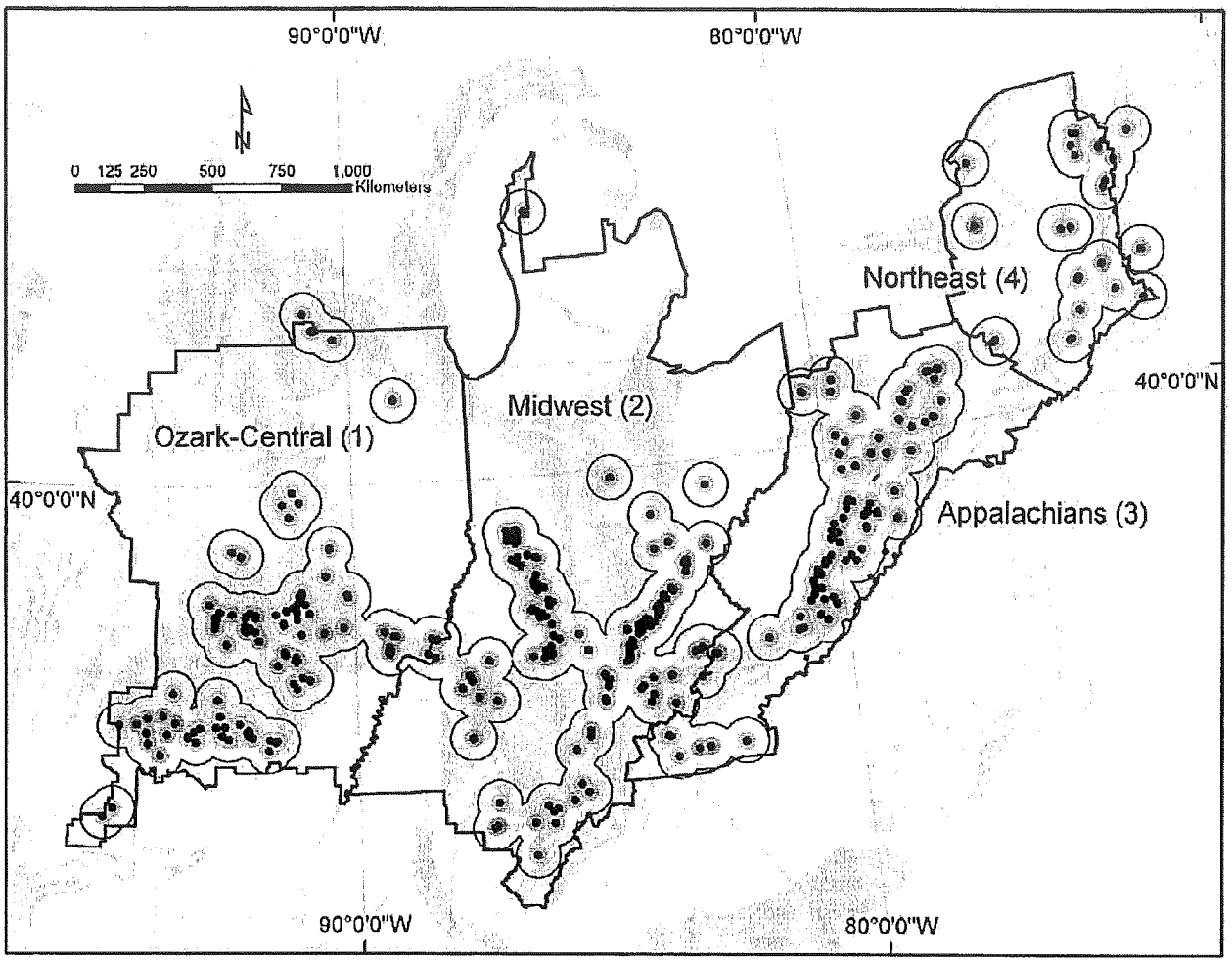

FIG. 1.—Historical hibernacula (in black) of Indiana bats in the United States, primarily associated with karst formations (gray), plotted by recovery unit and color-coded to reflect aggregations (or complexes) of hibernacula within 10-mile proximity. An additional buffer extends 25 miles around each hibernacula alluding to further potential connectedness of hibernacula.

years 2005 to 2009. This creates an inflection point at 2005, where the fitted line was allowed to change slope. The estimated coefficient corresponding to yr0609 is the estimated change in the baseline trend estimated from 1983 to 2005. Because the yr0609 estimate is relative to the 1983–2005 trend estimate, if the 1983–2005 trend estimate is greater than the yr0609 coefficient, the coefficient for yr0609 will be negative even if the population is increasing. Conversely, if the population from 2005–2009 is estimated to be decreasing, but decreasing at a slower rate than 1983–2005, the coefficient for yr0609 will be positive. Thus, the actual trend for 2005–2009 is the sum of the 1983–2005 trend and the coefficient yr0609 for the period 2005–2009.

The linear trend for each hibernaculum was estimated with WinBUGS 1.4 (Lunn et al. 2000) using R2WinBUGS (Sturtz et al. 2005) in the R statistical language (R Development Core Team 2010). WinBUGS is a statistical package conducting Bayesian inference with Markov chain Monte Carlo methods (Gibbs sampling; Link et al. 2002; Ntzoufras 2009). We modeled with noninformative, or flat, priors (Link and Barker 2010). The coefficient parameters were given diffuse (essentially flat) normal distributions with mean of 1 and variance equal to 1,000. The precision on error was gamma distributed with shape and scale equal to 0.1. For each model, we ran three chains for 60,000 iterations, discarding the first 40,000 iterations as burn-in and thinning by 5 to reduce serial correlation (Link et al. 2002, Lunn et al. 2000). We used the Gelman–Rubin convergence diagnostic to identify whether the chains had converged for each of the main model parameters (Ntzoufras 2009).

Of 462 hibernacula, 222 had estimable coefficients with standard errors for year and yr0609. Trends were inestimable when either the hibernaculum was no longer occupied in winter ($n = 106$) or had too few surveys to calculate model coefficients ($n = 116$); of wintering populations with inestimable trends, sums of counts from 1983–2009 averaged 178 bats (some of

the larger hibernacula were not revisited or were only recently discovered). It was the 222 hibernaculum-level estimates that were then used for the aggregations of trend at complex, recovery unit, and species level. If a hibernaculum did not have an estimable regression with standard errors, it had zero weight in aggregated estimates irrespective of the historically observed number of bats.

We defined complexes of hibernacula as a means of mitigating influences of interhibernaculum movement on trend estimation. This interhibernaculum movement (immigration/emigration) can yield rates of population change for individual wintering populations that are outside of that expected from a closed population (W. E. Thogmartin et al., in litt). A complex was defined as a collection of hibernacula within a 10-mile buffer of any other historical hibernaculum, irrespective of whether it was in present-day use. This distance was ad hoc but for our purposes yielded sensible rates of change (i.e., $\lambda \ll 2$).

The nonzero weights for each hibernaculum were calculated within each complex by dividing each hibernaculum mean population size by the total mean population size within that complex. Four time periods were investigated for their effect on these weights: 1983–2002, 1983–2009, 1997–2005, and 2006–2009. There were no appreciable differences in weights regardless of time period used, so the period 1983–2005 was used because it represents a baseline (prewhite-nose syndrome) mean condition.

Once weights were calculated, coefficients for the intercept, year, and yr0609 were combined as a weighted mean by complex level. Coefficients were assumed to be uncorrelated normal random variables with the standard error reported in the lm summary in R. Aggregated parameter means were then the sum of weights times each parameter estimate, and aggregated parameter variances were calculated by summing squares of the standard error multiplied by squares of the weights. Standard errors of aggregated parameters were square roots of these variances.

In our analysis, we assumed that there exists within each hibernaculum a linear relationship between year and log(count+1) with normal random error, with an inflection point at 2005. The linear relationship assumption within hibernaculum was checked by visual inspection, and was deemed reasonable for most hibernacula. Although resulting trend estimates are a useful first approximation, it should be noted that temporal correlation of the counts was ignored. It is likely, therefore, that standard error estimates are too small.

Another assumption is that hibernaculum counts were observed from a closed population, even though we know this is not true since bats are known to occasionally change hibernacula. We assessed the consequence of this assumption by removing demographically impossible counts and reanalyzing trend with these data points removed (<2% of all counts). We found a negligible influence on higher-level estimates of trend resulting from extreme fluctuations in counts caused by immigration, primarily because these changes generally affect only the smallest wintering populations.

Model coefficients are not straightforward in their interpretation given their logarithmic nature. Thus, we expressed estimates of population trend as percent annual change (with 95% *CI*s), where percent annual change = (exp[year coefficient from log-linear regression] − 1) × 100%.

Results

Hibernacula.—Wintering populations in the Ozark-Central Recovery Unit before white-nose syndrome exhibited a median decline of 9% (95% *CI* = −4, −13%) between 1983 and 2005. Conversely, wintering populations in Appalachian (+8% [3, 14%]) and Northeastern (+16% [3, 30%]) Recovery Units increased. Wintering populations in the core of the species range, the Midwest Recovery Unit, exhibited no credible change (+0.5% [−1, +3%]). This pattern in population trends suggested a west-to-east gradient (Fig. 2). This increasing trend from west to east was more obvious when wintering populations were combined via a population-weighted average to the complex level (Fig. 2), with trends in each recovery unit credibly different from its neighboring unit except for Appalachian and Northeast units (Table 1).

With the onset of white-nose syndrome (2006–2009), the species exhibited a 10.3% median annual decline from the earlier rate of change (95% *CI* = −21.1, +2.0%). However, it is not certain that this annual decline after 2005 can be explained wholly by white-nose syndrome at our level of examination, as spatial patterns in trends indicated considerable declines in abundance not apparently associated with the occurrence of this disease (e.g., in Tyson Quarry, St. Louis County, Missouri; Fig. 3). There were increasing populations of hibernating Indiana bats in white-nose syndrome-affected counties, as well (i.e., Skinner Hollow, Bennington County, Vermont, and Bellamy, Montgomery County, Tennessee).

For the 16 largest hibernacula, comprising more than 80% of the estimated population, 10 of 16 exhibited a reduction in the hibernating population since 2006, even in areas where white-nose syndrome was absent (Appendix II). The largest hibernaculum, Twin Domes in Harrison, Indiana, began with ~83,000 hibernating bats and declined to ~49,000 hibernating bats by 2005, and thereafter declined precipitously to ~17,000 hibernating bats by 2009. Conversely, Ray's Cave in Greene, Indiana, the 2nd-largest hibernaculum, increased from ~17,000 to ~72,000 between 1983 and 2005, and then began to decline (this decline may have begun as early as 1998), with a current population somewhere on the order of 54,000 hibernating bats. Wyandotte Cave in Crawford, Indiana also experienced a great increase in abundance, increasing from ~5,000 to ~52,000 hibernating bats; after 2005 the increase ameliorated with a 2009 population on the order of ~46,000 bats.

Recovery unit.—Recovery considerations for the Indiana bat under the Endangered Species Act are determined for populations within recovery units. The Midwest Recovery Unit possessed the largest population over the interval 1983–2009 (Fig. 4); although the median population estimates over

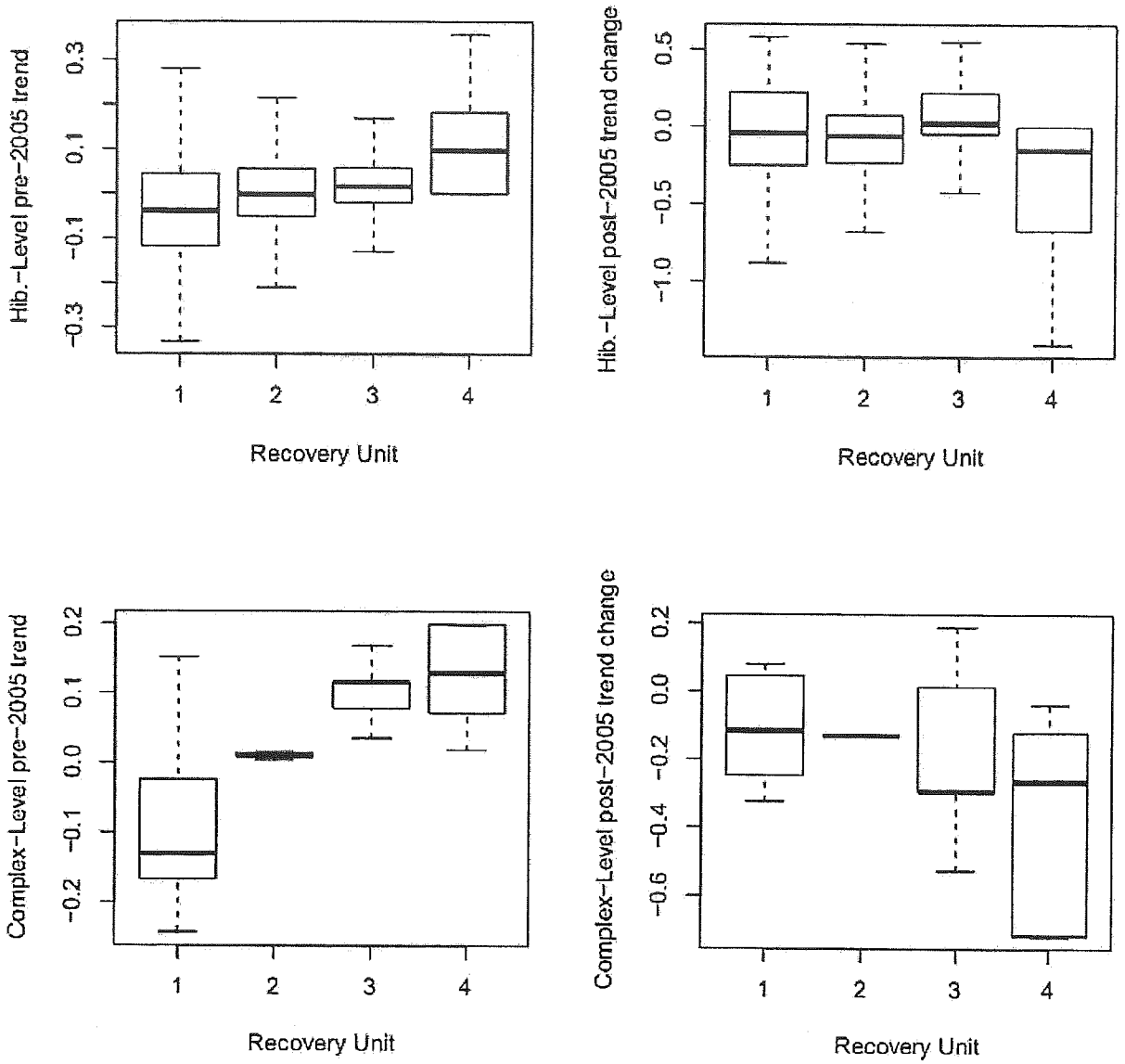

FIG. 2.—Mean (95% confidence interval) hibernacula and complex trend and changes in trend estimates plotted by recovery unit. Note differing ordinate. Recovery units are Ozark-Central (1), Midwest (2), Appalachian (3), and Northeast (4).

TABLE 1.—Mean parameter estimates (intercept, 1983–2003 trend, and 2003–2009 trend) for hibernacula, complex, and recovery unit levels (with 95% confidence intervals). *n* is the number of hibernacula per recovery unit contributing to the hibernacula trend estimates.

Recovery unit (*n*)	Hibernacula			Complex			Recovery unit		
	Intercept	1983–2005	2006–2009	Intercept	1983–2005	2005–2009	Intercept	1983–2005	2005–2009
1 (57)	4.65	−0.06	−0.11	7.29	−0.06	−0.11	9.15	−0.09	−0.06
	(−0.56, 11.81)	(−0.47, 0.27)	(−1.29, 0.99)	(0.88, 11.10)	(−0.24, 0.28)	(−0.32, 0.08)	(8.26, 10.04)	(−0.14, −0.04)	(−0.35, 0.23)
2 (101)	4.74	−0.0004	0.01	7.59	0.002	−0.02	9.65	0.01	−0.09
	(−0.76, 9.91)	(−0.26, 0.26)	(−0.84, 1.15)	(1.51, 10.43)	(−0.19, 0.05)	(−0.37, 2.50)	(9.39, 9.91)	(−0.01, 0.03)	(−0.21, 0.03)
3 (49)	2.25	0.02	0.07	5.20	0.10	−0.20	6.73	0.08	−0.15
	(−0.40, 6.63)	(−0.12, 0.16)	(−0.59, 0.70)	(−1.29, 7.96)	(−0.03, 0.18)	(−0.53, 0.19)	(5.86, 7.59)	(0.03, 0.13)	(−0.70, 0.40)
4 (14)	2.70	0.11	−0.46	4.59	0.13	−0.52	5.92	0.15	−0.53
	(−1.41, 7.56)	(−0.0003, 0.31)	(−1.85, 0.001)	(−1.79, 7.50)	(0.02, 0.20)	(−2.06, −0.04)	(3.62, 8.22)	(0.03, 0.27)	(−0.93, −0.13)

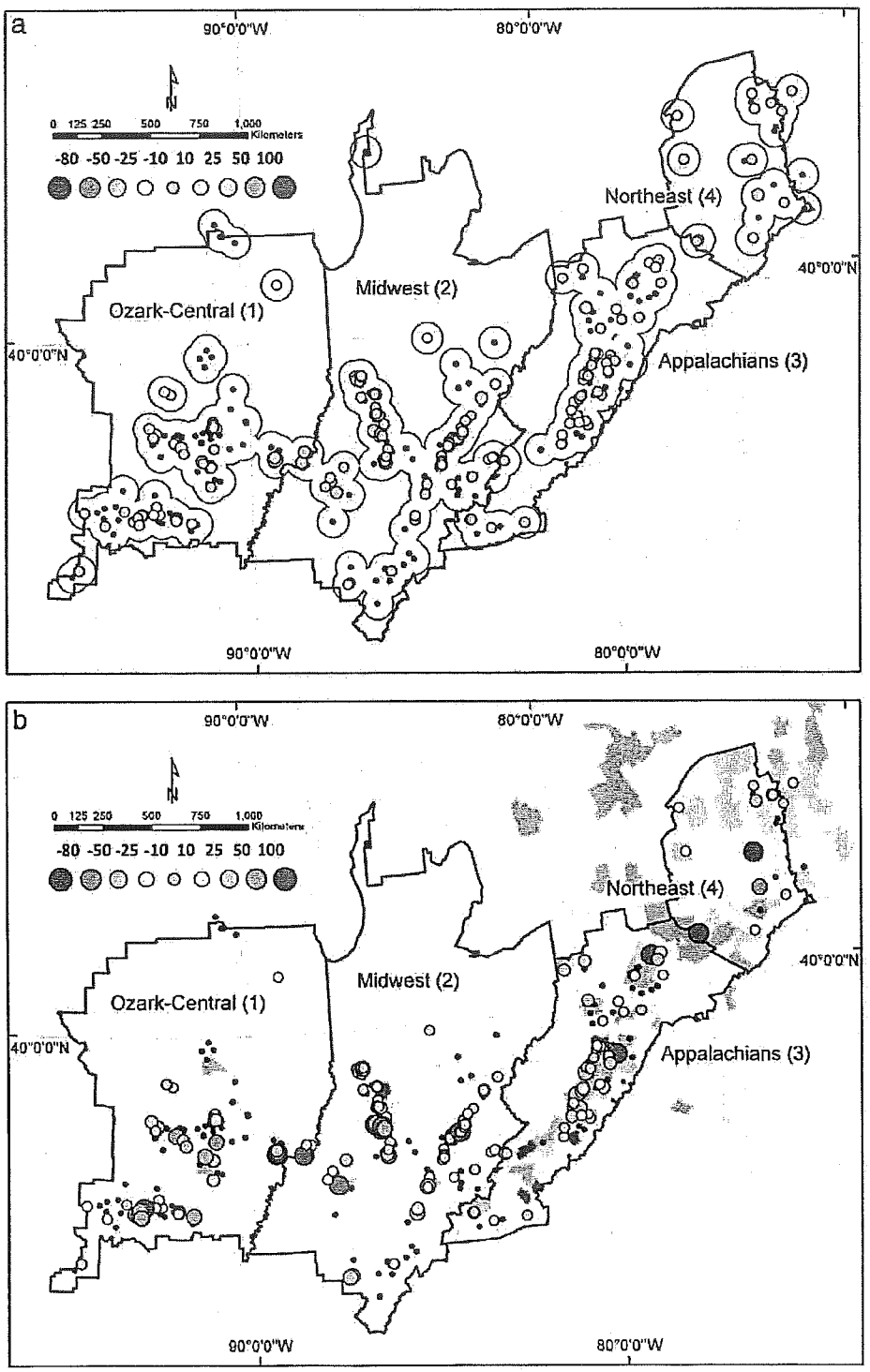

FIG. 3.—Hibernacula trends pre- and postonset of white-nose syndrome. Larger-sized bubbles denote greater trend magnitude; warmer colors denote negative trends; cooler colors denote positive trends. Scale is equivalent in both panels. White-nose syndrome-affected counties are shown in light red with postonset hibernacula trend estimates.

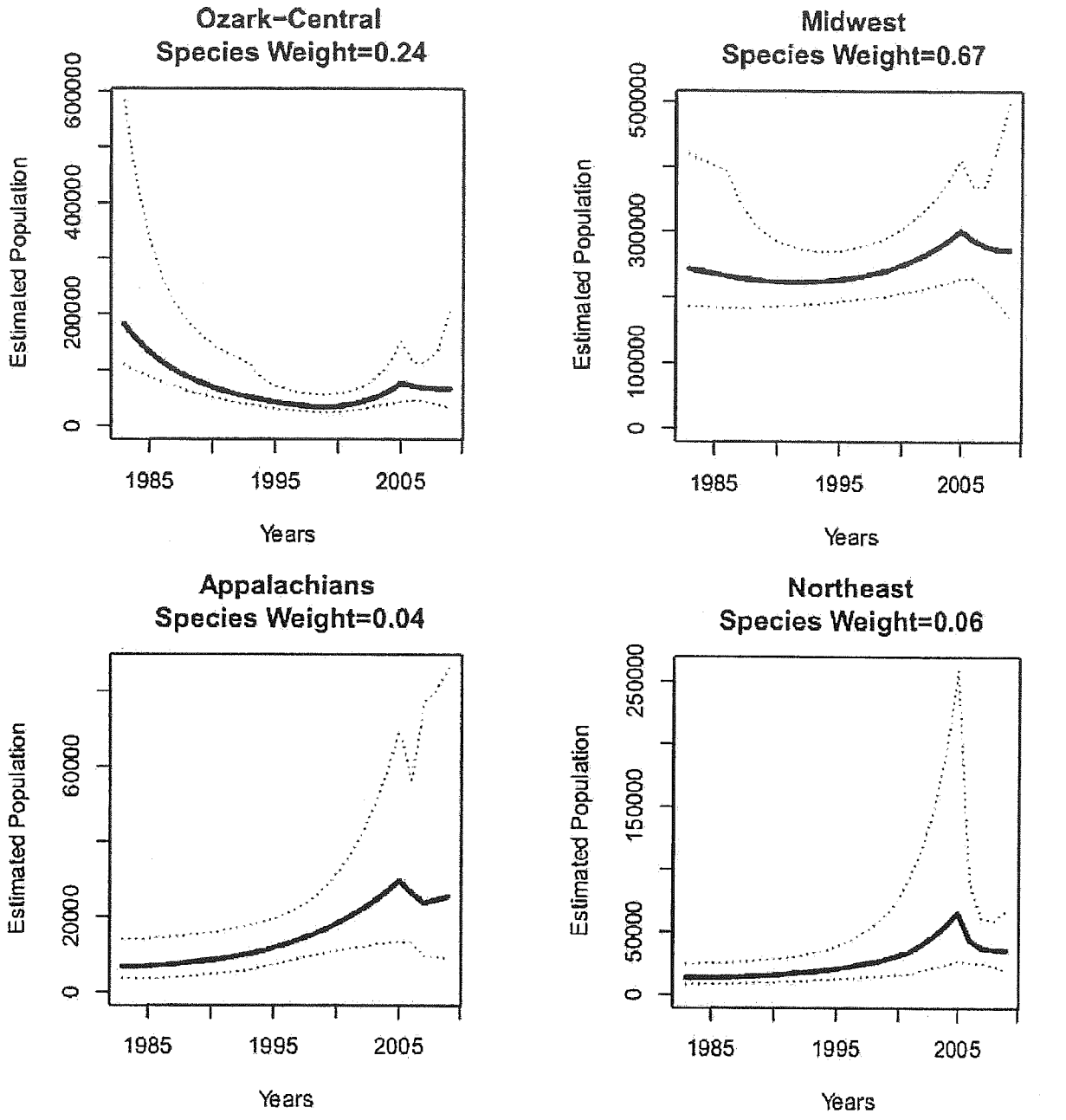

FIG. 4.—Patterns in estimated annual population size of Indiana bats in four recovery units (with 90% *CIs*). Species weights describe proportional weight of each recovery unit to the total species-level population size estimate.

the interval suggested an increase of ~29,000 bats (+12%), the wide confidence intervals around the estimates precluded definitive statements about population increase. This was not the case for the Appalachian Recovery Unit, which increased a credible 276%, increasing from ~7,000 to ~26,000 bats. Conversely, the Ozark-Central Recovery Unit declined 81% between 1983 and 1999, from 182,000 bats down to ~34,000 bats, but then rebounded by 130% from the 1999 population, increasing by ~33,000 bats; the overall decline for the period was 63%. The Northeast Recovery Unit grew 395% between 1983 and 2005 (from 13,000 bats to 66,000 bats), but then declined thereafter by 46% (2009 population estimate of 36,000 bats).

A significant portion of the decline after 2002 for the Northeast Recovery Unit appears to be due to white-nose syndrome (Fig. 5). Particularly hard hit were Walter Williams

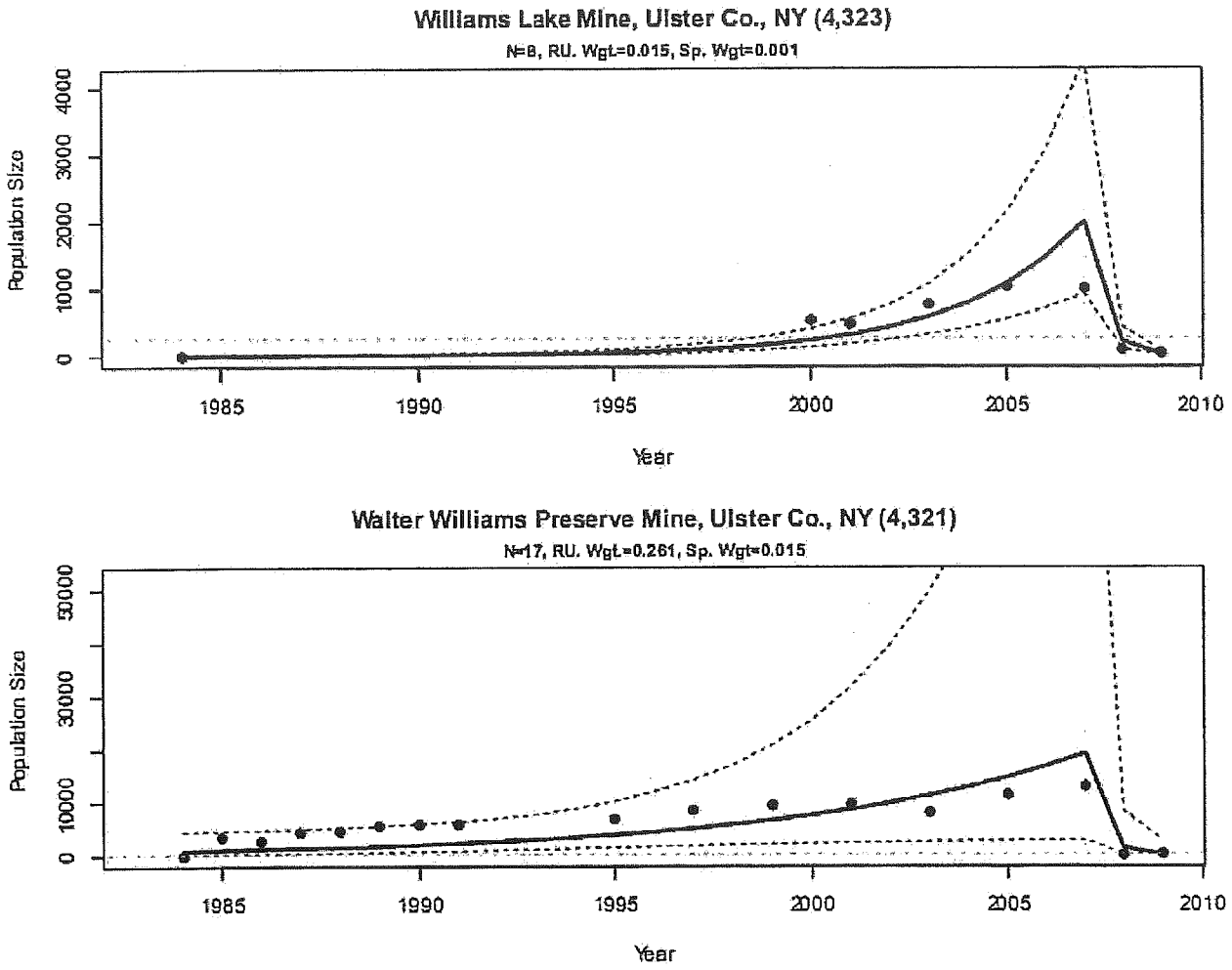

FIG. 5.—Patterns in population change (with 95% confidence intervals) for 2 hibernacula complexes known to be affected by white-nose syndrome; the change point in these particular models were fit to the year of known infection as opposed to year 2005.

Preserve Mine (possessing 26.1% of the recovery unit population) and Williams Lake Mine (1.5%) in a 5-hibernaculum complex in Ulster County, New York, a complex comprising approximately 67% of the Northeast Recovery Unit population. These populations declined by 90% (95% *CI* = 78–97%) and 84% (22–99%), respectively. Infection in a 55-hibernaculum complex in a 12-county area of Virginia and West Virginia also appears to have stalled a growing population in the Appalachian Recovery Unit.

Species.—The species exhibited a nonsignificant 0.5% annual decrease (95% *CI* = –2.8, +1.8%) between 1983 and 2005 (Fig. 6). On the basis of years for which we had the most survey information, 2004–2006, we predicted annual species population sizes of 432,720 (278,026–907,156), 473,537 (285,375–1,130,074), and 429,573 (292,339–712,898) hibernating Indiana bats, respectively (Table 2). In 2005, 1983, and 2009, estimates were the 1st, 2nd, and 7th highest median population sizes, respectively, for the period. The mean probability of the species exceeding the recovery criteria population size of 457,000 bats in any year was 20.5%.

DISCUSSION

The range-wide population of Indiana bat appears to have been in a stationary state for at least 2 decades before the onset of white-nose syndrome. White-nose syndrome has caused regional decline of Indiana bats in the northeastern United States, and halted a population increase in the Appalachians, but the species-wide population size has not credibly declined. Thus, as of 2009, the disease does not appear to be sufficiently prevalent across the core portion of the species range to alter species status.

Even in the Northeast Recovery Unit where the species was first and most afflicted by white-nose syndrome, some wintering populations experienced increases in abundance. There are at least two possible reasons for this increase. Indiana bats may have continued the prewhite-nose syndrome pattern

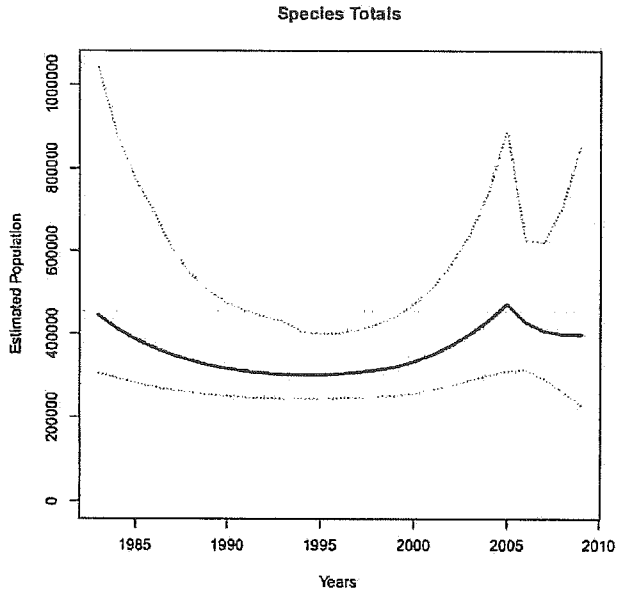

FIG. 6.—Predicted patterns in total annual population size of Indiana bats between 1983 and 2009 (with 90% *CI*). The dashed horizontal line is the recovery criteria for this species, 457,000 bats.

of increase in areas unaffected by disease. Alternatively, bats aroused from hibernation have been recorded switching hibernacula in the midst of winter likely in response to disturbance (Elder and Gunier 1978). The increases we observed in wintering populations in the Northeast Recovery Unit may be the mass movement of individuals to as-yet-unaffected hibernacula. Unfortunately, the lack of information on interhibernacula movement in *Myotis* species, let alone Indiana bats, precludes us from distinguishing between these hypotheses.

There was some evidence of a west-to-east gradient in population trends, possibly indicating a north and eastward movement in species range during the period of our observations. An increasing number of species are exhibiting shifts in range, often in association with changes in climate (Parmesan et al. 1999; Parmesan and Yohe 2003; Root et al. 2003; Walther et al. 2001, 2002). Both Frick et al. (2010b) and Adams (2010) indicated that higher precipitation was related strongly to higher bat reproduction, with Adams (2010) suggesting that these relations may lead to distributional changes in an altered climate. Humphries et al. (2002) described how warming winters may lead to increased overwinter survival in the northern portion of bat species ranges. Increased precipitation in the eastern United States since about 1970 coupled with warming winter conditions (Hayhoe et al. 2007; Karl and Knight 1998; McCabe and Wolock 2002) may allow for higher reproduction and winter survival in the Northeast Recovery Unit. Under a regime of increasing temperature and precipitation (Hayhoe et al. 2007; Najjar et al. 2000), conditions in the northeast are expected to continue improving for bats (Robinson et al. 2005). The

TABLE 2.—Annual estimated population size for Indiana bats between 1983 and 2009.

Year	Mean	2.5% confidence level	97.5% confidence level
1983	368,547	247,350	1,022,807
1984	339,960	237,329	778,866
1985	322,553	232,567	630,927
1986	307,881	226,033	856,380
1987	299,935	225,479	654,191
1988	292,417	224,234	540,295
1989	281,720	220,235	457,614
1990	273,771	217,662	409,226
1991	267,804	215,780	376,652
1992	263,391	214,376	381,704
1993	268,375	217,358	463,292
1994	266,990	217,288	385,867
1995	268,175	217,604	364,950
1996	279,927	224,112	388,422
1997	283,794	225,260	393,182
1998	290,654	227,581	410,188
1999	309,988	235,412	459,961
2000	324,143	240,666	504,157
2001	349,323	250,627	575,879
2002	372,195	259,819	649,742
2003	399,172	269,591	752,208
2004	432,720	278,026	907,156
2005	473,537	285,375	1,130,074
2006	429,573	292,339	712,898
2007	407,026	271,965	709,385
2008	383,207	233,865	808,103
2009	377,124	195,398	957,348

decrease in the Ozark-Central Recovery Unit could be climate mediated as well, but lack of similar declines in the Midwest Recovery Unit and in southern portions of the Appalachian Recovery Unit argues against latitudinally related climate characteristics (such as temperature) and instead favors longitudinal changes in precipitation gradients as the cause for declines in the southwestern portion of the species range.

Other nonclimate-related factors, such as gating of cave entrances, altered forest conditions, or loss of habitat from urbanization, are also likely to play a role in regional gradients in trend (Jones et al. 2009; United States Fish and Wildlife Service 2007), possibly one larger than climate. For instance, reduced insect prey accompanying widespread intensification of agricultural practices is one potential culprit for declines in the Ozark-Central and Midwest Recovery Units (Boyles et al. 2011; Kunz et al. 2011; Wickramasinghe et al. 2003, 2004). Recently, renewable energy generation has resulted in the erection of thousands of wind turbines in the midwestern United States, resulting in significant mortality of both migrant and resident bats (Arnett et al. 2008; Johnson et al. 2002; Kunz et al. 2007); few Indiana bats, however, have ever been recorded dying from wind turbine collision and to our knowledge no assessment of the species-level consequences of wind generation has been conducted for Indiana bats. If spatially and temporally varying covariates were available, examining these various causal factors in the context of the hierarchical log-linear models we used would allow us to

TABLE 3.—Winter population estimates for Priority 1A ($n = 16$) and 1B ($n = 7$) Indiana bat hibernacula as described in the draft recovery plan (United States Fish and Wildlife Service 2007, table 2). All P1 hibernacula ($n = 23$) have at some point in the recorded past had ≥10,000 hibernating Indiana bats and currently provide suitable winter habitat. P1A hibernacula have maintained a minimum of 5,000 Indiana bats during the last 10 years, whereas P1B hibernacula have not met this criterion in the last 10+ years.

State	County	Hibernaculum	Priority	Maximum estimate since 1960	Recovery plan 2005 estimate	Model-based 2005 estimate
Illinois	Alexander	Magazine Mine	P1A	33,500	33,500	49,354
Indiana	Crawford	Batwing Cave	P1A	50,000	6,850	6,195
Indiana	Crawford	Wyandotte Cave	P1A	54,913	54,913	52,343
Indiana	Greene	Ray's Cave	P1A	62,464	54,325	72,442
Indiana	Harrison	Jug Hole Cave	P1A	29,430	29,430	28,918
Indiana	Harrison	Twin Domes Cave	P1A	100,000	36,800	48,585
Indiana	Monroe	Coon Cave	P1A	10,675	9,270	11,531
Indiana	Monroe	Grotto Cave	P1A	10,338	9,875	6,613
Kentucky	Carter	Bat Cave	P1A	100,000	29,500	25,039
Kentucky	Edmonson	Dixon Cave	P1A	16,550	3,100	3,206
Missouri	Iron	Pilot Knob Mine	P1A	139,000	50,550	Inestimable[a]
Missouri	Washington	Great Scott Cave	P1A	85,700	6,450	5,115
New York	Ulster	Walter Williamms Preserve Mine	P1A	11,394	11,394	28,716
New York	Ulster	Williams Hotel Mine	P1A	15,438	15,438	18,366
Tennessee	Blount	White Oak Blowhole Cave	P1A	12,500	7,861	5,965
West Virginia	Pendleton	Hellhole Cave	P1A	11,890	11,890	20,233
Kentucky	Edmonson	Coach Cave	P1B	100,000	-	8
Kentucky	Edmonson	Long Cave	P1B	7,600	1,153	622
Kentucky	Letcher	Line Fork Cave	P1B	10,000	1,844	1,314
Missouri	Crawford	Onyx Cave	P1B	12,850	180	92
Missouri	Franklin	Copper Hollow Sink Cave	P1B	21,000	250	114
Missouri	Pulaski	Brooks Cave	P1B	19,461	70	93
Missouri	Pulaski	Ryden Cave	P1B	10,539	10	3

[a] Hazardous conditions precluded safe entry into this hibernaculum, preventing winter surveys. Fall surveys at the entrance to this mine, however, suggested that large numbers of bats existed until recent years (Clawson 2002, Elliott and Kennedy 2008).

examine their potential contributions to population trends (Thomson et al. 2010).

There are a few important points to make regarding our use of change-point analyses. Variances estimated around the change point (year 2005) increased considerably relative to other years to accommodate inflections in trend. The magnitude of this variance is symptomatic of the magnitude of the change in trend between the pre- and postwhite-nose syndrome periods. Further, our log-linear regression approach ably accommodated the >80% of the population occurring in hibernacula comprised of >1,000 individuals. This approach works less well for estimating small wintering populations because of the high influence these hibernacula experience from immigration and emigration. Our hierarchical method of combining hibernaculum counts into complex, recovery unit, and species-level estimates led to a smoothing of the trend, reducing the impact of this interhibernaculum movement on the estimation process. But if the focus of trend estimation is at the scale of the hibernaculum rather than coarser scales, then methods will need to be implemented that can accommodate: the irregular nature of survey effort, especially as hibernaculum size decreases; the neighborhood context of wintering populations; potentially abundant zero or near-zero counts; and, possibly, a flexible (spatiotemporally varying) change point. Hierarchical Bayesian count models with random effects for year and the error term (to accommodate overdispersion likely to occur in the smallest populations) are a good direction for future study (Link and Sauer 2002). A state–space formulation, which separates the observation process from the demographically determined population process, would help distinguish between environmental (process) and observational (nonprocess) sources of error (Dennis et al. 2006). Nonprocess error resulting from uncertainty in the observed counts may be reduced through incorporation of relevant covariates and smoothing of the random effect for year. Potential covariates to consider for modeling this observation process might include, for instance, survey-specific measures of observer effort, observer-generated levels of disturbance, cave complexity, air and substrate temperatures, and packing densities (Hayes et al. 2009; Tuttle 2003).

Our trend and population estimates have important implications for the federally endangered status and recovery considerations of Indiana bats. The United States Fish and Wildlife Service developed a plan to recover the species to a size sufficient for removal from the Endangered Species Act list (United States Fish and Wildlife Service 2007). We found that only in the year before the onset of white-nose syndrome (2005) did the mean estimate of Indiana bats exceed the recovery criterion of 457,000 individuals. Given our wide confidence intervals, we calculated that this criterion was exceeded with a probability of 20.5%. Our model-based results for the largest wintering populations are also quite comparable with those identified in the Recovery Plan (Table 3; United States Fish and Wildlife Service 2007, table 2), with 1

exception. We excluded an important wintering population, Pilot Knob Mine in Missouri. The Recovery Plan assumed a population size of 50,500 individuals for this hibernaculum, constituting >10% of the estimated range-wide population. We were unable to include Pilot Knob Mine in our analyses because hazardous conditions would not allow safe surveying in winter until very recently (Clawson 2002; Elliott 2008; Elliott and Kennedy 2008), resulting in too few surveys for inclusion in our estimation process. If we add 50,500 bats to each year over the period of analysis, we find that the mean estimate of Indiana bats exceeded the recovery criterion for 4 years, 2004–2007; it should be noted, however, that Elliott and Kennedy (2008) reported a much lower estimate of Indiana bats by 2008, 1,678 bats, so our model-based estimate for 2005 is likely the only year in which we can be confident that Indiana bats met the recovery goal. With the recent discovery of white-nose syndrome in the core of the species' range, subsequent population estimates are not likely to reach this recovery criterion any time soon.

Acknowledgments

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APPENDIX I

Collation of wintering population counts of Indiana bats.—In 1995, the Indiana Bat Recovery Team requested distributional data in a letter sent to consultants, researchers, and authorities on endangered species in 28 states (Gardner and Cook 2002). From the responses received from this data request and other published and unpublished records, Gardner and Cook (2002) developed a range-wide database of county distributional records for the Indiana bat and used geographical information system (GIS) software (ArcInfo® and ArcView®, Environmental Systems Research Institute, Redlands, California) to produce seasonal distribution maps. In June 2005, the United States Fish and Wildlife Service's Bloomington Field Office e-mailed an Indiana bat hibernaculum data request to over 75 individuals, including service biologists, recovery team members, bat researchers, state and federal agency biologists, consultants, and other bat conservation partners in 27 states, who in turn forwarded the request to other colleagues. Hibernaculum data were received from all 27 states. Bloomington Field Office biologists used the combined responses from the 1995 and 2005 data requests, existing recovery team records, and other published and unpublished records (Clawson 2002, Ellison et al. 2003) to develop a GIS-based hibernaculum database containing detailed information for all known (i.e., current and historic) hibernacula with one or more Indiana bat winter occurrence records (curated by A. King). The Bloomington Field Office also requested recovery team members and service biologists from across the species' range to provide updates to summer and winter distribution maps of Gardner and Cook (2002) during an Indiana Bat Risk Assessment Workshop in March 2005 and subsequent e-mails sent after the close of the 2005 summer reproductive season. All distribution records/maps have been updated through at least October 2006 but more are added as information becomes available. Since 2005, A. King has sent out a biennial data request to bat biologists throughout the Indiana bat's range, collated resulting population data, and published a range-wide population estimate every 2 years thereafter.

Appendix II

Annual observed Indiana bat hibernaculum counts between 1983 and 2009, with the fitted change-point regression lines (and 95% confidence intervals [*CI*]). Hibernaculum name, county, state, and numeric identifiers are provided; the numeric identifiers identify recovery unit (1 = Ozark-Central, 2 = Midwest, 3 = Appalachian, and 4 = Northeast) and hibernaculum. Sample size (*n* surveys), recovery unit population weight, and species-level population weight are also provided. Weight is the contribution of the hibernaculum count to the total annual estimated population size of Indiana bats between 1983 and 2003. Only hibernacula with populations averaging >400 bats are shown. A quasi-extinction level of 250 bats is shown in some plots with a dashed horizontal line; the vertical dashed line indicates the year (2005) of the fixed change point. Figures supporting this appendix are available online.

EXHIBIT 7-K

Research Article

Effect of Forest Structure and Fragmentation on Site Occupancy of Bat Species in Missouri Ozark Forests

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Abstract

*Changes in structure and arrangement of forests may influence the distribution of bat communities by affecting roosting and foraging habitat. Using Anabat bat detectors, we determined presence of bat species at 316 sample plots in southeastern Missouri, USA, through qualitative identification of echolocation calls collected. We used maximum-likelihood estimation techniques incorporating detection probabilities into estimation of site occupancy by species of bats. We compared a priori models at 2 geographic scales using information theoretic methods. At the local-site scale, eastern pipistrelle (*Pipistrellus subflavus*) and red bat (*Lasiurus borealis*) occupancy was most influenced by structural characteristics of forested areas, whereas Indiana bats (*Myotis sodalis*) were influenced most by density of large-diameter snags that could provide roosting habitat. At the landscape scale, occupancy of Indiana bats was directly related to amount of nonforested land cover. Northern long-eared bat (*M. septentrionalis*) occupancy was inversely related to edge. These data describe implications of forest fragmentation and provide information that can be used when integrating forest-management practices into bat conservation.* (JOURNAL OF WILDLIFE MANAGEMENT 70(5):1238–1248; 2006)

Key words

acoustic detection, forest fragmentation, Lasiurus borealis, *Missouri Ozarks,* Myotis septentrionalis, Myotis sodalis, *occupancy,* Pipistrellus subflavus.

The continued decline of several bat species associated with forests underscores the need for increased understanding of habitat relationships for North American bats (Fenton 1997, O'Shea et al. 2003, Menzel et al. 2005*a*). Miller et al. (2003) noted the paucity of research on forest-dwelling bats, with particular gaps in studies conducted in the midwestern United States. As with many other species, habitat suitability for bats may be influenced by various factors at multiple spatial scales (Balcom and Yahner 1996, Grindal and Brigham 1999, Hagan and Meehan 2002). These factors and scales may be particularly important for bats because of differences between roosting and foraging requirements (Mager and Nelson 2001, Menzel et al. 2005*a*). At smaller stand scales, basal area and size distribution of trees and snags (Crampton and Barclay 1998, Waldien et al. 2000, Aguirre et al. 2003), solar exposure (Callahan et al. 1997, Lacki and Schwierjohann 2001), and stand openness (Thomas 1988, Ford et al. 2005) have been found to influence bat presence. Supporting this, Aldridge and Rautenbauch (1987) and Norberg and Rayner (1987) described morphological differences in echolocation call structure and wing form that may influence species response to forest structure characteristics. In addition, the presence of water has been cited as being of great importance as a habitat resource for bat species, particularly for gray (*Myotis grisescens*) and Indiana bats (*M. sodalis*; Menzel et al. 2001, Johnson 2002, Ford et al. 2005, Menzel et al. 2005*b*).

Fewer studies have investigated habitat characteristics of bats at larger landscape scales. Krusic et al. (1996) discussed the importance of a matrix of different land cover types to fulfill all of the habitat requirements of bats. Gorresen and Willig (2004) found that bat diversity in a tropical forest was greatest in a landscape of diverse cover types. Example landscape characteristics that influence bat species distribution include extent of fragmentation, patch size, and presence of edge habitat (Grindal and Brigham 1999, Law et al. 1999, Estrada and Coates-Estrada 2002).

Current shifts in land use and land ownership patterns influence forest structure and composition characteristics at both the local site and landscape scale (Sampson and DeCoster 2000). Shifts in ownership patterns of the Midwest may indicate increased fragmentation due to development and greater number of forest-management units (Gobster et al. 2000), and parcelization affects age structure and arrangement of forest landscapes (Ko 2005). In Southeastern Missouri 82% of the forested area is held by nonindustrial private landowners (Moser et al. 2003). With increased pressure on forest ecosystems for a variety of resources, a critical component of forest-management planning should include an understanding of how changes across a forested landscape affect bat distribution. Accordingly, our goal was to determine the influence of forest composition, structure, and arrangement at multiple scales on the occupancy of bat species across 2 forested watersheds in the Ozark Highlands of Missouri, USA.

Study Area

We conducted our study within the upper portions of the St. Francis and Black River watersheds of southeastern Missouri (Fig. 1) during summers of 2002, 2003, and 2004. These 2 adjacent watersheds encompassed 708,000 ha (1.75 million acres) of the central hardwood forest region (Braun 1950) within the Ozark Highlands section, which

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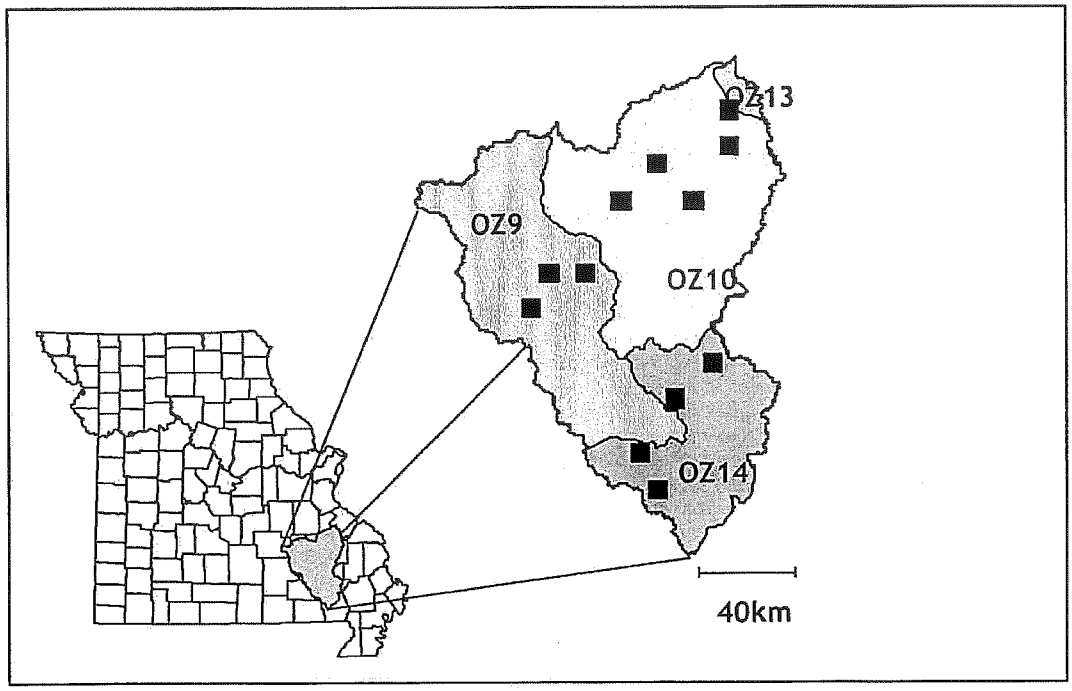

Figure 1. Study area (inset) in southeastern Missouri, USA, encompassing the watersheds of the St. Francis and Black Rivers. Ecological subsections of the study area are identified by shading and designated as OZ9, Current River Hills; OZ 10, St. Francis Knobs and Basins; OZ 13, Inner Ozark Border; and OZ 14, Black River Ozark Border. Squares represent locations of individual 23.3-km^2 study cells used for bat and habitat sampling in 2002–2004.

contained 4 different ecological subsections as described by Nigh and Schroeder (2002): 1) Current River Hills (OZ 9), 2) St. Francis Knobs and Basins (OZ 10), 3) Inner Ozark Border (OZ 13), and 4) Black River Ozark Border (OZ 14). This area was highly topographically dissected and geologically heterogeneous with a considerable number of karst features. Land cover classification derived from 30-m × 30-m-resolution Landsat imagery (1992) as determined by Missouri Resource Assessment Partnership (MoRAP) revealed a dominance of forested cover (90%), mostly in upland deciduous oak (*Quercus* spp.) forests with a lesser proportion in shortleaf pine (*Pinus echinata*)–mixed-hardwood forests.

Methods

Acoustic Detection

We collected bat echolocation calls using Anabat II bat detectors coupled with Zero-Crossing Analysis Interface Modules with CF memory card storage (CF ZCAIM; Titley Electronics, Ballina, New South Wales, Australia), passively sampling each location. To protect detectors from inclement weather, we housed the equipment in plastic containers with the microphone aligned with an opening leading to a 45° polyvinyl chloride (PVC) elbow directed upwards. We placed 2 detector units at each location for one evening during the 2002 and 2003 field season and 2 consecutive evenings during the 2004 field season. During the 2002 field season, we conducted acoustic sampling from July to the first week of September. During the 2003 and 2004 field seasons, we conducted acoustic sampling from mid-May to the first week of September. We suspended detectors 1 m above the ground and oriented detectors at a sample point to maximize the probability of recording bat calls and minimize overlap of detection zones between detectors (Larson and Hayes 2000, Weller and Zabel 2002, Duchamp et al. 2006). We calibrated detectors to minimize variation in zone of reception among detectors as described by Livengood (2003), as this variation can result in unequal sampling areas among detector sites and lead to biased occupancy rates associated with certain detectors (Hayes 2000, Larson and Hayes 2000). We recalibrated detectors from one field season to the next to minimize detector biases.

We downloaded the bat echolocation calls that were collected, and we analyzed them using Analook software (http://users.lmi.net/corben/anabat.htm). We identified species based on qualitative and quantitative parameters from known call libraries (C. Corben and M. O'Farrell, O'Farrell Biological Consulting, unpublished data) and published accounts (Fenton and Bell 1981, O'Farrell et al. 1999, Livengood 2003, Menzel et al. 2003). We made species determination by using call characteristics such as slope, and minimum frequency as calculated by Analook, as well as general shape and consistency of minimum frequency throughout the call sequence. To minimize error rates, we used a strict filter (Britzke 2003) to eliminate call sequences

Table 1. Model name, habitat covariates, and range of data values of each covariate included in a priori models used to explain bat occupancy at the local site scale during 2002–2004 in the St. Francis and Black River watersheds, Missouri, USA.

Model name	Covariates	Covariate value range	k^a
Topography model 1	Aspect	0–360°	2
Topography model 2	Aspect,	0–360°	3
	% slope	0–60%	
Topography model 3	Aspect,	0–360°	3
	Relative slope position	1–10[b]	
Roosting model 1	BA of live trees >30 cm dbh	0–23 m^2/ha	2
Roosting model 2	BA of snags >30 cm dbh	0–3 m^2/ha	2
Roosting model 3	BA of live trees >30 cm dbh,	0–23 m^2/ha	4
	BA of snags >30 cm dbh,	0–3 m^2/ha	
	Overstory height	6–30 m	
Roosting model 4	BA of all snags	0–7 m^2/ha	2
Roosting model 5	BA of shortleaf pine >30 cm dbh	0–14 m^2/ha	2
Clutter model 1	BA of all live trees,	8–45 m^2/ha	3
	Canopy closure	1–10[c]	
Clutter model 2	BA of all live trees,	8–45 m^2/ha	3
	Understory density from 1–2 m,	0–28[d]	
	Understory density from 2–3 m	0–30[d]	
Clutter model 3	Understory density from 1–2 m,	0–28[d]	3
	Understory density from 2–3 m,	0–30[d]	
	Overstory height	6–30 m	
Water Model 1	Distance to nearest water	0.008–5.7 km	2

[a] *k* represents the number of variables incorporated in the model with the addition of 1 for the intercept.
[b] Relative slope measured as a categorical variable where 1 represents bottom of the slope and 10 the top of the slope.
[c] Canopy closure measured as categorical variable where 1 = ≤5% canopy closure, 2 = 5–25% canopy closure, 3 = 25–50% canopy closure, 4 = 50–75% canopy closure, and 5 = 75–100% canopy closure.
[d] Understory density consists of 2 measurements each representing the number of 10-cm squares obscured more than 50% from a total of 30 squares.

Table 2. Model name, landscape covariates, and range of data values of each covariate included in a priori models used to explain bat occupancy at the landscape scale during 2002–2004 in the St. Francis and Black River watersheds, Missouri, USA. Landscape metrics were derived using Fragstats and all values other than proportional land cover are unitless.

Model name	Covariates	Covariate value range	k^a
Landtype model 1	Ecological subsection		4
Land index model 1	Patch richness density	827–1861	2
Land index model 2	Area-weighted shape index	1.18–1.47	2
Land index model 3	Contagion	70–89	2
Land index model 4	Area-weighted shape index,	1.18–1.47	3
	Contagion	70–89	
Land cover model 1	Upland deciduous forest cover,	31–90%	3
	Area-weighted mean patch area	3.4–7.8	
Land cover model 2	Non-forested cover,	6–64%	3
	Area-weighted mean patch area	3.4–7.8	
Land cover model 3	Urban cover,	0–1%	3
	Area-weighted mean patch area	3.4–7.8	

[a] *k* represents the number of variables incorporated in the model with addition of 1 for the intercept.

with <5 call pulses as well as call sequences of poor quality, and we identified each call sequence twice. If the 2 identifications of the call sequence differed, we accessed it a third time.

Bats are known to switch frequently among roost trees within a defined area (Lewis 1995, Vonhof and Barclay 1996, Brigham et al. 1997*b*, Hutchinson and Lacki 2000, Menzel et al. 2000, Mager and Nelson 2001). Therefore, to meet the requirement of a closed population, we divided a single evening into 4 equal time periods (2000–2230, 2230–0100, 0100–0330, and 0330–0600 hours) with each time period treated as a sampling visit. If a call was recorded during that time period, we considered that species present and occupying the site. We defined occupancy as having a species present during the time sampled. If no identifiable call was recorded during a time period, we considered that species as not detected. We analyzed the resulting detection history with methods discussed in MacKenzie et al. (2002) using the software package PRESENCE to estimate proportion of sites occupied (http://www.mbr-pwrc.usgs.gov/software.html#surviv).

Study Area and Sample Point Selection

Using Global Information System, we superimposed the 2 watersheds with a grid of cells each 23.3 km^2 (9 $mile^2$) in size. We randomly selected 12 cells distributed across the 2 watersheds as study cells in which to focus our acoustic sampling effort. Our study was a portion of a larger project accessing the sustainability of central hardwood forests incorporating social, economic, and biological dimensions of natural resource management (Swihart and Slade 2004). We selected these 2 watersheds as representative in both landownership patterns and land cover found in the Ozark Highlands of Missouri. Therefore, we delineated size of the study cell to encompass the needs of multiple research projects. To determine placement of sample points within each study cell, we used a random point generator in ArcView 3.2 under the constraint of being within either upland deciduous forest or shortleaf pine–mixed-hardwood forest. We categorized forest patches in either of these cover types into 1 of 3 size classes: small (0.5–25 ha), medium (25–100 ha), and large (>100 ha), for a total of 6 sample-unit categories. We apportioned sample effort according to relative area in each size class–forest cover type combination.

Model Selection

We developed a priori models to examine the relationship between bat species occupancy and site (Table 1) and

landscape (Table 2) characteristics based on the literature and field observations. We used information theoretic methods to determine which of the models within the selected set provided the best fit with the fewest parameters (i.e., most parsimonious model [Anderson et al. 2000]). Due to the relatively low number of sample points in relation to the number of covariates used in the models, we used Akaike's Information Criteria adjusted for small sample size (AIC_c) in the model selection process. We considered the model with the smallest AIC_c value to best fit the data in relation to others in the given model set. We tested data for each species at each spatial scale to determine if the sampling variance exceeded theoretical sampling variance using methods described by MacKenzie and Bailey (2004). We developed these models for both local site and landscape scale from our field observations and from results in related literature (Decher and Choate 1995, Vonhof and Barclay 1996, Carter et al. 1999, Foster and Kurta 1999, Mager and Nelson 2001).

To incorporate detection probability properly into estimation of occupancy, we compared models influencing ability to detect a bat species using AIC_c (Hayes 2000, Sherwin et al. 2000, Weller and Zabel 2002, Patriquin et al. 2003, Broders et al. 2004). Covariates for detectability included year, time of season a site was sampled as divided into 7 2-week time periods (25 May–31 Aug), Julian date, understory density, minimum temperature (range 6–25°C), maximum temperature (range 17–38°C), and total precipitation during the day sampling took place (range 0–3.8 cm). We obtained weather data from 4 weather stations within the bounds of the 2 watersheds from National Climate Data Center on the National Oceanic and Atmospheric Administration website. We used existing literature to develop a list of covariates that could be used to explain detectability of bat echolocation calls. We did not, however, conclude that existing knowledge on the topic was sufficiently comprehensive to allow for the creation of a priori models. Using the program PRESENCE, we compared the AIC_c values of each of the detection covariates alone, and we then combined the 2 covariates with the highest values to see if the combination yielded a model that better fit the data than the highest single covariate alone. Once we determined the most parsimonious combination of covariates for each species, we included this detection probability model as part of all occupancy model comparisons for both the local site and landscape scales of that species.

We used AIC_c weights (w_i) for model selection among a priori habitat occupancy models at both spatial scales. We used the global model containing all habitat covariates for a given scale to test whether a significant difference existed between the covariates of the detectability model alone and occupancy model with the lowest w_i, using likelihood ratio test ($P < 0.1$; Anderson et al. 2000). Due to high levels of model uncertainty, we used model averaging as described by Anderson et al. (2000) to increase precision and minimize bias of parameter estimates. For model averaging we included the model with the highest w_i, adding additional models of the next-highest w_i until their sum was ≥ 0.95. We considered covariates included in models within 2 AIC_c units of the best model important in describing probability of occupancy of a bat species at that spatial scale.

Forest Structure and Composition

We determined basal area (BA) of each sample site using a 10-factor prism and 5 variable-radius plots arrayed around the sample site (Avery and Burkhart 2002). At point center, we took a single variable-radius plot measurement and at 60 m in each cardinal direction from the center. We used these measures to estimate size and species composition of tree species at forest plots. We estimated overstory and understory density at each sample point by taking measurements 5 m from center in each cardinal direction. By observing the number of 10 × 10-cm squares obscured on a 3-m × 0.3-m-tall density cover board from plot center in each cardinal direction, we estimated the density of the understory (Nudds 1977) from 1–2 m and from 2–3 m. We measured overstory canopy closure using a 12.5-cm section of 5-cm-diameter PVC pipe and estimating amount of canopy closure as viewed through the tube and assigned measurement values into one of 5 categorical classifications. We measured distance to water in km from a particular sample plot center to the nearest water source designated in land cover image.

Landscape Metrics

To assess landscape-level habitat metrics, and to avoid the abrupt delineation associated with the cell, we digitally circumscribed each 23.3-km^2 study cell with a 1.6-km (1-mile) buffer. The buffer incorporated additional area surrounding each study cell to ensure that landscape characteristics influencing sample locations near the edge of the 23.3-km^2 cell would be included in the calculation of metrics at this scale. We calculated landscape metrics from the resulting 64.8-km^2 (25-$mile^2$) area of each study cell, using FRAGSTATS 3.3 (MacGarigal et al. 2002). We used area-weighted mean shape index as a measure of the patch shape complexity, with increasing values indicating greater complexity and amount of edge present in the landscape. We used contagion as index of land cover interspersion, where a low value indicated high levels of interspersion and, thus, indicated higher levels of fragmentation. Patch richness density reflected the diversity of patch types within a study cell. Area-weighted mean patch size represented a measure of the average patch size within a study cell. We calculated the proportion of the landscape found in upland deciduous forest, nonforested and urban cover types within the GIS of each of the study cells. The nonforested coverage class incorporated agricultural lands, glades, and grasslands, whereas urban and upland-deciduous forest cover types remained as defined by MoRAP classification.

Results

We detected bat presence at 48% of 316 sites. From bat calls, we identified 9 species; 5 of these were present at ≥10% of the sample points, and we used them for further

Table 3. Covariates incorporated into models for detection probability of each bat species as determined by lowest value of Aikaike's Information Criterion adjusted for small sample size. The indicated covariates were used as the null model during model selection process for occupancy rates during 2002–2004 in the St. Francis and Black River watersheds, Missouri, USA.

Species	Covariates	k[a]
Eastern pipistrelle	Minimum temperature, within-season time period	8
Red bat	Precipitation	2
Northern long-eared bat	Year, precipitation	4
Indiana bat	Year	3
Gray bat	Year	3

[a] k represents the number of variables incorporated in the model with addition of 1 for the intercept.

analysis: 1) eastern pipistrelle (*Pipistrellus subflavus*; 25% of sites), 2) red bat (*Lasiurus borealis*; 20% of sites), 3) northern long-eared bat (*Myotis septentrionalis*; 19% of sites), 4) gray bat (10% of sites), and 5) Indiana bat (11% of sites).

Detection Probability

The most parsimonious model for detectability varied among species (Table 3). Year during which sampling occurred was the most-frequently included covariate in the detectability model with the lowest AIC_c weight. Year alone was the model with the most support for both the gray bat ($AIC_c = 399.2$) and the Indiana bat ($AIC_c = 469.6$). For both of these species, detectability was lowest during the 2002 field season and highest during the 2003 field season. Year and precipitation (range = 0–3.75 cm) were the covariates in the detectability model with the most support for northern long-eared bat ($AIC_c = 684.3$). Detectability for the northern long-eared bat was lowest during 2002 and highest in 2003, while an inverse relationship existed between detectability and precipitation during sampling. Precipitation alone was the detectability model with lowest AIC_c value for red bat ($AIC_c = 795.8$) with an inverse relationship between detectability and precipitation. The detectability model with the most support for eastern pipistrelle included minimum temperature (range = 6–25°C) and 2-week period of field season during which sampling occurred ($AIC_c = 894.3$). Minimum temperature was inversely related to detectability. Detectability varied across field season with the sixth 2-week time period having the highest and the seventh 2-week period having the lowest detectability.

Local-Site Scale

None of the a priori models were significantly better than the null model at explaining the occupancy of gray bat or northern long-eared bat across the 2 watersheds ($P > 0.1$). Among the remaining 3 species, the global model including all of the site covariates in addition to the most parsimonious sampling covariate model was significantly greater than the null model consisting of sampling covariates ($P < 0.1$).

At the local-site scale, the model with the highest AIC_c weight for eastern pipistrelle consisted of variables describing structural complexity of the forest (Table 4). Live BA was inversely related to occurrence (odds ratio = 0.95, SE = 0.05), whereas overstory canopy density was directly related to occurrence (odds ratio = 1.08, SE = 0.14) of eastern pipistrelle. The second-most-important model included live BA and understory density. Understory density from 1–2 m was directly related (odds ratio = 1.01, SE = 0.02), whereas understory density from 2–3 m was inversely related to probability of site occupancy (odds ratio = 0.99, SE = 0.01). The averaged model output for eastern pipistrelle estimated the proportion of sites occupied as 0.31 (SE = 0.032), an increase of 0.06 over observed occupancy.

Red bat occurrence at a site was best explained by the same covariate model as eastern pipistrelle (Table 4), with an inverse relationship with live BA (odds ratio = 0.97, SE = 0.03) and a direct relationship with overstory canopy density

Table 4. All a priori local-site habitat characteristic models for 3 species of forest-dwelling bats in the Ozark Highlands of Missouri, USA. Covariate components[a] of each model listed with the number of parameters (k), Aikaike's Information Criterion adjusted for small sample size (AIC_c), distance from the most parsimonious model (ΔAIC_c) and AIC_c weight (w_i). Lower AIC_c and ΔAIC_c and greater w_i represent models with more substantial support.

	Eastern pipistrelle				Red bat				Indiana bat			
Model	k	AIC_c	ΔAIC_c	w_i	k	AIC_c	ΔAIC_c	w_i	k	AIC_c	ΔAIC_c	w_i
Null	9	912.9	5.08	0.03	3	795.8	4.43	0.04	4	469.6	5.71	0.03
Topography model 1	10	911.8	3.95	0.06	4	796.2	4.80	0.03	5	471.7	7.77	0.01
Topography model 2	11	913.9	6.10	0.02	5	792.2	0.81	0.24	6	473.4	9.53	0.005
Topography model 3	11	913.8	6.02	0.02	5	798.2	6.86	0.01	6	471.6	7.68	0.01
Roosting model 1	10	914.7	6.93	0.01	4	796.0	4.64	0.04	5	470.0	6.05	0.03
Roosting model 2	10	910.5	2.68	0.11	4	795.0	3.65	0.06	5	463.9	0	0.54
Roosting model 3	12	914.4	6.58	0.02	6	797.0	5.60	0.02	7	466.1	2.14	0.18
Roosting model 4	10	913.1	5.35	0.03	4	797.9	6.45	0.01	5	468.7	4.80	0.05
Roosting model 5	10	910.1	2.28	0.13	4	797.0	5.63	0.02	5	471.8	7.76	0.01
Clutter model 1	11	907.8	0	0.41	5	791.4	0	0.35	6	469.4	5.50	0.03
Clutter model 2	12	909.7	1.88	0.16	6	796.6	5.26	0.03	7	468.9	4.99	0.04
Clutter model 3	12	917.6	9.75	0.003	6	797.2	5.81	0.02	7	469.7	5.79	0.03
Water Model	10	914.53	6.73	0.01	4	797.8	6.42	0.01	5	470.0	6.1	0.03
Global	21	920.3	12.45	0.001	15	793.6	2.20	0.12	16	475.6	11.66	0.002

[a] Specific covariates for each model are described in Table 1.

Table 5. All a priori landscape habitat characteristic models for 3 species of forest-dwelling bats in the Ozark Highlands of Missouri, USA. Covariate components[a] of each model listed with the number of parameters (k), Aikaike's Information Criterion adjusted for small sample size (AIC_c), distance from the most parsimonious model (ΔAIC_c) and AIC_c weight (w_i). Lower AIC_c and ΔAIC_c and greater w_i represent models with more substantial support.

	Red bat				Northern long-eared bat				Indiana bat			
Model	k	AIC_c	ΔAIC_c	w_i	k	AIC_c	ΔAIC_c	w_i	k	AIC_c	ΔAIC_c	w_i
Null	3	795.8	4.71	0.03	5	684.3	7.09	0.02	4	469.6	8.90	0.01
Land index model 1	4	793.7	2.64	0.10	6	683.4	6.23	0.03	5	470.6	9.84	0.01
Land index model 2	4	796.4	5.35	0.03	6	677.2	0	0.57	5	468.1	7.38	0.02
Land index model 3	4	797.7	6.57	0.01	6	682.8	5.62	0.03	5	468.4	7.65	0.02
Land index model 4	5	798.5	7.37	0.01	7	679.0	1.82	0.23	6	469.1	8.42	0.01
Land type model 1	6	791.9	0.83	0.24	8	682.1	4.89	0.05	7	468.4	7.64	0.02
Land cover model 1	5	792.4	1.31	0.19	7	687.6	10.38	0.003	6	469.1	8.37	0.01
Land cover model 2	5	798.5	7.42	0.01	7	683.3	6.13	0.03	6	460.7	0	0.82
Land cover model 3	5	797.2	6.08	0.02	7	686.8	9.65	0.004	6	470.2	9.46	0.01
Global	13	791.1	0	0.36	16	682.6	5.46	0.07	14	465.7	4.98	0.07

[a] Specific covariates for each model are described in Table 2.

(odds ratio = 1.32, SE = 0.32). The model with next-highest AIC_c weight included aspect (odds ratio = 0.91, SE = 0.16) and percent slope (odds ratio = 0.99, SE = 0.02). Probability of red bats occurring at a site decreased as the aspect deviated from south and decreased with steeper slopes. Estimated proportion of sites occupied from averaged model was 0.24 (SE = 0.028), an increase of 0.04 over observed occupancy.

The greatest weighted model for Indiana bat occurrence at the local-site scale involved BA of snags >30-cm diameter at breast height (dbh; Table 4). There was a direct relationship between the number of large-diameter snags (odds ratio = 2.06, SE = 0.51) and occurrence of Indiana bats. No other model was within 2 AIC_c units of this model. Using model averaging, the proportion of sites occupied was estimated to be 0.18 (SE = 0.032), an increase of 0.07 over observed occupancy.

Landscape Scale

None of the a priori models were significantly better than the null model at explaining the occupancy of gray bats and eastern pipistrelle across the 2 watersheds ($P > 0.1$). There was a significant difference between the global model and the null model for the red bat, northern long-eared bat, and Indiana bat ($P < 0.1$).

At the landscape scale the model with the greatest support for red bat was the global model containing all landscape covariates (Table 5). The model with the second-highest AIC_c weight incorporated ecological subsection. The red bat was most likely to be found in St. Francis Knobs and Basins ecological subsection (odds ratio = 6.8, SE = 2.52) and least likely to be found in the Black River Ozark Border subsection (odds ratio = 0.93, SE = 0.79). A model consisting of proportion of the landscape in upland-deciduous forest cover type (odds ratio = 2.85, SE = 4.20) and average patch size (odds ratio = 1.50, SE = 0.58) was also within 2 AIC_c units. Estimated proportion of sites occupied from model averaging was 0.24 (SE = 0.029), an increase of 0.04 over the observed occupancy.

Northern long-eared bat occupancy was best explained by area-weighted shape index (odds ratio = 0.91, SE = 0.07) where probability of northern long-eared bat occupancy decreased as average patch shape increased in complexity (Table 5). The second-most supported model included area-weighted shape index and contagion (odds ratio = 0.97, SE = 0.08). Although decreasing with shape complexity, northern long-eared bat occupancy increased with greater interspersion of patch types. Estimated proportion of sites occupied using model averaging was 0.31 (SE = 0.043), an increase of 0.12 over the observed occupancy rate.

The best model for the Indiana bat included area-weighted mean patch size and the proportion of landscape in nonforested cover types (Table 5). There was a direct relationship between both area-weighted mean patch size (odds ratio = 1.64, SE = 0.27) and proportion of landscape in nonforested cover type (odds ratio = 217.75, SE = 2.50) and the probability of Indiana bat occupancy at a sample point. There was no other model within 2 AIC_c units of this model. The average proportion of sites occupied by Indiana bat as estimated through model averaging was 0.16 (SE = 0.002), an increase of 0.05 over the observed occupancy rate.

Discussion

Species occupancy rates were influenced by characteristics at both the local site and landscape scales in the St. Francis and Black River watersheds during this study. Significant trends were found for red bats and Indiana bats at both the local site and landscape scales. Only models including variables measured at the local-site scale influenced the occupancy rates of eastern pipistrelle, while landscape metrics more appropriately explained the occupancy of northern long-eared bats. None of the variables measured at either scale adequately explained the occupancy of gray bats.

Detection Probability

While not directly influencing occupancy, the ability to detect species may drastically influence perceived occupancy as data from this study indicate. It is important, therefore, to highlight the environmental factors influencing the acoustic detection of species in forested areas. The probability of

detecting a given species is generally <1 (MacKenzie et al. 2002, Gu and Swihart 2004), and this is particularly true of bats (Hayes 2000, Sherwin et al. 2000, Patriquin et al. 2003, Duchamp et al. 2006). We used methods described by MacKenzie et al. (2002) to incorporate estimates of detection probability into occupancy estimates. Gu and Swihart (2004) suggested that some variables are interpreted as affecting occupancy when they may actually be influencing detection, leading to inappropriate conclusions. With this in mind, we included year as a detectability covariate rather than a covariate estimating occupancy.

Detection probabilities for the gray bat, the Indiana bat, and the northern long-eared bat were lowest in 2002. While annual shifts in population size may alter site occupancy among species with high reproductive potential, bats are long-lived and have low reproductive rates with noncyclic population patterns (Kunz and Racey 1998, Kunz and Fenton 2003). Small changes in population density may affect detectability of a species in a landscape, while not influencing occupancy (Royle and Nichols 2003). Shifts in general weather conditions among years may also influence levels of bat activity. Erickson and West (2002) found that bat detections in the Pacific Northwest were highest in areas with low precipitation and high temperatures. Shifts in overall weather patterns among years may have had a similar impact on the activity levels of bats during our study. Additionally, experience in placement of detectors gained during the 2002 field season may have led to increased detectability during 2003 and 2004. Weller and Zabel (2002) highlighted the impact of positioning of detectors on detectability of bats during acoustic surveys. Our use of 2 detectors at each sample location on each evening may compensate in part for inadequate placement for presence data; however, having 2 detectors did not eliminate the problems with detection from inappropriate placement.

Precipitation influenced the probability of detection for both the northern long-eared bat and the red bat. Precipitation can influence both activity levels of bat species and the attenuation of echolocation calls (Hayes 2000, Erickson and West 2002). Increased humidity following rainfall may negatively affect echolocation call detection distance, resulting in a decrease in the probability that a bat would fly through the zone of reception (Griffin 1971, Livengood 2003).

Eastern pipistrelle detection was most influenced by minimum air temperature and 2-week time period during the field season. Changes in detectability across field season could represent shifts in foraging activity caused by changing energy requirements during birth and rearing of pups (Racey and Swift 1985, Barclay 1989). Increases in foraging activity and more frequent returns to roosting location increase the probability of detection for lactating bats (Clark et al. 2002). The lowest probability of detection occurred during the fourth 2-week time period (7–20 Jul) and coincided with the onset of juvenile volancy (Whitaker 1998). Immediately after 20 July, an increase in detection probability occurred for 4 weeks until a decrease in the final 2-week time period. Increases in activity likely correspond with increasing temperature, a trend noted by Erickson and West (2002).

There were no significant models at either scale describing gray bat occupancy, even though calls were identified at 10% of the study sites. While variables included in models at both scales are appropriate for describing habitat for forest-dwelling bats, the gray bat is a cave-obligate species, using caves as both winter and summer roost sites (Decher and Choate 1995). A dependence on cave habitat may supersede other forest habitat characteristics in determining its distribution across the landscape. Although including cave locations could provide improved modeling information these data were not available. Open water or large rivers represent dominant foraging areas for gray bats (LaVal et al. 1977, Johnson 2002); hence, the time this species spends in the forest would be minimized, thereby explaining the lack of correlation between species presence and measured habitat characteristics we observed.

Local-Site Scale

The most parsimonious occupancy models at this scale for eastern pipistrelle and red bat included total BA as a covariate. Increases in live BA corresponded with decreases in the occupancy rate of these 2 bat species. The red bat is a foliage-roosting species, preferring clumps of leaves at the end of branches of deciduous trees as day roosts (Shump and Shump 1982, Hutchinson and Lacki 2000, Schwartz and Schwartz 2001). Eastern pipistrelles are known to roost in anthropogenic structures (Fujita and Kunz 1984, Whitaker 1998, Schwartz and Schwartz 2001); however, Veilleux et al. (2003) found eastern pipistrelles roosting in foliage of deciduous trees in Indiana, and others have reported eastern pipistrelles roosting in cavities (Carter et al. 1999, Kurta et al. 1999). Carter and Menzel (2006) further discuss the importance of foliage roost sites for eastern pipistrelle bats. Upland deciduous tree species (e.g., oak and hickory [*Carya* spp.]) dominated the 2 watersheds in our study, providing abundant roost sites across the landscape for foliage-roosting species (Lewis 1995).

Elmore et al. (2004) found that stand-level characteristics were more important than individual tree characteristics in explaining roost location for the red bat. Contrary to our findings, Hutchinson and Lacki (2000) found significantly lower BA surrounding red bat roost sites. The covariate of live BA includes all size classes and therefore could represent an increase in structural complexity within the stand a potential impediment for navigation (Crome and Richards 1988, Erikson and West 1996, Brigham et al. 1997*a*).

Although red bats are known to forage along forest edges, above canopies, and in forest openings, Mager and Nelson (2001) found that selected roosts were larger in diameter than randomly selected trees and suggested that the thicker canopies of such trees provided greater concealment from predators or protection from wind (Menzel et al. 2003, Elmore et al. 2004). Similarly, Menzel et al. (2000) found red bats roosting in areas with relatively dense overstory canopies.

The model with the second-highest AIC_c weight for

eastern pipistrelle included live BA and measures of understory density. Probability of occupancy for eastern pipistrelle was directly related to density at 1–2 m and inversely related to density at 2–3 m. Increased density of vegetation from 2–3 m represented a greater amount of shrubs and midstory vegetation in the forest, creating additional obstacles during commutes from roosting sites to foraging areas. Meanwhile, increases in vegetation density from 1–2 m represented greater density of lower shrubs, which may indicate a less dense midstory and greater light levels reaching the forest floor. This pattern represents additional evidence that changes in structural complexity beneath the forest canopy impact the occupancy of a site by eastern pipistrelle.

Aspect and slope were components of the model with the second-highest AIC_c weight for the red bat and the probability of occupancy decreased with deviance from south. This trend may be linked to thermoregulation needs during diurnal roosting periods since less solar exposure might compromise the increased energy requirements of lactating females and developing young (Crampton and Barclay 1998). Hutchinson and Lacki (2000) noted that red bats prefer upland habitats rather than bottomland habitats and attributed this habitat preference to increased solar radiation. Probability of red bat occupancy decreased as percent slope increased.

The most parsimonious model for the Indiana bat indicated a direct relation between the probability of occupancy and BA of large-diameter snags. Previous studies have indicated the use of large-diameter trees and snags by Indiana bats as roosting sites for maternity colonies (Callahan et al. 1997, Foster and Kurta 1999, Britzke et al. 2003, Carter and Feldhamer 2005). Larger snags can contain larger cavities and areas of loose bark, providing greater-capacity roosts for sheltering numerous bats. This increase in numbers of individuals in a roost provides greater thermoregulatory benefits for pup-rearing females in maternity colonies through concentrating of body heat. Other benefits may include possible information transfer among individuals within the same roost about quality foraging areas (Wilkinson 1992).

Surprisingly, the local-site model consisting of distance to water was ranked low for all species. Water is a dominant foraging habitat for several bat species (Krusic et al. 1996, Menzel et al. 2001, 2003, 2005*b*, Johnson 2002). This model was not included in any of the averaged models at the local-site scale, possibly attributed to the coarse scale at which we measured water. Owing to the ephemeral nature of many stream systems in the Ozark Highlands region (Nigh and Schroeder 2002), the land cover classification of water we used included only permanent water sources in the landscape easily visible from satellite imagery, and represents an under-representation of aquatic or riparian habitat.

Landscape Level

The global model including all covariates included in landscape models had the greatest amount of support for red bat, indicating that no one model was able to adequately predict occupancy of this species. Similarly, Elmore et al. (2004) failed to find distinguishing landscape characteristics influencing red bat roost selection, attributing this to the ubiquitous nature of foliage roost sites. Ecological subsection had the next-largest support for prediction of red bat occupancy. Additional investigation is necessary to further determine differences among these 4 subsections of the Ozark highlands. A third relevant model included a direct relationship with proportion of upland deciduous forest and an inverse relationship with mean patch size. Increase in upland deciduous forest type in the landscape would represent an increase in roosting habitat (Hutchinson and Lacki 2000).

The most parsimonious model for the northern long-eared bat indicated an inverse relation between occupancy and shape index. Higher values of shape index indicate a greater amount of edge in the landscape and can result in less core area of forest. Northern long-eared bats are associated with forested areas, roosting in snags and trees (Sasse and Pekins 1996, Waldien et al. 2000, Menzel et al. 2002), and foraging beneath the forest canopy (LaVal et al. 1977, Schwartz and Schwartz 2001, Owen et al. 2003, Ford et al. 2005). Our findings agree with studies that suggest this species requires contiguous tracts of forest cover (Lacki and Schwierjohann 2001, Owen et al. 2003). The model with the next-highest AIC_c weight for describing northern long-eared bat occupancy again inferred an inverse relationship with shape index, but it additionally suggests an inverse relationship with levels of contagion in the landscape. As cover type interspersion became greater, the probability of occupancy increased; therefore, it appears that fragmentation has no obvious negative influence on northern long-eared bats at levels found in these 2 watersheds. It should be noted that in the landscapes studied, the interspersion represents parcelization of different forest types rather than fragmentation by nonforested cover type.

Indiana bat occupancy at the landscape scale was directly related with the proportion of landscape in nonforested land cover type. Many studies have shown that Indiana bats roost and forage in forested and forest riparian areas (LaVal et al. 1977, Callahan et al. 1997, Ford et al. 2005, Menzel et al. 2005*a*), suggesting that increased proportion of nonforested area in the landscape should decrease the habitat occupancy of an area. Menzel et al. (2005*a*) tracked foraging Indiana bats and found that they avoided open areas, preferring bottomland forests and linear landscapes; however, the landscape in that study consisted of only 33% forested land cover, compared to 90% in our study. Miller (1996) found no significant difference in Indiana bat presence between forest- and nonforest-dominated landscapes in northern Missouri; however, Sparks et al. (2005) found that while Indiana bats foraged in forested areas more than expected by availability, they did spend nearly 50% of the time foraging over agricultural land cover types. Our results suggest that in a southern Missouri landscape dominated by forest cover, nonforest areas may provide landscape heterogeneity ful-

filling some habitat requirement not provided in a fully forested landscape.

Caveats

Although acoustic data may provide insight into trends in bat activity, caution should be taken when using results to develop management plans. Inability to distinguish among individuals and sexes within species as well as variability in detectability can lead to limited interpretation of species data collected acoustically. Difficulty in separating certain groups, such as *Myotis*, must be acknowledged and efforts made to avoid errors in classification of recorded calls. One method of minimizing errors drawn from misidentified call sequences is to combine similar species into groups or clades. We chose not to combine since it may result in the homogenization of habitat characteristics among and between bat species. While acoustic detection methods indicate the presence of bats, these methods provide little insight into how bats are using the site, a primary concern when developing management plans. Using recent methods incorporating detection probability addresses some of the limitations associated with acoustic sampling. Results from this study demonstrate the need to further investigate habitat relationships for bats in the Missouri Ozark region.

Management Implications

Several species of bats are endangered or of special concern, making it important to include bat habitat considerations when developing management plans. The St. Francis and Black River watersheds are dominated by contiguous forest cover, yet even within a landscape with little fragmentation, our data indicate that bat occupancy rates can be influenced by forest-management practices. We found trends indicating that occupancy rates of red bat and eastern pipistrelle were higher in stands with a more open understory, particularly from 2–3 m in height. Our study also suggests that management practices promoting retention of large-diameter snags (>30-cm dbh) may provide valuable roosting habitat for the federally endangered Indiana bat. In addition, our results showed that in a heavily forested landscape some heterogeneity in land cover may fulfill some additional habitat requirements for both Indiana and northern long-eared bats.

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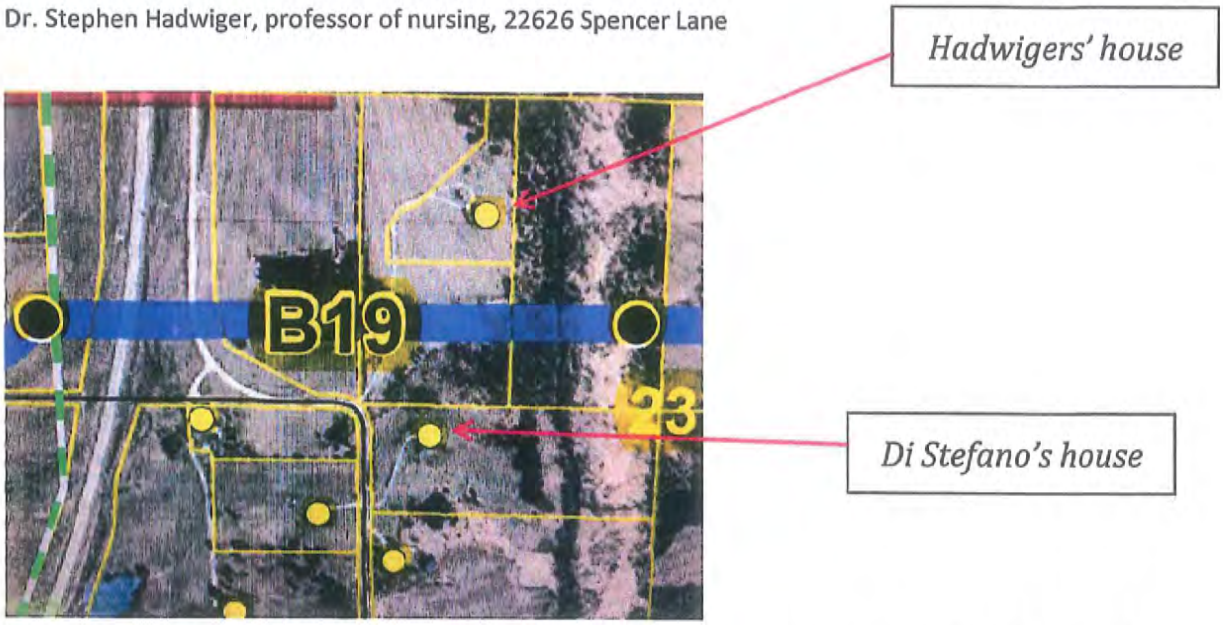
Associate Editors: Brooks and Ford.

EXHIBIT 7-K

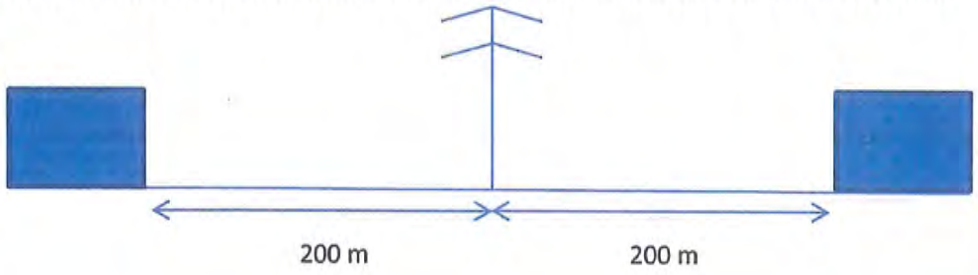
EXHIBIT 7-K

Dr. Stephen Hadwiger, professor of nursing, 22626 Spencer Lane

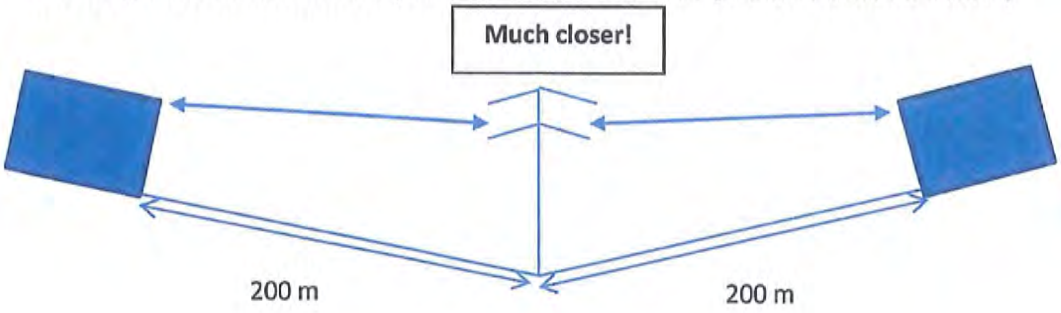


22626 Spencer Lane: Location across the southern 10 acres is a wetland valley between the homes of 22626 Spencer Lane (Hadwiger home) and Di Stefano home

Mark Twain Transmission diagrams depict flat lands when they calculate distances to homes



In reality, the distance from the powerlines to the homes is: [See the bolder blue lines!]



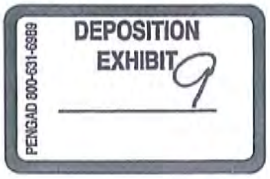


EXHIBIT 9-K

Dr. Stephen Hadwiger, professor of nursing, 22626 Spencer Lane

There have been several epidemiological studies that have investigated the risk ratios for acute lymphoblastic leukemia (ALL) among children. Draper et al. (2005) found a higher risk for children within 200 meters compared to children > 600 meters of electrical powerline high voltage (ELHV). Rodriguez-Garcia and Ramos (2010) found standardized rates of ALL and acute myeloblastic leukemia (AML) to be correlated as higher the closer proximity to high power lines. Kroll, Swanson, Vincent, and Draper [same author as first citation] (2010) found relative risks to be increased for leukemia, CNS/brain tumors, and other cancers, but these risks were statistically insignificant; they concluded "Magnetic-field exposure during the year of birth is unlikely to be the whole cause of the association with distance from overhead power lines that we previously reported" (p.1122). Sermauge-Faure et al. (2013) found an increased risk of childhood acute leukemia for areas within 50 meters of a high voltage overhead powerline. Pedersen et al. (2014) found a slightly elevated risk for childhood leukemia according to distance from high voltage power lines, but they concluded that too many other risk factors confounded their results; this study was done in Denmark.

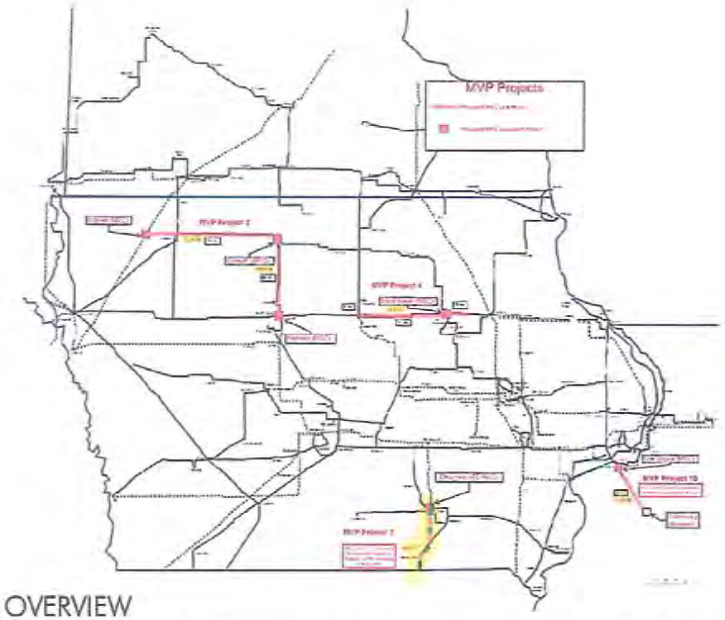
These results are inconclusive. There is NO evidence of causation, but there is enough evidence to question the safety of living close to high voltage electric overhead power lines. The evidence DOES NOT rule out health hazard. The public relations media campaign by Mark Twain Transmission denies ANY health hazard associated with electromagnetic radiation or overhead power lines. According to their representative for health issues, even pacemakers are not in risk of altered settings even though we teach patients to avoid power lines and other sources of electromagnetic radiation.

I have chronic lymphocytic leukemia (CLL)—it's not the same as acute lymphoblastic leukemia. But my form of leukemia is associated with other forms of cancer, including ALL. Again, these are only epidemiological correlations. But now I feel like I am going to be trapped in my own home, unable to sell because of the presence of a high voltage power line going across the field in front of my house and exposed to electromagnetic radiation at a much higher chronic dose than otherwise; my prognosis negatively affected by AMEREN's determination to force this power line through our neighborhood.

EXHIBIT 9-K

EXHIBIT 11-K

EXHIBIT 11-K

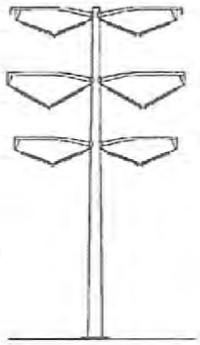


OVERVIEW

In December 2011, the Midcontinent Independent Transmission System Operator, Inc. board of directors unanimously approved the organization's Transmission Expansion Plan 2011. The plan is a comprehensive long-term regional plan for the electric grid that will bring more than $2 billion in annual benefits to energy consumers throughout the Midwest.

MidAmerican Energy is assisting with the construction of four Multi-Value Projects, or MVPs, included in the plan. MVPs with partial MidAmerican Energy ownership include:

- O'Brien to Kossuth to Webster counties in Iowa – MVP 3
- Emery to Black Hawk to Hazleton, Iowa – MVP 4
- Ottumwa, Iowa, to Adair, Mo. – MVP 7
- Oak Grove to Galesburg, Ill. – MVP 16



HOW WAS THE ROUTE SELECTED?

MidAmerican Energy retained an engineering company to perform comprehensive route studies for transmission lines that would run across northern Iowa and western Illinois. The studies were performed to develop a route in accordance with Iowa and Illinois statutes and the regulations of the Iowa Utilities Board and Illinois Commerce Commission while minimizing overall impact on property owners and natural resources. Among the factors considered were land use criteria, environmental considerations, engineering design criteria and setbacks.

WHY ARE THE PROJECTS NECESSARY?

The projects are primarily designed to:

- Improve system reliability
- Relieve existing transmission congestion
- Improve utilization of existing generation
- Lower the cost of delivered energy
- Optimize wind generation placement
- Allow for the regional delivery of renewable generation

WHAT ARE THE BENEFITS TO A LOCAL COMMUNITY OR LANDOWNER?

The projects create several economic benefits, including landowner easement payments, an increase in annual property tax payments to local counties, construction jobs, and future generation interconnection possibilities. The new single-pole structures will replace the existing two- or three-pole structures, which means there will be fewer poles per mile resulting in more land available for farming.

MULTI-VALUE PROJECT 3

- MidAmerican Energy will construct approximately 120 miles of 345-kV lines, rebuild the existing 161-kV transmssion lines, construct two new substations and modify one existing substation.

TIMELINE	
2012-2014	SITING AND RIGHT OF WAY
SEPTEMBER 2014 TO NOVEMBER 2016	CONSTRUCTION
YEAR-END 2016	IN-SERVICE

MULTI-VALUE PROJECT 4

- MidAmerican Energy will construct approximately 71 miles of 345-kV lines, rebuild the existing 161-kV transmission lines and modify one existing substation.

TIMELINE	
2012-2014	SITING AND RIGHT OF WAY
JULY 2014 TO DECEMBER 2016	CONSTRUCTION
YEAR-END 2016	IN-SERVICE

MULTI-VALUE PROJECT 7

- The project entails construction of approximately 20 miles of 345-kV, rebuilding the existing 160-kV transmission lines.

TIMELINE	
2015-2017	SITING AND RIGHT OF WAY
NOVEMBER 2017 TO MAY 2018	CONSTRUCTION
YEAR-END 2018	IN-SERVICE

MULTI-VALUE PROJECT 16

- The project entails construction of approximately 32 miles of 345-kV transmission lines, rebuilding the existing 161-kV transmission lines, and expanding existing substations at Oak Grove and Galesburg, Ill.

TIMELINE	
2013-2014	SITING AND RIGHT OF WAY
NOVEMBER 2015 TO NOVEMBER 2016	CONSTRUCTION
YEAR-END 2016	IN-SERVICE

- **TOTAL LINE LENGTH FOR:** Approximately 243 miles traversing portions of 12 Iowa and four Illinois counties
  - MVP 3 – Clay, Humboldt, Kossuth, O'Brien, Palo Alto and Webster counties in Iowa
  - MVP 4 – Black Hawk, Butler and Franklin counties
  - MVP 7 – Appanoose, Davis and Wapello counties
  - MVP 16 – Henry, Knox, Mercer and Rock Island counties
- **POLE TYPE:** The poles are made of self-weathering steel and do not require painting or periodic maintenance.
- **HEIGHT OF POLES:** The height of the single-circuit structures will be approximately 100 to 120 feet. The height of the double-circuit structures will be approximately 120 to 150 feet.
- **DISTANCE BETWEEN POLES:** The span length will be approximately 1,000 to 1,100 feet. Existing 161-kV line poles are approximately 660 feet.
- **LOCATION OF POLES:** The poles will primarily be located along lines of land division, road rights of way and railroads. The poles also may be located along existing transmission line routes.
- **DISTANCE BETWEEN THE GROUND AND THE TRANSMISSION LINE:** The line height at the structure is approximately 60 feet. The line height at midspan will be at least 27 feet.
- **RIGHT OF WAY REQUIRED/WIDTH OF EASEMENT:** MidAmerican Energy is requesting a project right of way width of 150 feet.
- **COMPENSATION FOR LANDOWNERS:** MidAmerican Energy will pay a predetermined percent of the average land value for permanent easement and a predetermined percent of the average land value for temporary construction work space. An additional payment will be made if a pole is located on a property.
- **TRANSMISSION LINE MAINTENANCE:** MidAmerican Energy will contact property owners before accessing the right of way for line repair or maintenance; however, in an emergency, MidAmerican Energy has the right to make repairs before landowners respond to initial contact.

QUESTIONS?

866-950-9588 – Land Services
www.midamericanenergy.com/MVPtransmission

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OBSESSIVELY, RELENTLESSLY AT YOUR SERVICE.

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EXHIBIT 11-K

MIDAMERICAN ENERGY COMPANY'S MULTI-VALUE PROJECTS

MidAmerican ENERGY
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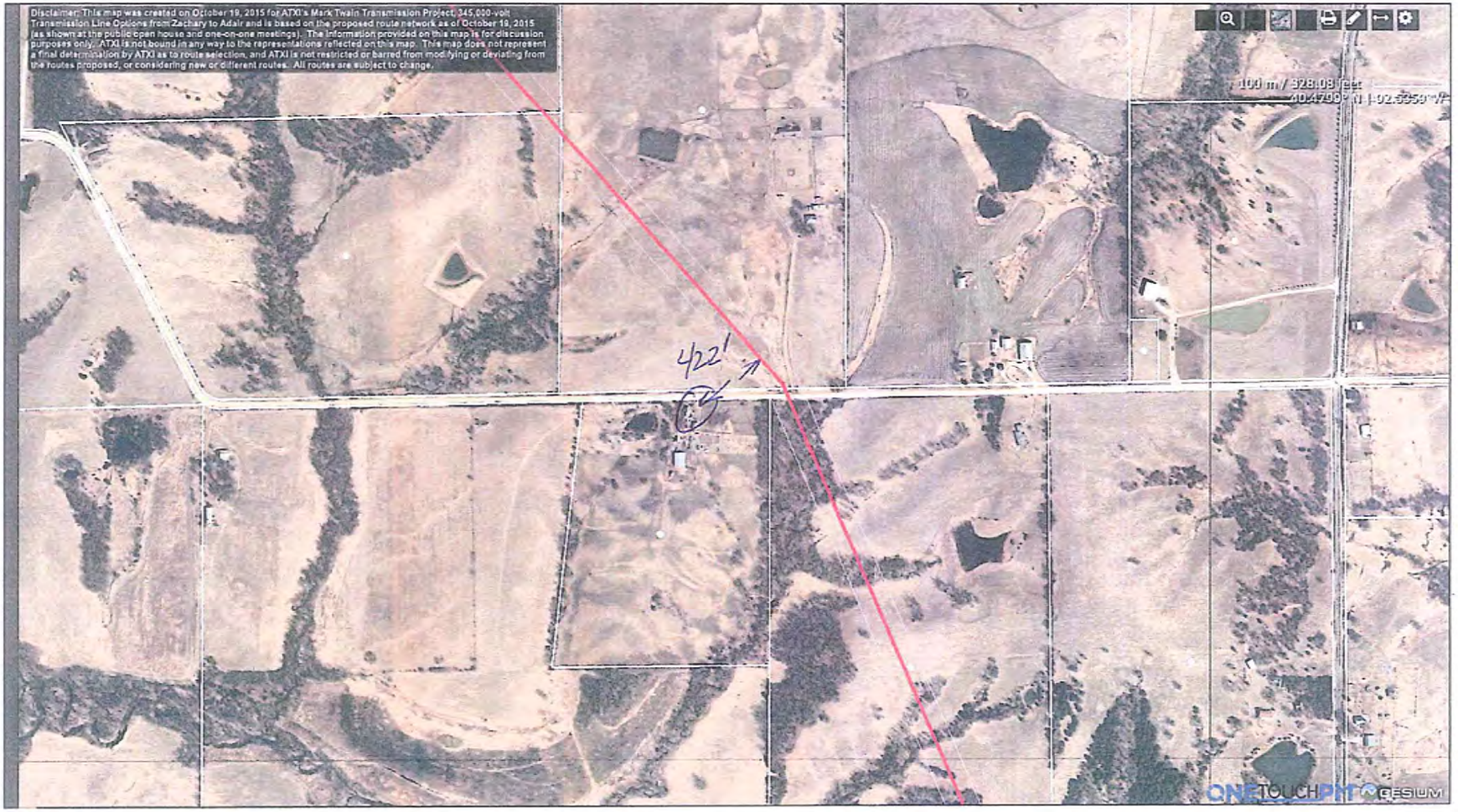
MidAmerican Energy Company provides electric service to 739,000 customers and natural gas service to 719,000 customers in Iowa, Illinois, Nebraska and South Dakota. It is headquartered in Des Moines, Iowa.



11010020606000000360 JOHN & DEBRA LEUNEN

EXHIBIT 11-K


Disclaimer: This map was created on October 19, 2015 for ATXI's Mark Twain Transmission Project, 345,000-volt Transmission Line Options from Zachary to Adair and is based on the proposed route network as of October 19, 2015 (as shown at the public open house and one-on-one meetings). The information provided on this map is for discussion purposes only. ATXI is not bound in any way to the representations reflected on this map. This map does not represent a final determination by ATXI as to route selection, and ATXI is not restricted or barred from modifying or deviating from the routes proposed, or considering new or different routes. All routes are subject to change.
100 m / 328.08 feet
40.5574° N | 92.6355° W
N
ONETOUCHPM
CESIUM

EXHIBIT 11-K


Disclaimer: This map was created on October 19, 2015 for ATXI's Mark Twain Transmission Project, 345,000-volt Transmission Line Options from Zachary to Adair and is based on the proposed route network as of October 19, 2015 (as shown at the public open house and one-on-one meetings). The information provided on this map is for discussion purposes only. ATXI is not bound in any way to the representations reflected on this map. This map does not represent a final determination by ATXI as to route selection, and ATXI is not restricted or barred from modifying or deviating from the routes proposed, or considering new or different routes. All routes are subject to change.
100 m / 328.08 feet
40.5885° N | 92.6370° W
202
202
202
N
ONETOUCHPM
CESIUM
bing

EXHIBIT 11-K


Disclaimer: This map was created on October 19, 2015 for ATXI's Mark Twain Transmission Project, 345,000-volt Transmission Line Options from Zachary to Adair and is based on the proposed route network as of October 19, 2015 (as shown at the public open house and one-on-one meetings). The information provided on this map is for discussion purposes only. ATXI is not bound in any way to the representations reflected on this map. This map does not represent a final determination by ATXI as to route selection, and ATXI is not restricted or barred from modifying or deviating from the routes proposed, or considering new or different routes. All routes are subject to change.
200 m / 656.17 feet
40.5946° N | 92.6287° W
202
ONETOUCHPM CESIUM

EXHIBIT 11-K


Disclaimer: This map was created on October 19, 2015 for ATXI's Mark Twain Transmission Project, 345,000-volt Transmission Line Options from Zachary to Adair and is based on the proposed route network as of October 19, 2015 (as shown at the public open house and one-on-one meetings). The information provided on this map is for discussion purposes only. ATXI is not bound in any way to the representations reflected on this map. This map does not represent a final determination by ATXI as to route selection, and ATXI is not restricted or barred from modifying or deviating from the routes proposed, or considering new or different routes. All routes are subject to change.
200 m / 656.17 feet
40.5424° N | 92.6244° W
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EXHIBIT 11-K

April 3, 2015

Missouri Public Service Commission

PO Box 360

Jefferson City, Missouri 65102-0360

Dear Commissioner's:

Re: case# EA-2015-0146

I am strongly opposed to Ameren transmission Company of Illinois' proposed Mark Twain Transmission Project, and ask that they be denied public utility status and the project not be approved.

This company has indicated that they intend to build a power line at a diagonal (not along property lines) across over 100 acres of my parent's best farm land. My parents are over 90 years old and are confined to a nursing home. They must sell their farm to meet nursing home costs. My father is a World War II veteran and his farm is a result of a lifetime of hard work and sacrifice. I am concerned that this power line may result in a decrease in the value of their farm by as much as 50% at a time when they are being forced to sell their property to meet their needs.

Attached is a copy of a Kirksville Daily Express Newspaper article dated October 31, 2014. This article illustrates how arrogantly they treat Missouri citizens and how little regard they have for the rights of Missouri citizens and the laws of the state of Missouri. It also is an example of how their actions contradict their statements and how unreliable they are.

They invited the public to attend their "open house" meeting and to "come ask questions". Their company spokesman is quoted as saying "we want to hear their questions, their concerns, respond to them and make certain that when they leave here today they have the facts". I ask that same spokesman (in a civil manner) about Missouri state law 229.100. I asked him about the reports that several Missouri counties were using that law to refuse to allow the company to construct power lines across their counties. I was surprised that he responded by saying he did not know the answer to that question and that if I ask that question again he was going to have me "escourted" off the property. At his request I was escourted out of the meeting. To my knowledge they had no legal right to treat me in that manner. Please protect us from this company.

Thank you for your consideration.

David Sidwell

PO Box 323

Queen City, Missouri 63561

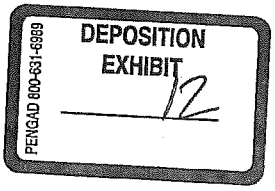


EXHIBIT 12-K

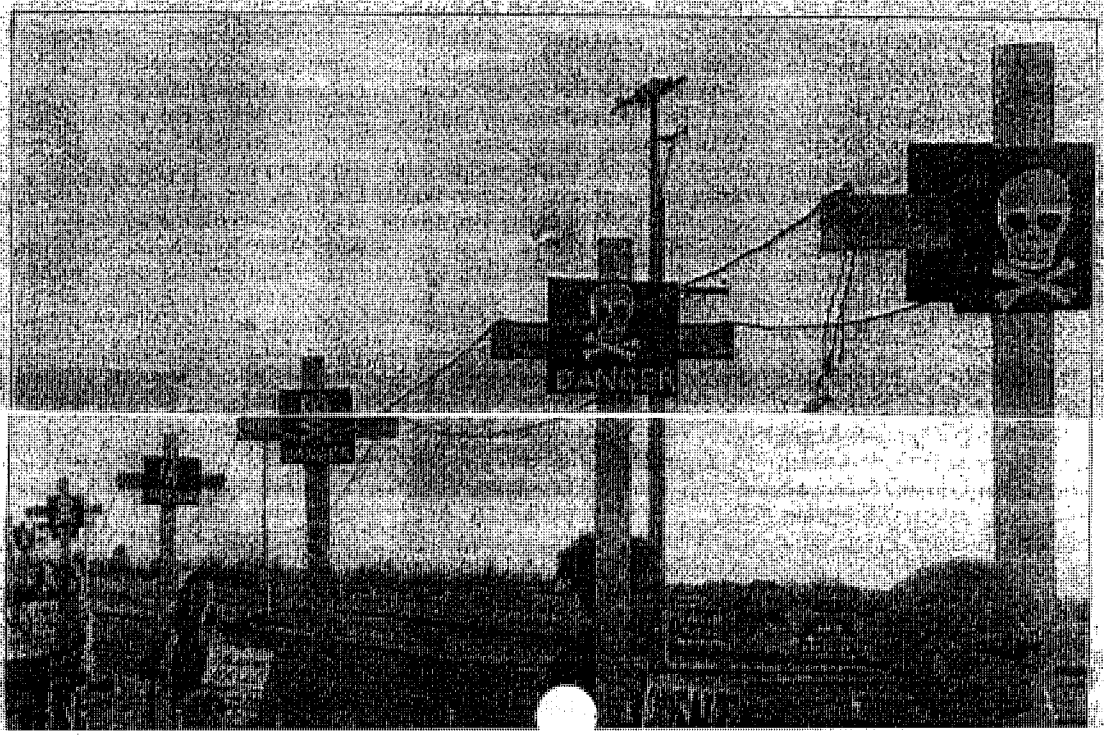
Kirksville Daily Express

FRIDAY, October 31, 2014 | KirksvilleDailyExpress.com | Vol. 113, No. 257 | 75¢

WHAT'S INSIDE

KIRKSVILLE

AMEREN FACES THE PUBLIC



KIRKSVILLE

Leaders meet on Missouri's energy future

Meeting part of effort for new statewide energy plan

JASON HUNSICKER
jhunsicker@kdeq

Energy leaders and interested citizens came together Thursday afternoon at Truman State University for the seventh and final meeting of the Missouri Comprehensive Statewide Energy Plan.

Meetings have been hosted statewide by the Missouri Division of Energy as part of an executive order signed by Gov. Jay Nixon this year that directed the division of the Missouri Department of Economic Development to research and create a comprehensive statewide energy plan for Missouri's future.

Division of Ener... Director

HIS CHANCE

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Neighbors United Against Ameren's Power Line protest outside of Ameren's open house session.
DANIELLE BROWN/DAILY EXPRESS

Protestors, questions at Mark Twain Transmission Project open house

Above: A Neighbors United Against Ameren's Power Line member protests against Ameren's Mark Twain Transmission Project. Below: Nearby residents speak with Ameren representatives at Thursday's open house. DANIELLE BROWN/DAILY EXPRESS

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Who is this going to benefit? Why in Kirksville? Will the property value go down? Does this line go through my property?

These were the types of questions Ameren representatives were faced with Thursday night during the second series of open house sessions regarding Ameren's proposed Mark Twain Transmission Project – a 345,000-volt transmission line that will run from Palmyra to Kirksville and then turn north towards the Iowa border, where the lines will interconnect with others.

Ameren Transmission Company of Illinois, or ATXI, representatives pushed possible benefits northeast Missouri residents will see from the transmission line and said the purpose of the evening was to hearing community feedback and present them the project plans after receiving some public scrutiny.

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...campus and touted energy efficiency projects the university has taken on in recent years. Five solar panel systems have been installed, each generating 32,000 kilowatt hours per year. In 2014 alone the power value generated is already $9,300, exceeding the year's lease cost.

The university also installed a mid-sized steam boiler in 2010. The unit provides steam in non-winter months and saves Truman about $60,000 annually. A majority of computer servers have also been eliminated, with the move to virtual servers significantly dropping the university's consumption for heating and cooling.

Thursday's meeting brought to-

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FORT KENT, MAINE

Court order temporarily restricts nurse's movement

(AP) – Maine health officials obtained a 24-hour court order restricting Kaci Hickox's movement after the nurse repeatedly defied the state's quarantine for medical workers who have treated Ebola patients.

A judge granted the order Thursday limiting Hickox's travel, requiring a three-foot buffer if she encounters people, and banning her from public places until there's a further decision Friday.

The state went to court Thursday, following through

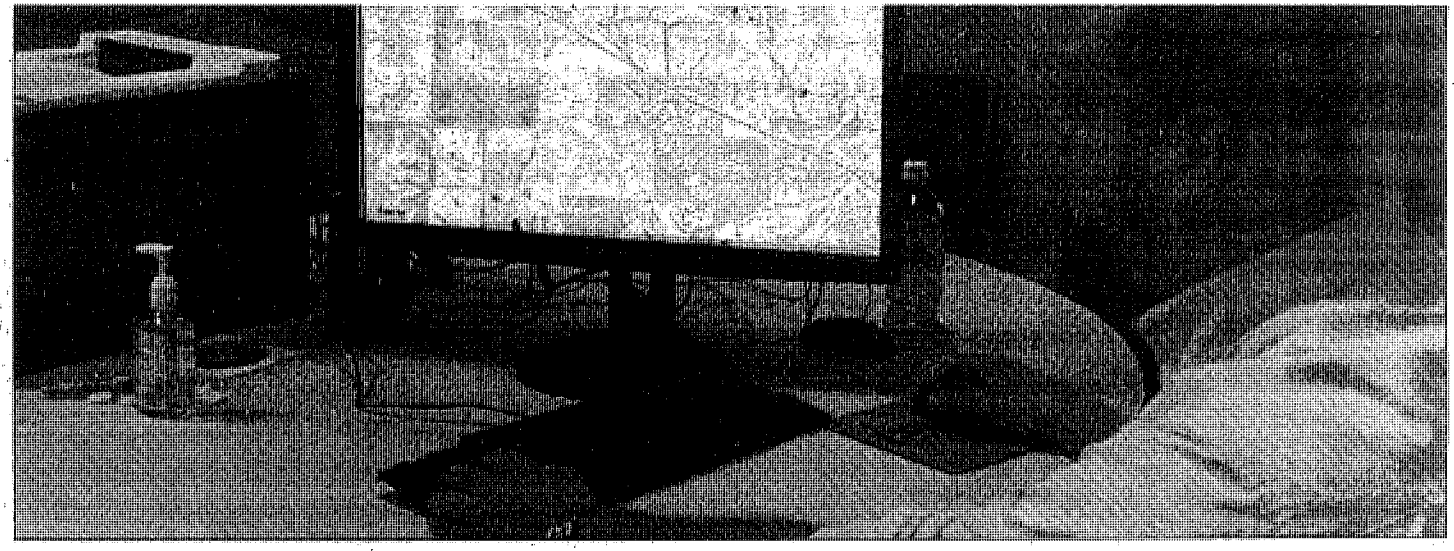
EXHIBIT 12-K

we want to hear their questions, their concerns, respond to them and make certain that when they leave here today they have the facts," spokesman for the Mark Twain Transmission Project Leigh Morris said.

"Not theory, not supposition, not what somebody said. They're getting it from the horse's mouth here today, and they're going to get the truth."

Local residents and landowners were taken from station to station to hear those facts, see the purpose and planning of the project and get their questions answered.

Morris said one of the main reasons for building the transmission lines is to bring renewable power to the state of Missouri.



An Ameren rep shows landowners how close their properties will be to the transmission line (red line). DANIELLE BROWN/DAILY EXPRESS

He also said the transmission line will fall under Missouri's Renewable Energy Standard, which was approved by voters in 2008. The standard requires 20 percent of the power delivered by the state's public utility companies to come from renewable resources, according to Morris.

"MISO (Midcontinent Independent System Operator) has already determined that this line has to be built, and if Ameren Transmission Company doesn't build it then they'll select somebody else to build it," ATXI spokesman for the Mark Twain Transmission Project Leigh Morris said.

Morris said the transmission lines will also serve to create jobs, system reliability and reduce transmission congestion. Current transmission lines are becoming too small to move large amounts of energy from one place to the next.

Substations will transfer power through the 100 miles of transmission lines to distribution utilities. Morris said one of the substations being used for the li[illegible] located in Kirksville which is why the proposed routes come through the area. The utility companies will then deliver that power to their customers.

When asked if the power being delivered by the transmission line will be used to service the nearby area, Morris repeated that the power is "transferred to utilities who in turn wind up delivering that power" to all customers, not specifically to one area.

Ameren has also offered to residents whose property will be affected by the transmission lines a one-time lump-sum payment for the use of the properties or decreased property value.

Some local landowners present at the open house were still not happy with Ameren after the open house session and questioned the some of the company's responses to them.

"I think a lot of what they say is actually disingenuous, and it's not real factual. It's very controlled. Only what they want you to know," landowner Rosanna Abreo said. "It's really difficult to understand why they can't tag on to an existing line with all the technology that's out there, instead of ruining additional farmlands and habitats."

"They know how to pass the buck on to the next station, and you'll have that person there or this person here this is what we're used to," Dwight Peterson, whose property is on one of the proposed routes, said.

"We're just working with them to make sure our rights are protected," his wife Judy Peterson said.

The Petersons are also a part of the Neighbors United Against Ameren's Power Line group, who were protesting outside of the open house.

Some attendees were escorted out during the open house session.

Schuyler County resident David Sidwell said he was escorted out after asking specifically about Missouri State Law 229.100, which reads:

"No person or persons, association, companies or corporations shall erect poles for the suspension of electric light, or power wires, or lay and maintain pipes, conductors, mains and conduits for [illegible] purpose whatever, through, on, under or across the public roads or highways of any county of this state, without first having obtained the assent of the county commission of such county..."

"I was just curious. If eight or nine counties say they won't support your line, where does that put you with your line," Sidwell said. "They said 'We don't know. There's nobody here that knows, and if you ask that question again we're going to ask you to leave the premises.' I'm just trying to ask one basic question that I'm curious about. They asked me to leave. I just thought that was a basic question that was OK to ask."

Ameren representatives also met with city staff earlier in the day at community forum concerning the transmission lines. Kirksville City Council member Rick Steele released the following statement about the forum:

"The questions presented by Kirksville City Staff were department specific and dealt with many issues such as how these lines would affect air traffic at our airport.

My concerns were if any of this project would be within the city limits; why they weren't working with the Missouri Public Service Commission; how vegetation control would be done; issues regarding Use Taxes; and the need for timely and complete information to be provided to the municipality - not the up to one year delay in responding to our queries.

But, perhaps my greatest concern is the issue over eminent domain and trying to force property owners to accept a smaller lump-sum payment that would bind the land forever instead of negotiated leases. This worries me in that it would appear that a private company would be exercising the powers of a government body and while today it may not directly affect those within the city limits it would set a most dangerous precedent. Also of concern were the often contradictory answers."

The next step for the project will be to select a final route for the transmission line. Currently, there are two proposed routes for the project. Morris said the routes will most likely be finalized by the end of th[illegible].