Avian Monitoring and Risk Assessment at Tehachapi Pass and San Gorgonio Pass Wind Resource Areas, California: Phase 1 Preliminary Results

by

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Introduction

Awareness of avian fatalities at large scale wind energy developments first emerged in the late 1980s at the Altamont Pass Wind Resource Area (WRA) in Central California, U.S.A. Observations of dead raptors at the Altamont Pass WRA (Anderson and Estep 1988; Estep 1989) triggered concern on the part of regulatory agencies, environmental/conservation groups, resource agencies, and the wind and electric utility industries.

In addition to the results from the Altamont Pass WRA, other studies and observations have also established that birds die as a result of collisions with wind turbines and related facilities within wind plants. Although fatalities of many bird species have been documented, raptors have received the most attention in California and also in Spain (Anderson and Estep 1988; Estep 1989; Howell and Noone 1992; Orloff and Flannery 1992; Hunt 1994; Luke and Watts 1994; Howell 1995; Martí 1995; Janss, this volume). Other WRA studies have documented deaths of songbirds (Orloff and Flannery 1992; Pearson 1992; Higgins et al. 1995; Winkelman 1995), water birds (Pearson 1992; Winkelman 1995), and bats (Higgins et al. 1995). Generally, these "other birds" have been common species in those areas, not subject to the degree of concern associated with raptor fatalities.

This paper provides preliminary results for a cooperative research project undertaken by the California Energy Commission, the National Renewable Energy Laboratory (NREL), and Western EcoSystems Technology, Inc. (WEST). The project includes studies in the Tehachapi Pass and San Gorgonio Pass WRAs, California. The studies were designed to document bird behavior, bird use, bird fatalities, and bird risk. These were to be determined as a function of turbine size, turbine type, turbine density, wind plant characteristics, and environmental variables within the operating wind plants. These differences can be important in site selection and layout of a new wind plant. The results also provide information that can help developers and regulators estimate effects at new development sites.

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Study Areas

Tehachapi Pass WRA.—The Tehachapi Pass WRA is located in south-central California at elevations of 1000-1600 meters (3300-5300 feet) above sea level. The natural communities are diverse and complex botanically. The study area was divided into three subareas: *west ridge*, *middle ridge*, and *east slope*. Approximately 5000 turbines were in operation at Tehachapi during this research project.

The *west ridge* is heavily influenced by Central Valley grasslands, the Sierra Nevada foothills, and Sierra Nevada forest ecosystems. This area occurs at the highest elevations, and consists primarily of annual grassland. Some of the annual grassland has a subshrub component and there are wooded ravines and seasonal-stream riparian habitat in several locations. The *middle ridge* area also is located along a ridge, but at an elevation somewhat lower than the *west ridge*. The *middle ridge* area is a combination of annual and perennial grasslands with subshrubs as a common component. There are also small patches of Joshua trees (*Yucca brevifolia*), junipers (*Juniperus californicus*), willows (*Salix* sp.), and oaks (*Quercus* sp.). The *east slope* is dominated by components of the desert province and is predominantly shrubland with a significant component of perennial grasslands. Patches of junipers, Joshua trees, and creosote bushes (*Larrea tridentata*) occur.

Over 200 bird species use the WRA during a portion of the year. Many of these are migratory species that pass through on their way north and south. Both diurnal and nocturnal resident and migrant species are present in the WRA.

San Gorgonio Pass WRA.—San Gorgonio Pass is a narrow, low elevation pass situated at approximately 180-850 m (600-2800 ft) in elevation. The pass is bordered on the north by Mt. San Gorgonio (3505 m or 11,499 ft) and on the south by Mt. San Jacinto (3293 m or 10,804 ft). The great differences in elevation and topography are a result of the San Andreas and San Jacinto fault systems, which over millions of years have created a wedge in the San Bernardino Mountains. This wedge is known as the San Gorgonio Pass. It is a windy area because of the natural tendency for air pressure to equalize between the Pacific coast and the interior deserts.

The vegetation in the San Gorgonio WRA includes components of both the Mojave and Colorado deserts. Vegetation types in the WRA include the following: creosote bush, creosote bush-white bursage (*Ambrosia dumosa*), brittlebush (*Encelia farinosa*), and scalebroom (*Lepidospartum squamatum*) (Sawyer and Keeler-Wolf 1995). This area receives less than ten inches of rain annually, with most occurring during winter. Temperatures range from around freezing to 120°F.

The WRA at San Gorgonio Pass was developed during the early 1980s. During this project, approximately 3750 wind turbines were in operation. This WRA is the third-largest developed WRA in California and produces approximately 25 percent of the electricity produced annually from wind energy in California. The developed WRA was subdivided into four study subareas: the *high* elevation areas above 610 m (2000 ft) above sea level, the *medium* elevation areas at 305-610 m (1000-2000 ft.), and the *low* areas below 305 m (1000 ft). The low elevation area often includes hundreds of acres of surface water. This surface water is created by runoff from Whitewater Creek and by water diverted from other sources and pumped into recharge basins. This surface water often remains year-round in some of the basins. Permanent study sites were selected at the three elevations and from the *watered* area.

Geographic Information System.—Both study areas were mapped using a Geographic Information System (GIS). GIS coverages were created using Arc/Info, ArcView, and DIMPLE. Aerial photographs provided the base information for the GIS coverage. The GIS data included a layer showing topography.

Key Questions

The key questions in this study included the following: What influence does wind plant operation have upon birds? Do bird risk, bird use, and bird mortality vary within the operating wind plant due to physical or environmental parameters, or by bird species?

Parameters and factors to be studied included the following:

- Lattice versus tubular tower turbines
- Large versus small rotor swept areas
- End-of-row versus mid-row turbine locations
- Turbine height
- Turbine operation time
- Topography and location thereon
- Vegetation type
- Wildlife habitat attributes such as water
- Bird behavior near turbines
- Turbine and other structure density

Study Design

At Tehachapi, approximately 180 permanent sample sites were selected using a stratified random process. Approximately 50-60 sites were established per study sub-area (West Ridge, Middle Ridge, East Slope), all at turbines. The 180 sample sites include large and small turbines, tubular and lattice tower turbines, end-of-row turbines, and a variety of distinct natural and physical settings.

At San Gorgonio, there were also approximately 180 stratified random sample sites. These sites included 30 sites ≥1 km from the nearest turbines, 30 sites 400-800 m from turbines, and 120 sites at turbines. The sites at turbines included large and small turbines, lattice and tubular tower turbines, end-of-row turbines, water sites, and a variety of distinct natural and physical settings. Additionally, 40 remote observation sites were selected at random to include 20 sites near the water recharge basins and 20 sites at least 1 km from water. These sample sites were considered necessary to document waterbird usage of the recharge basins. The birds leave the water area as an observer approaches. Therefore, both remote and conventional bird utilization counts were conducted near the water basins.

Methods and Metrics

The protocol employed in these studies is a product of review and consensus by scientists representing a diverse stakeholder group. They included representatives from the wind energy industry, environmental organizations, utilities, federal and state agencies, and consulting scientists. Although each component of the methodology seems simple and straightforward, their details and execution are complex (California Energy Commission 1996; Anderson et al. 1996, 1997). The following are methods that were used to collect data on the study areas, and metrics that may be used in data analysis:

Bird Utilization Counts.—These are modified point counts conducted to document bird use at study sites. They are conducted in repeatable ways using standard methods, so that results can be compared with bird utilization counts from other studies. The Bird Utilization Counts are obtained during defined time periods to document behavior and relative abundance of birds using the area at different seasons.

Bird Utilization Rate.—Bird Utilization Rate is derived from the Bird Utilization Counts. The Bird Utilization Rate can be expressed in numerous ways. These can include the number of birds detected using a defined area, such as 50 m radius circle or per square meter, or the duration of use by birds (e.g., bird-minutes) during the Bird Utilization Count time period. One formula for utilization rate is

$$\frac{\text{\# birds observed}}{\text{time or time and area}} = \text{Bird Utilization Rate}$$

Dead Bird Search.—Dead Bird Searches are conducted at study sites. Complete coverage of the search area is important in detecting dead birds. The number of dead birds or dead bird parts found at each search site is documented.

Bird Mortality.—Bird Mortality is the number of dead birds or dead bird parts documented per defined search area. Two indices for bird mortality are

$$\frac{\text{\# dead birds}}{\text{search area}} \quad \text{and} \quad \frac{\text{\# dead birds}}{\text{unit rotor swept area}}$$

where unit rotor swept area is the area swept by a rotor per rotation.

Bird Risk.—Bird Risk establishes a relationship between bird utilization and bird deaths in an area. One formula for bird risk rate is

$$\frac{\text{\# dead birds/area}}{\text{\# birds observed/time, or time and area}}$$

Attributable Risk.—The differences in Bird Risk among sampling sites may be used to discuss Attributable Risk. This is the risk that may be attributed to a specific location or situation.

Rotor Swept Hour and Rotor Swept Hour Risk.—A final adjustment is necessary to take into account the size differences of the rotors and the time of operation. The rotor swept area has been treated in past instances as having a direct relationship with bird mortality. There are no data to support the concept that larger rotor swept area, along with other turbine characteristics, may cause more (or less) fatalities when bird utilization rates are unchanged. Addressing this issue will require standardizing the metrics so that the size differences can be isolated for comparison. Rotor swept hour combines the size of the rotor (rotor swept area) with the time it operates. Risk calculated on a rotor swept hour basis will allow comparison of risk associated with different rotor swept areas or turbine sizes in relation to the time they operate:

$$\text{Rotor swept area } (m^2) \times \text{ hours of operation} = \text{Rotor swept hour (RSH)}$$

This formula assumes that a large turbine operating a low percentage of the time is comparable to a smaller turbine that operates a high percentage of the time. This may or may not be true. Whatever the case, differences in bird mortality, bird use, and bird risk can be determined by the methods applied in these studies, and normalized to compare the risk associated with each type of turbine.

Rotor Swept Hour Risk relates the rotor swept area and duration of operation (RSH) with the risk rate to create Rotor Swept Hour Risk. The inverse of the dividend is used in order to more easily comprehend the comparisons between RSHR.

$$\text{Rotor Swept Hour Risk (RSHR)} = \frac{1}{\text{Rotor swept hour/Risk rate}}$$

Other metrics that incorporate the rotations per minute of the turbine may also be investigated.

Carcass Removal Study.—In this study a known number of bird carcasses are placed at randomly chosen locations and monitored for removal by scavengers or by other means. Carcass removal activity can be quantified and calculated as a rate. If not detected, significant differences in carcass removal rate would result in misleading estimates of Bird Mortality and Bird Risk. This study is used to determine the ***Carcass Removal Rate***. This is the rate at which bird carcasses are removed by scavengers or by other means. The results could be used to adjust the number of dead birds to allow for those not detected. Alternatively, we may calculate the mean length of time a carcass may remain on the study area using the same data.

Observer Detection Efficiency Study.—This study involves placing a known number of dead birds or bird parts in a variety of locations with differing vegetative structure and color (green or brown). These searches take place throughout the day with differing sunlight angles (shadows) and differing observer alertness (1st, 2nd, 3rd search of the day). This study is used to determine the ***Observer Detection Rate***. This is a measure of the searchers' detection probability in varying vegetative conditions, by time of day, and during their 1st, 2nd, 3rd, etc. search of the day.

Statistical Methods.—Factors influencing the use of study plots by birds (such as vegetation structure and food availability) are assumed to be approximately the same for different turbine types and locations within a given study block. Also, factors influencing the number of carcasses found (carcass removal rate, detection rate, etc.) are assumed to be approximately the same for different turbine types and within a block. These assumptions are never fully satisfied on any one pair of plots, but with the large number of pairs in this study (75), the influence of these factors should "average" out to allow meaningful statistical inferences.

For each metric, the basic hypothesis to be tested is that there is "no difference in the metric for risk between different turbine types and turbine locations". Analyses will be conducted by standard analysis of variance methods for blocked (paired) designs. Randomization or other nonparametric methods (Manly 1991) may be used if assumptions for standard analysis of variance are not satisfied. Mean differences between standardized measures of risk will be computed and compared, both graphically and statistically, for different turbine types and other variables.

For important tests of hypotheses, the power (i.e., probability of rejecting the hypothesis of no difference in means if it is false) will be calculated. This will be done for various effect sizes based on baseline studies and initial data collected during this study. These power calculations will be done as soon as sufficient data to estimate variance are available. The power of the test to detect an effect is a function of the sample size, estimates of variance, and the magnitude of the effect. We propose to use a significance level of α=0.10, although *P*-values for comparisons will be reported. The power for detecting differences in the various metrics will depend upon the number of fatalities along with utilization rates and other factors.

Preliminary Tehachapi Results

During the initial studies in Tehachapi Pass WRA, 830 carcass searches and 3320 five-minute bird utilization counts were conducted. Two back-to-back 5-min utilization counts were conducted at most, but not all, sample sites. Therefore, only the first 5-min counts (total of 1659 counts) are analyzed for this paper. During the first 5-min bird utilization counts, 2923 individual bird observations of 39 different bird species were made.

A total of 95 fatalities were detected during carcass searches, involving 26 bird species and one bat. Table 1 lists bird species found dead.

Bird Utilization Rates.—Bird Utilization Rates were calculated for numerous study area parameters. Figure 1 graphically presents results for the overall WRA. Based on 2923 birds seen during 1659 counts, the average Bird Utilization Rate for Tehachapi was 1.7690 birds/Bird Utilization Count

Bird Mortality.—Table 1 lists the dead birds found during Dead Bird Searches. During the initial work, 95 dead birds were found at Tehachapi. Bird Mortality rate is the number of bird carcasses found per search site. With 95 dead birds found in 830 searches, the Bird Mortality rate is 0.11446 dead birds/search.

TABLE 1. Dead birds found during searches at Tehachapi Pass WRA.

Species	No.	Species	No.
Red-tailed Hawk	8	Horned Lark	2
Ferruginous Hawk	1	Northern Flicker	3
Unidentified Buteo sp.	1	Western Scrub-Jay	1
American Kestrel	7	Common Raven	3
Prairie Falcon	1	Rock Wren	1
California Quail	2	European Starling	1
Chukar	2	Yellow-rumped Warbler	1
Rock Dove	9	Dark-eyed Junco	1
Mourning Dove	6	Unidentified Sparrow sp.	1
Barn Owl	2	Western Meadowlark	6
Flammulated Owl	1	Brewer's Blackbird	1
Long-eared Owl	1	Unidentified Passerine sp.	4
Great Horned Owl	10	Unidentified Bird sp.	16
Greater Roadrunner	2	Unidentified Bat sp.	1
		Total	95

Bird Risk.—Bird Risk establishes the relationship between Bird Mortality and Bird Utilization. Bird Risk is calculated as Bird Mortality/Bird Utilization Rate. In this case, with 0.11446 dead birds found per search site, and 1.76190 birds detected per utilization count, bird risk is 0.06496 (Fig. 1).

Preliminary San Gorgonio Results

During these studies, 830 carcass searches and 3320 five-minute bird utilization counts were conducted in San Gorgonio Pass WRA. Back-to-back five-minute utilization counts were conducted at most but not all sample sites; only the first 5-min counts (1661 counts) are analyzed for this paper. During the first 5-min counts, there were 9043 individual bird observations of 75 different bird species.

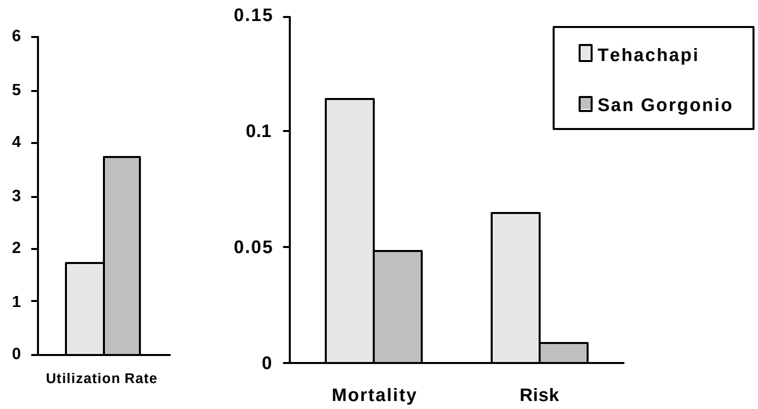

FIGURE 1. Comparison of bird utilization, mortality, and risk rates at Tehachapi vs. San Gorgonio WRAs during Phase 1 of this study.

A total of 40 fatalities were detected by carcass searches, including 14 bird species and one bat (Table 2). These included 31 carcasses at turbine sample sites and nine at sample sites 400 m or farther away from turbines.

Bird Utilization Rates.**—**Bird Utilization Rates were calculated for the study area using data from turbine sites (1261 counts and 4717 bird observations; Fig. 1). The average Bird Utilization Rate for San Gorgonio was 3.74068 birds/count.

Bird Mortality.—Table 2 lists the dead birds found during all Dead Bird Searches**.** Bird Mortality is the rate of bird fatalities, calculated as the number of bird carcasses found per search site. Average Bird Mortality for San Gorgonio was 0.04921 dead birds/search site, based on 31 dead birds found at 630 search sites (Fig. 1).

Bird Risk.**—**Bird Risk establishes a relationship between Bird Mortality and Bird Utilization, and is calculated as Bird Mortality/Bird Utilization Rate. Based on 0.04921 dead birds/search site and 3.74068 birds detected/bird utilization count, Bird Risk at San Gorgonio was 0.01315, as compared with 0.06496 at Tehachapi (Fig. 1).

TABLE 2. Dead birds found during searches at San Gorgonio WRA.

Species	No.	Species	No.
Unidentified Grebe sp.	1	Mourning Dove	1
Unidentified Egret sp.	1	Burrowing Owl	1
Mallard	3	White-throated Swift	1
Unidentified Teal sp.	1	Common Raven	1
Sora	1	European Starling	1
American Coot	8	Western Meadowlark	1
Red-tailed Hawk	1	Unidentified Bird sp.	9
Rock Dove	8	Unidentified Bat sp.	1
		Total	40

Discussion

The following paragraphs summarize the preliminary results to date as they pertain to some of the key questions about bird utilization, mortality, and risk in California wind plants. We emphasize that these comments are based on preliminary interpretation of "Phase 1" data collected during ongoing studies. Detailed statistical analysis has not yet been done.

Different Wind Resource Areas.—Tehachapi and San Gorgonio Pass WRAs differ in numerous ways including vegatation type, climate, topography, standing water, and bird species and numbers. These two WRAs also differ in bird utilization (BU), bird mortality (BM), and bird risk (BR; Fig. 1). There was a higher utilization rate at San Gorgonio. This was attributable to higher utilization of the watered area. Tehachapi had higher bird mortality and higher relative bird risk than San Gorgonio. This may be related to the different bird species composition in the two areas, and differences in how birds use those areas.

Figure 2 compares raptor use at San Gorgonio, Tehachapi, Altamont, and Solano WRAs. The values for Altamont and Solano WRAs were calculated from data provided by Orloff and Flannery (1992). They counted raptors for 10-min periods from vantage points. We have included high and low counts for Altamont instead of average counts because counts were obtained at Solano only in the fall, a season of high raptor utilization there. San Gorgonio and Tehachapi data are from the 5-min utilization counts conducted throughout the year. Figure 2 compares raptors seen per minute of observation time for the various WRAs.

Although the numbers are derived using different methods, the differences are large and indicative of actual differences among the various WRAs. These values indicate that raptor utilization at Altamont Pass WRA was roughly 19-36 times higher than at San Gorgonio Pass WRA, and 10-18 times higher than at Tehachapi Pass WRA. Given this, it is logical that fewer dead raptors have been found in San Gorgonio and Tehachapi WRAs than in Altamont Pass WRA. On the other hand, the values summarized in Figure 2 suggest that Solano WRA has 2-3.6 times more raptor use than Altamont. Expansion of wind energy development in the Solano WRA could result in raptor fatality rates at least as high as those in the Altamont Pass WRA.

Subareas and Seasons within WRAs.—Figures 3 and 4 compare BU, BM, and BR among different subareas within the Tehachapi and San Gorgonio study areas. Different subareas have different combinations of vegetation, topography, elevation, and predominant bird species. It is interesting to note the relatively high BU in the watered area of San Gorgonio. This illustrates the potential for great variability within and between WRAs. This may be useful in siting future projects or modifying existing facilities. Seasonal differences in BU, BM, and BR are also evident in both WRAs (Fig. 5, 6).

Turbine Size and Tower Type.—All sizes of turbines that were studied caused bird kills (Fig. 7, 8). Little analysis has been done on these data at this preliminary stage. For example, rotor swept area was not considered in this comparison.

All tower-types that were studied were associated with bird kills at both Tehachapi and San Gorgonio Pass (Fig. 9, 10). There were differences, but none seemed significant at this stage of analysis.

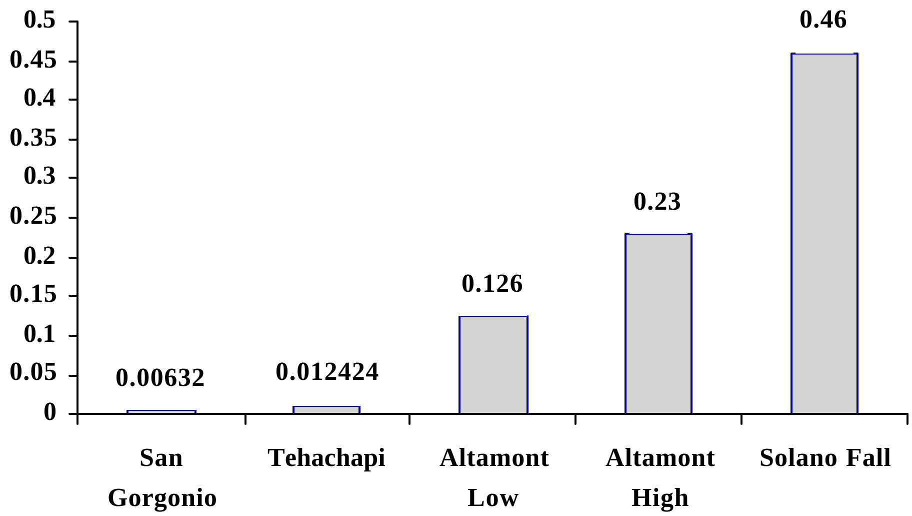

FIGURE 2. Comparison of raptor utilization rates in four Wind Resource Areas in California.

Mid- vs. End-of-Row Turbines.—Orloff and Flannery (1992) presented evidence from the Altamont Pass WRA showing that end-of-row turbines caused a disproportionate number of raptor deaths compared to mid-row turbines. (But see Thelander and Rugge, this volume, for preliminary evidence from more recent Altamont studies.) Our results for both Tehachapi and San Gorgonio found bird risk to be higher at mid-row than at end-of-row turbines (Fig. 11, 12). This illustrates that there can be differences between WRAs.

Summary

There can be important differences in bird utilization, bird mortality, and bird risk between and within WRAs. A very high Bird Utilization Rate may be an important early warning of a potential problem site, but the influences of other variables on bird mortality and bird risk should be scrutinized appropriately.

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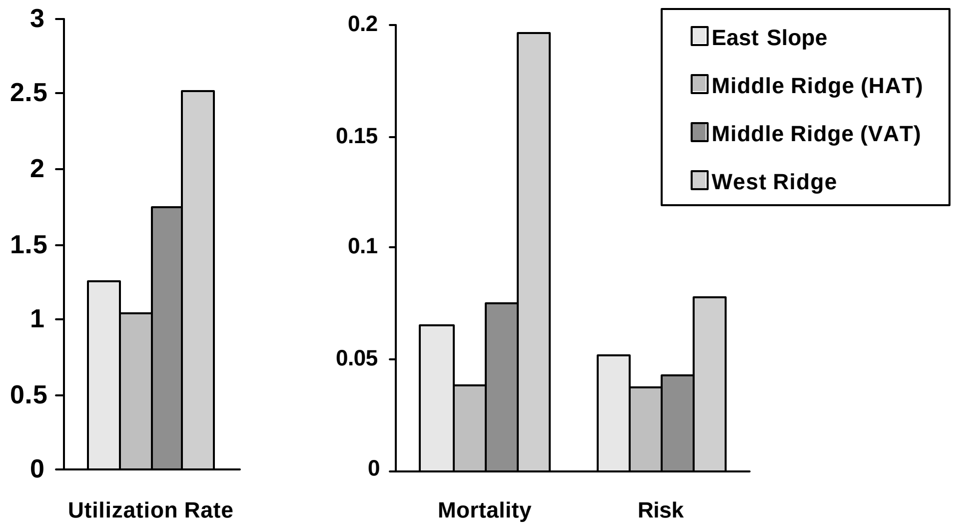

FIGURE 3. Effect of geographic subarea within Tehachapi Pass WRA, Phase 1.

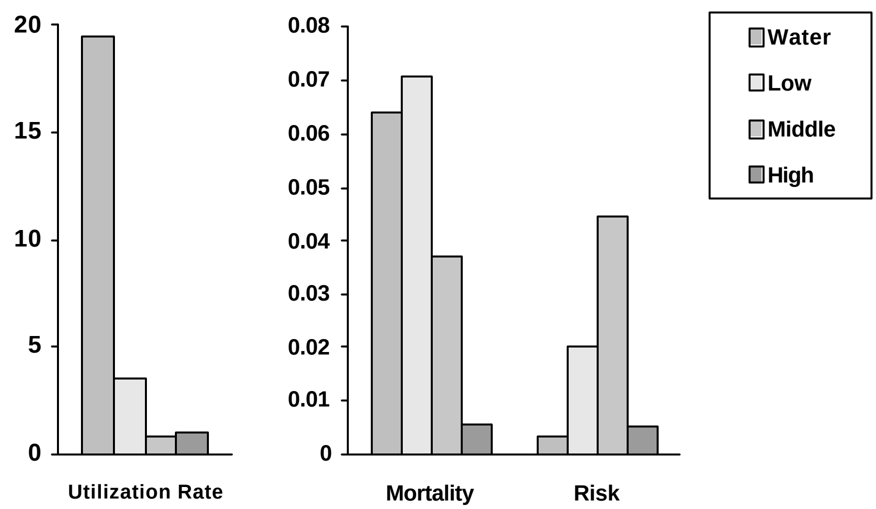

FIGURE 4. Effect of geographic subarea within San Gorgonio Pass WRA, Phase 1.

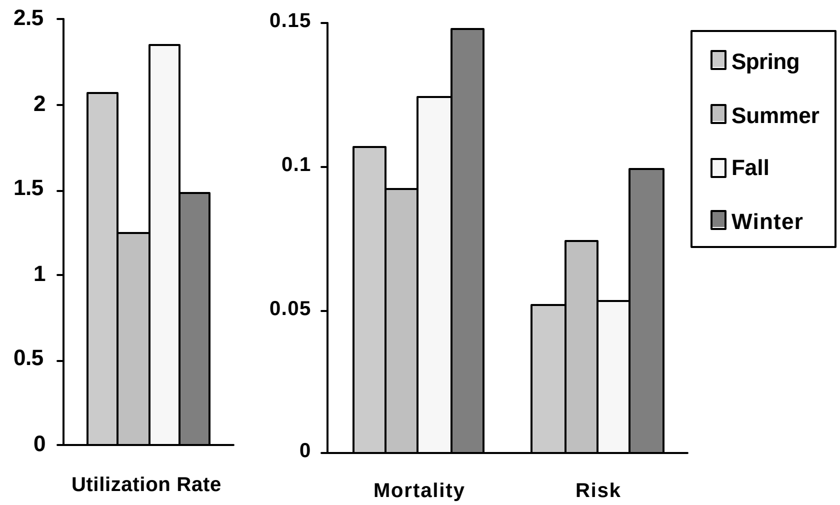

FIGURE 5. Effect of season, Tehachapi Pass, Phase 1.

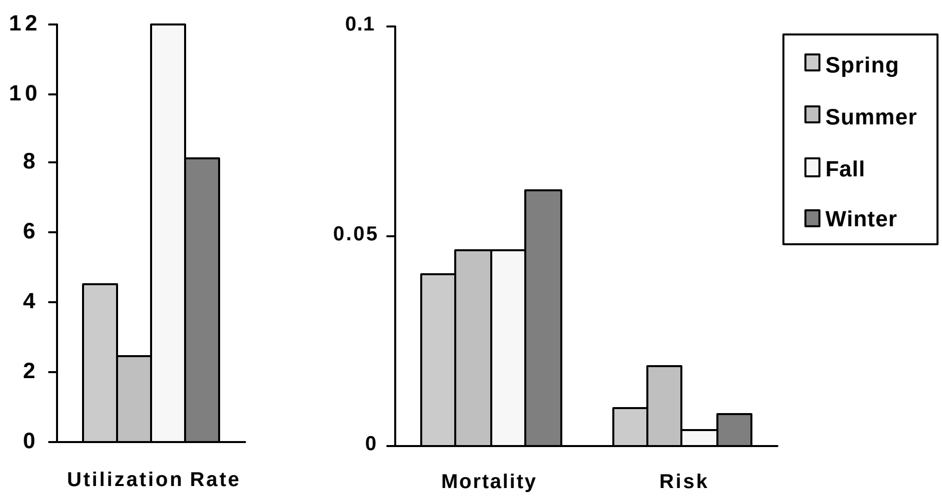

FIGURE 6. Effect of season, San Gorgonio Pass, Phase 1.

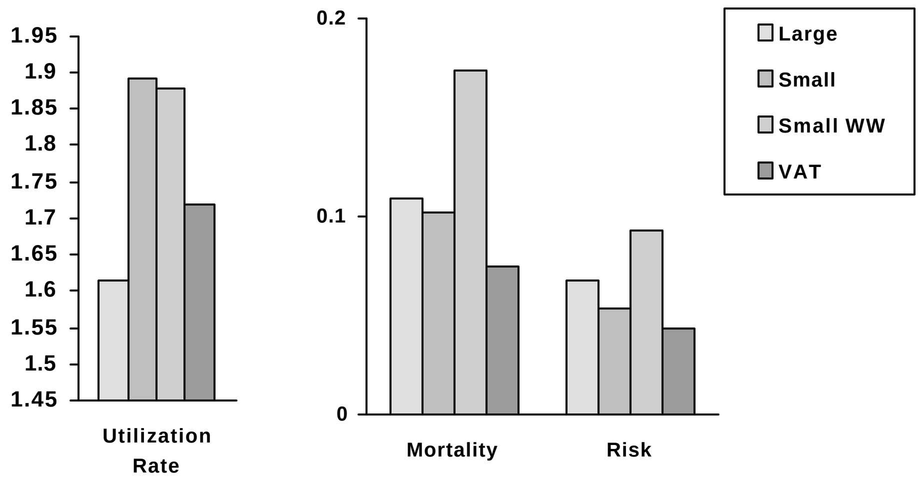

FIGURE 7. Effect of turbine size, Tehachapi Pass, Phase 1.

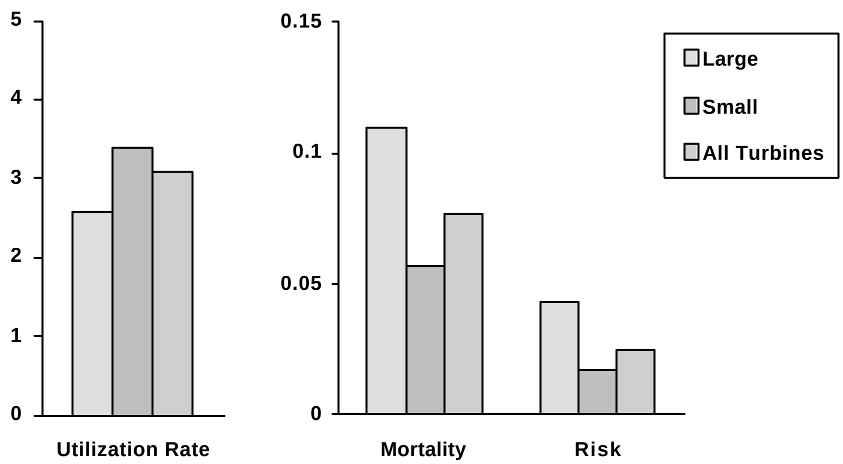

FIGURE 8. Effect of turbine size in low elevation subarea within San Gorgonio Pass, Phase 1.

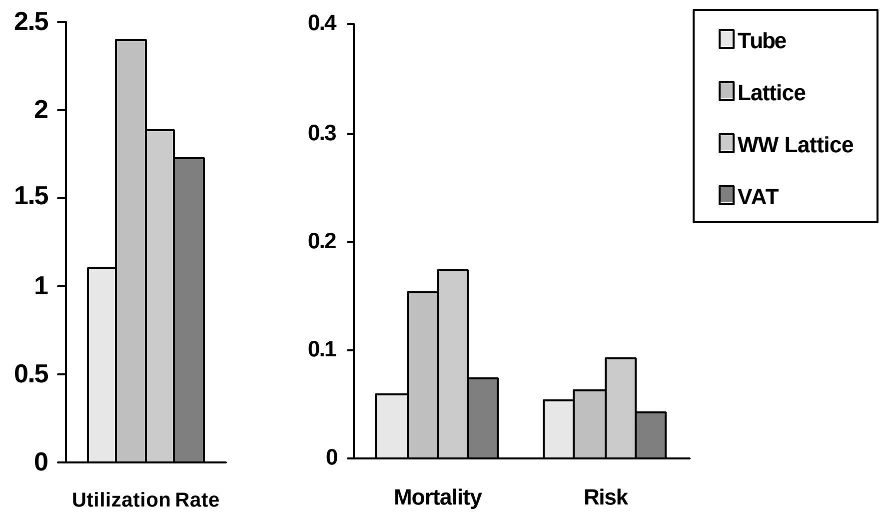

FIGURE 9. Effect of type of tower, Tehachapi Pass, Phase 1.

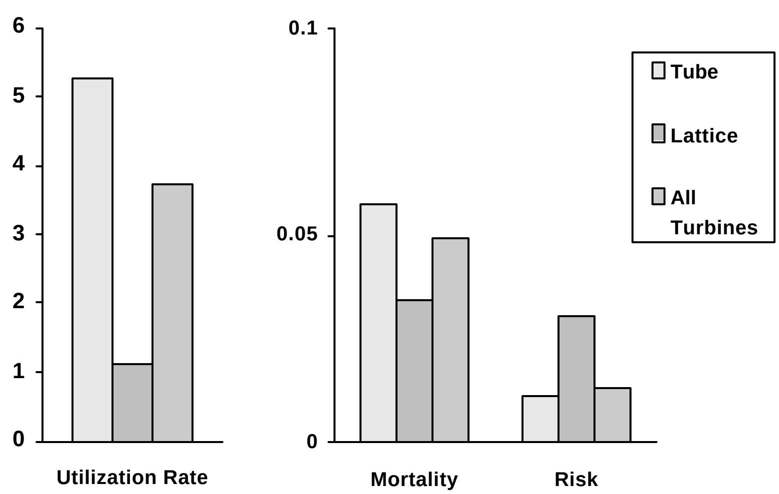

FIGURE 10. Effect of type of tower, San Gorgonio Pass, Phase 1.

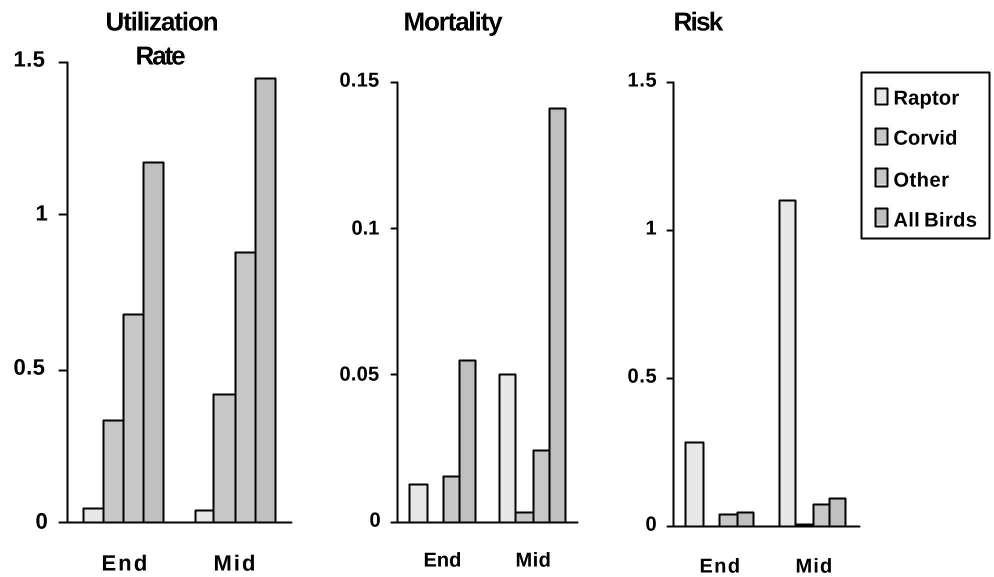

FIGURE 11. Effect of turbine position (end-of-row vs. mid-row), Tehachapi Pass, Phase 1.

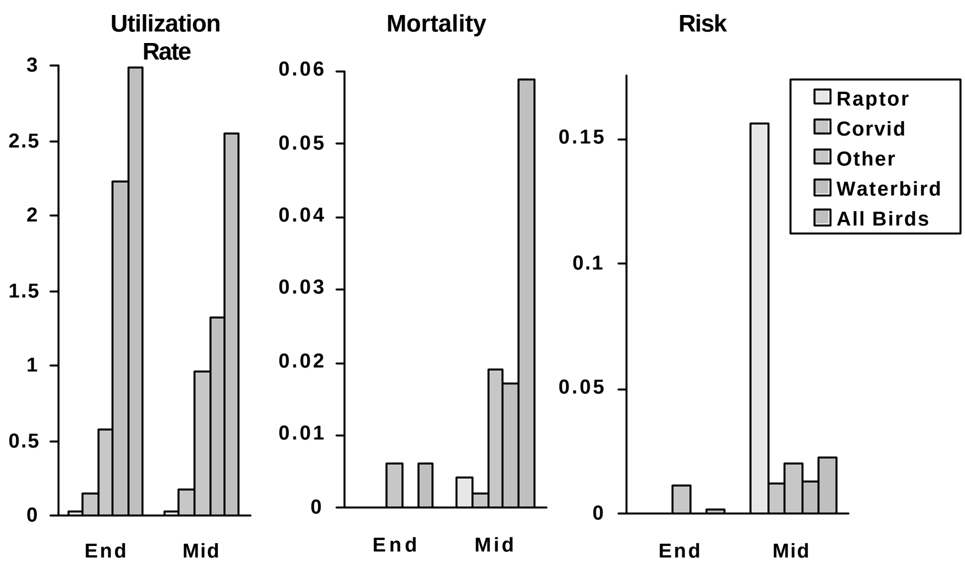

FIGURE 12. Effect of turbine position (end-of-row vs. mid-row), San Gorgonio Pass, Phase 1.

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General Discussion

There was no general discussion after this presentation. However, Mr. Anderson provided some recommendations for continued work at the Tehachapi and San Gorgonio WRAs. He noted that it would be desirable to (1) continue the projects for a longer period – at least 2 years; (2) continue the part of the San Gorgonio research associated with the water-covered area, which attracts larger numbers of birds than other subareas within the San Gorgonio WRA; and (3) use radar, acoustic or other suitable methods to conduct studies of nocturnal bird activity.