AVIAN MORTALITY AT ROTOR SWEPT AREA EQUIVALENTS ALTAMONT PASS AND MONTEZUMA HILLS, CALIFORNIA

by

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INTRODUCTION

Avian mortality at wind energy facilities has become the focus of diverse research to understand the causes of collisions and to find methods to reduce and/or eliminate mortality of birds. This study evolved out of seven years of avian mortality research in the Altamont Pass and the Montezuma Hills, California. Kenetech Windpower installed their new variable speed wind turbine type in late 1992. The KVS-33 (33M-VS) wind turbine with a blade diameter of 33 m was designed to replace the older smaller KCS-56 (56-100) wind turbines with a blade diameter of 18.5 m. Because of the larger blade diameter, the US Fish and Wildlife Service (FWS) put forth the hypothesis that the larger KVS-33 wind turbine would sweep more area than the KCS-56 wind turbines potentially killing more birds. The ratio of the area swept by the rotor between the KVS-33 and KCS-56 is 3.46:1. Based on this hypothesis of increased rotor swept area (RSA), they predicted that a KVS-33 wind turbine would have three times the likelihood of an avian collision than a KCS-56 turbine.

The purpose of this project was to test the RSA hypothesis. This was done by comparing avian mortality at adjacent KVS-33 and KCS-56 turbine strings. Twenty and sixteen KVS-33 turbines were installed in late 1992 and 1993, at Dyer and at Midway, respectively, in the Altamont Pass, Alameda and Contra Costa Counties, California. These KVS-33 turbines were selected for the study. An additional seventeen KVS-33 wind turbines were installed in mid 1994 in the Montezuma Hills, Solano County, California. These KVS-33 turbines were included in the study. For comparison, adjacent strings of KCS-56 turbines were selected in numbers to provide total rotor-swept-area that was equivalent to that of the selected KVS-33 turbines.

Avian collisions with wind turbines in Central California, Altamont Pass and Montezuma Hills, were systematically studied specifically for Kenetech Windpower (Howell and DiDonato 1990, Howell et al. 1991, Howell and Noone 1992) and in general for the industry in the Altamont Pass (Orloff and Flannery 1992). During this period six sampling years were recorded, four sampling years in the Altamont Pass and two sampling years in the Montezuma Hills. The mean raptor mortality from pooled data for the two Altamont studies equaled 2.857/100 turbines/year ($s = 2.813$, $n = 4$), and the mean raptor mortality for Solano equaled 2.839/100 turbines/year ($s = 1.519$, $n = 2$). The means were not significantly different (Student's t-test for unequal sample sizes, p = 0.05). These results indicated that the survey method used to date provides similar data for estimating the number of carcasses found near turbines. The studies also examined bias from scavenging and observer variation. Their studies revealed that mortality is a rare event, therefore, difficult to relate to the numerous factors that might be involved in the collisions (e.g. turbine type, weather, topography).

Nevertheless, avian mortality, especially that of golden eagles and other raptors, is of concern. This report presents the results of eighteen months of mortality searches in the Altamont Pass and ten months of mortality searches in the Montezuma Hills.

STUDY SITE LOCATION

Two of the three study sites were located in the Altamont Pass (eastern Alameda and south eastern Contra Costa Counties)(Fig. 1). The two study areas are 6.8 mi. (10.98 km) apart. Dyer lies north of US Interstate Highway 580, and Midway lies south of US Interstate Highway 580. Altamont Pass exhibits wide diversity in topographic relief. Hill top elevations to the north of Highway I-580 range from about 750 feet to 1,200 feet above sea level. The valley elevations range from about 250 feet to 600 feet above sea level. Hill top elevations to the south of Highway I-580 range from about 1,100 feet to 1,500 feet above sea level. The valley elevations range from 600 feet to 1,100 feet above sea level. The average difference between hill tops and valleys is approximately 450 feet (s = 145.99, SE = 51.61, n = 8). These statistics reflect the high variability of the topographic relief. The Altamont Pass land use was almost exclusively cattle grazing on non-native annual grassland. The grass grows rapidly during the rainy season, sets seed and dies during the long summer drought. The KCS-56 turbines are spaced at approximately 80-100 foot (24.4-30.5 m) intervals along prominent ridges in linear formation perpendicular to prevailing winds. The KVS-33 turbines are spaced at approximately 150 foot (45.7 m) intervals along prominent ridges in linear formation perpendicular to prevailing winds.

The third study site was located in the Montezuma Hills, southeastern Solano County (Fig. 1). Montezuma Hills exhibits less diversity in topographic relief. Hill top elevations range from about 200 feet to 300 feet above sea level. The valley elevations range from about 25 feet to 50 feet above sea level. The principle habitat of the area was grain fields. After the grain harvest, sheep grazed the stubble. Some of the fields were fallow or disked to bare soil. Heating in the Central Valley of California produces winds by drawing in the cooler, dense marine air through topographic gaps in the Coast Range such as the Altamont Pass and over the Montezuma Hills in the Sacramento-San Joaquin Delta region. The spacing and physical location of the two turbine types are similar to the Altamont Pass.

METHODS

We designed methods to survey the Dyer and Midway KVS-33 turbines and sample the randomly selected sets of KCS-56 turbines, within an area adjacent to the KVS-33 turbines. Sets of turbines, rather than individual machines, were randomly chosen to keep KCS-56 turbine strings as units of study. The KCS-56 turbines had, by experimental design, a combined RSA approximately equal to the combined RSA of the KVS-33 turbines. The same approach was used to select a KCS-56 RSA equivalent in the Montezuma Hills for the Sacramento Municipal Utility District wind plant.

I randomly selected seven KCS-56 turbine strings from 17 turbine strings located around the 20 KVS-33 turbines at the Dyer site totaling 68 turbines:

Tower Numbers	Number of Turbines
2038-2053	16
2206-2209	4
2210-2219	10
2232-2242*	10
2355-2373	19
2289-2292	4
2294-2298	5

* 2240 excluded

I randomly selected four KCS-56 turbine strings from 15 turbine strings located around the 16 KVS-33 turbines at the Midway site totaling 61 turbines:

Tower Numbers	Number of Turbines
1283-1307	25
1256-1269	14
1176-1183	8
1162-1175	14

I randomly selected five KCS-56 turbine strings from 20 turbine strings near the 17 KVS-33 turbines at the Montezuma Hills site totaling 59 turbines:

Tower Numbers	Number of Turbines
8037-8050	14
8101-8115	15
8116-8127	12
8148-8158	11
8270-8276	7

We surveyed 36 KVS-33 turbines in six strings with a combined RSA = 30,609 m^2 in the Altamont Pass. We surveyed 129 KCS-56 turbines in eleven randomly selected strings with a combined RSA = 31,811 m^2 in the Altamont Pass. The difference in RSA between the KCS-56 and KVS-33 turbines was 3.9% in the Altamont Pass. We surveyed 17 KVS-33 turbines in one string with a combined RSA = 14,454 m^2 in the Montezuma Hills. We surveyed 59 KCS-56 turbines in 5 randomly selected strings with a combined RSA = 14,549 m^2 in the Montezuma Hills. The difference in RSA between the KCS-56 and KVS-33 turbines was 0.7% in the Montezuma Hills.

We sampled turbine strings twice each week between December 1993 and September 1995, in the Altamont Pass, and between November 1994 and September 1995, in the Montezuma Hills. We used ground search methods described in Howell et al. (1991) and Howell and Noone (1992). Two field observers walked 250 ft wide transects upwind and downwind of the turbines in transects to find carcasses of birds. The transect width was reduced to 150 ft because carcass distribution data indicated that the original transect was too wide. We included observations of carcasses in the study areas reported by Kenetech Windpower personnel. This was the basis for determining bird mortality associated with the 36 KVS-33 and 129 KCS-56 wind turbines in the Altamont Pass and 17 KVS-33 and 59 KCS-56 wind turbines in the Montezuma Hills. Carcasses were visually examined (without touching per FWS request) to determine species. Other information collected included nature and extent of injuries and weather conditions at estimated time of death (sample data sheet attached). We tagged raptor carcasses with blue flagging, reported to Kenetech Windpower's avian specialist, and left the carcass for recovery by FWS staff (per their request).

I compared mortality rates and number of carcasses per month between turbine types. I analyzed data and prepared manuscripts following statistical procedures of Steel and Torrie (1960), Zar (1974), Lehmann (1975), Tukey (1977), Box et al. (1978), Norusis (1988), and Wilkinson (1990a, 1990b).

RESULTS

A total of 104 birds and one mammal were recovered from the Altamont Pass and Montezuma Hills during the field surveys. Of the 104 birds, field surveyors identified a total of 72 confirmed collision mortalities in the Altamont Pass during the 18 month period when both turbine types were operating from December 1993, to May 1994 and August 1994 to September 1995. Field surveyors identified 13 confirmed collision mortalities in the Montezuma Hills during the 10 month period from November 1994 to September 1995. Ten birds recovered at KCS-56 turbines were excluded because the KVS-33 turbines were not in service for three months in the Altamont Pass. Field surveyors attributed seven mortalities to other causes, such as predation, and two injured birds were rehabilitated and released to the wild.

We identified carcasses of 16 species including seven species of raptors and one species of bat. We also had two unidentified raptors and three unidentified passerines. Avian mortalities in the Altamont Pass consisted of 44 raptors and 28 non-raptors. The KVS-33 wind turbines were not operational in the Altamont Pass from May through July, 1994. No avian mortalities were recorded at the KVS-33 wind turbines while nine mortalities and one injury occurred at the KCS-56 wind turbines during that interval. Data from that period were therefore, excluded from the analysis. One red-tailed hawk was found under a power pole, and one American kestrel was recovered with oil coating the plumage. We recovered 21 red-tailed hawks, 12 American kestrels, five barn owls, one great horned owl, one burrowing owl, one Swainson's hawk, and one prairie falcon (Table 1). Seasonal variation in mortalities at Midway and Dyer occurred with a greater number observed in late summer through early winter at KCS-56 turbines (Fig. 2) and KVS-33 turbines (Fig. 3). No seasonal pattern was apparent for Montezuma Hills (Fig 4).

Avian mortality in the Altamont Pass was different for the RSA of the two turbine types (Table 2). The overall avian mortality ratio between KVS-33 and KCS-56 turbines with equivalent RSA was 1:4.14 and the raptor mortality ratio was 1:3.40. These ratios are significantly ($p < 0.001$) different than the even ratios expected if RSA was a factor. The null hypothesis of no difference between KVS-33 and KCS-56 turbines with equivalent RSA's was rejected. Avian mortality at KVS-33 turbines was one fourth of the mortalities observed at the KCS-56 turbines. A one third ratio was evident for raptors in the Altamont Pass.

Avian mortality for all species in the Montezuma Hills at the two turbine types was not significantly different. The frequency of species mortalities was different. From November 1994 to September 1995 one red-tailed hawk and four American kestrels were recovered under KVS-33 wind turbines. Four red-tailed hawks, one mallard, one rock dove, and two red-winged blackbird were recovered under KCS-56 turbines. By combining the Montezuma Hills data with the Altamont Pass data the avian mortality ratio was 1:3.47 (Chi-square = 25.98, df = 1, $p < 0.001$) for KVS-33 and KCS-56 wind turbines. This ratio is significantly different than the even ratio that would be expected if RSA was a factor.

Table 1. Species recovered during mortality searches under KVS-33 and KCS-56 wind turbines, Altamont Pass and Montezuma Hills, California. Dec. 1993 - Aug. 1995, (excludes May - Jul. 1994, since KVS-33's were out of service).

	Number of Mortalities per Turbine Type	
SPECIES	KVS-33 (*)	KCS-56 (*)
RAPTORS		
Red-tailed hawk	5 (1)	16 (4)
Swainson's hawk		1
American kestrel	2 (4)	10
Prairie falcon	1	
Barn owl	2	3
Great horned owl		1
Burrowing owl		1
Raptor (unk.)		2
OTHER		
Mallard		(1)
Black-crowned night heron	1	
Rock dove		7 (1)
European starling	1	2
Western meadowlark	1	7
Horned lark		3
Brewers blackbird		2
Red-winged blackbird		(2)
Mountain bluebird		1
Passerine (unk.)	1	2
MAMMAL		
Hoary bat	1	
TOTAL	**15 (5)**	**58 (8)**

(* = recovered from Montezuma Hills)

Table 2. Avian mortality rates between KVS-33 and KCS-56 wind turbines, Altamont Pass, California, Dec. 1993 - Aug. 1995 (excludes May - Jul. 1994, since KVS-33's were out of service).

	Turbine Type	
	KVS-33	KCS-56
Turbine numbers	36	129
Mortality numbers		
Dyer	6	22
Midway	8	36
TOTAL	14	58
Species numbers (excludes unknowns)	7	12
Raptor numbers	10	34

Excludes an American kestrel, oil soaked, and one red-tailed hawk at power pole.
Chi-square = 26.94, df = 3, $p < 0.001$
Avian mortality ratio: 1:4.14
Raptor mortality ratio: 1.3.40

DISCUSSION

The evidence to date from the Altamont Pass does not support the hypothesis that the larger rotor swept area of the KVS-33 wind turbines contributes proportionately to avian mortality, i.e. larger area results in more mortalities. On the contrary, the ratio of KCS-56 turbines to KVS-33 turbines rather than RSA was approximately 3.4:1 which was consistent with the 4.1:1 mortality ratio. It appears that the mortality occurred on a per-turbine basis, that is each turbine simply represented an obstacle. This would mean that replacing the RSA of KCS-56 turbines with KVS-33 turbines would reduce mortality by two thirds. In addition the KVS-33 had relatively low numbers of non-raptor species recovered during mortality searches.

It is reasonable to assume that within-site scavenging rates and observer search abilities were the same between the two turbines types because conditions at each site were very similar and distances between turbine types were small (Howell and Noone 1992). The sampling period of twice each week, one three day interval and one four day interval, was an effort to minimize scavenging bias, since previous studies showed that raptor carcass scavenging was very low in the first few days (Howell and Noone 1992, Orloff and Flannery 1992). This was especially true for larger birds such as red-tailed hawks. Search bias was assumed to be consistent across each sampling site, since the same observers used the same methods at each site. Observers have a higher probability of seeing larger birds in the short grasslands which were the conditions that predominated during this study (Faanes 1987, Orloff and Flannery 1992).

One objective of this study was to estimate the time of death by examining the bird carcass for insect infestation and decomposition. With a decomposition phenology we wanted to back date to time of death. The purpose was to look for correlations between time of death, weather, and wind speeds at the sites. We were not permitted to examine the birds which eliminated the possibility of field necropsies. In future studies it will be important to permit researchers to conduct detailed examinations of mortalities.

Although results between turbine types in the Montezuma Hills were not significantly different, there was a difference in proportions of raptor species affected. The mortality ratio for red-tailed hawks was 4:1 for KCS-

56 turbines versus KVS-33 turbines. Four American kestrels were found at KVS-33 turbines and none were found at KCS-56 turbines. I think that the small sample size and short duration of the study in that locale accounts for these results and a more accurate ratio would result given more time. Even by adding the Montezuma Hills data to the Altamont data the avian mortality ratio between the two turbine types was significantly different from the 1:3.4 ratio predicted by the RSA hypothesis.

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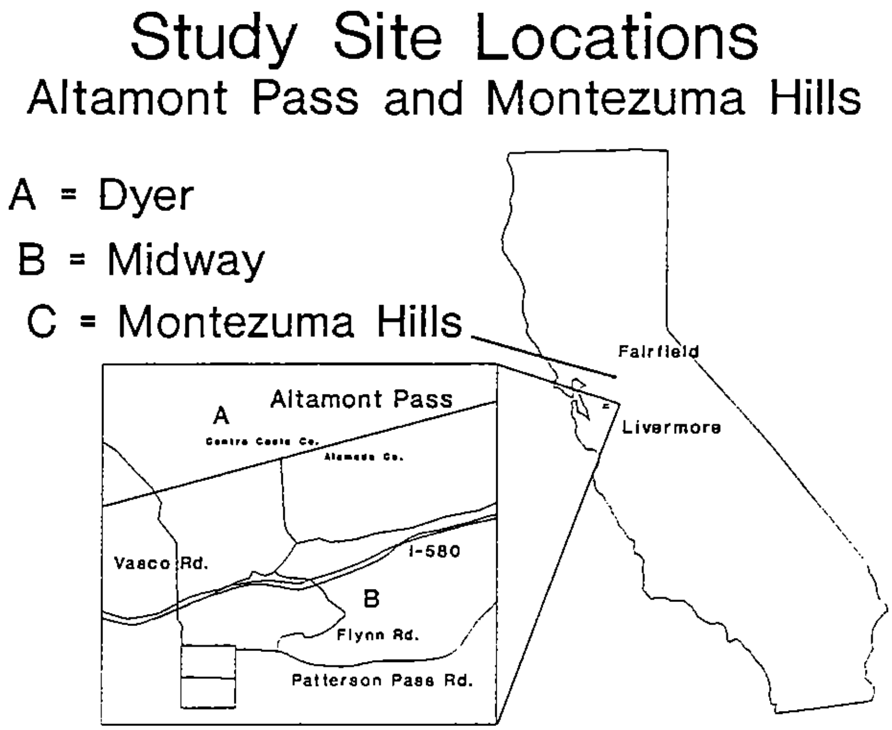


Figure 1. Study Site Locations, Altamont Pass, Alameda and Contra Costa Counties, and Montezuma Hills, Solano County, California.

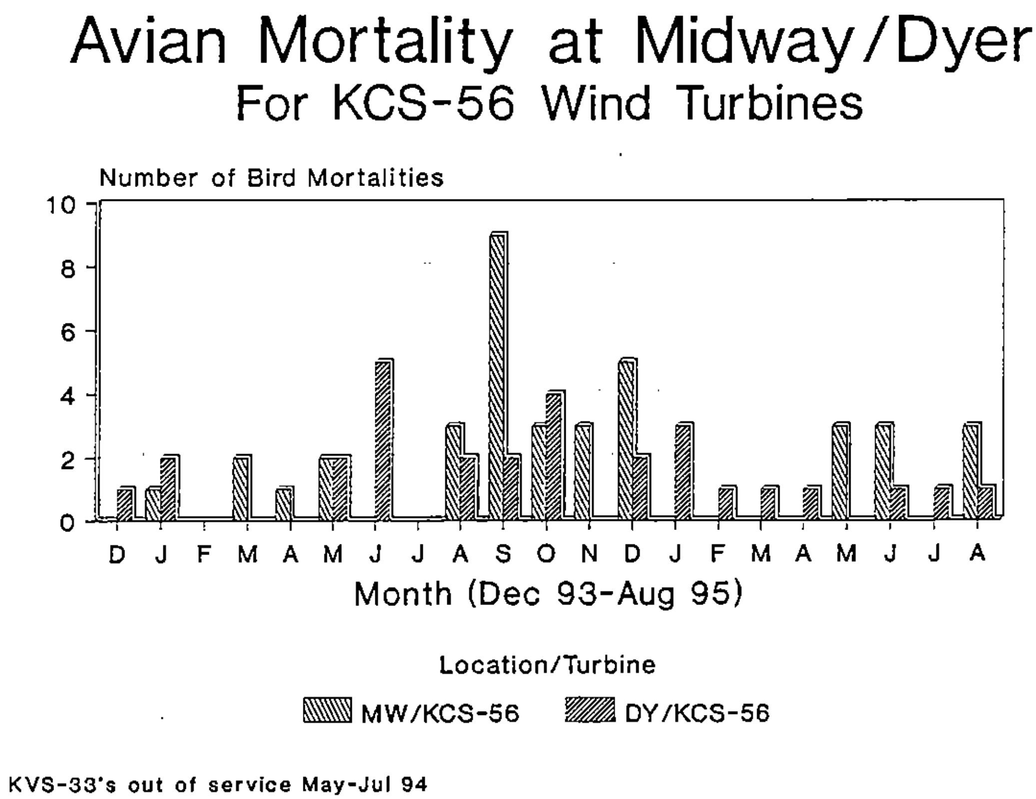


Figure 2. Monthly avian mortality at KCS-56 wind turbines at Dyer (DY) and Midway (MW), Altamont Pass, California.

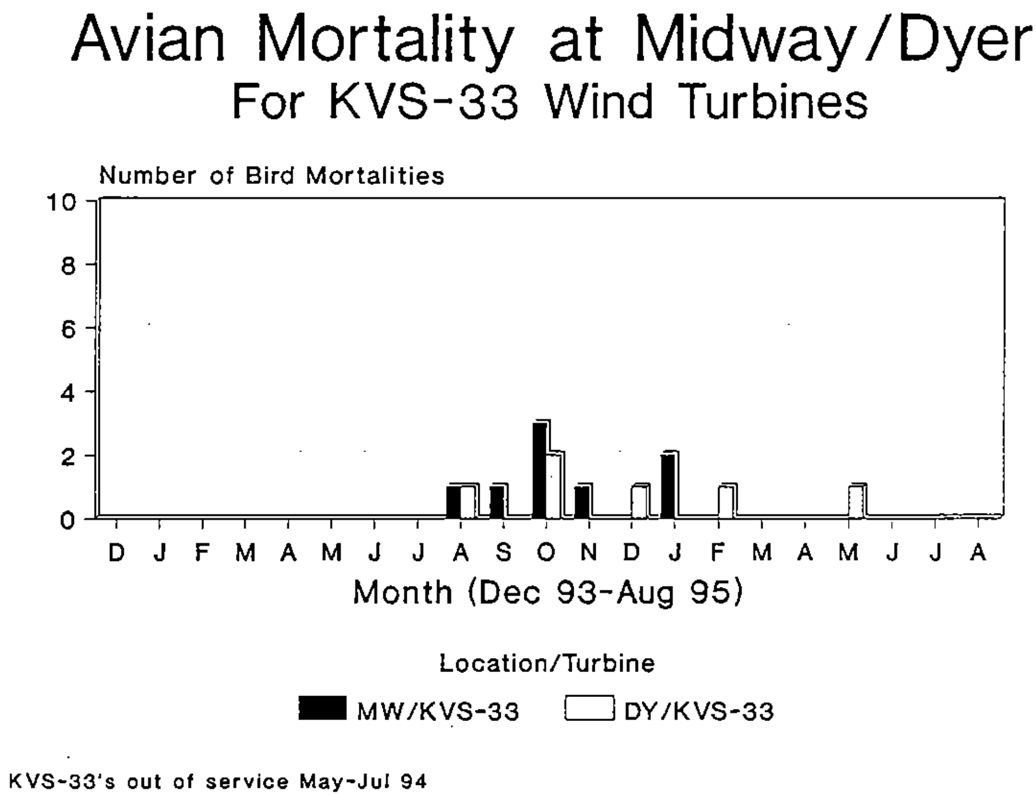


Figure 3. Monthly avian mortality at KVS-33 wind turbines at Dyer (DY) and Midway (MW), Altamont Pass, California.

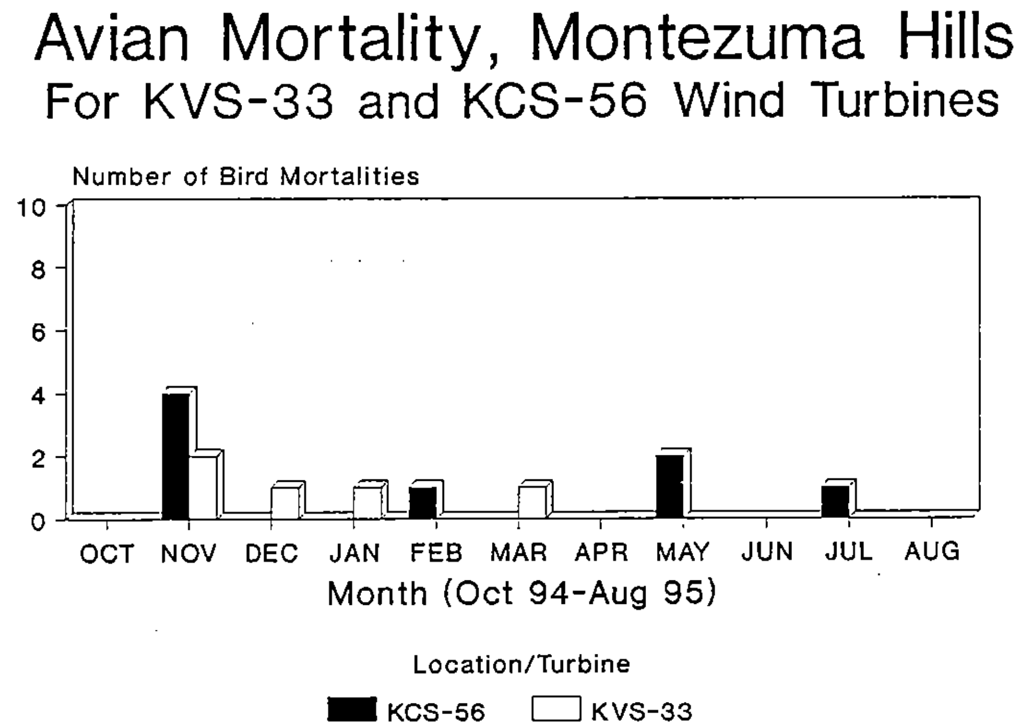
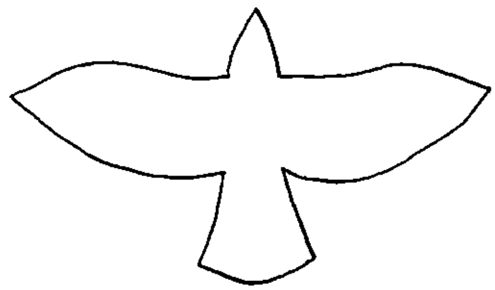


Figure 4. Monthly avian mortality at KVS-33 and KCS-56 wind turbines at Montezuma Hills, Solano Co., California.

Diagram: Indicate location and nature of injury (to the best of your ability, without touching bird)
Slice = /
Contusion = 0
Broken Bone = Z



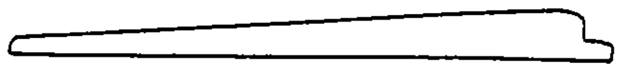
(Dorsal View)

Judd Howell & Associates
COLLISION INJURY/MORTALITY DATA SHEET

Date:	Time:	1. Observer:
Site: DY MY SO	Weather: CLR CDY RNY FOG	2. Observer:
	Wind Speed:	Wind Direction:

Nearest Turbine #:		
Part #1:	Distance (ft.) from Turbine:	Direction:
Part #2:	Distance (ft.) from Turbine:	Direction:
Part #3:	Distance (ft.) from Turbine:	Direction:
Blade Inspection: Y N	Blood Present: Y N	

Location:



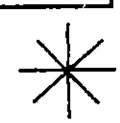
Estimated Time of Collision:	Date:

Species ID:	Age:	Sex:
Field Marks Used:		

Physical Condition
(Use diagram on back as well)

Decomposed	Body parts reduced to skeleton and feathers	Y	N
Dehydrated	Carcasses not scavenged or decomposed; carcass shows signs of desiccation such as dried blood, flesh, or eyes	Y	N
Dismembered:B	Body severed	Y	N
Dismembered:H	Decapitated	Y	N
Dismembered:LL	Left leg severed	Y	N
Dismembered:LR	Right leg severed	Y	N
Dismembered:WL	Left wing severed	Y	N
Dismembered:WR	Right wing severed	Y	N
Fresh	Recently killed; blood still liquid, body warm, eyes not dry	Y	N
Infested	Evidence of carcass consumption by invertebrates	Y	N
Injury	Bird still alive	Y	N
Intact	Carcass intact; not separated into multiple body parts	Y	N
Scavenged	Evidence of carcass consumption by vertebrates	Y	N
Comments:			

Map: Indicate turbine numbers, location of parts, end of string, and north (on compass) →
* = turbine



*   *   *   *   *   *

Equal Rotor Swept Area
Comparison of Fatalities

ALTAMONT PASS

DYER SITE

KVS-33

Tower	Date Reported	Species	ID#
0206	1/11/94	WEME	371
0201	8/25/94	RTHA	511
0212	10/25/94	EUST	NR76
0219	10/25/94	BCNH	627
0218	11/8/94	COBO	655
0218	12/30/94	RTHA	712
0205	2/16/95	COBO	734
0206	5/23/95	WEME	768
0209	9/2/95	AMKE	799
0214	10/18/95	AMKE	830
0202	10/25/95	UNPA	834

Total: 11 Fatalities

KCS-56

Tower	Date Reported	Species	ID#
2358	12/8/93	BRBL	416
2237	1/13/94	BUOW	375
2042	1/24/94	RTHA	389
2233	5/24/94	EUST	NR43
2206	5/31/94	EUST	467-NR
2360	8/5/94	RODO	NR53
2360	8/26/94	AMKE	512
2360	8/26/94	UNID	514
2366	9/13/94	RODO	NR65
2359	9/23/94	EUST	NR70
2358	10/4/94	AMKE	585
2372	10/14/94	HOLA	604
2362	10/14/94	RODO	NR83
2360	10/14/94	AMKE	605
2047	12/6/94	EUST	NR81
2371	12/20/94	COBO	701
2360	1/17/95	RTHA	725
2045	1/17/95	RTHA	724
2211	1/20/95	UNPA	726
2359	2/23/95	UNHA	735
2209	3/9/95	GHOW	743
2235	4/17/95	WEME	751
2291	6/20/95	RODO	777-NR
2362	7/18/95	RODO	785-NR
2239	8/2/95	UNPA	789
2366	8/12/95	UNPA	793
2209	9/23/95	BAT	810-NR
2041	10/11/95	SCJA	822
2214	10/11/95	GHOW	823
2289	10/21/95	AMKE	832
2355	10/25/95	WEME	835
2237	11/7/95	WEME	843
2216	11/17/95	RODO	847-NR
2368	12/1/95	WEME	854
2240	1/26/96	MODO	876

Total: 35 Fatalities

Equal Rotor Swept Area
Comparison of Fatalities

ALTAMONT PASS

MIDWAY SITE

KVS-33

Tower	Date Reported	Species	ID#
0225	12/6/93	AMKE	415
0240	8/22/94	PRFA	503
0228	9/20/94	BAT	NR69
0237	9/22/94	AMKE	567
0225	10/10/94	RTHA	592
0227	10/13/94	COBO	603
0225	10/31/94	RTHA	637
0240	11/3/94	AMKE	647
0237	1/5/95	UNPA	715
0239	1/23/95	RTHA	709
0237	7/29/95	BAT	788-NR
0232	9/18/95	WEME	806
0239	12/11/95	AMKE	857
0229	12/23/95	MODO	868

Total: 14 Fatalities

KCS-56

Tower	Date Reported	Species	ID#
1261	1/25/94	WEME	392
1182	3/7/94	MOBL	432
1162	3/14/94	AMKE	437
1182	4/28/94	HOLA	454
1173	5/19/94	EUST	NR30
1173	5/19/94	EUST	NR31
1267	5/26/94	WEME	465
1307	7/7/94	HOLA	478
1301	7/18/94	AMKE	482
1301	7/18/94	AMKE	483
1297	7/18/94	AMKE	484
1303	7/25/94	AMKE	487
1180	8/8/94	RODO	NR54
1283	8/22/94	RTHA	504
1285	8/29/94	AMKE	515
1287	9/15/94	AMKE	551
1297	9/19/94	RTHA	556
1300	9/19/94	AMKE	557
1299	9/26/94	COBO	569
1266	9/26/94	COBO	570
1263	9/26/94	RTHA	571
1183	9/26/94	AMKE	572
1299	9/27/94	RODO	NR72
1293	9/29/94	RTHA	578
1269	10/3/94	WEME	596
1265	10/3/94	RTHA	I35
1307	10/17/94	RTHA	612
1265	11/7/94	RTHA	653
1294	11/10/94	RTHA	658
1262	11/28/94	RTHA	684
1285	12/5/94	RTHA	687
1290	12/8/94	UNID	693
1262	12/8/94	UNHA	694
1256	12/19/94	WEME	700
1266	12/26/94	AMKE	705
1265	5/20/95	RTHA	765
1266	5/31/95	HOLA	770
1294	5/31/95	HOLA	769
1304	6/3/95	WEME	772
1259	6/21/95	WEME	778
1297	6/28/95	AMKE	781
1173	8/14/95	WEME	794
1263	8/24/95	RTHA	796
1172	8/28/95	BRBL	797
1266	9/4/95	UNPA	800
1300	9/18/95	WEME	805
1303	10/9/95	RODO	820-NR
1301	10/23/95	RODO	833-NR
1299	11/29/95	RODO	853-NR
1179	12/30/95	EUST	869-NR

Total: 50 Fatalities