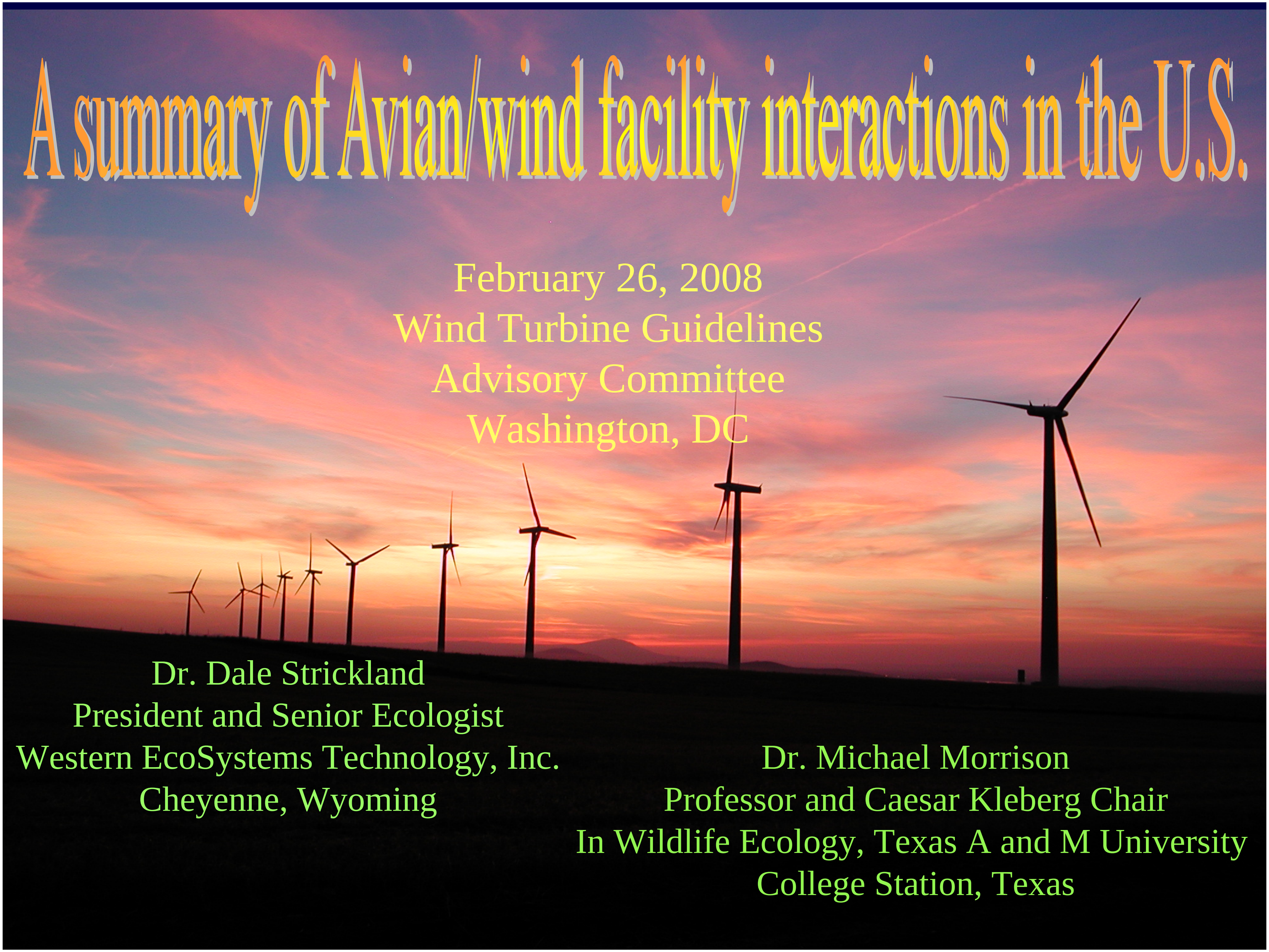
A summary of Avian/wind facility interactions in the U.S.



February 26, 2008
Wind Turbine Guidelines
Advisory Committee
Washington, DC

Dr. Dale Strickland
President and Senior Ecologist
Western EcoSystems Technology, Inc.
Cheyenne, Wyoming

Dr. Michael Morrison
Professor and Caesar Kleberg Chair
In Wildlife Ecology, Texas A and M University
College Station, Texas

Outline

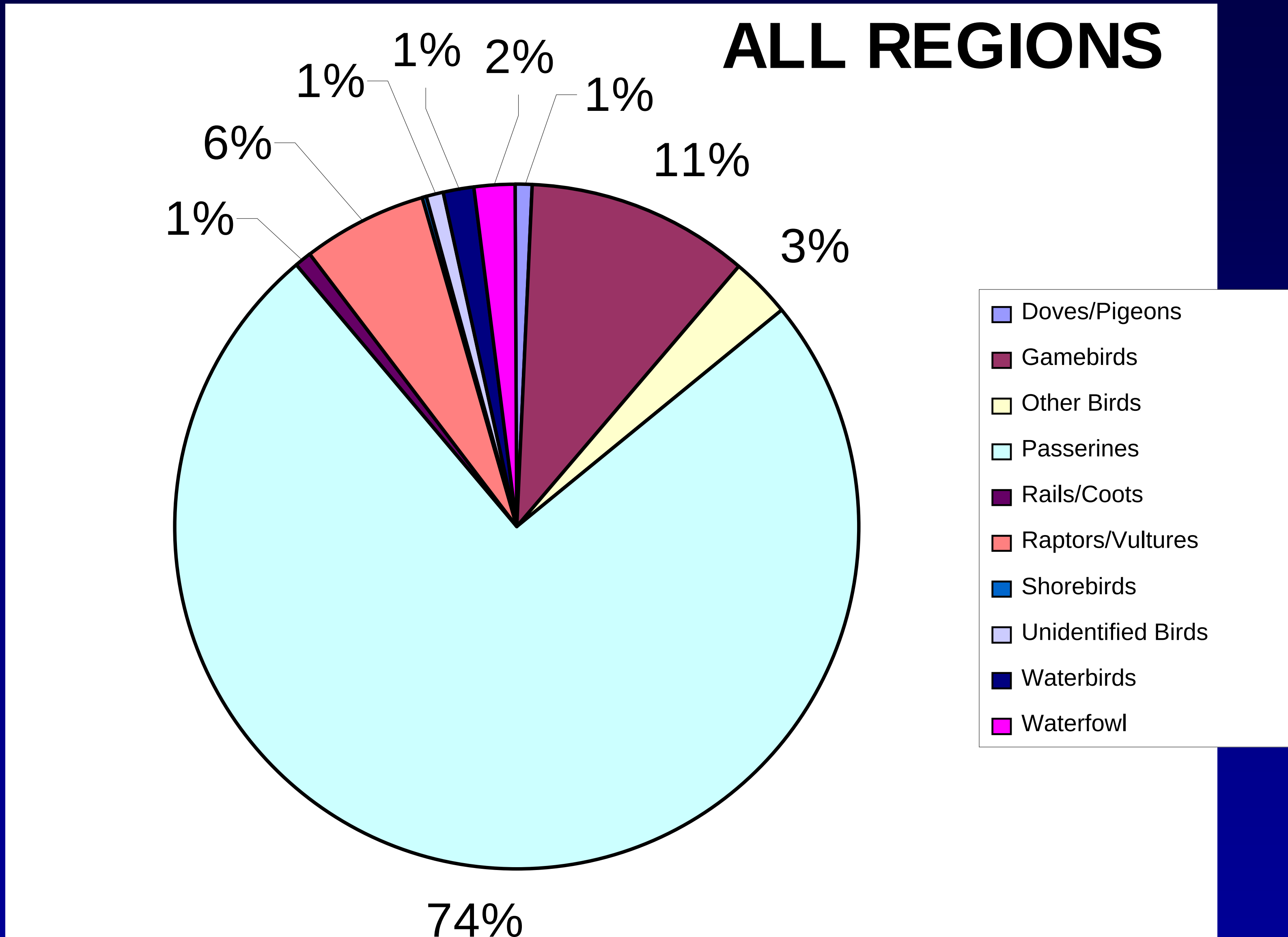
- Impacts
  - Fatalities
  - Habitat
  - Cumulative
- Methods and Metrics
- Conclusions and Uncertainties
- Selected References

Fatality Impacts

- Fatality rates are based on studies of all seasons of occupancy during a continuous 12 month period.
- Fatality composition based on all studies reporting fatalities by species.

List of FAC Questions we were asked to address

- What is the range of avifauna impacted, or suspected of impact?
- What do we know about the degree of impact? (direct mortality, habitat impact?)
- What do we know about cumulative impacts, from wind, from wind and other human induced affects?
- What do we know about available methods and metrics to predict probability of impact? What is our level of certainty that these methods are accurately predicting impacts?
- What do we know about habituation, or other behavioral aspects?
- What are the major areas of uncertainty?
- References and resources for the FAC to know about?



Proportion of fatalities at sites reporting fatalities by species, summarized for All Regions Where studies have been conducted (Pacific North West Mid-West, Rocky Mountains, and East (sources in literature cited).

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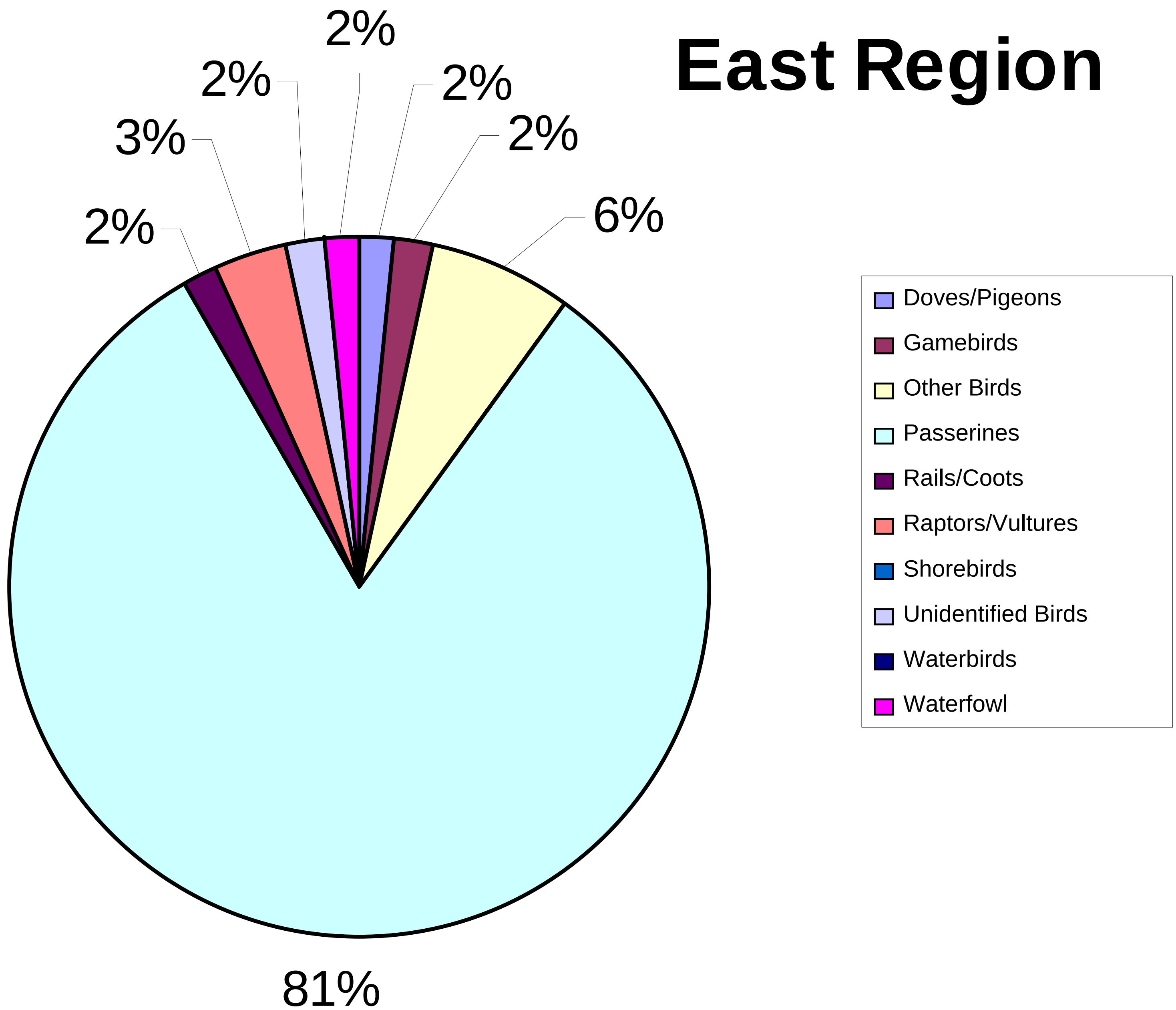
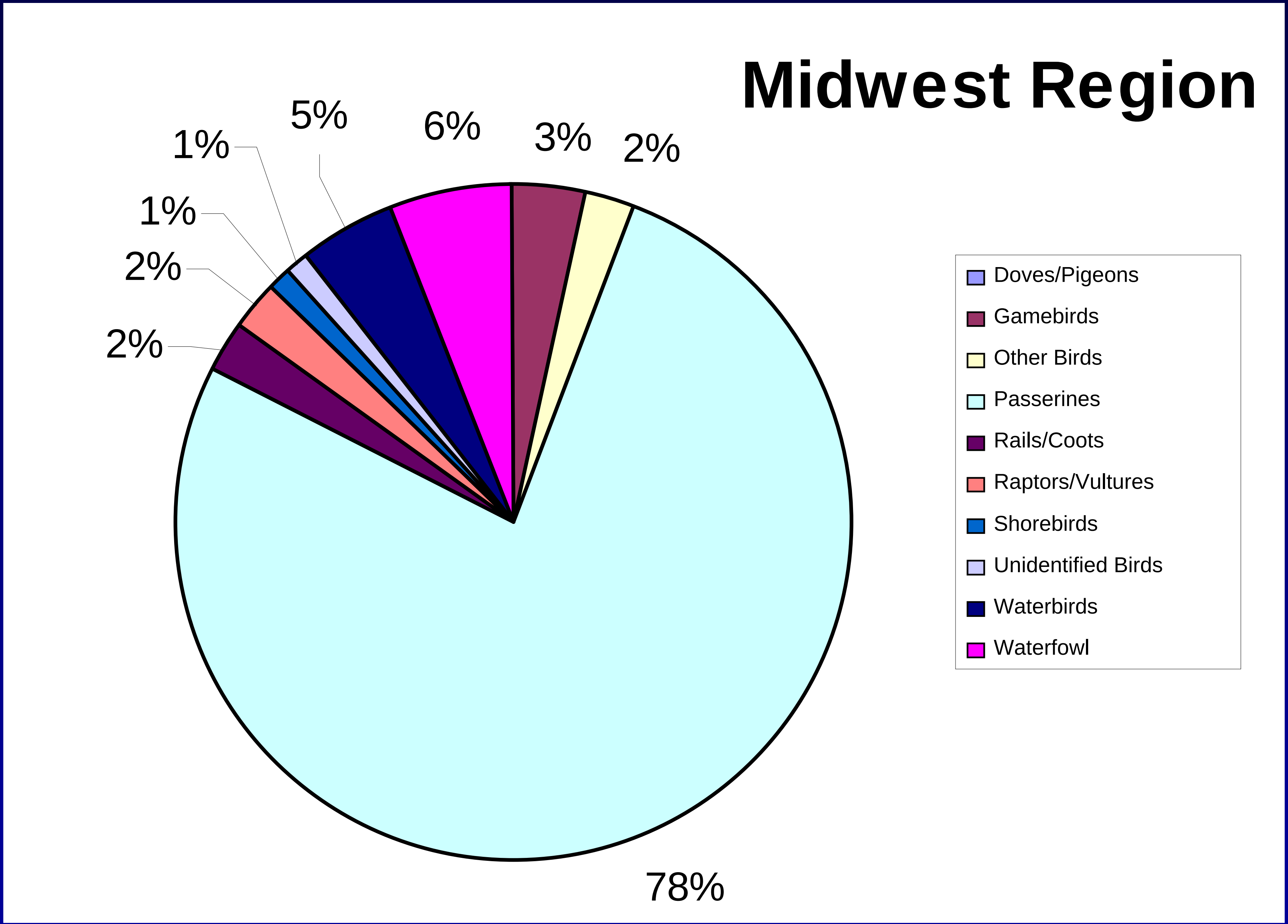
East Region


2%
2%
3%
2%
2%
2%
6%
81%
Doves/Pigeons
Gamebirds
Other Birds
Passerines
Rails/Coots
Raptors/Vultures
Shorebirds
Unidentified Birds
Waterbirds
Waterfowl



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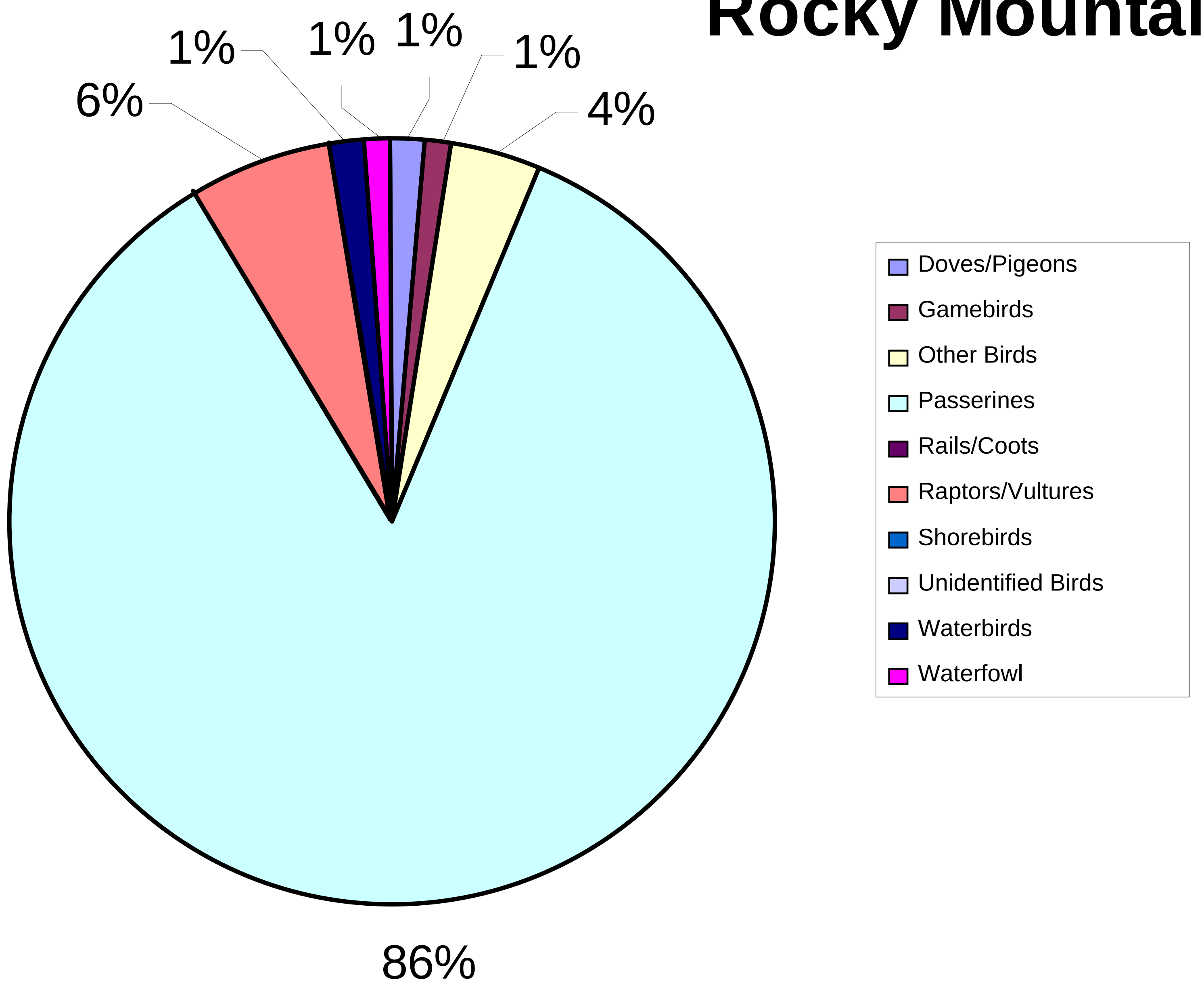
Rocky Mountain



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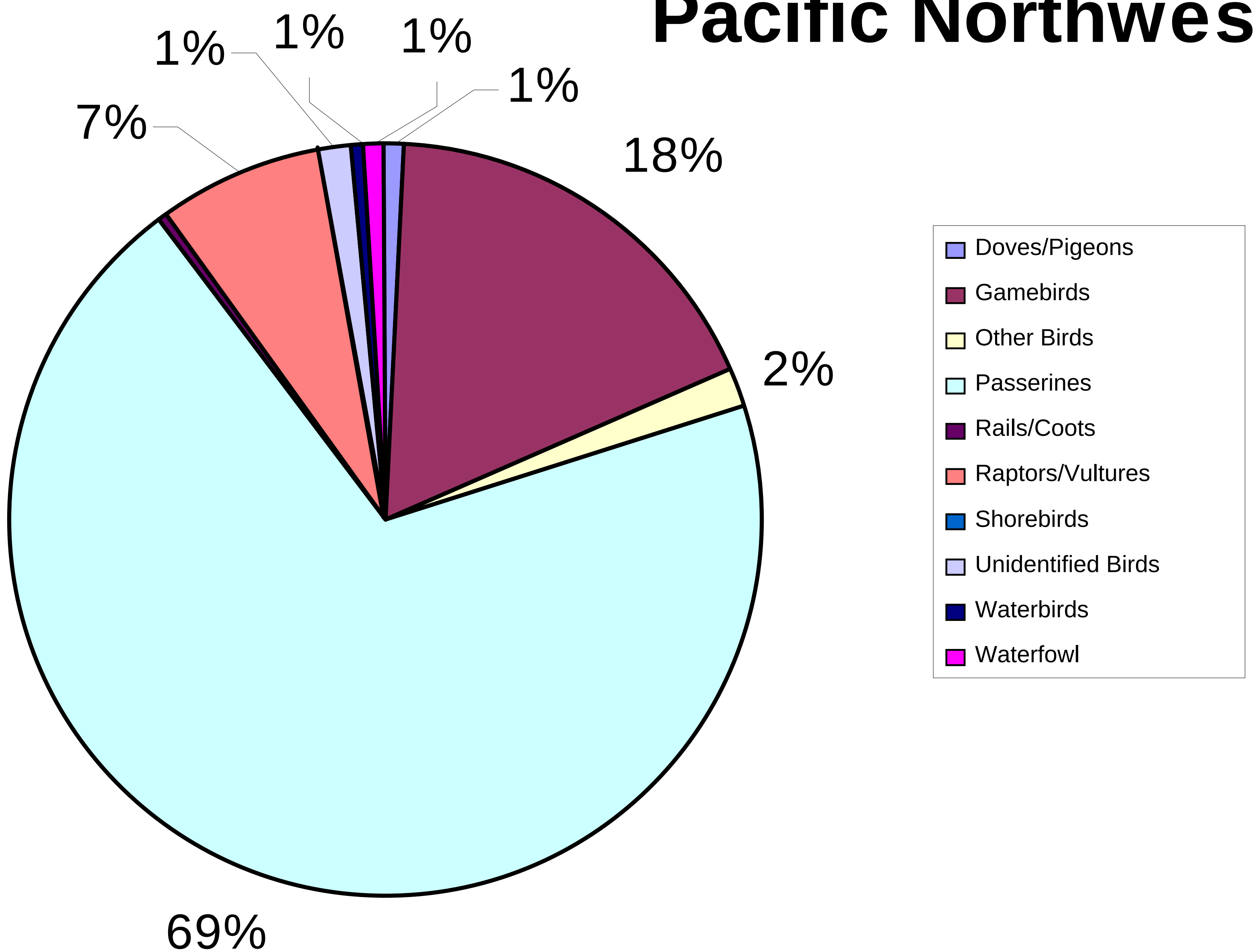
Pacific Northwest



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Top 10 fatalities by species ranked by number of carcasses[1]

Species	Pacific NW	Midwest	Rocky Mtns.	East	Grand Total	Rank
horned lark	90	1	18		109	*1*
ring-necked pheasant	24	2			26	*2*
golden-crowned kinglet	20	3		1	24	*3*
western meadowlark	14	1	2		17	*4*
gray partridge	13	1			14	*5*
unknown passerine	6	1	4	1	12	*8*
red-tailed hawk	9	2		1	12	*7*
European starling	7	4		1	12	*6*
white-crowned sparrow	10		1		11	*9*
chukar	10				10	*10*
Total for 126 Species	**263**	**86**	**80**	**60**	**489**	

[1] Assumes no background fatalities.

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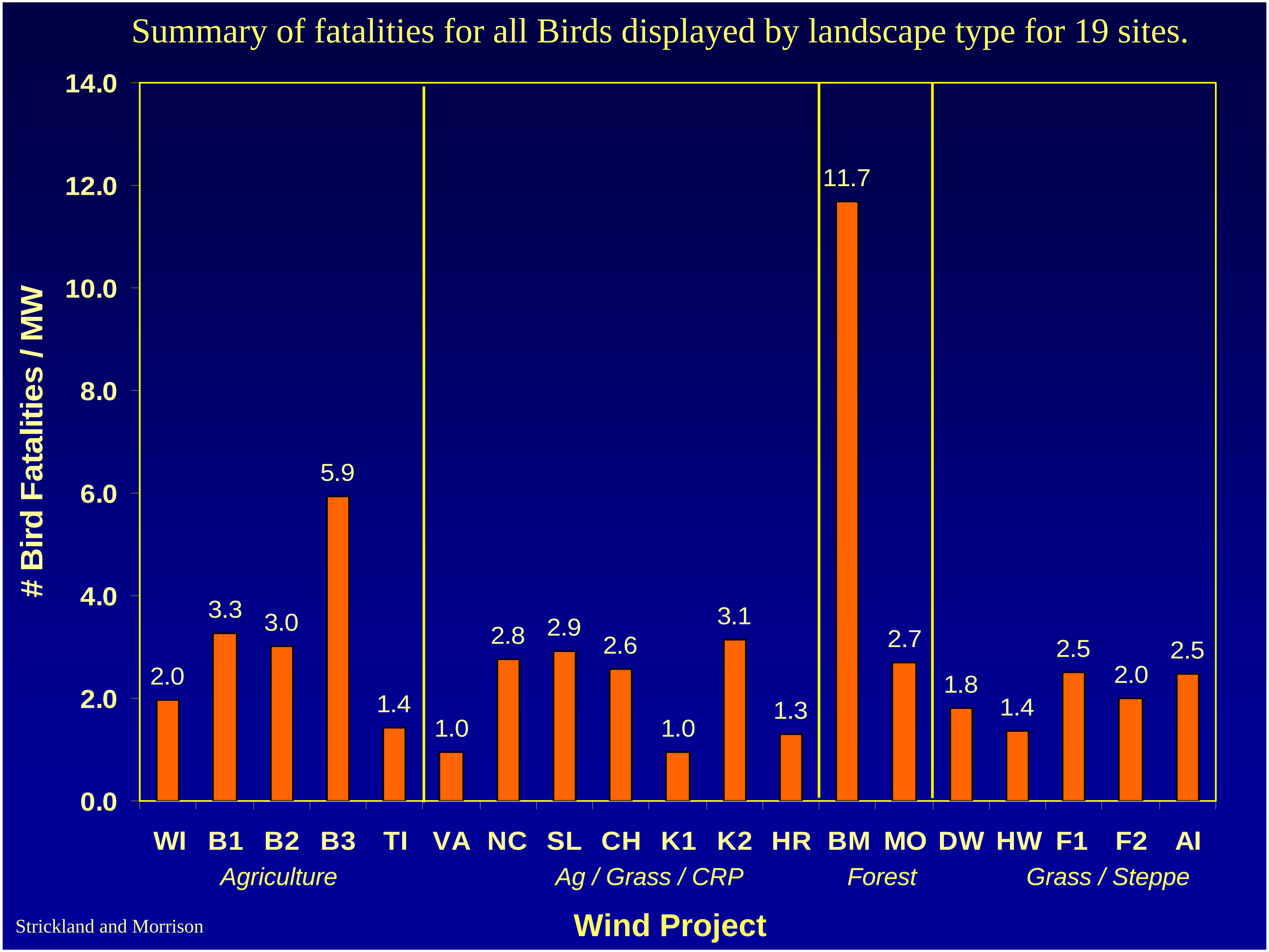

Summary of fatalities for all Birds displayed by landscape type for 19 sites.
Bird Fatalities / MW
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
2.0
3.3
3.0
5.9
1.4
1.0
2.8
2.9
2.6
1.0
3.1
1.3
11.7
2.7
1.8
1.4
2.5
2.0
2.5
WI B1 B2 B3 TI VA NC SL CH K1 K2 HR BM MO DW HW F1 F2 AI
Agriculture
Ag / Grass / CRP
Forest
Grass / Steppe
Wind Project
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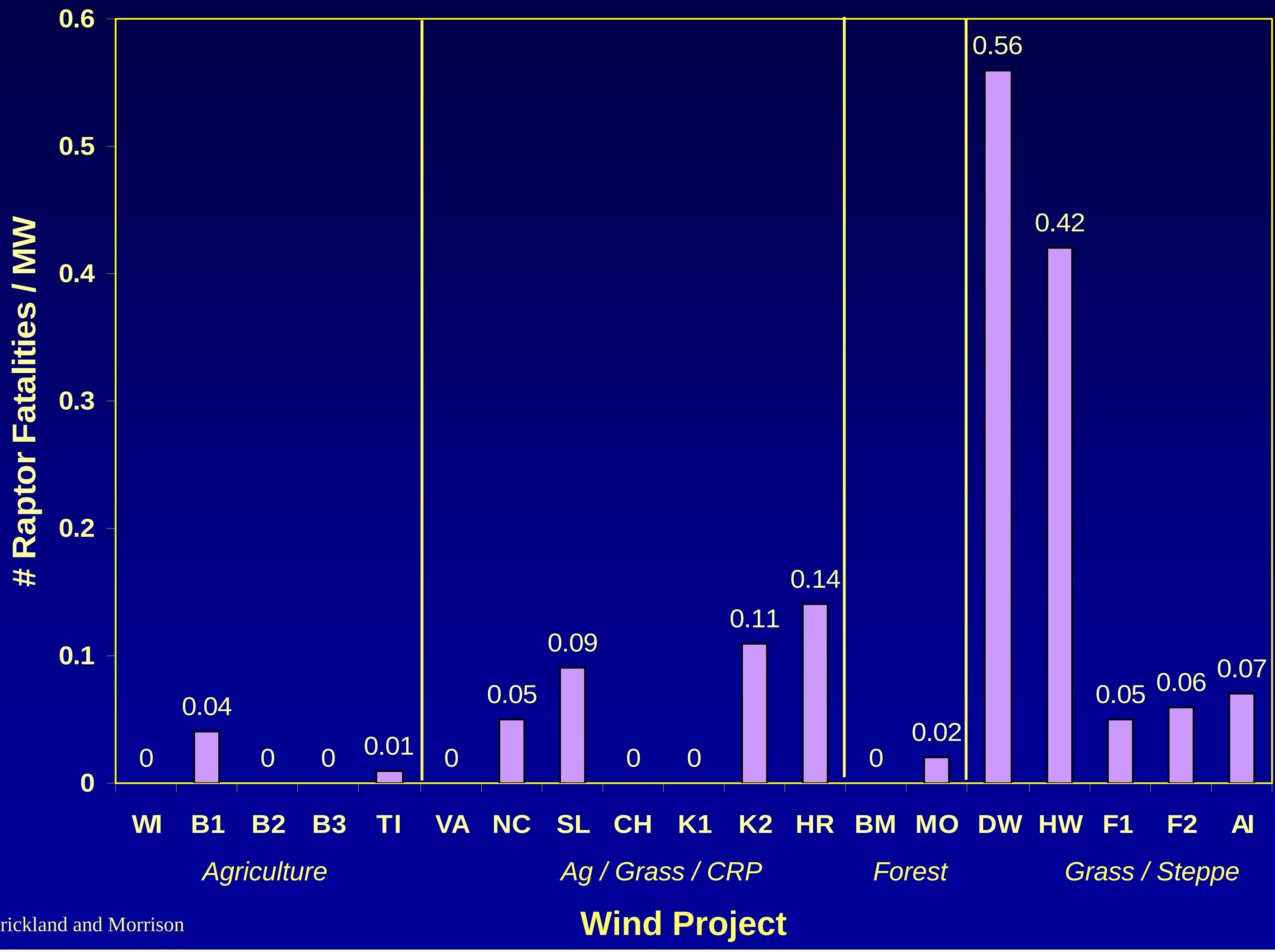
Summary of fatalities for raptors displayed by landscape type for 19 sites.



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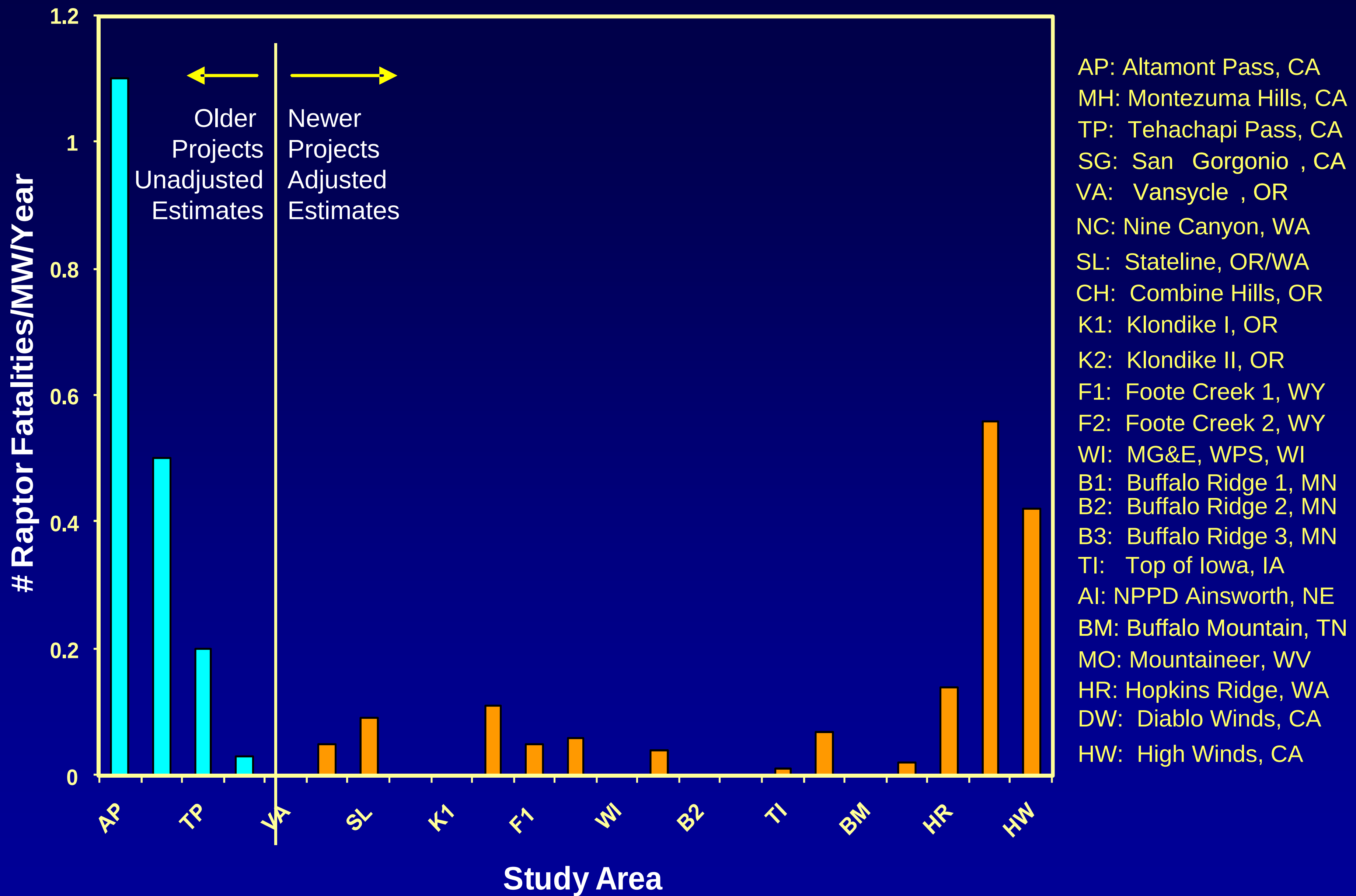

Raptor fatality rates for newer projects adjusted for carcass detection and removal biases and older projects with unadjusted rates.

Other Anthropogenic Sources of Avian Fatalities (Erickson et al. 2001)

- most studies conducted in response to episodic events
- few long-term studies
- other than wind turbine studies, scavenging and detection bias adjustments typically not conducted
- projections typically made from very limited data (best available)

Avian fatalities from communication towers from Erickson et al. (2001)

- >80,000 towers greater than 199 feet in height in U.S.
- >50,000 lit towers
- 4 million to 50 million bird fatalities per year
- Communication Tower Working Group and USFWS Guidelines

Avian fatalities from vehicles from Erickson et al. (2001)

- 4 million miles of road in the U.S. in 1997
- Number of registered vehicles increased by 35% from 1990 to 1998
- 60-80 million birds die annual due to collision with vehicles
  - Estimate based on England study (Hodson and Snow 1965)
  - very few recent studies

Avian fatalities from buildings and windows from Erickson et al. (2001)

- 4,579,000 commercial buildings in U.S. (1995)
- ~100 million houses in 1986
- Banks (1979) estimated 3.5 million avian fatalities per year
- Klem(1990) estimated 100 million – 1 billion annually in the U.S.

Avian fatalities from high tension lines from Erickson et al. (2001)

- ~500,000 miles of bulk transmission line in U.S.
- Unknown number of miles of distribution line (likely much more than 500,000 miles).
- Limited number of studies, most often conducted in areas of concern
- Using Netherlands study and extrapolating to 500,000 miles of bulk transmission line, 130 million to 174 million bird collision fatalities per year in U.S.
- Most other estimates lower

Habitat Impacts

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Potential Sources of Habitat Impact

- Direct loss of habitat
  - Turbine pads, roads, substations, transmission lines
- Indirect loss of habitat from behavioral response to wind plant facilities
  - Turbines, transmission lines, roads, human activity
- Long-term impacts
  - Permanent structures and/or avoidance with no habituation
- Short-term impacts
  - Construction, restoration and/or habituation

Predicted Impacts Due to Habitat Disturbance from planning documents (e.g. EIS)

- Temporary (construction) impacts from roads, pads, substation, etc. (estimated)
  - 0.4 to 3 acres/turbine
- Permanent (operations) impacts (estimated)
  - 0.7 to 1 acres/turbine
- Impacts and Reclamation success due to
  - Turbine type
  - Site characteristics
  - Reclamation plan
  - Climate
- Permanent footprint 5-10% of site (BLM 2005)

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Completed and ongoing displacement Studies

- Grassland Songbird Displacement Studies
  - Buffalo Ridge, MN (Leddy 1999, Johnson et al. 2000): Small scale displacement (~80-100m)
  - South Dakota: 1 of 3 species (grasshopper sparrow) showed reduced density within 150m in the first year and no difference in the second year in South Dakota (Schaffer and Johnson 2007)

  - Stateline: Grasshopper sparrow showed displacement effect within 50m
  - Oklahoma: No displacement for grassland species as a group (O'Connell and Piorkowski 2006)

- Ongoing and potential studies of bird displacement (e.g., Stateline, N & S Dakota, and prairie chicken in Kansas)

Raptor nesting impacts reported in the literature

- No effect
  - Montezuma Hills, CA (Howell and Noone 1992)
  - Foote Creek Rim, WY (Johnson et al. 2000)
  - Altamont, CA (Hunt and Hunt 2006)
  - Nine Canyon, OR (Johnson et al. 2003)
- Effect
  - Buffalo Ridge, MI (Usgaard et al. 1997)
  - 261 Km^2 surrounding facility density of 5.94/100 Km^2
  - No nests present in the 32 Km^2 facility, 2 predicted
  - Assumes uniform distribution of nests

Habitat impacts report for other bird species

- Mountain Plover – Foote Creek Rim, WY declined at wind plant, a reference area, and regionally
- Canada geese – Top of Iowa no displacement in corn fields
- Europe
  - Some species unaffected while certain waterfowl, shorebirds, and songbirds avoid turbines (e.g., European golden plover, northern lapwing, Eurasian curlews)
  - Pink-footed goose displaced up to 600m

Methods and Metrics

For Estimation and Prediction

Historical Progression of fatality estimation

- Mid 90's, Altamont was the only project with fatality data
- Reliable data only for a portion of Altamont and only raptors
- 2001 – Vansycle, Foote Creek Rim, and Buffalo Ridge
- 2001 – 2003: most predictions based on those 3 projects
- Technological differences confounded with biological differences
- 2007 – 19 studies with data suitable for use in making predictions

Progression of fatality predictions metrics

- Altamont = ~0.1/turbine/year or 1/MW/yr (Orloff 1992)
- Per turbine estimates from a few studies
  – Assumes fatality rates the same for 600 kw to 1.8 kw
- Per Nameplate MW or per RSA estimates
  – Assumes rates increase proportional to RSA
- Would like actual power production

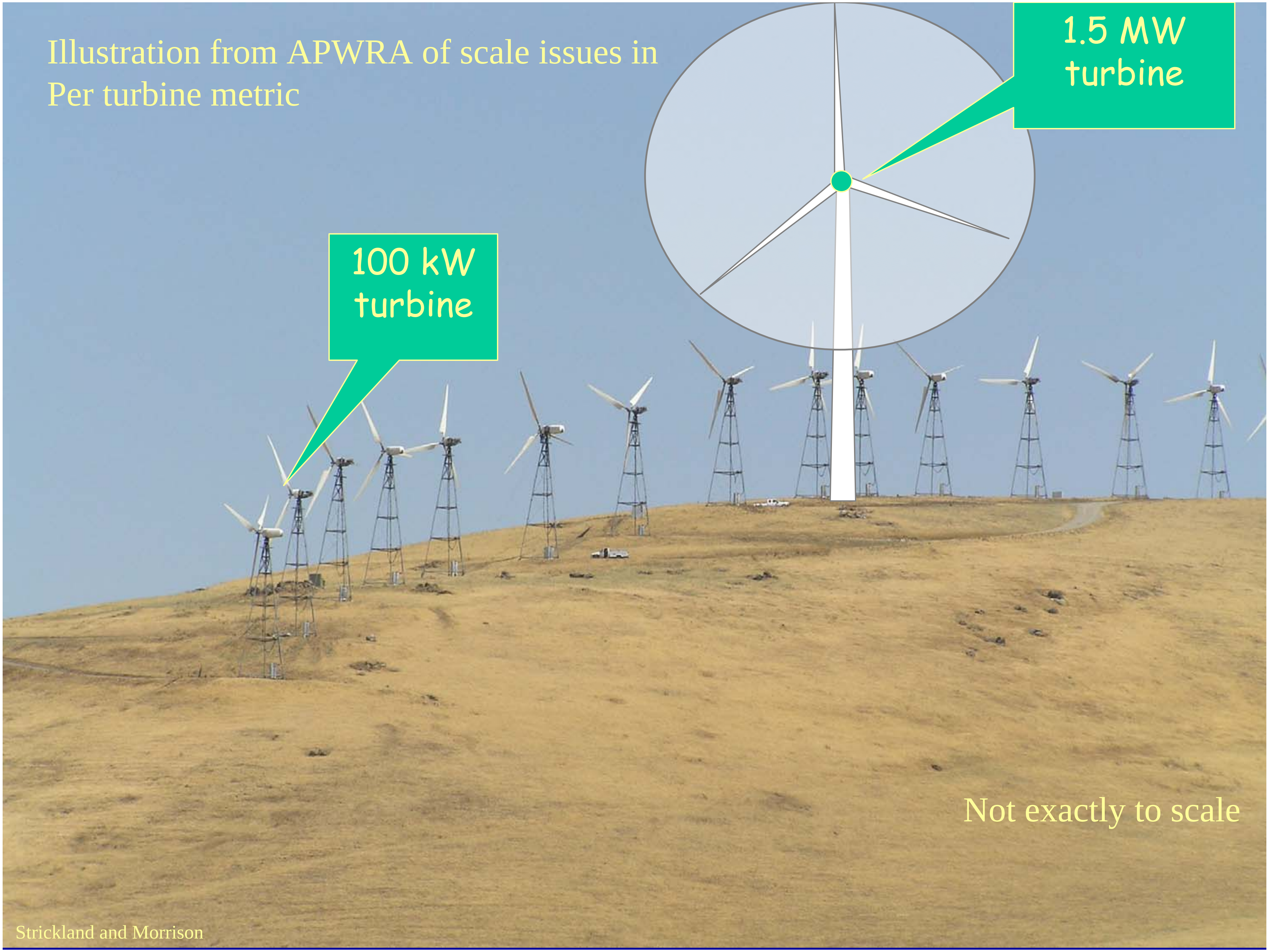
Illustration from APWRA of scale issues in
Per turbine metric
1.5 MW
turbine
100 kW
turbine
Not exactly to scale
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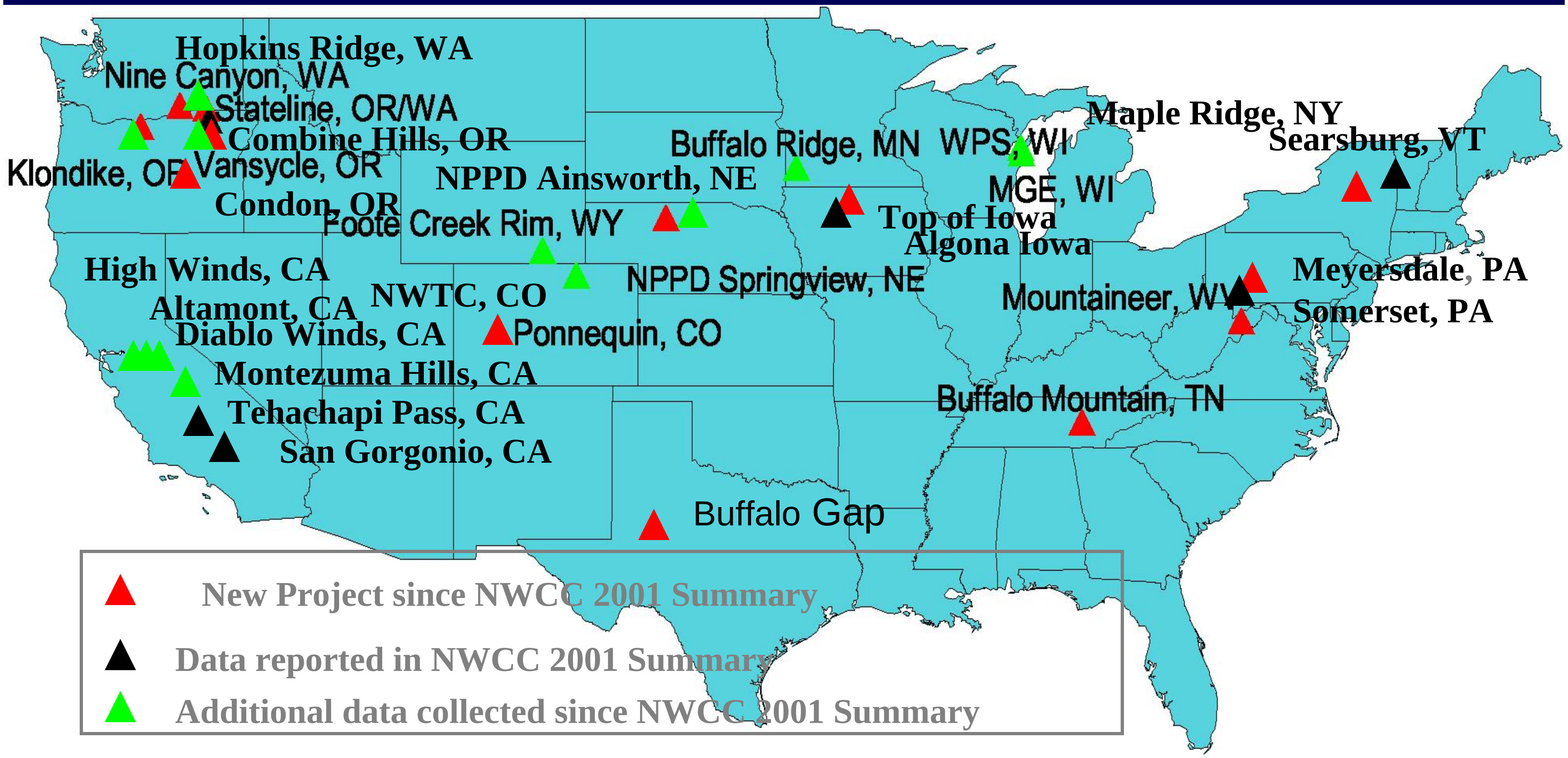
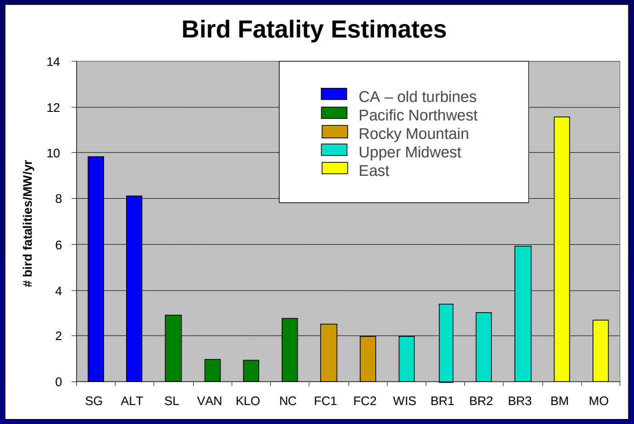
Fatality monitoring studies covering all seasons of occupancy for a 12 month period adjusted for carcass detection and carcass removal biases



Fatality Monitoring Objectives

- Determine whether overall avian and bat fatality rates or raptor fatality rates are low, moderate, or high relative to other projects
- Determine whether raptor mortality is low moderate or high
- Determine whether predicted mortality is a reasonable estimate
- Determine whether a wind project has a fatality problem

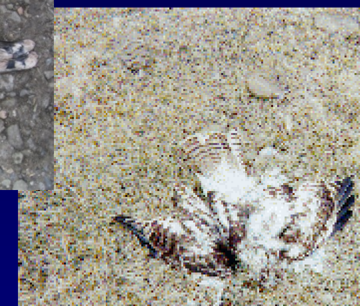


Other fatality monitoring objectives

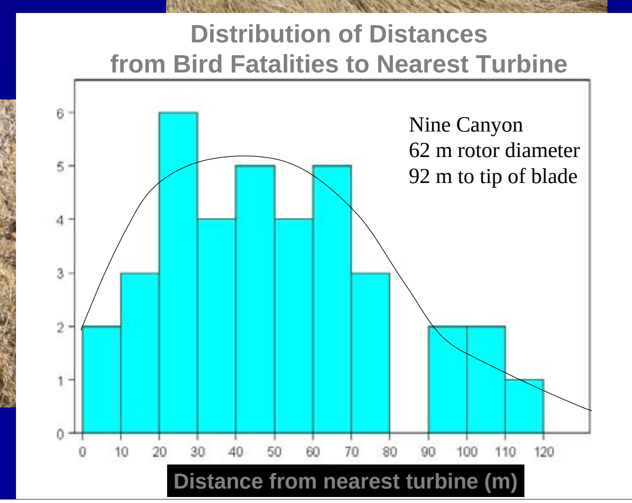
- Compare rates to exposure or relative abundance to fatality
- Estimate the influence of weather on fatality levels
- Estimate the effect of lighting
- Determine effectiveness of mitigation measures
- Similar methods and metrics for across site comparisons

Potential Field Biases to Consider

- Carcass removal
  - Experimental trial carcasses not representative of actual fatalities
  - Too many at once
  - More or less cryptic
- Carcasses may land outside search plot
- Background Mortality
- Low searcher detection





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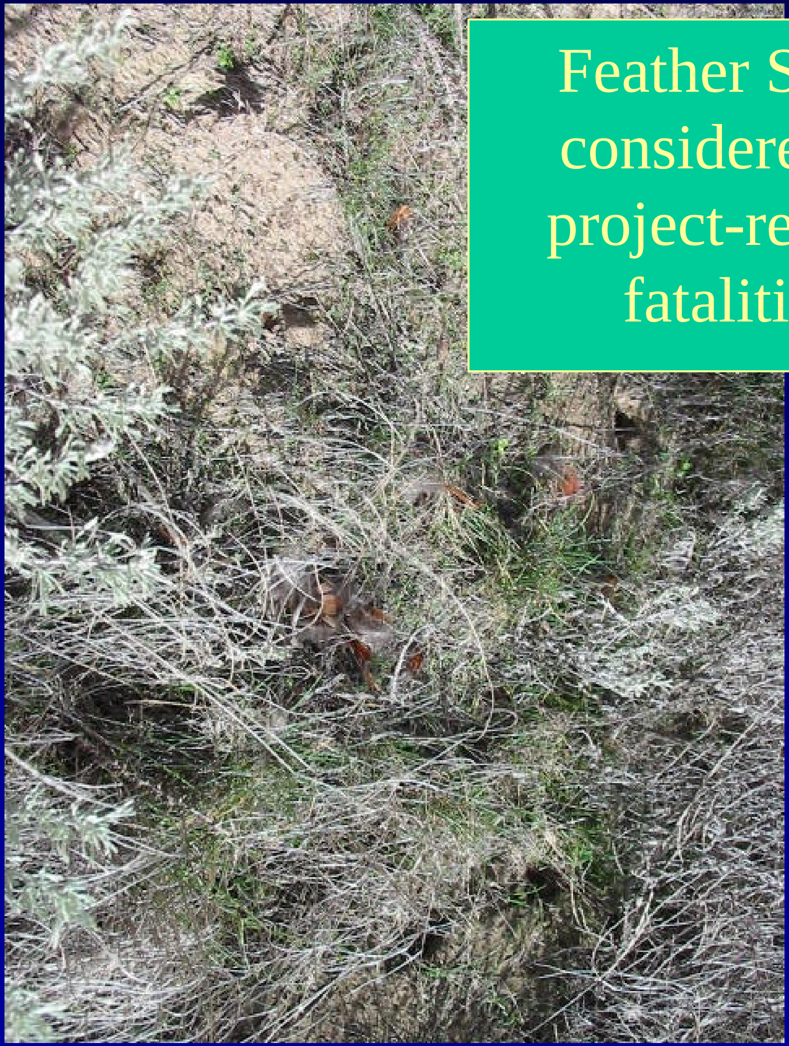
Feather Spots



Feather Spots considered as project-related fatalities

Variance in Fatality Estimates

- Turbine to turbine variation in observed fatality
- Scavenging rates
- Observer detection

$$m = \frac{\bar{c}}{\hat{\pi}}$$

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Studies of all seasons of occupancy during a minimum of one year with bias corrections

Wind Facility	Vegetation	Dates of Study	Search Interval (Days)	# of Turbines in Facility	# of Turbines searched
Vansycle, OR	Ag/Grass/CRP	1/99 – 12/99	28	38	38
Nine Canyon, WA	Ag/Grass/CRP	9/02 – 8/03	14 - Sp, Su, F 28 W	37	37
Stateline, OR/WA	Ag/Grass/CRP	1/02 – 12/03	14	454	124-153
Hopkins Ridge, WA	Ag/Grass/CRP	1/06-12/06	28	83	41
Combine Hills, OR	Ag/Grass/CRP	2/04 – 2/05	28	41	41
Klondike I, OR	Ag/Grass/CRP	2/02 – 2/03	28	16	16
Klondike II, OR	Ag/Grass/CRP	8/05-8/06	14 Sp, F 28 Su, W	50	25
Foote Creek Rim, WY Phase I	Short-grass Steppe	11/98 – 12/00	28	69	69
Foote Creek Rim, WY Phase II	Short-grass Steppe	7/99 – 12/00	28	36	36
NPPD Ainsworth, NE	Grassland	3/06-11/06	14	36	36
Diablo Winds, CA	Grassland	3/05-2/06	30	31	31
High Winds, CA	Grassland	8/03-7/05	14	90	90

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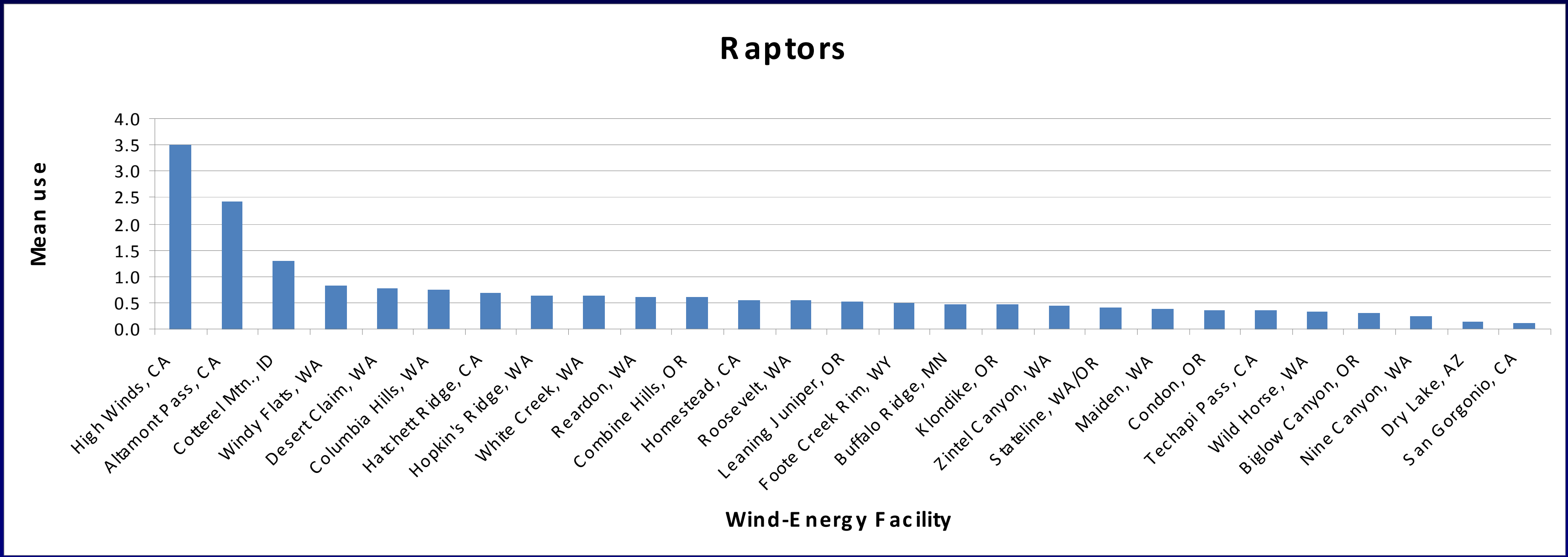
Studies of all seasons of occupancy during a minimum of one year with bias corrections

Wind Facility	Vegetation	Dates of Study	Search Interval (Days)	# of Turbines in Facility	# of Turbines searched
Wisconsin	Agriculture	Spring 98 – 12/00	Daily-Weekly	31	31
Buffalo Ridge, MN Phase I	Agriculture	4/94 – 12/95 ------------- 3/96 – 11/99	7 --------- 14	73 ---------- 73	50 ----------- 21
Buffalo Ridge, MN Phase II	Agriculture	3/98 – 11/99	14	143	40
Buffalo Ridge, MN Phase III	Agriculture	3/99 – 11/99	14	138	30
Top of Iowa, IW	Agriculture	4/03 – 12/03	2 – 3	89	26
Buffalo Mountain, TN	Forest	10/01 – 9/02	2/week – weekly	3	3
Mountaineer, WV	Forest	4/03 – 11/03	Sp – 11 Su – 28 F – 7	44	44

Fatality predictions based on existing fatality data at seven sites vs. post-construction empirical estimates

	PER MW ESTIMATES			
Site	All Birds	Empirical Estimates	Raptors Prediction	Empirical Estimate
Klondike	1	1	<0.05	0.00
Nine Canyon	1-2	2.8	<0.05	0.05
Hopkins Ridge	1-3	1.3	<0.04	0.14
Stateline	2	2.8	0.06	0.09
Combine Hills	na	2.6	<0.05	0.00
Leaning Juniper	1-4	3.5	0.09	<0.1
High Winds	na	1.4	0.16	0.41

Available data on raptor use at existing sites



- Most sites in the west have measures of raptor use
- 12 of these sites have some measure of fatality
- Should Turkey vultures be included?

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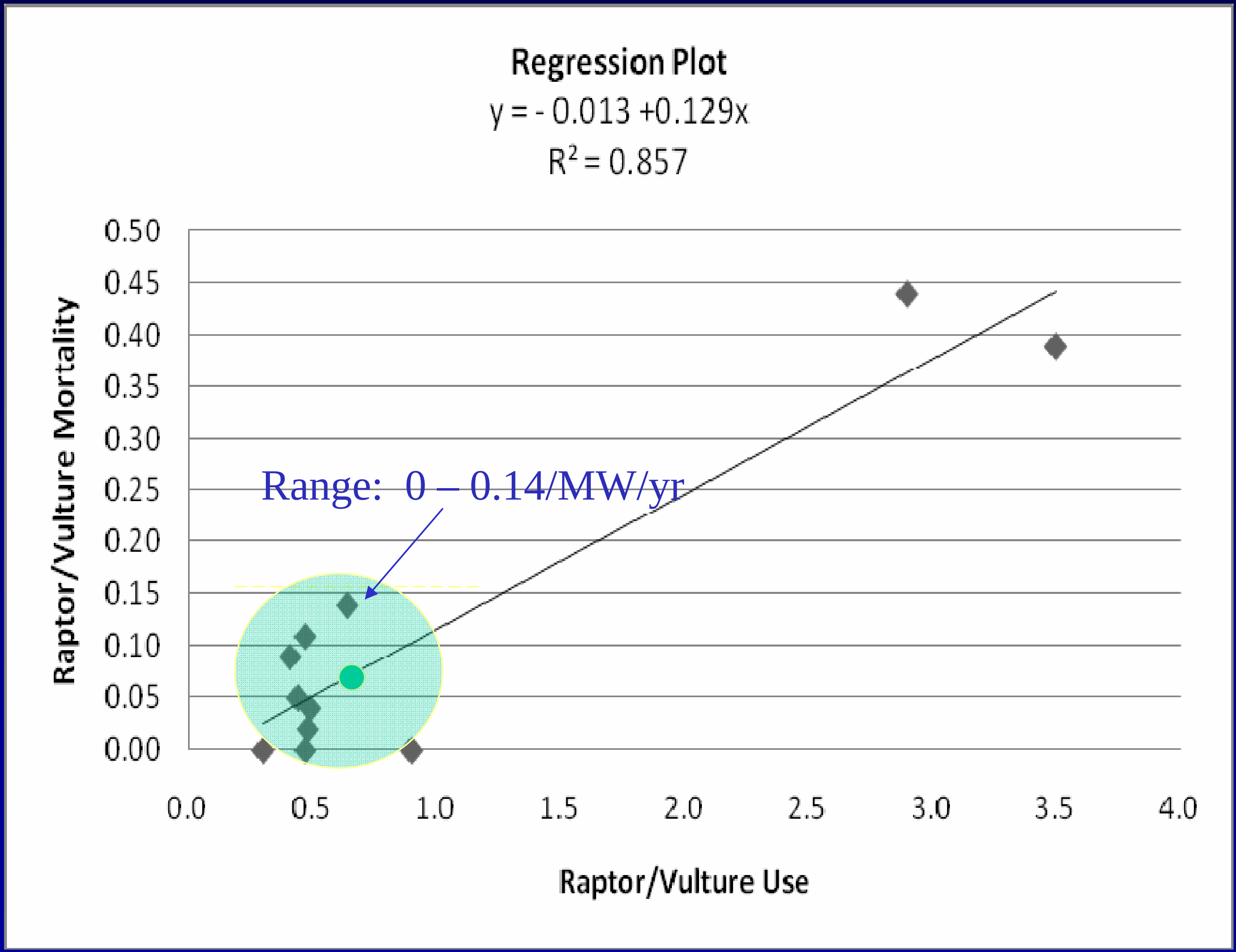
Raptor Use → Raptor Fatality



Facilities

High Winds

Diablo Winds

Hopkins Ridge

Klondike

Klondike II

Stateline

Nine Canyon

Foote Creek Rim

Vansycle

Buffalo Ridge

Combine Hills

Selected uncertainties for relating raptor fatalities to raptor use

- Survey bias
  - Owl presence not adequately surveyed
- Behavioral bias
  - High use and high fatality at HW is primarily AMKE
  - High use and high fatality at DW is primarily RTHA and BUOW?
  - TUVU use high but lower risk of collision than other raptors
- Technology bias
  - TUVU risk may increase at new sites with very high use
  - Height of RSA influences risk to raptors (flight behavior)
  - Height of RSA may influence risk to migrating songbirds and bats

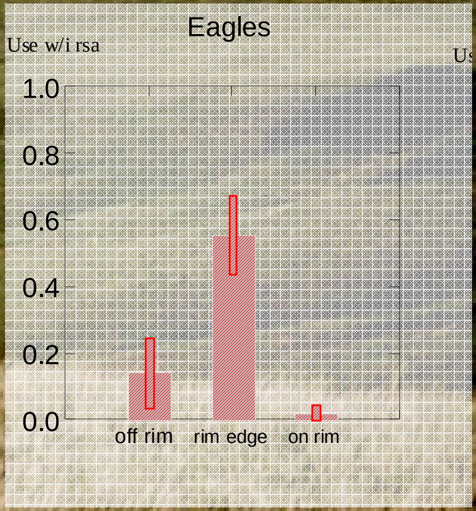
Proportion of flights below and within the rotor swept area from studies conducted in the Pacific Northwest

	Pacific Northwest Studies Flight Height Characteristics	
Species	0 - 25m	26 - 125 m
American kestrel	82	15
Ferruginous hawk	42	50
Red-tailed hawk	45	45
Golden eagle	15	67
Northern harrier	85	10
Swainson's hawk	23	67

From select studies: not a full summary of all studies

FOOTE CREEK RIM WYOMING

Lower apparent golden eagle and other raptor fatalities than predicted by the BLM EIS due to other confounding factors (i.e., turbine siting)



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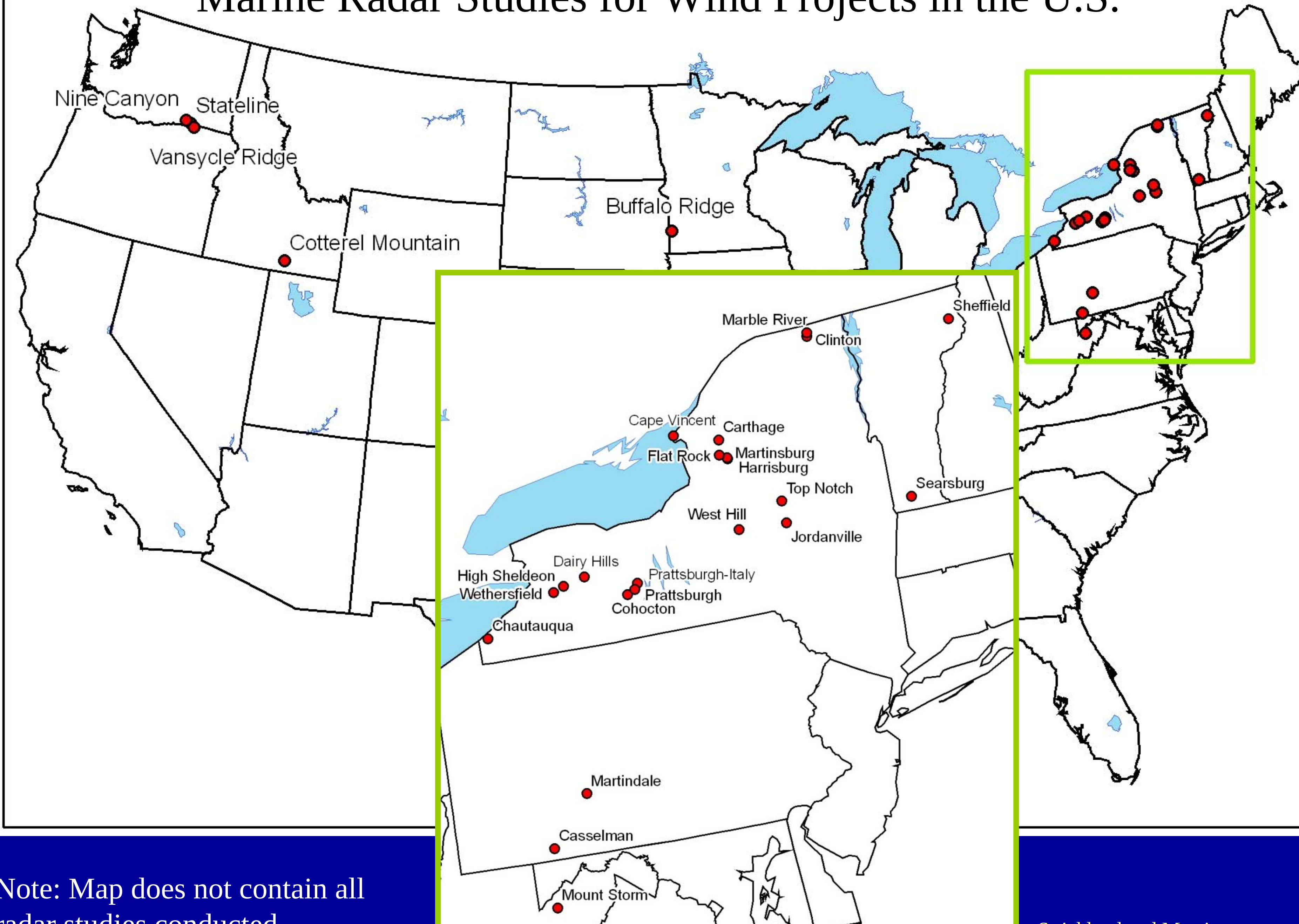
Marine Radar Studies for Wind Projects in the U.S.



Note: Map does not contain all radar studies conducted

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Predictability of Impacts from Marine Radar Studies

- Few studies with radar and mortality
- Variation in target rates relatively low
- All sites show targets migrating through
- Most sites show low % of targets at rotor heights and below
- Radar survey typically does not cover all seasons, all weather conditions and the entire WRS
- Detection bias is not considered

Comparison of Spring Target Rates and Migrant Fatality Rates

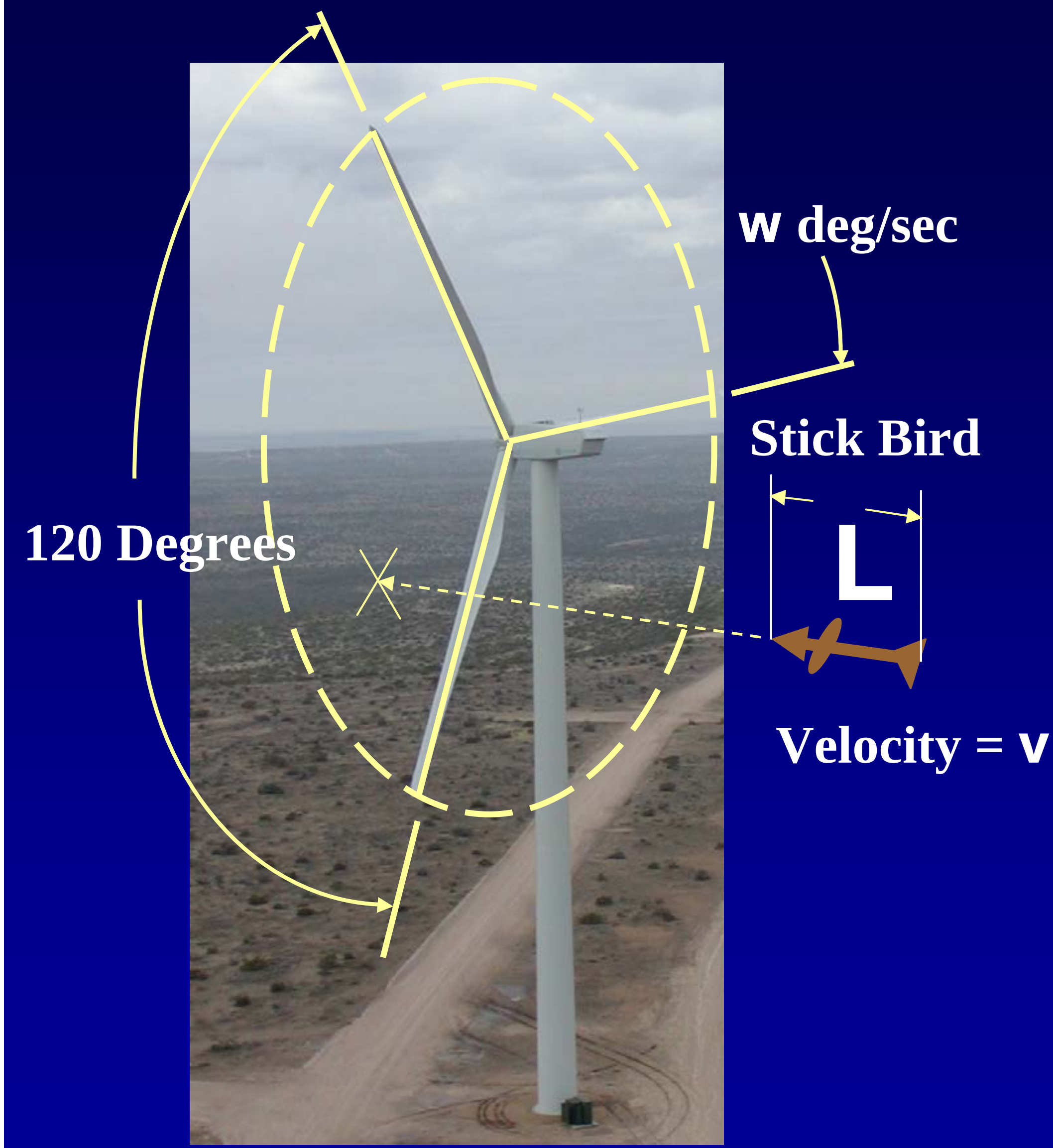
- Three wind projects have conducted both fatality monitoring and radar studies for nocturnal migrants:

Comparison of Spring Target Rates and Migrant Fatality Rates

Parameter	Stateline OR/WA	Buffalo Ridge MN	Nine Canyon WA
Spring Nighttime Surveillence Radar Data			
sampling dates	3/15-5/15/01	3/26 – 5/12/96	3/15-5/15/01
Targets/hr/2.8 km (March 15- May 15)	140	260	273
Estimated % of targets below 100 m	13.0%	not collected	14.4%
Width of WRA (km)	16	27	2.4
Estimated Spring Night Target Passage Rate	576,000	1,805,143	168,480
Spring Nighttime Migrant Fatality Data			
Estimated Spring Nighttime Fatalities	34	104	6
Fatality Rate / Target Passage Rate	<0.01%	<0.01%	<0.01%

Major Assumptions: (1) 1 target = 1 migrating bird, (2) no detection bias, (3) targets counted are migrating birds

Theoretical fatality predictions - Simple Stick Model



Stick Turbine

Bird passage time through the rotor:

$t_p = L/V =$ **Length speed ratio** (sec)

Blocked Sector of Turbine Rotor:

$B = t_p\, w$ (deg)

Probability of collision:

$P_c = \text{Blocked Area}/\text{Disk Area}$

$P_c = 3B/(360\,\text{deg})$

$P_c = 3(L/V)\{w(\text{deg/sec})/360\,\text{deg}\}$

To account for avoidance:

$P_c = 3\,A\,(L/V)\{w(\text{deg/sec})/360\,\text{deg}\}$

$$\text{where } A = \begin{cases} <1 \text{ for avoidance} \\ 1 \text{ for no behavior} \\ >1 \text{ for attraction} \end{cases}$$

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Modeled Fatality Estimates

Collision Factors

P1: Pr. of Flying at or Below Maximum Tip Height - Radar Study

P2: Pr. of Encountering Swept Area, if flying at Swept Area Height - Area Calc./Simulation

P3: Pr. of Collision if Encountering Swept Area - Tucker Model

P4: Pr. of Turbine Operating During Migration - Wind Turbine Operators

P5: Non-Avoidance Probability - Unknown

P6: Pr. a bird passing over WRA collides with a turbine - Multiply Factors Above

B: # birds passing over site - Radar Study

P6*B: Estimated # of kills

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Displacement study methods

- Field studies of impacts of wind turbines absent for most species but impacts are likely (EXO et al. 2003)
- Grassland Songbird Displacement Studies
  - Buffalo Ridge, MN: Small scale displacement (~80-100m) using <u>point counts</u>
  - South Dakota: 1 of 3 species showed reduced density within 150m in South Dakota using <u>plot mapping</u>
  - Stateline: Grasshopper sparrow showed displacement effect within 50m using <u>line transect</u>
  - Oklahoma: No displacement for grassland species as a group <u>point counts</u>
  - Maple Ridge: two species investigated: Bobolinks showed reduced density to 75 m, Savannah sparrows no apparent reduction using <u>point counts</u>
  - Kansas: ongoing study of greater prairie-chickens using radio-telemetry

Cumulative Impacts Define

- Impacts to populations
- Accumulation of impacts

Impact to Population

- Need approaches to address potential impacts to populations
- Cumulative Impacts of Concern
- Golden Eagle at Altamont (Hunt 2002, Hunt and Hunt 2006)
- Example – Columbia Basin

Illustration of accumulation of fatalities under future wind development scenario in the Columbia Basin

Columbia Basin of Oregon and Washington				
Assume 6000 MW				
	Annual #	Population	Adult Mortality	Background
Species	Estimated killed	Size	% killed	Mortality
red-tailed hawk	118	77000	0.15%	20%
American kestrel	207	170000	0.12%	40%
ferruginous hawk	30	1000	3.00%	24%
Golden-crowned kinglet	1000	720,000	0.14%	
horned lark	4200	2,200,000	0.19%	

- Fatality estimates from 7 studies in the region
- Population size from BBS data and PIF modeling
- Background mortality from literature
- Population effect?

Conclusions and Recommendations

Summary – Estimating Fatalities

- No big surprises in cases where mortality data collected in the area/region
- We know a great deal about rates in some landscapes (e.g., Ag) and some regions (e.g., PNW)
- Lack of replication of fatality studies, particularly in the northeast (ongoing studies will be valuable additions)
- Lack of information in some areas already developed (e.g. SW) and proposed for development (e.g. coastal)
- Limited studies with pre-construction diurnal avian use data and post-construction fatality limit predictive ability
  - Raptor use and mortality appear to be related

Fatality Estimation (continued)

- Reliability of predictors are being tested with fatality data
- Better predictions will occur with more fatality data
- Suggest more emphasis on denominator of risk index (response/exposure = risk)
- Different ways to estimate the probability of availability and detection
- Most methods used to date do ok when interval between searches greater than mean removal time for carcasses
- Modifications forthcoming for the case when interval is short compared to mean removal time

Summary - Habitat

- Estimated direct habitat impacts are relatively small for birds
- Displacement of grassland nesting birds is likely but the magnitude is uncertain and may range from near 0 to several hundred meters for song birds and even greater for other species (e.g., nesting effects may be much larger for prairie grouse)
- Wind project (macro) and wind turbine (micro) siting believed to be best way to minimize impacts
- Mitigation measures poorly evaluated
- Cumulative impacts poorly understood
- Data better for wind than other sources of impact

Summary - Limitations of Methods and Metrics

- Limited empirical testing of methods for their ability to predict impacts and/or risk
- Empirical estimates of exposure are inadequate for nocturnal migrating birds and for bats
- Models of fatality risk generally lack empirical estimates of avoidance behavior
- Biases have not been adequately considered with some methods (e.g., detection bias w/radar, carcass search intervals)
- Metrics could be improved with more information of energy production (e.g., MW produced)
- Direct habitat impacts have not been empirically measured
- Limited studies of displacement

Priority Research Needs

- Better synthesis of existing information
- Fatalities and habitat-related impacts in unstudied and new locations and unstudied species are needed
- Estimation of exposure for nocturnal migrating passerines and bats
- Habitat fragmentation and cumulative impacts
- Models for prediction of impacts and risk
- Determine mitigation effectiveness
- Cumulative impacts - linkage of fatality and non fatality impacts to population dynamics and biological significance

Recommendations for guidelines

- Studies should be based on specific objectives and use appropriate methods, metrics, and study design – "one-size does not fit all"
- Predictions are best made using empirical data on relative abundance and fatalities from existing facilities – models need verification
- Monitoring should use tools that have been evaluated and provide useful data to meet monitoring objectives
  - Continue evaluation (radar, NEXRAD; e.g. TX coast study)
  - Develop new tools (acoustic, IR, chemical and genetic markers)
- Use new developments in areas of uncertainty as learning opportunities

Selected References

- National Research Council of NAS – Environmental Impacts of Wind-Energy Projects
- The Wildlife Society – Impacts of Wind Energy Facilities on Wildlife and Wildlife Habitat
- National Wind Coordinating Committee –
  - Studying Wind Energy/Bird Interactions: A Guidance Document
  - Nocturnal Methods and Metrics


Questions?