

DEVELOPING METHODS TO REDUCE BIRD MORTALITY IN THE ALTAMONT PASS WIND RESOURCE AREA



Arnold Schwarzenegger
Governor



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Prepared By:
BioResource Consultants

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Prepared By:

K. Shawn Smallwood
Carl G. Thelander
BioResource Consultants
Contract No. 500-01-019

Prepared For:

California Energy Commission

Linda Spiegel
Program Manager

Kelly Birkinshaw
Program Area Lead
Energy Related Environmental Research

Marwan Masri
Deputy Director
Technology Systems Division

Robert L. Therikelsen
Executive Director

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- FINAL REPORT -

PIER-EA Contract No. 500-01-019



By:

K. Shawn Smallwood
Carl G. Thelander

BioResource Consultants
P.O. Box 1539
Ojai, CA 93024-1539
805.646.3932

Program Manager
Linda Spiegel
California Energy Commission

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PREFACE

The Public Interest Energy Research (PIER) Program managed by the California Energy Commission (Commission) supports public interest energy research and development that will help to improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace. The PIER Program annually awards up to \$62 million to conduct the most promising public interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions. PIER funding efforts are focused on the following six RD&D program areas:

- Buildings End-Use Energy Efficiency
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy
- Environmentally Preferred Advanced Generation
- Energy-Related Environmental Research
- Strategic Energy Research

What follows is the final report to the California Energy Commission for Contract Number 500-019-01, conducted by BioResource Consultants of Ojai, California, as a contribution to the Energy-Related Environmental Research Program. For more information on the PIER Program, please visit the Commission's Web site at: <http://www.energy.ca.gov/research/index.html> or contact the Publications Unit at 916-654-5200.

REPORT ORGANIZATION

Chapter 1, *Understanding the Problem*, reviews the hypotheses and speculations of the causal factors of bird mortality at wind farms. Beginning in Chapter 1, the term “wind farm” is used throughout. A wind farm consists of more than one wind turbine and the related infrastructure needed to collect the generated power. It presents a framework and terminology for discussion of the problem, as well as the experimental and analytical approaches used in this study, and why they were used. This chapter also describes the objectives and the study area.

Chapter 2, *Cause of Death and Locations of Bird Carcasses in the APWRA*, presents a summary of the causes of death attributed to carcasses found in the APWRA, and it analyzes the distances of carcasses found from wind turbines. The mortality estimates presented in Chapter 4 are adjusted based on an analysis of the distances that carcasses were found away from the wind turbines.

Chapter 3, *Bird Mortality in the Altamont Pass Wind Resource Area*, presents the fatality search methods and the mortality estimates. These estimates were adjusted by search effort and searcher deficiencies such as the limitations of the search radius, removal of carcasses by scavengers, and searcher detection rates. Mortality is estimated and compared inter-annually, as well as summarized for the study period with low and high estimate values for mortality per species.

Chapter 4, *Impacts to Birds Caused by Wind Energy Generation*, integrates standardized estimates of bird mortality among those wind energy facilities from which estimates have been reported. This chapter places the bird mortality of the APWRA in context with other wind energy facilities. It compares bird mortality and bird activity levels in the APWRA among studies that reported these metrics from the early 1990s through the present study nearly a decade later.

Chapter 5, *Range Management and Ecological Relationships in the APWRA*, summarizes ecological patterns observed in the APWRA and how they relate to rodent control, physiography, elevation, and other measured variables. This chapter examines vegetation height, cattle grazing intensity, the abundance of certain raptor prey species, and speculates on how each might relate to the wind turbine-caused mortality of various bird species.

Chapter 6, *Distribution and Abundance of Fossorial Animal Burrows in the APWRA and the Effects of Rodent Control on Bird Mortality*, presents an analysis of how ground squirrels and pocket gophers responded to a rodent control program conducted in the APWRA, as well as to other measured variables, such as slope grade and elevation. The distribution and abundance of ground squirrels and pocket gophers is related to raptor mortality in this chapter, and the effectiveness of the rodent control program is evaluated.

Chapter 7, *Bird Fatality Associations and Predictive Models for the APWRA*, begins by reviewing hypothesized causes of bird collisions with wind turbines. It then provides details about the variables that were measured and the methods used to test for significance of associations between predictor variables and bird fatalities. All possible relationships between fatalities and measured variables were tested. The most meaningful results are presented and used to formulate indicators of threat posed by wind turbines to selected bird species in the APWRA. Maps of predicted levels of threat are presented for future planning purposes (e.g., turbine siting).

Chapter 8, *Bird Behaviors in the Altamont Pass Wind Resource Area*, presents the experimental and analytical methods used to study bird activity levels and behaviors in the APWRA. Significant and meaningful associations between measured predictor variables and behaviors are summarized.

Chapter 9, *Conclusions and Recommendations*, identifies mitigation measures that follow from the research results and that will most effectively reduce bird mortality caused by the continued operation of the existing wind turbines in the APWRA. This chapter also prioritizes the recommended mitigation measures, and recommends discontinuing some that remain in use.

Appendix A is a paper entitled, *Measuring Impacts to Birds Caused by Wind Turbines*. The standard measurement of mortality currently being used by researchers is the number of fatalities per wind turbine per year. This paper presents a new metric for reporting bird mortality at energy generation facilities, including wind energy facilities. This metric, the number of deaths per megawatt of power generation per year, standardizes comparisons of impacts among wind farms composed of very different wind turbine models, as well as between wind power generation and other forms of power generation. The term will be easier for the public to comprehend because it is one simple step away from presenting the impacts on a per capita or a per household basis. This chapter, and this metric, provides much of the foundation for data presented in Chapter 4.

Additional technical appendices (B, C, and D) are provided in the order in which they are referenced in the report.

TABLE OF CONTENTS

PREFACE	iii
REPORT ORGANIZATION	iv
EXECUTIVE SUMMARY	1
ABSTRACT	6
1. UNDERSTANDING THE PROBLEM	7
1.1 Introduction	7
1.1.1 Natural Behaviors and Ecological Relationships: Susceptibility.	8
1.1.2 Exposure to Wind Farm Operations: Vulnerability.	9
1.1.3 Measuring Effects on Birds: Impacts.	10
1.1.4 Relating Impacts to Causal Variables: Predictions and Solutions	11
1.2 Objectives	12
1.3 Study Area	13
2. CAUSE OF DEATH AND LOCATIONS OF BIRD CARCASSES IN THE APWRA	28
2.1 Introduction	28
2.2 Methods	28
2.3 Results	29
2.3.1 Overview of Bird Fatalities in the APWRA	29
2.3.2 Distances of Bird Carcasses from Wind Turbines	38
2.4 Discussion.	45
3. BIRD MORTALITY IN THE APWRA	46
3.1 Introduction	46
3.2 Methods	47
3.3 Results	52
3.4 Discussion	76
4. IMPACTS TO BIRDS CAUSED BY WIND ENERGY GENERATION.	77
4.1 Introduction	77
4.2 Methods	77
4.3 Results	78
4.4 Discussion.	80
4.4.1 APWRA Impacts Relative to Other Wind Energy Generating Facilities.	80
4.4.2 Reporting Shortfalls	86
5. RANGE MANAGEMENT AND ECOLOGICAL RELATIONSHIPS IN THE APWRA.	87
5.1 Introduction	87
5.2 Methods	90
5.2.1 Statistical Analysis	91
5.3 Results	91
5.3.1 Vegetation Height	91
5.3.2 Cattle Use Intensity	94

5.3.3 Cottontail Abundance	99
5.3.4 Lizard Abundance	103
5.4 Discussion.	106
6. DISTRIBUTION AND ABUNDANCE OF FOSSORIAL ANIMAL BURROWS IN THE APWRA AND THE EFFECTS OF RODENT CONTROL ON BIRD MORTALITY	109
6.1 Introduction	109
6.2 Methods	111
6.3 Results	114
6.3.1 Density and Distribution of Burrowing Animals	114
6.3.2 Seasonal and Inter-annual Variation in Distribution and Abundance	124
6.3.3 Associations with Wind Turbine String Attributes and Range Management	124
6.3.4 Relationships Between Raptor Mortality and Small Mammal Burrow Distributions	149
6.3.5 Relationships Between Bird Mortality and Rodent Control	172
6.4 Discussion.	172
7. BIRD FATALITY ASSOCIATIONS AND PREDICTIVE MODELS FOR THE APWRA	179
7.1 Introduction	179
7.2 Methods	182
7.2.1 Variables.	182
7.2.2 Analysis	184
7.2.3 Measures of Effect	188
7.2.4 Predictive Model	188
7.3 Results	189
7.3.1 Sample Characteristics	189
7.3.2 Fatality Associations	203
7.3.3 Predictive Models of Mortality	222
7.4 Discussion.	242
7.4.1 Model Predictions	242
7.4.2 Wind Turbine/Tower Attributes	243
7.4.3 Physiography	244
7.4.4 Wind Farm Configuration	245
7.4.5 Rodent Control and Burrowing Animals	245
8. BIRD BEHAVIORS IN THE APWRA	246
8.1 Introduction	246
8.2 Methods	246
8.2.1 Level of Plot Analysis	251
8.2.2 Wind Turbine Level of Analysis	252
8.2.3 Statistical Tests	253
8.2.4 Measures of Effect	255
8.3 Results	255
8.3.1 Characteristics of the Observation Sessions	255
8.3.2 Overall Raptor Use	256
8.3.3 Association Analysis	268
8.3.4 Flight Heights Relative to Existing and Future Rotor Planes	308

8.4 Discussion.	313
8.4.1 Golden Eagle Behaviors.	313
8.4.2 Red-tailed Hawk Behaviors	314
8.4.3 American Kestrel Behaviors	315
8.4.4 Bird Behaviors and Fatalities	326
8.4.5 Wind Turbine Perceptions by Birds	330
8.4.6 Flight Heights Relative to Existing and Proposed Future Rotor Planes	331
9. CONCLUSIONS AND RECOMMENDATIONS	333
9.1 Assessment and Recommendation of Mitigation Measures	333
9.2 Implement Measures to Reduce Impacts	348
9.3 Future Research Needs for Improved Performance of the Predictive Model	352
9.4 What Have We Learned?	352
REFERENCES	356
APPENDIX A Measuring Impacts to Birds Caused by Wind Turbines	A-1
1.0 Introduction	A-1
2.0 Methods	A-1
3.0 Results	A-2
4.0 Discussion.	A-11
APPENDIX B An Explanation for Differences in Reported Results Between the Present Study and Those of Kerlinger and Curry (2003), Plus Identification of Experimental Design Shortfalls in Both..	B-1
APPENDIX C Chi-square Test Statistics and Derived Measures of Effect for Various Birds	C-1
Table C1. Chi-square test statistics and derived measures of effect for golden eagles.	C-1
Table C2. Chi-square test statistics and derived measures of effect for red-tailed hawks.	C-8
Table C3. Chi-square test statistics and derived measures of effect for American kestrels.	C-15
Table C4. Chi-square test statistics and derived measures of effect for burrowing owls.	C-22
Table C5. Chi-square test statistics and derived measures of effect for barn owls.	C-29
Table C6. Chi-square test statistics and derived measures of effect for great horned owls.	C-36
Table C7. Chi-square test statistics and derived measures of effect for mallards.	C-43
Table C8. Chi-square test statistics and derived measures of effect for California horned larks.	C-50
Table C9. Chi-square test statistics and derived measures of effect for western meadowlarks.	C-57
Table C10. Chi-square test statistics and derived measures of effect for Mourning doves.	C-64
Table C11. Chi-square test statistics and derived measures of effect for rock doves.	C-71
Table C12. Chi-square test statistics and derived measures of effect for European starlings.	C-78
APPENDIX D Chi-square Test Statistics and Derived Measures of Effect for Hawks, Raptors, and All Birds	D-1
Table D1. Chi-square test statistics and derived measures of effect for all hawks.	D-1
Table D2. Chi-square test statistics and derived measures of effect for all raptors.	D-8
Table D3. Chi-square test statistics and derived measures of effect for all birds.	D-15

LIST OF TABLES

Table 1-1. Wind turbine models and associated attributes in the APWRA. Information provided by Altamont Infrastructure Company, Altamont Power Co., EnXco, SeaWest, and WindWorks.	19
Table 2-1. Summary of 1,189 bird (and bat) fatalities found in our study area from May 1998 through May 2003.. . . .	32
Table 2-2. Summary of significant test results related to distances of carcasses of large-bodied bird species from wind turbines.	45
Table 3-1. Summary of wind turbine-caused fatalities found by BioResource Consultants at the Altamont Pass Wind Resource Area from May 1998 through May 2003.	64
Table 3-2. Status of birds found killed by wind turbines in the APWRA May 1998 -- May 2003.	66
Table 3-3. Tests for inter-annual changes in mortality.	67
Table 3-4. Inter-annual changes in mortality for selected turbine strings that were searched during first and second years, $df = 1, 19$	67
Table 3-5. Inter-annual changes in mortality for selected turbine strings that were searched during second and fourth years, $df = 1, 57$	68
Table 3-6. Inter-annual changes in mortality for selected turbine strings that were searched during third and fourth years, $df = 1, 75$	68
Table 3-7. Inter-annual changes in mortality for selected turbine strings that were searched during first, third and fourth years, $df = 2, 32$	68
Table 3-8. Inter-annual changes in mortality for selected turbine strings that were searched during second, third and fourth years, $df = 2, 29$	69
Table 3-9. Summary of unadjusted mortality estimates for two sets of wind turbines searched at different time periods at the Altamont Pass Wind Resource Area	70
Table 3-10. Summary of mortality estimates in the APWRA and adjusted for searcher detection and scavenger removal rates and specific to sets of wind turbines sampled at different time periods as well as a set not sampled.. . . .	71
Table 3-11. Bird mortality estimates across the APWRA.	73

Table 3-12. Mortality estimates across the APWRA in terms of deaths per wind turbine per year.	75
Table 5-1. LSD test results comparing vegetation height per turbine string to physical relief.	91
Table 5-2. LSD test results comparing vegetation height per turbine string to slope aspect.	92
Table 5-3. Correlation test results between vegetation height and independent variables (n = 192).	92
Table 5-4. LSD test results comparing vegetation height per wind turbine to slope aspect, where t denotes $0.10 > P > 0.05$, * denotes $P < 0.05$, and ** denotes $P < 0.005$	93
Table 5-5. LSD test results comparing vegetation height per wind turbine to slope aspect, where t denotes $0.10 > P > 0.05$, * denotes $P < 0.05$, and ** denotes $P < 0.005$	93
Table 5-6. LSD test results comparing vegetation height per wind turbine to edge index, where t denotes $0.10 > P > 0.05$, * denotes $P < 0.05$, and ** denotes $P < 0.005$	94
Table 5-7. Mean comparisons of the number of cattle pats by rodent control intensity, where t denotes $0.10 > P > 0.05$, * denotes $P < 0.05$, and ** denotes $P < 0.005$	94
Table 5-8. Correlation test results between number of cattle pats and independent variables (n = 192), where t denotes $0.10 > P > 0.05$, * denotes $P < 0.05$, and ** denotes $P < 0.005$	95
Table 5-9. LSD test results comparing mean number of cattle pats per turbine string to physical relief, where t denotes $0.10 > P > 0.05$, * denotes $P < 0.05$, and ** denotes $P < 0.005$	96
Table 5-10. LSD test results comparing mean number of cattle pats per turbine string to slope aspect of the string of turbines, where t denotes $0.10 > P > 0.05$, * denotes $P < 0.05$, and ** denotes $P < 0.005$	97
Table 5-11. LSD test results comparing mean number of cattle pats per turbine string to tower type, where t denotes $0.10 > P > 0.05$, * denotes $P < 0.05$, and ** denotes $P < 0.005$	97
Table 5-12. LSD test results comparing mean number of cattle pats per wind turbine to edge condition, where t denotes $0.10 > P > 0.05$, * denotes $P < 0.05$, and ** denotes $P < 0.005$	98

Table 5-13. LSD test results comparing mean number of cattle pats per wind turbine to position of the tower in the string, where t denotes $0.10 > P > 0.05$, * denotes $P < 0.05$, and ** denotes $P < 0.005$.	98
Table 5-14. Mean comparisons of the cottontail abundance index by rodent control intensity.	100
Table 5-15. Correlation test results between cottontail abundance index and independent variables ($n = 192$), where t denotes $0.10 > P > 0.05$, * denotes $P < 0.05$, and ** denotes $P < 0.005$.	100
Table 5-16. LSD test results comparing mean cottontail abundance index values per turbine string to tower type, where t denotes $0.10 > P > 0.05$, * denotes $P < 0.05$, and ** denotes $P < 0.005$.	101
Table 5-17. LSD test results comparing mean cottontail abundance index values per turbine string to physical relief, where t denotes $0.10 > P > 0.05$, * denotes $P < 0.05$, and ** denotes $P < 0.005$.	101
Table 5-18. LSD test results comparing mean cottontail abundance index values per turbine string to physical relief, where t denotes $0.10 > P > 0.05$, * denotes $P < 0.05$, and ** denotes $P < 0.005$.	102
Table 5-19. Correlation test results between cottontail abundance index and independent variables ($n = 1325$), where t denotes $0.10 > P > 0.05$, * denotes $P < 0.05$, and ** denotes $P < 0.005$.	102
Table 5-20. LSD test results comparing mean cottontail abundance index values per wind turbine to the edge index, where t denotes $0.10 > P > 0.05$, * denotes $P < 0.05$, and ** denotes $P < 0.005$.	103
Table 5-21. Correlation test results between lizard abundance and independent variables ($n = 192$), where t denotes $0.10 > P > 0.05$, * denotes $P < 0.05$, and ** denotes $P < 0.005$.	105
Table 5-22. LSD test results comparing lizard abundance per wind turbine to physical relief, where t denotes $0.10 > P > 0.05$, * denotes $P < 0.05$, and ** denotes $P < 0.005$.	105
Table 5-23. LSD test results comparing mean lizard abundance per wind turbine to dominant slope aspect of the string of turbines, where t denotes $0.10 > P > 0.05$, * denotes $P < 0.05$, and ** denotes $P < 0.005$.	105
Table 5-24. LSD test results comparing mean lizard abundance per wind turbine to tower type, where t denotes $0.10 > P > 0.05$, * denotes $P < 0.05$, and ** denotes $P < 0.005$.	106

Table 5-25. Highlighted associations between variables based on level of statistical significance and shared variation with other associations.	107
Table 6-1. Mean comparison (ANOVA) of observed ÷ expected number of gopher burrow systems in areas treated with rodenticide.	145
Table 6-2. Associations between raptors killed throughout the study period and particular ranges of density and clustering of fossorial animal species.	164
Table 6-3. Associations between raptors killed within a year of burrow mapping and particular ranges of density and clustering of fossorial animal species.	165
Table 6-4. Associations between golden eagles killed throughout the study period and particular ranges of density and clustering of fossorial animal species.	166
Table 6-5. Associations between golden eagles killed within a year of burrow mapping and particular ranges of density and clustering of fossorial animal species.	166
Table 6-6. Associations between red-tailed hawks killed throughout the study period and particular ranges of density and clustering of fossorial animal species.	167
Table 6-7. Associations between red-tailed hawks killed within a year of burrow mapping and particular ranges of density and clustering of fossorial animal species.. . . .	167
Table 6-8. Associations between American kestrels killed throughout the study period and particular ranges of density and clustering of fossorial animal species.	168
Table 6-9. Associations between American kestrels killed within a year of burrow mapping and particular ranges of density and clustering of fossorial animal species.	169
Table 6-10. Associations between burrowing owls killed throughout the study period and particular ranges of density and clustering of fossorial animal species.	170
Table 6-11. Associations between burrowing owls killed within a year of burrow mapping and particular ranges of density and clustering of fossorial animal species.	171
Table 6-12. Summary of mortality estimates by rodent control intensity in the APWRA from May 1998 through September 2002.	172
Table 6-13. Summary of significant relationships between factors measured in our study and small mammal distribution and abundance.	174

Table 7-1. Chi-square values of association between the number of fatalities of raptor species and independent variables, where t denotes $0.10 > P > 0.05$, denotes $P < 0.05$, and ** denotes $P < 0.005$, and GOEA = golden eagle, RTHA = red-tailed hawk, AMKE = American kestrel, BUOW = burrowing owl, BAOW = barn owl, and GHOW = great-horned owl.	203
Table 7-2. Chi-square values of association between the number of fatalities of non-raptor species and independent variables, where t denotes $0.10 > P > 0.05$, denotes $P < 0.05$, and ** denotes $P < 0.005$, and MALL = mallard, WEME = western meadowlark, HOLA = horned lark, MODO = mourning dove, RODO = rock dove, and EUST = European starling.	204
Table 7-3. Chi-square values of association between the number of fatalities of bird species and independent variables, where t denotes $0.10 > P > 0.05$, * denotes $P < 0.05$, and ** denotes $P < 0.005$	205
Table 7-4. The directions and magnitudes of the associations between wind turbine-caused fatalities and attributes of the turbine or tower, and identified from the most reliable statistical test results.	210
Table 7-5. The directions and magnitudes of the associations between wind turbine-caused fatalities and attributes of the turbine’s location, and identified from the most reliable statistical test results.	215
Table 7-6. The directions and magnitudes of the associations between wind turbine-caused fatalities and attributes of the range conditions surrounding the wind turbine, and identified from the most reliable statistical test results.	218
Table 7-7. The directions and magnitudes of the associations between wind turbine-caused fatalities and season of the year, and identified from the most reliable statistical test results.	219
Table 7-8. Chi-square test results that were significant, composed of expected cell values mostly >5 , and resulting in accountable mortality values that formed distinct gradients across categories or levels of the association variable.	223
Table 7-9. The directions and magnitudes of the associations between wind turbine-caused golden eagle fatalities and levels within independent variables.	224
Table 7-10. The distribution of known golden eagle fatalities between wind turbines classified according to their relative likelihoods of causing the fatalities.	224
Table 7-11. The distributions and magnitudes of the associations between wind turbine-caused red-tailed hawk fatalities and levels within independent variables.	225

Table 7-12. The distribution of known red-tailed hawk fatalities between wind turbines classified according to their relative likelihoods of causing the fatalities. . . .	225
Table 7-13. The directions and magnitudes of the associations between wind turbine-caused American kestrel fatalities and levels within independent variables. . . .	228
Table 7-14. The distribution of known American kestrel fatalities between wind turbines classified according to their relative likelihoods of causing the fatalities. . . .	228
Table 7-15. The directions and magnitudes of the associations between wind turbine-caused burrowing owl fatalities and levels within independent variables. . . .	233
Table 7-16. The distribution of known burrowing owl fatalities between wind turbines classified according to their relative likelihoods of causing the fatalities. . . .	233
Table 7-17. The distribution of known golden eagle, red-tailed hawk, American kestrel and burrowing owl fatalities between wind turbines classified according to their relative likelihoods of causing the fatalities.	234
Table 7-18. The distribution of known barn owl fatalities between wind turbines classified according to their relative likelihoods of causing the fatalities.	234
Table 7-19. The distribution of known great horned owl fatalities between wind turbines classified according to their relative likelihoods of causing the fatalities.	238
Table 7-20. The distribution of known mallard fatalities between wind turbines classified according to their relative likelihoods of causing the fatalities.	238
Table 7-21. The distribution of known California horned lark fatalities between wind turbines classified according to their relative likelihoods of causing the fatalities.	239
Table 7-22. The distribution of known western meadowlark fatalities between wind turbines classified according to their relative likelihoods of causing the fatalities.	239
Table 7-23. The distribution of known mourning dove fatalities between wind turbines classified according to their relative likelihoods of causing the fatalities.	240
Table 7-24. The distribution of known rock dove fatalities between wind turbines classified according to their relative likelihoods of causing the fatalities.	240
Table 7-25. The distribution of known European starling fatalities between wind turbines classified according to their relative likelihoods of causing the fatalities.	241
Table 7-26. The distribution of known bird fatalities between wind turbines classified according to their relative likelihoods of causing the fatalities.	241

Table 8-1. Plot number, types of wind turbine, and power output for 1,500 wind turbines included in behavioral observation sessions.	249
Table 8-2. Flight behaviors and perching structures recorded during 30-min observation sessions in the study plots.	250
Table 8-3. Summary of behavioral activities by species.	265
Table 8-4. Flight behaviors recorded per bird observation during 241 sessions, where AMKE = American kestrel, BUOW = burrowing owl, FEHA = ferruginous hawk, GOEA = golden eagle, MERL = merlin, NOHA = northern harrier, PRFA = prairie falcon, RLHA = rough-legged hawk, and RTHA = red-tailed hawk.	266
Table 8-5. Perching behaviors recorded per bird observation during 241 sessions, where AMKE = American kestrel, BUOW = burrowing owl, FEHA = ferruginous hawk, GOEA = golden eagle, MERL = merlin, NOHA = northern harrier, PRFA = prairie falcon, RLHA = rough-legged hawk, and RTHA = red-tailed hawk.	267
Table 8-6. Chi-square tests of association between minutes of perching and independent variables expressing weather, time of day and seasonal factors; t denotes $0.10 > P > 0.05$; * denotes $P < 0.05$; and ** denotes $P < 0.005$.	270
Table 8-7. Chi-square tests of association between minutes of flight and independent variables expressing weather, time of day and seasonal factors, where t denotes $0.10 > P > 0.05$, * denotes $P < 0.05$, and ** denotes $P < 0.005$.	271
Table 8-8. Chi-square tests of association between mean flight height and independent variables expressing weather, time of day and seasonal factors, where t denotes $0.10 > P > 0.05$, * denotes $P < 0.05$, and ** denotes $P < 0.005$.	272
Table 8-9. Chi-square tests of association between mean distance from nearest wind turbine and independent variables expressing weather, time of day and seasonal factors, where t denotes $0.10 > P > 0.05$, * denotes $P < 0.05$, and ** denotes $P < 0.005$.	273
Table 8-10. Chi-square tests of association between flight time within 50 m of rotor zone and independent variables expressing weather, time of day and seasonal factors, where t denotes $0.10 > P > 0.05$, * denotes $P < 0.05$, and ** denotes $P < 0.005$.	274
Table 8-11. Chi-square tests of association between dependent variables and proximity level to the wind turbines, where t denotes $0.10 > P > 0.05$, * denotes $P < 0.05$, and ** denotes $P < 0.005$.	275

Table 8-12. Chi-square tests of association between time spent perching and independent variables expressing attributes of the nearest wind turbine, where t denotes $0.10 > P > 0.05$, * denotes $P < 0.05$, and ** denotes $P < 0.005$.	283
Table 8-13. Chi-square tests of association between time spent flying and independent variables expressing attributes of the nearest wind turbine, where t denotes $0.10 > P > 0.05$, * denotes $P < 0.05$, and ** denotes $P < 0.005$.	288
Table 8-14. Chi-square tests of association between flight height and independent variables expressing attributes of the nearest wind turbine, where t denotes $0.10 > P > 0.05$, * denotes $P < 0.05$, and ** denotes $P < 0.005$.	293
Table 8-15. Chi-square tests of association between mean distance from nearest wind turbine and independent variables expressing attributes of the nearest wind turbine, where t denotes $0.10 > P > 0.05$, * denotes $P < 0.05$, and ** denotes $P < 0.005$.	298
Table 8-16. Chi-square tests of association between time spent flying within 50 m of the rotor zone and independent variables expressing attributes of the nearest wind turbine, where t denotes $0.10 > P > 0.05$, * denotes $P < 0.05$, and ** denotes $P < 0.005$.	303
Table 8-17. Chi-square tests of association between dependent variables and whether model predicted lower or higher likelihood of fatalities to occur at wind turbine, where t denotes $0.10 > P > 0.05$, * denotes $P < 0.05$, and ** denotes $P < 0.005$.	307
Table 8-18. The directions and magnitudes of significant associations between measured golden eagle behaviors and independent variables	315
Table 8-19. The directions and magnitudes of significant associations between measured red-tailed hawk behaviors and independent variables	318
Table 8-20. The directions and magnitudes of significant associations between measured American kestrel behaviors and independent variables	321
Table 8-21. The directions and magnitudes of significant associations between measured turkey vulture behaviors and independent variables	323
Table 8-22. Correspondence between measures of the magnitude and directions of fatalities with independent variables and behaviors with independent variables for golden eagles.	328
Table 8-23. Correspondence between measures of the magnitude and directions of fatalities with independent variables and behaviors with independent variables for red-tailed hawks.	329
Table 8-24. Correspondence between measures of the magnitude and directions of fatalities with independent variables and behaviors with independent variables for American kestrels	330

LIST OF FIGURES

Figure 1-1. Location of the Altamont Pass Wind Resource Area (APWRA) in west-central California.	14
Figure 1-2. Distribution of wind tower types in the APWRA.	21
Figure 1-3. Distribution of wind walls in the APWRA.	22
Figure 1-4. Distribution of wind turbines inside and outside of ‘canyons’ in the APWRA.	23
Figure 1-5. Distribution of wind turbines on various types of topographic features in the APWRA.	24
Figure 1-6. Distribution of wind turbines by elevation in the APWRA.	25
Figure 1-7. Distribution of wind turbines among levels of rodent control implemented in the APWRA during 1997 - 2002.	26
Figure 2-1. Frequency distribution of carcasses by typical body length of the species.	29
Figure 2-2. Pie-chart distribution of causes of fatalities attributed to carcasses found in the APWRA.	30
Figure 2-3. Frequency distribution of types of injury attributed to wind turbine-caused fatalities among birds found in the APWRA.	31
Figure 2-4. Pie-chart distribution of age classes of birds killed by wind turbines in the APWRA.	35
Figure 2-5. Number of bird fatalities found per season.	36
Figure 2-6. Number of bird carcasses found next to each wind turbine model surveyed in the APWRA.	36
Figure 2-7. Frequency distribution of estimated number of days since death caused by wind turbines in the APWRA.	37
Figure 2-8. Frequency distribution of wind turbine-caused fatalities found in the APWRA (by elevation).	38
Figure 2-9. Frequency distributions of distance from the wind tower among carcasses of large-bodied (A) and small-bodied (B) birds species.	39

Figure 2-10. Frequency distributions of bearing from the wind tower among carcasses of large-bodied (A) and small-bodied (B) bird species.	40
Figure 2-11. Distance of the carcass from the wind tower was a positive linear function of tower height for both large-bodied (A) and small-bodied (B) bird species.	41
Figure 2-12. Mean distances from models of wind turbines for large-bodied (A) and small-bodied (B) bird species.	43
Figure 2-13. Mean distances of bird carcasses from wind turbines according to their positions in the string.	44
Figure 3-1. Frequency distribution of the annual number of carcass searches performed per wind turbine string during our study. Most turbine strings were searched between 6 and 9 times per year.	49
Figure 3-2. The number of carcass searches performed at each turbine string was a simple linear function of the span of time the searches were performed there (A). The searches per year decreased slightly with time span (B).	50
Figure 3-3. Fatality searches were performed in a regular pattern, which was adjusted to fit the terrain but that never compromised on the coverage of the 50-m search radius.	51
Figure 3-4. The frequency distributions of mortality estimates (unadjusted for the effects of search radius, searcher detection, and removal of carcasses by scavengers) were right skewed for all birds (A) and for raptors (B).	53
Figure 3-5. Inter-annual variation in mean mortality for red-tailed hawks, based on wind turbine strings searched for at least one year.	54
Figure 3-6. Inter-annual variation in mean mortality for red-tailed hawks, based on wind turbine string searched at least four years.	54
Figure 3-7. Inter-annual variation in mean mortality for burrowing owls, based on wind turbine strings searched for at least one year.	55
Figure 3-8. Inter-annual variation in mean mortality of barn owls, based on wind turbine strings searched at least one year.	55
Figure 3-9. Inter-annual variation in mean mortality of barn owl, based on wind turbine strings searched at least four years.	56
Figure 3-10. Inter-annual variation in mean mortality of all hawks, based on wind turbine strings searched at least four years.	56

Figure 3-11. Inter-annual variation in mean mortality of all raptors, based on wind turbine strings searched at least one year.	57
Figure 3-12. Inter-annual variation in mean mortality of all raptors, based on wind turbine strings searched at least four years.	57
Figure 3-13. Inter-annual variation in mean mortality of all birds, based on wind turbine strings searched at least one year.	58
Figure 3-14. Inter-annual variation in mean mortality of all birds, based on wind turbine strings searched at least four years.	58
Figure 3-15. Relative search effort devoted to each wind turbine in the study, represented as year since carcass searches began.	59
Figure 3-16. Spatial distribution of golden eagle mortality at the wind turbine string-level of analysis.	60
Figure 3-17. Spatial distribution of red-tailed hawk mortality at the wind turbine string-level of analysis.	61
Figure 3-18. Spatial distribution of American kestrel mortality at the wind turbine string-level of analysis.	62
Figure 3-19. Spatial distribution of burrowing owl mortality at the wind turbine string-level of analysis.	63
Figure 4-1. Mortality estimates for all birds related positively but not significantly to the number of birds seen per hour during point counts.	79
Figure 4-2. Mortality estimates for raptors related positively and significantly to the number of birds seen per hour during point counts.	79
Figure 4-3. Bird mortality in the APWRA was nearly three times the mean of all reported estimates (A), and so was raptor mortality (B).	81
Figure 4-4. Estimates of the risk index, or the mortality divided by the birds seen per hour of point counts, were more platykurtic in distribution than were estimates of mortality alone, and the risk index of all birds in the APWRA was twice the mean among all reports (A) and that of raptors in the APWRA was close to mean among all reports (B).	82
Figure 4-5. The mortality of all birds and raptors tended to increase with the rate of bird observations per hour during point counts (A), whereas the mortality of raptors tended to decline with increasing number of raptors seen per hour of point counts (B).	83

Figure 4-6. Mortality estimates of birds (A) and raptors (B) have tended to increase through time in the APWRA, though not significantly.	84
Figure 4-7. Bird observations per hour increased over the past 15 years in the APWRA, whereas raptor observations per hour did not (A), and the risk of death by wind turbine collision remained unchanged for birds but increased for raptors (B).	85
Figure 5-1. Cattle pat abundance was greatest along transects at wind turbine strings where rodenticide was deployed intermittently.	95
Figure 5-2. Desert cottontail abundance near wind turbines was greatest where no rodenticide was deployed, and it was greater at wind turbines more than 40 m away where rodenticide was heavily deployed.	99
Figure 5-3. Lizard abundance near wind turbines was greatest where no rodenticide was deployed.	104
Figure 6-1. Frequency distributions of the density of burrow systems of pocket gophers (A) and ground squirrels (B) within 90 m of wind turbines.	115
Figure 6-2. Frequency distributions of the density of burrow systems of desert cottontails (A) and all fossorial mammal species (B) within 90 m of wind turbines.	116
Figure 6-3. Frequency distribution of the density of burrowing owl burrows within 90 m of wind turbines.	117
Figure 6-4. Density of burrow systems within 15 m of wind turbines related to density within 90 m for pocket gophers (A) and ground squirrels (B), illustrating the pocket gopher's greater affinity for the areas immediately next to the wind turbines.	118
Figure 6-5. Density of desert cottontail burrow systems within 15 m of wind turbines related to density within 90 m.	119
Figure 6-6. Frequency distributions of the degree of clustering of pocket gopher burrow systems at wind turbines represented by (A) the slope of log density regressed on log search area around each wind turbine string, and (B) the observed ÷ expected number of burrow systems within 15 m of the wind turbines, where strings of wind turbines were combined into groups when contiguous and mapped during the same year and season.	120
Figure 6-7. Relationship between two methods of characterizing the degree of clustering of burrow systems at wind turbines.	121
Figure 6-8. Frequency distributions of the degree of clustering of ground squirrel (A) and desert cottontail (B) burrow systems around wind turbines.	122

Figure 6-9. Frequency distribution of the degree of clustering of burrow systems of all fossorial mammals species around wind turbines.	123
Figure 6-10. Locations of groups of wind turbines monitored for burrow system distributions by season during 2001 and 2002.. . . .	125
Figure 6-11. Wind turbine monitoring Group 1 viewed from the south (A) and from the northern aspect of the wind turbines toward the south (B).	126
Figure 6-12. Seasonal distribution of burrow systems around wind turbine monitoring Group 1.	127
Figure 6-13. Wind turbine monitoring Group 2 viewed from its southern aspect.	128
Figure 6-14. Seasonal distribution of burrow systems around wind turbine monitoring Group 2.	129
Figure 6-15. Wind turbine monitoring Group 3 viewed from the north.	130
Figure 6-16. Seasonal distribution of burrow systems around wind turbine monitoring Group 3.	131
Figure 6-17. Wind turbine monitoring Group 4 viewed north from the southern aspect of the wind turbines.	132
Figure 6-18. Seasonal distribution of burrow systems around wind turbine monitoring Group 4.	133
Figure 6-19. Wind turbine monitoring Group 5 viewed north from the southern aspect of the wind turbines.	134
Figure 6-20. Seasonal distribution of burrow systems around wind turbine monitoring Group 5.	135
Figure 6-21. Wind turbine monitoring Group 6 viewed south from the middle of the eastern row (A) and north from the middle of the western row (B).	136
Figure 6-22. Seasonal distribution of burrow systems around wind turbine monitoring Group 6.	137
Figure 6-23. Wind turbine monitoring Group 7 viewed north from the southern aspect of the wind turbines.	138
Figure 6-24. Seasonal distribution of burrow systems around wind turbine monitoring Group 7.	139

Figure 6-25. Wind turbine monitoring Group 8 viewed south from the middle of the row (A) and north from the middle of the row (B).	140
Figure 6-26. Seasonal distribution of burrow systems around wind turbine monitoring Group 8.	141
Figure 6-27. Seasonal pattern of the degree of clustering of burrow systems at wind turbines for (A) pocket gopher and (B) ground squirrel.	142
Figure 6-28. Trends through the study in density of burrow systems out to 90 m from wind turbines for (A) pocket gophers and (B) ground squirrels.	143
Figure 6-29. Relationship between degree of clustering of pocket gopher and ground squirrel burrow systems around wind turbines and the intensity of rodent control applied in the area.	144
Figure 6-30. Relationship between degree of clustering of desert cottontail burrow systems around wind turbines and the intensity of rodent control applied in the area.	146
Figure 6-31. Relationship between degree of clustering of burrow systems of all fossorial mammal species around wind turbines and the intensity of rodent control applied in the area.	147
Figure 6-32. Relationship between mean density of pocket gopher and ground squirrel burrow systems within 15 m (A) and 90 m (B) of wind turbines and the intensity of rodent control applied in the area.	148
Figure 6-33. Relationship between mean density of burrow systems of all fossorial mammal species within 15 m and 90 m of wind turbines and the intensity of rodent control applied in the area.	150
Figure 6-34. Spatial distribution of fossorial mammal burrow systems within 90 m of wind turbines in the Mountain House area where rodent control was not applied until 2002	151
Figure 6-35. Spatial distribution of fossorial mammal burrow systems within 90 m of wind turbines in the Midway area where rodent control was not applied until 2002.	152
Figure 6-36. Spatial distribution of fossorial mammal burrow systems within 90 m of wind turbines in the east-central area of the APWRA and where rodent control was not applied until 2002.	153
Figure 6-37. Spatial distribution of fossorial mammal burrow systems within 90 m of wind turbines in the central aspect of EnXco's turbines and where rodent control was applied intermittently.	154

Figure 6-38. Spatial distribution of fossorial mammal burrow systems within 90 m of wind turbines on the northern fringe of EnXco’s turbine field and where rodent control was applied intermittently.	155
Figure 6-39. Spatial distribution of fossorial mammal burrow systems within 90 m of wind turbines in the northern aspect of EnXco’s turbine field and where rodent control was applied intermittently.	156
Figure 6-40. Spatial distribution of fossorial mammal burrow systems within 90 m of wind turbines in the central aspect of EnXco’s turbine field and where rodent control was applied intermittently.	157
Figure 6-41. Spatial distribution of fossorial mammal burrow systems within 90 m of wind turbines in the southern aspect of EnXco’s turbine field, and where rodent control was applied intermittently.	158
Figure 6-42. Spatial distribution of fossorial mammal burrow systems within 90 m of wind turbines in the Patterson Pass area and where rodent control was applied intensively	159
Figure 6-43. Spatial distribution of fossorial mammal burrow systems within 90 m of wind turbines in center of the APWRA, and where rodent control was applied intensively	160
Figure 6-44. Spatial distribution of fossorial mammal burrow systems within 90 m of wind turbines where rodent control was applied intensively.	161
Figure 6-45. Raptor mortality related to the density of ground squirrel burrow systems within 90 m differently depending on rodent control context, increasing with ground squirrel density in areas of intense rodent control, and declining with ground squirrel density in areas of no control.	162
Figure 6-46. Raptor mortality related to the density of ground squirrel burrow systems within 15 m differently depending on rodent control context, increasing with ground squirrel density in areas of intense rodent control, and tending to decline with ground squirrel density in areas of no control.	163
Figure 7-1. The number of fresh bird carcasses found at wind turbine strings was a linear function of carcass search effort (A) and turbine-caused bird mortality was an inverse power function of search effort (B).	187
Figure 7-2. Frequency distributions of wind turbine models and search effort at those models in our sample in the APWRA.	190
Figure 7-3. Frequency distributions of wind tower types and search effort at those tower types in our sample in the APWRA.	191
Figure 7-4. Frequency distributions of rotor swept area and search effort at those rotor swept areas characteristic of wind turbines in our sample in the APWRA.	192

Figure 7-5. The rotor swept area swept per second was a linear function of blade tip speed among the wind turbine models in the APWRA (A), but it was more responsive and precisely related to rotor diameter (B).	193
Figure 7-6. The time period intervening blade sweeps at the edge of the rotor place did not relate to blade tip speed (A), but it was a linear function of rotor diameter (B).	194
Figure 7-7. Frequency distributions of wind tower heights and search effort at those tower heights in our sample in the APWRA.	195
Figure 7-8. Frequency distributions of wind turbine orientations to the wind and search effort at those orientations among wind turbines in our sample in the APWRA.	195
Figure 7-9. Frequency distributions of wind turbine positions in the string and search effort at positions in our sample in the APWRA.	196
Figure 7-10. Frequency distributions of wind turbine locations in the wind energy generating facility and search effort at locations in the APWRA.	196
Figure 7-11. Frequency distributions of types of physical relief at wind turbines and search effort at these types of relief in the APWRA.	197
Figure 7-12. Frequency distributions of wind turbines in and out of canyons and search effort at these turbines in the APWRA.	197
Figure 7-13. Frequency distributions of wind turbines and search effort at these turbines among slope aspects in the APWRA.	198
Figure 7-14. Frequency distributions of wind turbines (A) and search effort (B) at these turbines among elevations in the APWRA.	199
Figure 7-15. Frequency distributions of wind turbines (A) and search effort (B) at these turbines among slope grades in the APWRA.	200
Figure 7-16. Frequency distributions of wind turbines (A) and search effort (B) at these turbines among counts of other wind turbines within 300 m of each wind turbine in the APWRA.	201
Figure 7-17. Frequency distributions of wind turbines and search effort at these turbines among levels of rodent control intensity applied in the APWRA.	202
Figure 7-18. Frequency distribution of search effort at these turbines during the four seasons of the year.	202

Figure 7-19. Golden eagle fatalities relative to search effort applied to wind turbines in the APWRA.	207
Figure 7-20. Red-tailed hawk fatalities relative to search effort applied to wind turbines in the APWRA.	208
Figure 7-21. Burrowing owl fatalities relative to search effort applied to wind turbines in the APWRA.	209
Figure 7-22. Observed divided by expected number of fatalities of raptor species during each season of the year during our study in the APWRA.	220
Figure 7-23. Observed divided by expected number of fatalities of non-raptor species during each season of the year during our study in the APWRA.	221
Figure 7-24. Most of the wind turbines documented to have killed golden eagles were correctly classified as more dangerous to golden eagles by the empirical model we developed (A), the mean values of which increased with the actual number of golden eagles killed by the wind turbine (B).	226
Figure 7-25. Wind turbines predicted by our model to be more dangerous to golden eagles are widely distributed across the APWRA.	227
Figure 7-26. Most of the wind turbines documented to have killed red-tailed hawks were incorrectly classified as more dangerous to red-tailed hawks by the empirical model we developed (A), the mean values of which increased with the actual number of red-tailed hawks killed by the wind turbine (B).	229
Figure 7-27. Wind turbines predicted by our model to be more dangerous to red-tailed hawks are distributed less widely across the APWRA than we actually documented.	230
Figure 7-28. Most of the wind turbines documented to have killed American kestrels were incorrectly classified as more dangerous to American kestrels by the empirical model we developed (A), the mean values of which generally increased with the actual number of American kestrels killed by the wind turbine (B).	231
Figure 7-29. Wind turbines predicted by our model to be more dangerous to American kestrels are widely distributed across the APWRA.	232
Figure 7-30. Most of the wind turbines documented to have killed burrowing owls were correctly classified as more dangerous to burrowing owls by the empirical model we developed (A), the mean values of which increased with the actual number of burrowing owls killed by the wind turbine (B).	235

Figure 7-31. Wind turbines predicted by our model to be more dangerous to burrowing owls are distributed rather narrowly across the APWRA.	236
Figure 7-32. Wind turbines predicted by our model to be more dangerous in combination to golden eagles, red-tailed hawks, American kestrels and burrowing owls are distributed relatively narrowly across the APWRA.	237
Figure 8-1. The rotor plane of a Bonus turbine and the upper and lower reaches of the rotor zone of a string of four turbines.	248
Figure 8-2. An example of a buffer created in GIS and corrected to fit the 3-dimensional landscape in order to test for patterns of behavior in relation to proximity to wind turbines.	252
Figure 8-3. Frequency distribution of start times for the 241 behavioral observation sessions.	257
Figure 8-4. Frequency distribution of behavioral observation sessions among months of the year.	257
Figure 8-5. Frequency distribution of temperature at the start of 241 behavioral observation sessions.	258
Figure 8-6. Frequency distribution of wind directions (origin) during behavioral observation sessions.	258
Figure 8-7. Frequency distribution of wind speeds among behavioral observation sessions.	259
Figure 8-8. Wind speed during behavioral observation sessions as functions of direction of origin.	259
Figure 8-9. The by-the-minute frequency of behavioral observations increased with the number of minutes into the behavioral observation session and appeared to reach an asymptote by 25 minutes (A), whereas the frequency of special behavioral events (e.g., crossing the turbine string, entering or exiting the plot) appeared to increase only during the first 8 minutes of the session (B).	260
Figure 8-10. Frequency distribution of the distance to the nearest turbine recorded for raptors flying (A) and perching (B) during the behavioral observation sessions.	261
Figure 8-11. The number of passes of birds through the rotor zone increased with the number of observations of flights during the session (A), but not with the number of observations of perching (B).	262
Figure 8-12. The average time raptors spent flying was greatest during intermediate winds (A) and the average time spent perching was greatest during slow winds (B).	263

Figure 8-13. Histogram of flight heights by golden eagles and percentages of flights within the rotor height domains of existing wind turbines indicated by the red bar, proposed new wind turbines indicated by the green bar, and turbines on tallest tower indicated by the blue bar. 309

Figure 8-14. Histogram of flight heights by red-tailed hawks and percentages of flights within the rotor height domains of existing wind turbines indicated by the red bar, proposed new wind turbines indicated by the green bar, and turbines on tallest tower indicated by the blue bar. 310

Figure 8-15. Histogram of flight heights by American kestrels and percentages of flights within the rotor height domains of existing wind turbines indicated by the red bar, proposed new wind turbines indicated by the green bar, and turbines on tallest tower indicated by the blue bar. 311

Figure 8-16. Histogram of flight heights by all raptors combined and percentages of flights within the rotor height domains of existing wind turbines indicated by the red bar, proposed new wind turbines indicated by the green bar, and turbines on tallest tower indicated by the blue bar. 312

LIST OF PHOTOS

Photo 1-1. Bonus 150-kW wind turbines mounted on tubular towers, plus Flowind 150-kW vertical-axis wind turbines to the right.	15
Photo 1-2. In the foreground are two Bonus wind turbines mounted on grey tubular towers. Downhill are five Danwin 110-kW wind turbines mounted on white tubular towers.	15
Photo 1-3. A string of Flowind 150-kW vertical axis turbines.	16
Photo 1-4. Micon 65-kW wind turbines near Mountain House.	16
Photo 1-5. KVS-33 turbines painted with stripes (experimentally) to increase their visibility to birds.	17
Photo 1-6. An Enertech 40-kW wind turbine with two turkey vultures flying nearby.	17
Photo 1-7. Example of a wind wall. KCS-56 turbines are mounted on two different tower heights to catch a larger height domain of the wind.	18
Photo 1-8. Windmatic 65-kW turbine adjacent to Old Altamont Pass Road.	18
Photo 2-1. A golden eagle electrocuted at an electrical distribution pole with riser elements.	30
Photo 2-2. A decapitated American kestrel found under a wind turbine.	33
Photo 2-3. A mallard cut in half by a wind turbine.	34
Photo 2-4. The wing of a golden eagle found under a wind turbine.	34
Photo 2-5. A golden eagle cut in half by a wind turbine.	35
Photos 5-1 A and B. Cattle congregate near wind turbines, where they leave more pats and graze the grass more intensively.	88
Photo 5-2. Desert cottontails burrow under concrete pads of wind turbines and are concentrated around the turbines.	89
Photo 5-3. Desert cottontails use rock piles that were originally created near turbine laydown areas as a mitigation measure for San Joaquin kit fox.	89
Photos 5-4 A and B. Desert cottontails use rock piles created as a mitigation measure for San Joaquin kit fox nearby turbine laydown areas.	89

Photo 6-1. Pocket gopher burrow systems (see the light-colored mounds) typically occurred near wind turbines, such as along the cuts made into hillsides for wind tower laydown areas and access roads.	110
Photo 6-2. Ground squirrel burrow systems typically occurred on slopes below wind turbines located on ridge crests, such as those seen in this photo.	110
Photo 6-3. Ground squirrel burrow systems typically occurred on slopes below wind turbines located on ridge crests, such as to the lower left-center area in this photo.	111
Photo 6-4. All wind turbines included access roads, but those in the foreground also were near regularly disked soil, either as a firebreak or over a pipeline.	113
Photo 6-5. Desert cottontails burrowed under some wind turbine pads.	174
Photo 6-6. A California red-legged frog found in the APWRA.	176
Photo 6-7. A California tiger salamander found in the APWRA.	177
Photo 6-8. The broadcasting of rolled oats laced with chlorophacinone poses a hazard to the San Joaquin kit fox, a species that was documented to use the APWRA. Wind turbine installation in the APWRA originally required mitigation measures for San Joaquin kit fox conservation.	177
Photo 9-1. Vertical edge is often abundant along the string of wind turbines, which attracts certain small mammals and likely attracts foraging raptors.	335
Photo 9-2. Rocks gathered from wind turbine laydown areas and piled nearby.	336
Photo 9-3. Cattle routinely congregate in the shade of wind towers on hot days.	337
Photo 9-4. Cattle congregate around wind turbine for shade and foraging, and they reduce grass height and expose small mammals to foraging raptors.	338
Photo 9-5. Cattle pats abound where cattle congregate near the shadow of a wind turbine. These pats attract numerous grasshoppers, which in turn attracts raptors that feed on the grasshoppers close to turbine blades.	338
Photo 9-6. Burrows appear under concrete pads in the APWRA, and these might attract foraging raptors into close proximity of wind turbines.	339
Photo 9-7. A golden eagle perches on a lattice tower while the wind turbines of the entire string are not operating.	340
Photo 9-8. A raptor perches on the work platform while wind turbine is not operating.	341

Photo 9-9. A raptor perches on the work platform of a tower that is missing its wind turbine, and while the adjacent wind turbines are not operating.	341
Photo 9-10. Red-tailed hawk perched on tip of wind turbine blade.	342
Photo 9-11. Hardware cloth (i.e., chicken wire) used as perch guard on lattice tower.	343
Photo 9-12. Two poles placed at the end of a turbine row might divert bird flights away from the end turbine, thereby reducing mortality.	344

EXECUTIVE SUMMARY

For decades, research has shown that wind turbines in the Altamont Pass Wind Resource Area (APWRA) kill many birds, including raptors, which are protected by the Migratory Bird Treaty Act, the Bald and Golden Eagle Protection Act, and/or state and federal Endangered Species Acts. Each violation of these acts can result in fines and/or criminal convictions.

Early research in the APWRA on these bird fatalities mainly attempted to identify the extent of the problem. However, in 1998, the National Renewable Energy Laboratory (NREL) initiated research to address the causal relationships between wind turbines and bird mortality. The Public Interest Energy Research Environmental Area (PIER-EA) of the California Energy Commission funded a project by BioResource Consultants to build upon and expand those previous endeavors and determine whether measures could be implemented to reduce bird collisions with wind turbines in the APWRA.

Two factors heighten the urgency and importance of resolving this issue. First, one goal of California's renewable portfolio standard (RPS) is meeting 20% of the State's electricity needs through renewable energy sources by 2010. Second, Alameda County placed a moratorium on issuing permits to increase electrical production capacity in the APWRA beyond the existing 580 MW permitted capacity until there is demonstrable progress toward significantly reducing bird mortality.

With more than 2,000 megawatts (MW) of installed generating capacity in California, wind turbines provide up to 3.5 billion kilowatt-hours (kWh) of emissions-free electricity for the state annually. By identifying and implementing new methods and technologies to reduce or resolve bird mortality in the APWRA, power producers may be able to increase wind turbine electricity production at the site and apply the mortality-reduction methods at other sites around the state and country.

It is the mission of PIER-EA to develop cost-effective approaches to evaluating and resolving environmental effects of energy production, delivery, and use in California. In addition, an objective of the PIER Renewable Area is to expand renewable distributed generation technologies to help provide electricity generation in high-demand, high-congestion areas. By addressing bird mortality issues in the APWRA, the PIER-EA is helping to alleviate the most important environmental issue being associated with wind power generation, while also supporting the development of renewable energy generation in the State.

Objectives

This four-year research effort involving more than 4,000 wind turbines was aimed at better understanding bird mortality at the world's largest wind farm—the Altamont Pass Wind Resource Area (APWRA) in central California. Electricity-generating wind turbines installed in the APWRA kill large numbers of birds of many different species, including many raptors. Researchers studied bird behaviors, raptor prey availability, wind turbine/tower design, inter-turbine distribution, landscape attributes, and range management practices in their effort to explain the variation in bird mortality with the goal of developing predictive models that could be useful for future planning decisions in the APWRA.

The primary objectives of this research were to: (1) quantify bird use, including characterizing and quantifying perching and flying behaviors exhibited by individual birds around wind turbines; (2) evaluate the flying behaviors and the environmental and topographic conditions associated with flight behaviors; (3) identify possible relationships between bird mortality and bird behaviors, wind tower design and operations, landscape attributes, and prey availability; and (4) develop predictive, empirical models that identify areas or conditions that are associated with high vulnerability.

Approach

Other studies have evaluated bird mortality in the APWRA. For this study, researchers adopted the following approaches to help improve accuracy and the usability of the resulting data. For example, the researchers:

- conducted searches at 2,548 wind turbines in addition to the 1,526 wind turbines they had studied previously,
- adjusted mortality estimates to account for errors in detection rates and the rates of removal of carcasses by scavengers,
- used the number of fatalities per MW per year as the mortality metric, thereby avoiding the potentially false appearance that larger wind turbines kill more birds, and
- presented mortality estimates as ranges, where the lower end of the range was the mortality adjusted for fatalities that were likely missed beyond the 50-m search radius, and the upper end was the mortality adjusted for fatalities missed due to undetected carcass removal by scavengers.

Outcomes

Researchers found that at least three years of carcass searches are needed before the sample of wind turbines sufficiently stabilizes in the percentage of non-zero mortality values. Using a monitoring duration less than three years may yield unreliable estimates of mortality.

Researchers explored the relationship between the time each bird species spent close to wind turbines and the number of fatalities. They found that:

- inter-specific variation in mortality could not be explained by variation in the number of flights within close proximity to wind turbines, and
- some bird species spent more time flying within 50 meters (m) of wind turbines than expected, and they spent less time within 51–100 m or 101–300 m, which indicated that those species were attracted to the areas near to wind turbines,
- most flights by golden eagles, red-tailed hawks, American kestrels and all raptors combined were at heights at or below the rotor planes existing wind turbines in the APWRA.

Unique suites of attributes are related to mortality of each species, so the researchers conducted species-specific analyses to understand the factors that underlie wind turbine-caused fatalities. They found the following:

- Golden eagles are killed more frequently than expected by chance alone at wind turbines located in areas in the APWRA characterized as canyons.
- Higher mortality of a number of species within part of the APWRA was related to rock piles that were produced during wind tower installation. This correlation could be a result of desert cottontails and ground squirrels (prey species for large raptors) inhabiting these rock piles.
- The degree of clustering by pocket gophers around wind towers was associated with red-tailed hawk mortality, and the degree of clustering of gophers appeared greatest on steeper slopes where laydown areas and access roads were cut. The degree of clustering of pocket gophers and desert cottontails was also greatest where rodent control measures were applied.

In terms of bird fatalities attributable to turbine designs or arrangements, researchers found the following:

- Turbines mounted on tubular towers killed disproportionately more red-tailed hawks and other raptors—as did wind turbines on taller towers, those with larger rotor diameter, and those with slower to intermediate blade tip speeds.
- Perching on wind turbines or their towers is a less important factor contributing to mortality than previously suspected.
- Wind turbines installed in wind wall configurations¹ are safer for birds, as are wind turbines within dense clusters of turbines and those forming the interior of wind turbine strings.
- Wind turbines were most dangerous at the ends of turbine strings, at the edges of gaps in strings, and at the edges of clusters of wind turbines.
- The most isolated wind turbines killed disproportionately more birds.

Researchers also observed seasonal variations:

- Winter and summer were the two seasons of the year when disproportionately larger numbers of birds were killed, although there were species-specific differences.

The study estimated that between 881 and 1,300 raptors are killed annually in the APWRA. For all birds combined, that number is estimated at between 1,766 and 4,721. These estimates translate to 1.5 to 2.2 raptor fatalities/MW/year and 3.0 to 8.1 bird fatalities/MW/year. Over 40 different bird species are represented in the fatalities. Among these, researchers estimate that the APWRA wind turbines are annually killing 75 to 116 golden eagles, 209 to 300 red-tailed hawks, 73 to 333 American kestrels, and 99 to 380 burrowing owls.

¹ A *wind wall configuration* consists of parallel rows of wind turbines closely aligned to each other but with alternating tower heights.

Over the past 15 years, the risk to birds of turbine-caused fatalities increased substantially in the APWRA. The number of raptors observed per hour declined while mortality remained steady, so the ratio of the number of deaths per MW to the number of raptors seen per hour increased.

To assert that the APWRA is anomalous in its bird mortality may be misleading when comparing it to other wind energy facilities. While a relatively large number of raptors are killed per annum in the APWRA, the ratio of the number killed to the number seen during behavior observations is similar among wind farms where both rates of observation have been reported. It appears, based on the research reports reviewed for this project, that when comparing wind energy facilities birds tend to be killed at rates that are proportional to their relative abundance among wind farms.

For the development of the predictive models, researchers performed tests that accounted for differential search efforts among groups of wind turbines, and examined test results for associations that were both statistically and biologically sound. The models ranged in predictive power from 37% to 82% correct classification, and projected that of the 4,075 wind turbines in the sample, 6% to 67% posed greater threat levels, depending on the bird species considered. To demonstrate the utility of the modeling approach, the report focused on four raptors species, even though the fatality associations used for model development were also estimated for multiple other species. The modeling results were more reliable for golden eagles and burrowing owls than they were for red-tailed hawks and American kestrels.

Conclusions, Recommendations, and Benefits to California

The researchers conclude that many of the bird collisions with wind turbines are associated with factors that could not be understood within the scope of this project, or that may simply be random. Most of the variation for some species may be explained by factors not addressed in this study. However, the findings are sufficiently robust for the wind industry to begin repowering with larger turbines according to recommended guidelines, or implementing a series of mitigation measures that will avoid, reduce, and offset impacts caused by existing and future wind turbines in the APWRA.

The researchers conclude that the most effective solution to reduce bird mortality would be to replace the numerous small turbines currently installed with fewer, larger turbines. A repowering program is beginning in the APWRA that replaces many of the existing turbines at a ratio of approximately seven to twelve older, smaller turbines with one newer, larger turbine. The effect that the repowering program will have on bird mortality is unknown; however, the research presented in this report suggests that repowering may reduce mortality, especially if turbines are installed on the tallest practicable towers. Also, these research results should aid the siting process of any new turbines with a primary goal being to install new turbines in locations and in arrangements that will result in fewer bird kills than in the past.

If the wind turbine owners fail to repower with larger turbines, then the report provides the foundation for the aggressive implementation of management strategies that will most likely

promote a partial reduction in bird mortality. To help alleviate bird mortality in the APWRA, the project researchers recommend implementing the following mitigation measures:

- Cease the rodent control program
- Relocate selected, highly dangerous wind turbines
- Move rock piles away from wind turbines
- Retrofit tower pads to prevent under-burrowing by small mammals
- Remove broken and non-operating wind turbines
- Install wind turbine designs beneficial to the APWRA bird fatality issue
- Implement the means to effectively monitor the output of each wind turbine
- Retrofit, using APLIC guidelines (minimum), noncompliant power poles

The following measures would be appropriately applied experimentally, due to the degree of uncertainty in their likely effectiveness. However, these measures could also be applied universally, but with the understanding that they might not substantially reduce bird mortality.

- Reduce vertical and lateral edge in slope cuts and nearby roads
- Exclude cattle from around wind turbines
- Install flight diverters
- Paint blades using the Hodos et al. scheme
- Experiment with devices that will identify when to operate problem wind turbines with the least effect on birds.

Researchers also recommend that certain measures be abandoned by the owner/operators as options for reducing bird mortality in the APWRA:

- Rodent control program
- Installing perch guards on wind turbines
- Providing alternative perches
- Barricading the rotor planes of turbines

If all mitigation measures supported by this project's findings were implemented, mortality might be reduced by up to 20–40%, depending on the species, and perhaps as high as 40–50% should the mitigation measures act synergistically to reduce mortality. The remaining, random portion of the mortality would likely continue in the APWRA for as long as the existing wind turbines operate at or above the current output capacity. To compensate suitably for these continuing and unavoidable losses of birds, off-site mitigation directed to protecting regionally important wildlife habitat may be warranted.

Benefits to California will accrue if there is a demonstrable reduction of bird mortality in the APWRA. Doing so will encourage more energy capacity to be permitted by Alameda and Contra Costa counties. By repowering with fewer, larger wind turbines mounted on the tallest practicable towers, and/or implementing some or all of the recommended mitigation measures identified in this report, the owner/operators of the APWRA can expect to achieve improved compliance with state and federal laws and regulations protecting birds.

ABSTRACT

Wind turbines in the Altamont Pass Wind Resource Area (APWRA) provide on average 1.1 billion kilowatt-hours (kWh) of emissions-free electricity annually, enough to power almost 200,000 average households per annum, but these turbines also kill birds that are legally protected, and have been doing so for decades.

This five-year research effort focused on better understanding the causes of bird mortality at the world's largest wind farm. Researchers studied 2,548 wind turbines and combined their data with results from 1,526 wind turbines they had studied previously. They sought to: (1) quantify bird use, including characterizing and quantifying perching and flying behaviors of individual birds around wind turbines; (2) evaluate flight behaviors and the environmental and topographic conditions associated with them; (3) identify possible relationships between bird mortality and bird behaviors, wind tower design and operations, landscape attributes, and prey availability; and (4) develop predictive, empirical models that identify turbine or environmental conditions that are associated with high vulnerability.

Researchers concluded that bird fatalities at the APWRA result from various attributes of wind turbine configuration and placement, and that species-specific behavior plays a large role in how each contributory factor affects mortality. The report details numerous specific observations.

Researchers identified and evaluated possible measures to mitigate bird mortality in the APWRA. They offer recommendations to discontinue or modify some current management actions, to implement new ones immediately, and to experiment with others. Data presented in the report support these recommendations. The results suggest that repowering with carefully placed, modern wind turbines mounted on taller towers may be the preferable means to substantially reduce bird mortality.