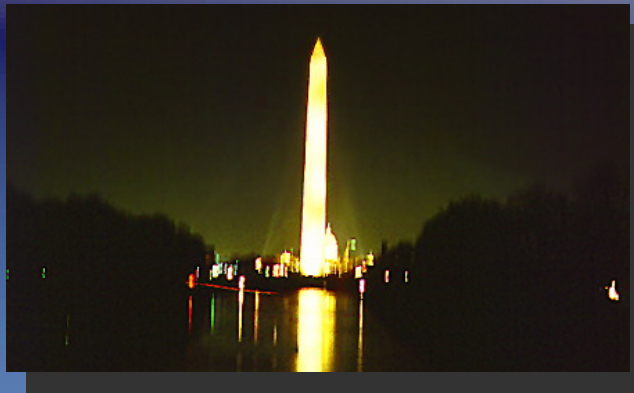
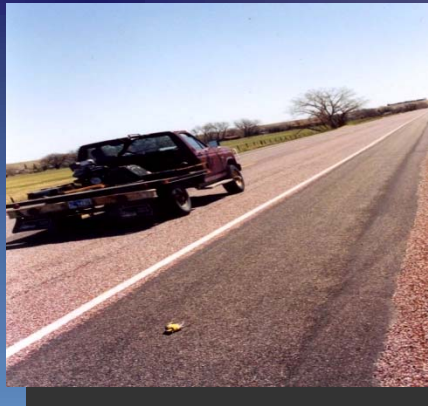


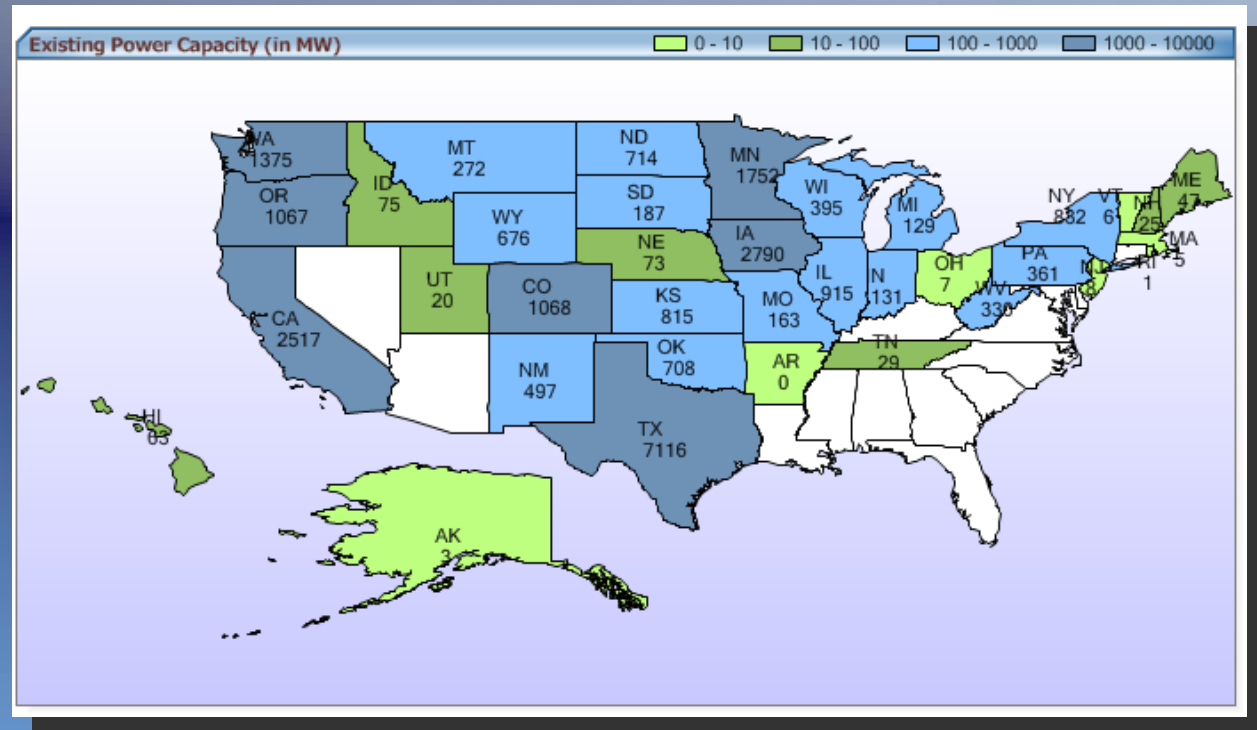
# Cumulative Fatality Impacts: Synthesis and Approaches to Address Them



Wallace Erickson

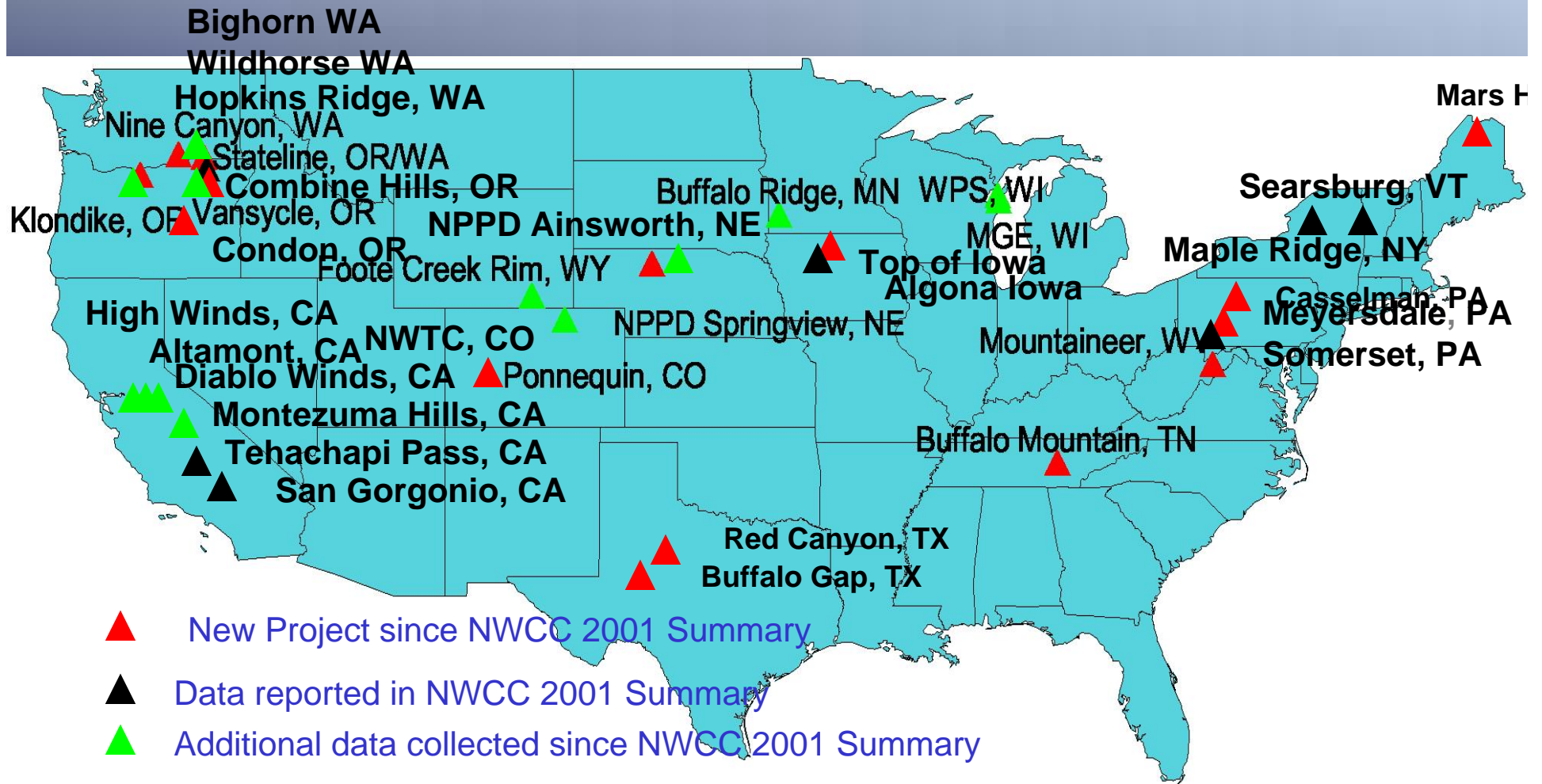
# US Wind Energy

- 25,170 installed MW
- 4,451 MW under construction



SOURCE: [www.awea.org](http://www.awea.org)

# Fatality Monitoring Studies



# Large vs. Small Turbines

- Diablo Winds – 660 kW turbines in the Altamont
- Other Turbines in the Altamont (40-150 kW)
  - All raptors – 63% fewer raptors killed per MW/yr
  - American kestrels - 84% fewer
  - Red-tailed hawks - 34% fewer
  - Golden eagles – none found
  - Burrowing owls - 34% fewer
- Reference (Altamont Monitoring Team 2008)



# Avian Strike Probability vs. Turbine Size

## Altamont Scale



15 Meter Diameter and 100 kW

## Next Generation Scale



93 Meter Diameter and 2.5MW

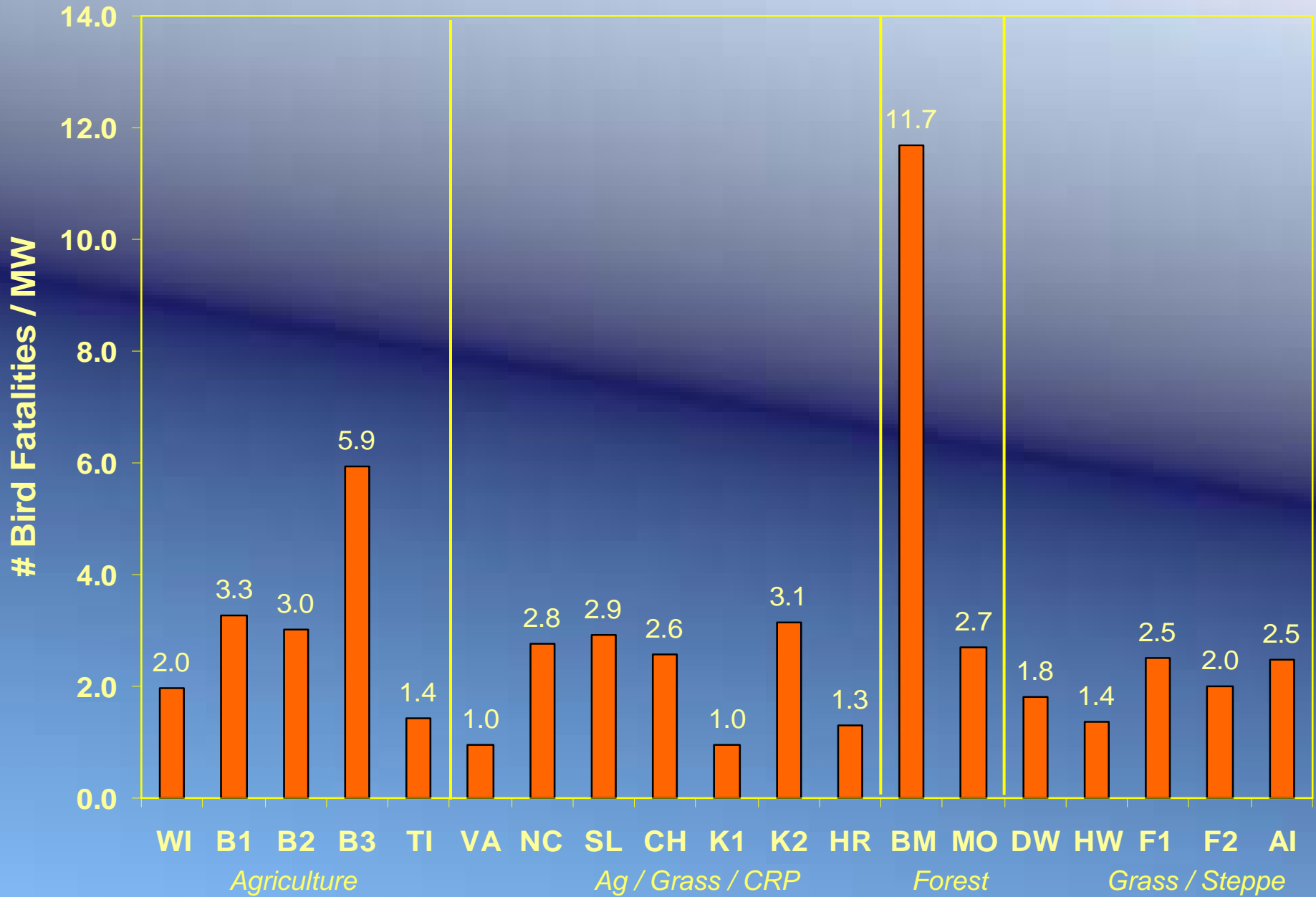
# Lighting and Birds

- Meta-analysis suggests no large differences in fatality rates at lit and unlit turbines
- Gehring (2008) work in Michigan supports this result

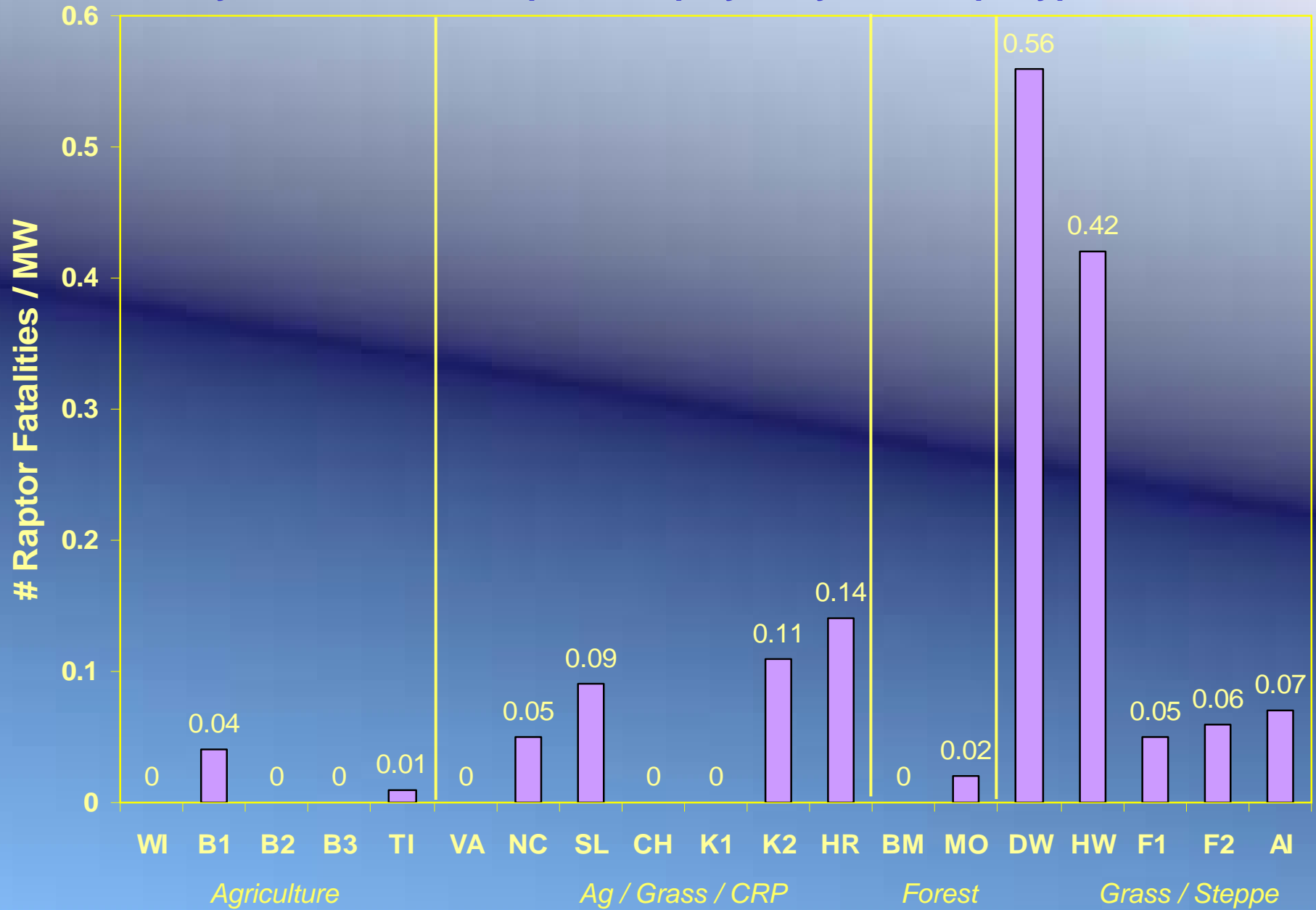


Project	Fatality Comparison		Stat. sign.
	lit	unlit rate	
Klondike	-		not sign.
Stateline	+		not sign.
Nine Canyon	+		not sign.
High Winds	+		not sign.
Wisconsin	+		not sign.
Vansycle	+		not sign.
Mountain	+		not sign.
Big Horn	-		not sign.
Wildhorse	+		not sign.

# Summary of fatalities for all Birds displayed by landscape type for 19 sites.



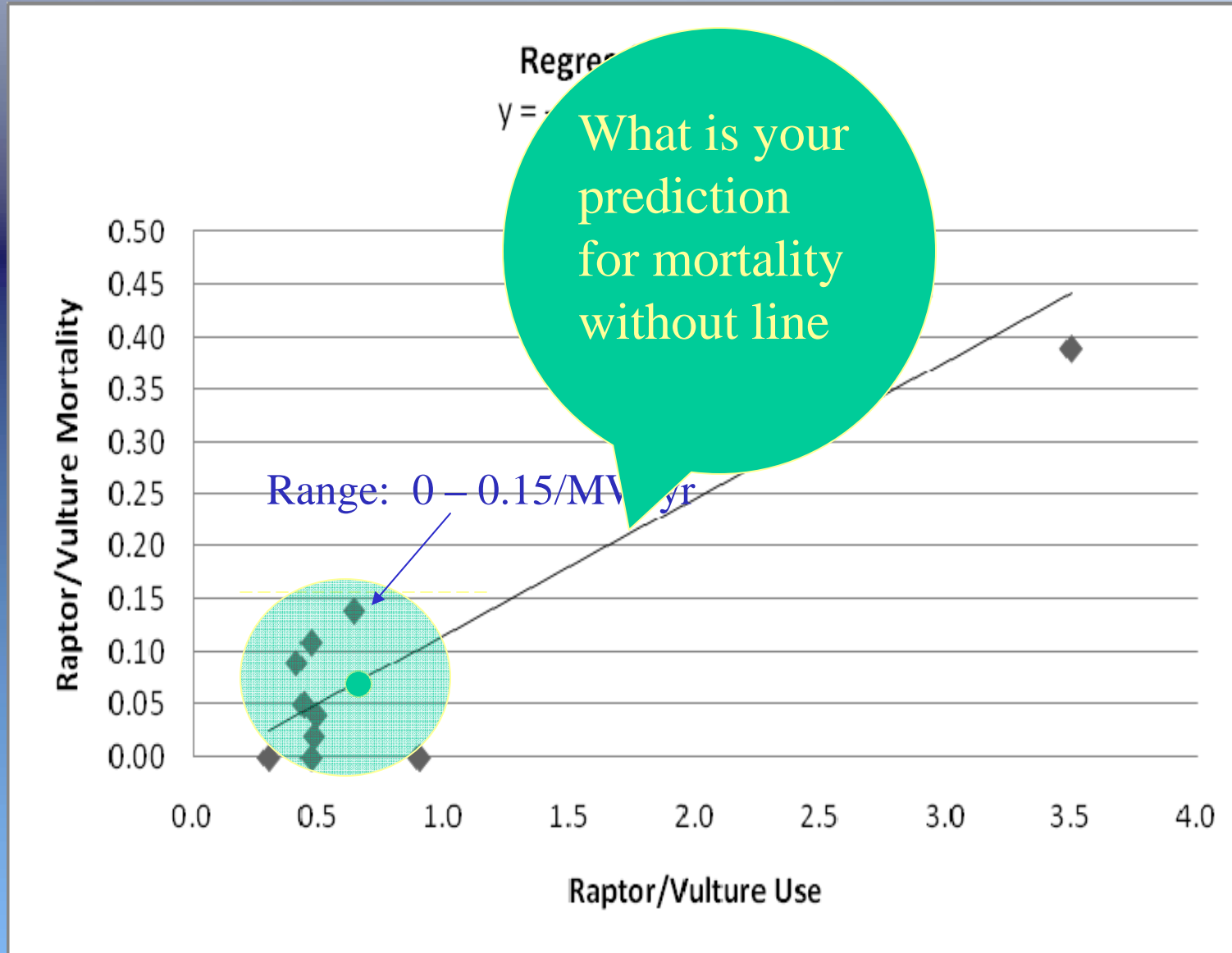
## Summary of fatalities for raptors displayed by landscape type for 19 sites.



# Projected Mortality

- All birds: 75,000 +/- 25,000
  - 3/MW/yr +/- ~1 bird/MW/yr
- Raptors: 2,500 +/- 1,300 (excludes the Altamont)
- Based on 25,000 MW
- Assumption: studies are unbiased and studies are “like” a random sample of wind projects

# 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

# Other Sources of Avian Mortality

**Vehicles: 60-80 million**



**Buildings & Windows:  
98-980 million**

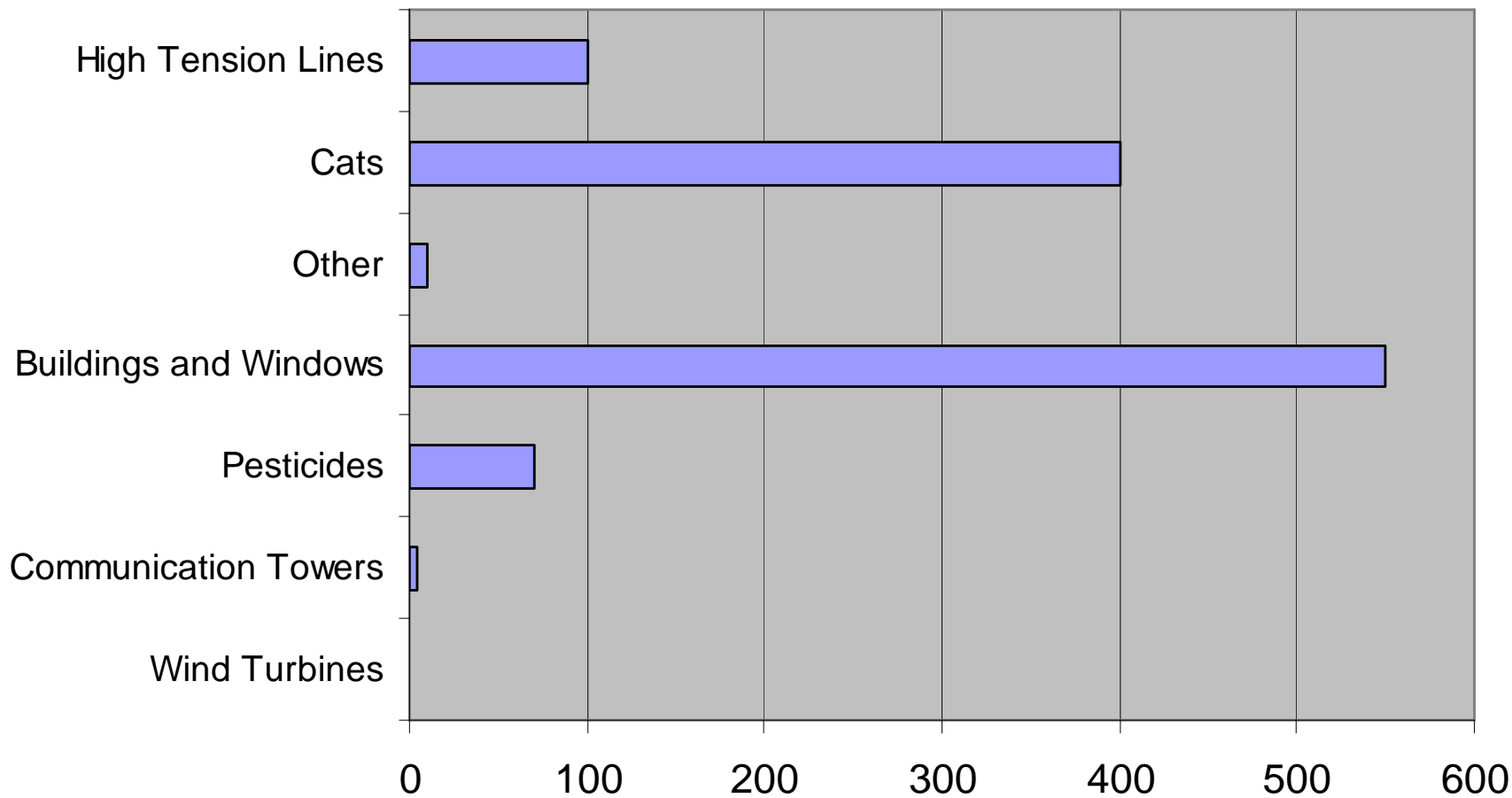


**Powerlines: millions**

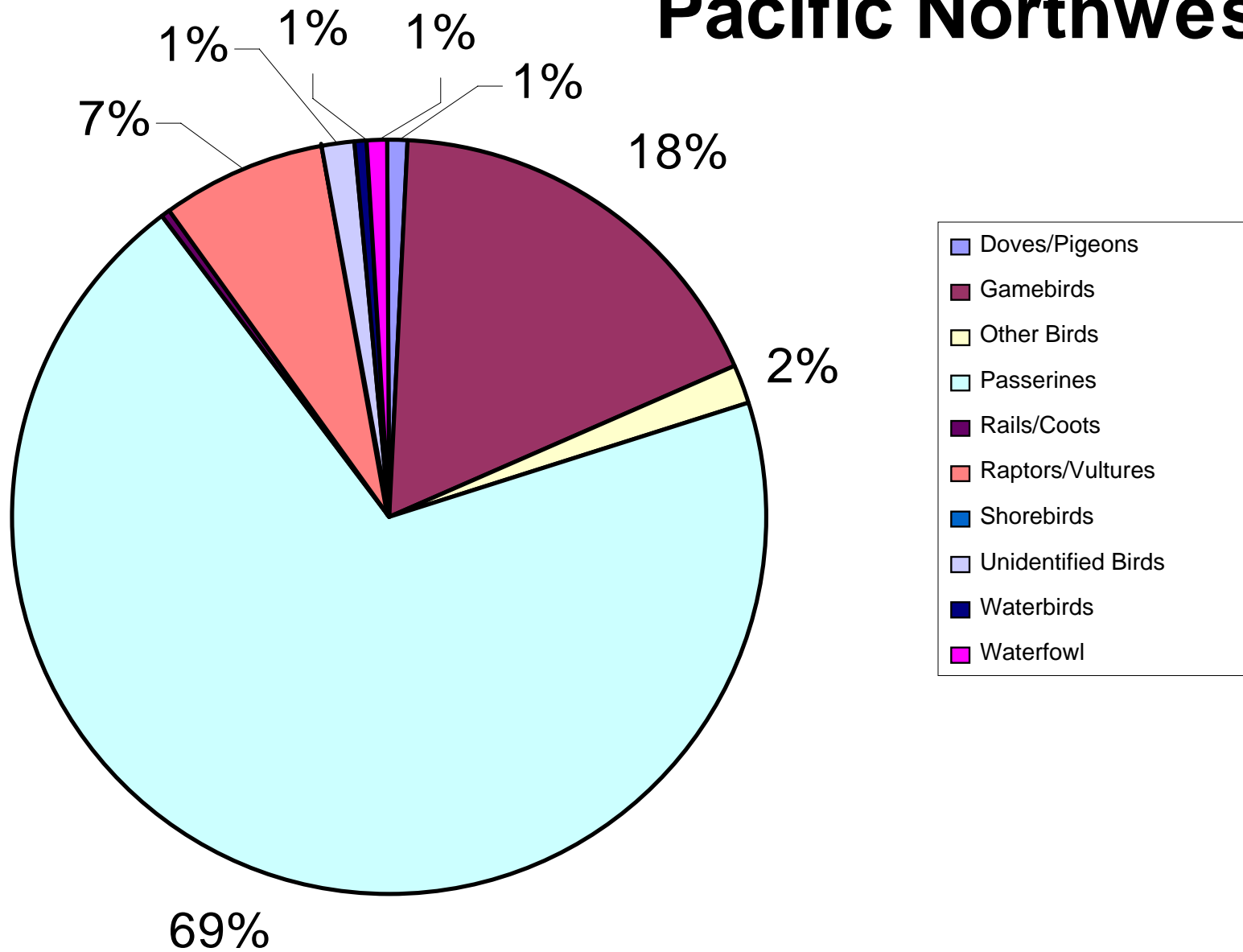


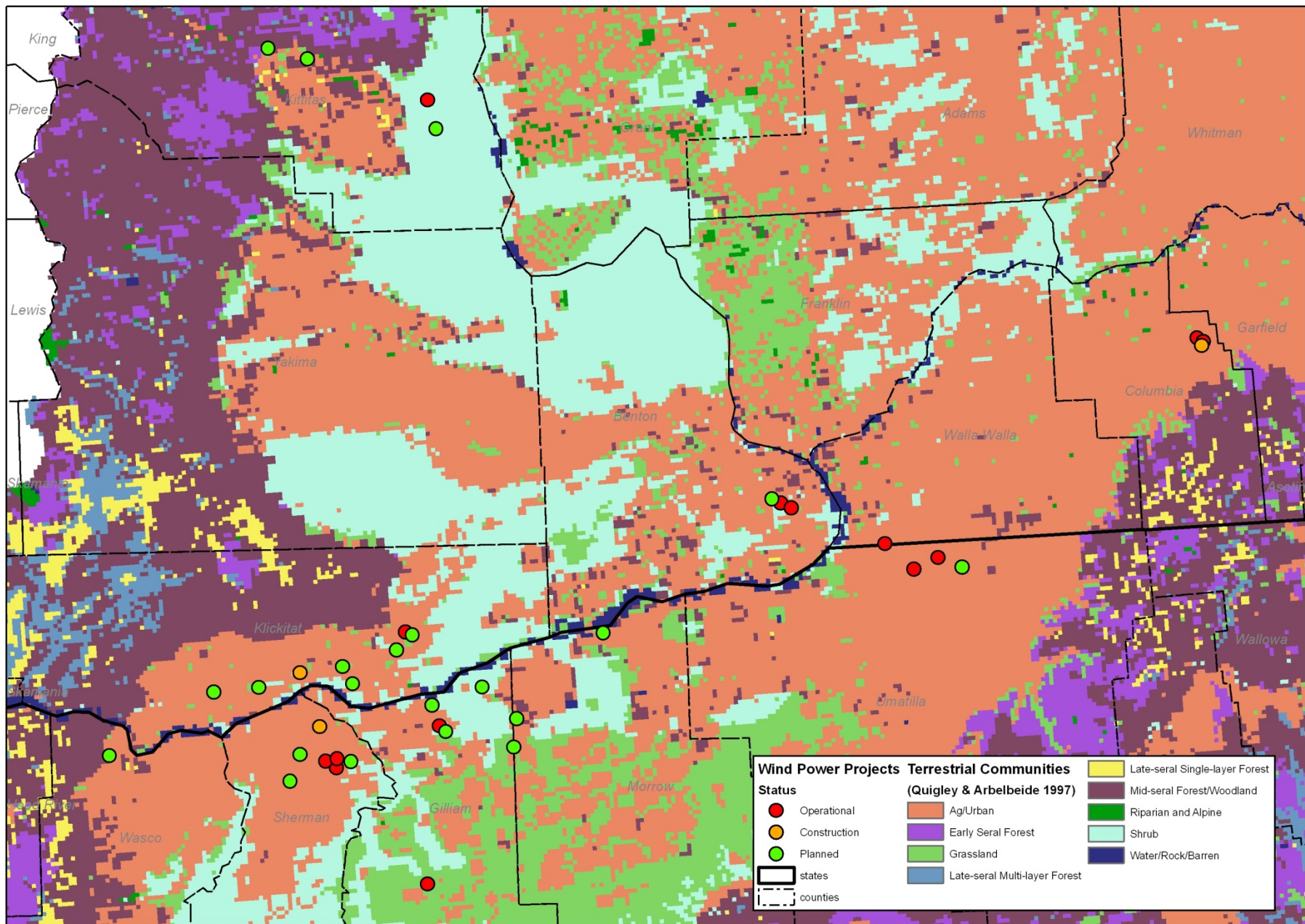
**Source:** Erickson et al. (2001) Avian Collisions with Wind Turbines: A Summary of Existing Studies and Comparison to Other Sources of Avian Collision Mortality in the United States. **National Wind Coordinating Committee Resource Document.**

### Fatalities (Millions)

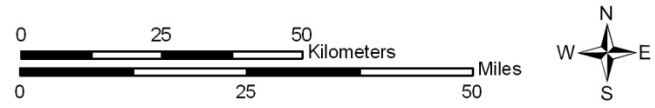


# Pacific Northwest





Created By: VP Date: 06/25/2008



**Table 2. Avian use estimates and avian fatality estimates for existing wind energy projects in the Columbia Plateau Ecoregion.**

Project	Mean annual avian use (#/20-min survey)		Mean annual mortality (#/MW/year)			Source
	Raptors	All birds	Raptors	All birds	Nocturnal Migrants	
Combine Hills, OR	0.60	6.0	0	2.6	0.27	Young et al. 2005
Klondike, I OR	0.47	17.5	0	0.9	0.35	Johnson et al. 2003a
Klondike II, OR	0.47	17.5	0.11	3.1	2.11	NWC and WEST, 2007
Vansycle, OR	0.41	13.1	0	1.0	0.32	Erickson et al. 2000
Stateline, WA/OR	0.41	13.1	0.09	2.9	0.73	Erickson et al. 2004
Hopkins Ridge, WA	0.64	8.7	0.14	1.2	0.46	Young et al. 2007
Nine Canyon, WA	0.26	9.4	0.05	2.8	0.45	Erickson et al. 2003
Wild Horse, WA	0.40	5.0	0.09	1.6	0.88	Erickson et al. 2008
Bighorn I, WA	0.90	16.6	0.15	2.6	0.57	Kronner et al. 2008
Leaning Juniper, OR	0.52	23.6	0.06	3.2	na	Kronner et al. 2007
Condon, OR	0.37	5.8	0.02 <sup>a</sup>	0.05 <sup>a</sup>	NR	Fishman Ecological Services 2003
<b>Mean</b>	<b>0.50</b>	<b>12.4</b>	<b>0.07</b>	<b>2.2</b>	<b>0.68</b>	

<sup>a</sup> not adjusted for searcher efficiency or scavenger removal; study methods differed from other projects and were not as rigorous; therefore this estimate should be regarded as a minimum mortality estimate and it was not used in calculation of the mean values.

- 636 records
- 73 species
- Horned lark
- Golden-crowned kinglet

Species	Number of Fatalities	Percent Composition
horned lark	202	31.8
golden-crowned kinglet	41	6.4
ring-necked pheasant	35	5.5
gray partridge	34	5.3
chukar	22	3.5
western meadowlark	21	3.3
American kestrel	21	3.3
unidentified passerine	21	3.3
European starling	17	2.7
dark-eyed junco	15	2.4
mourning dove	15	2.4
white-crowned sparrow	13	2.0
red-tailed hawk	12	1.9
yellow-rumped warbler	10	1.6
rock pigeon	10	1.6
unidentified bird	9	1.4
winter wren	8	1.3
short-eared owl	8	1.3
ruby-crowned kinglet	8	1.3
black-billed magpie	5	0.8
northern flicker	5	0.8
unidentified sparrow	5	0.8
house wren	5	0.8
Townsend's warbler	5	0.8
Brewer's sparrow	5	0.8
red-breasted nuthatch	4	0.6
American robin	4	0.6
Canada goose	4	0.6
common nighthawk	4	0.6
unidentified kinglet	4	0.6

# Songbird Cumulative Impacts

- 6000 MW in CPE
- Annual songbird background mortality is 30-70%
- Horned lark
  - 2.2 million individuals in CPE
  - 4000 wind farm fatalities or 0.5%
- Golden-crowned kinglet
  - 720,000 individuals
  - 1000 windfarm fatalities or <0.5%

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

Species	Pacific Northwest Studies Flight Height Characteristics	
	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

# Cumulative Fatality Impacts Illustration

- Col. Plateau Ecoregion/OR&WA
- 6,000 MW built or planned
- 77,000 RTHA in CPE
  - juv mort – 54%, adult – 20%
  - Wind turbine kills 0.05% – 0.2%
- 170,000 AMKE in CPE
  - Juv mort – 69%, adult - 45%
  - Wind turbine kills ~0.05% - 0.2%
- 1,000 FEHA
  - Juv mort - ~60%, adult – 24%
  - Wind turbine kills <1-2%



# Falconry Harvest Approach

- Milsap and Allen (2006) – Effects of Falconry Harvest on Wild Raptor Populations of the U.S.
- Approach used to propose take limits for falconry

# Demographics

## Demographics for some raptor species

Species	Annual juvenile survival	Annual subadult survival	Annual adult survival	No. young per occupied site	Age at first breeding
Red-tailed hawk	0.46	0.8	0.8	1.4	2
American kestrel	0.31		0.55	3.3	1
Golden Eagle	0.84	0.9	0.91	0.8	5

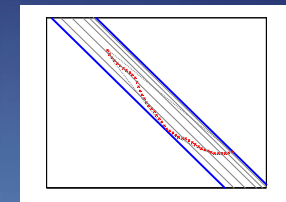
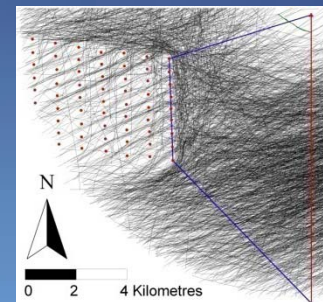
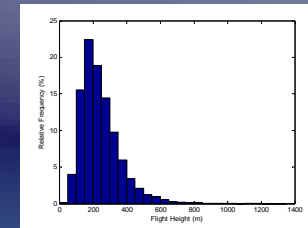
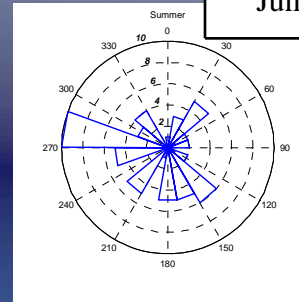
# Suggested Potential Take Limits

Species	North American Pop size	Juvenile %	Juvenile pop size	take	%
SSHA	291500	0.5	145750	1458	1%
COHA	276450	0.5	138225	1382	1%
NOGO	120050	0.5	36015	1801	5%
FEHA	11500	0.3	3450	35	1%
RTHA	979000	0.3	293700	13217	5%
AMKE	2175000	0.6	1305000	19575	1.50%
				37467	

# Collision Risk Modeling

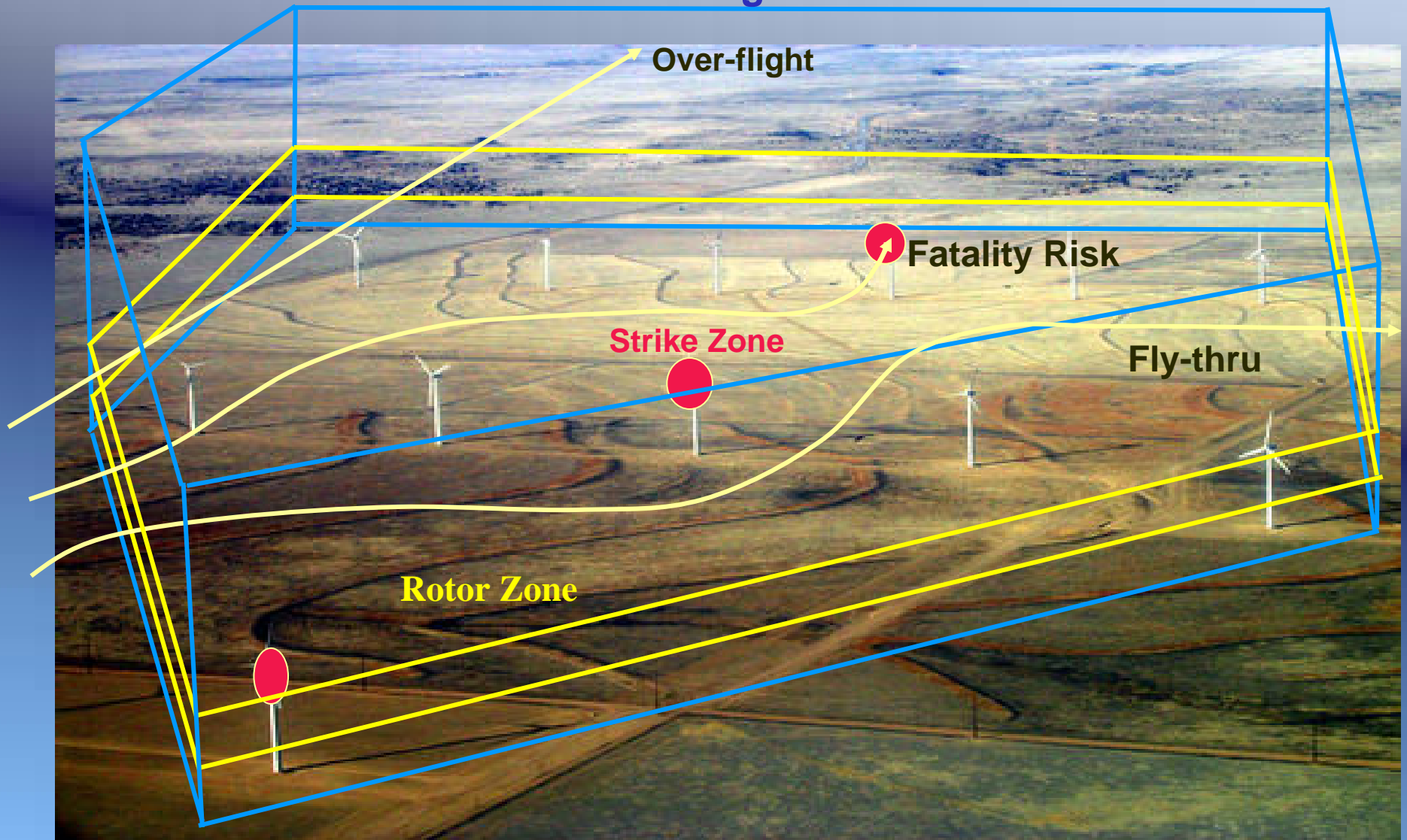
- Passage rates
- Flight directions
- Flight heights
- Turbine arrangement
- Turbine characteristics
- Avoidance
- Weather data

Season	Period of Day	Daily Passage Rate	Number of Days at Risk	Total Annual Passage Rate
Jan – Mar	AM	2.14	90	193
	PM	0.92	90	83
Apr – Jun	AM	1.65	75	124
	PM	0.71	75	53

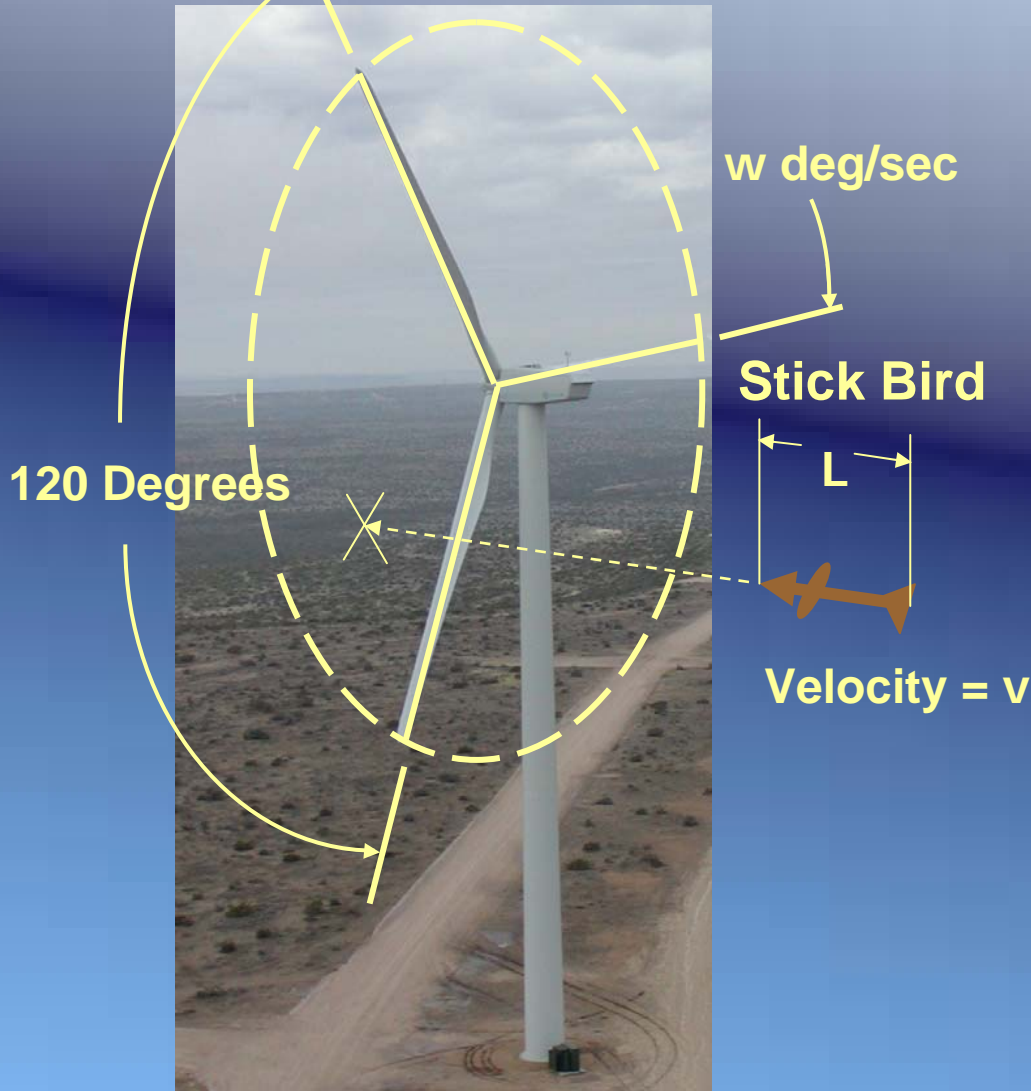


# Visualization of Avian Interaction Zones

## Windfarm Flight Zone



# Collision Model



Stick Turbine

Bird passage time through the rotor:

$$t_p = L/V = \text{Length speed ratio (sec)}$$

Blocked Sector of Turbine Rotor:

$$B = t_p w \text{ (deg)}$$

Probability of collision:

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

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

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

To account for avoidance:

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

$$\text{where } A = \left\{ \begin{array}{l} <1 \text{ for avoidance} \\ 1 \text{ for no behavior} \\ >1 \text{ for attraction} \end{array} \right\}$$

# Example Output

Inputs			Results					
Avoidance			Probability of Collision				Fatalities	
Tower, Nacelle	Tucker	Flight Height	Total	Rotor	Tower	Nacelle	Year	20 Years
0.75	N	Low	0.0001571	0.0001303	0.0000142	0.0000127	0.122	2.447
		High	0.0000259	0.0000230	0.0000015	0.0000014	0.020	0.409
	Y	Low	0.0000545	0.0000273	0.0000140	0.0000132	0.044	0.871
		High	0.0000079	0.0000052	0.0000013	0.0000014	0.006	0.128
0.90	N	Low	0.0001423	0.0001306	0.0000062	0.0000056	0.112	2.249
		High	0.0000244	0.0000233	0.0000006	0.0000006	0.019	0.384
	Y	Low	0.0000393	0.0000286	0.0000055	0.0000052	0.032	0.636
		High	0.0000063	0.0000051	0.0000006	0.0000006	0.005	0.103
0.99	N	Low	0.0001300	0.0001292	0.0000003	0.0000005	0.103	2.067
		High	0.0000244	0.0000243	0.0000000	0.0000001	0.019	0.383
	Y	Low	0.0000270	0.0000260	0.0000005	0.0000005	0.022	0.445
		High	0.0000053	0.0000052	0.0000000	0.0000001	0.004	0.085

# Summary

- Avian risk from individual wind projects is a risk to individual birds and not populations
- Data suggests avian abundance is important factor in risk, although species behavior, technology and landscape are contributing factors
- Wind turbine lights not currently documented as a significant attractant for birds – very important result for nocturnal migrant cumulative impacts
- Overall Mortality low compared to other sources – gives perspective – helps in understanding what to focus on
  - Not all groups and species
- Preliminary data suggest cumulative avian mortality from wind generally low
  - Most concern over species in decline (FEHA)
  - Impacts dependent on populations
- Less certainty for bats, since little known about population sizes



**Questions?**