ICF INTERNATIONAL

Memorandum

Date:	July 16, 2010
To:	Sandi Rivera Alameda County Community Development Agency 224 W Winton Avenue, Room 110 Hayward CA 94544
Cc:	Alameda County Scientific Review Committee
From:	Doug Leslie and Jesse Schwartz Avian Monitoring Team
Subject:	**Use of a 3-Year Rolling Average to Replace the Baseline Contained in the Settlement Agreement**

Introduction

The Altamont Pass Wind Resource Area (APWRA) is an active wind-energy production facility located in central California approximately 56 miles (90 kilometers) east of San Francisco. In September 2005 the Alameda County Planning Department issued extensions to 54 conditional use permits to allow for the continued operation of 3,344 turbines with a nameplate capacity of 321.81 megawatts (MW) within the boundaries of Alameda County. The extension was issued based on a number of conditions that are subject to the provisions of a settlement agreement made in January 2007 between Alameda County and various parties, including the owner/operators of most of the nameplate capacity in the Alameda portion of the APWRA.

Some key provisions of the settlement agreement are as follows.

1. Reduction of raptor fatalities by 50% in the APWRA by September 2009 (seemingly APWRA-wide with no explicit reference to county boundaries).
2. A baseline for evaluating reduction of 1,300 fatalities per year.
3. Evaluation of the reduction using four focal species—golden eagle, red-tailed hawk, American kestrel, and burrowing owl.
4. The use of field data to determine the reduction, and the use of "scaling factors" to address searching efficiency and scavenging removal rates as approved by the Scientific Review Committee (SRC).
5. "*In the event the above-referenced scaling factors exceed 2.5, the Wind Power Companies, Audubon, and the County, in consultation with the SRC, along with any other individuals or entities that both the Wind Power Companies, Audubon and the County agree to, shall meet and confer to*

> *re-determine a mutually acceptable baseline for determining raptor mortality and/or reduction percentage in raptor mortality that triggers adaptive management measures as specified in section 3(c) of this Agreement."* (page 2 Section 3(a)iii; available online at http://www.altamontsrc.org/ alt_settlement.php)

During the 2005–2009 current study period (current study), the SRC has worked to address several aspects of the settlement agreement, including the five provisions referenced above. Numerous technical issues have been discussed and deliberated regarding the scientific approach outlined in the settlement agreement. Biases, information gaps, and critical uncertainties have been identified that bring into question the validity of using the point estimate from the baseline study of 1,300 fatalities as the benchmark for evaluating the 50% reduction goal.

The baseline established in the settlement agreement is based on the work of Smallwood and Thelander (2008), who monitored avian fatality in the APWRA from March 1998 through May 2003. The current study has been in operation since 2005. Substantial issues have been raised regarding use of the original baseline because the baseline and current studies have substantially different turbine sampling designs and other sampling characteristics that may bias comparisons between these data (Table 1).

Design differences between the baseline and current study have been used to call into question the representativeness of the baseline sample, and its applicability to the APWRA as a whole. There is some evidence that the turbines monitored in the baseline study had disproportionately higher fatality rates than those that examined in the current study (ICF Jones & Stokes 2009). In addition there is no information that describes actual differences in searcher efficiency between the two studies. Although one can assume that the scavenger removal rates differ between the two studies based only on search interval and bird type (Smallwood 2007), this assumption ignores variability in search interval.

In addition to these study biases, it appears that the 1,300 fatality estimate was incorrectly incorporated and applied in the settlement agreement. The California Attorney General accurately identified problems with the use of the point estimate to evaluate a 50% reduction (Altamont Document S14). The value was originally derived from Table 3-11 in Smallwood and Thelander (2004). In this report to the California Energy Commission, the value 1,300 was an estimate of APWRA-wide annually fatalities for all raptors, not specific to the four focal species associated with the 50% reduction question in the settlement agreement. The corresponding value for the four focal species would have been 1,130 fatalities per year.

Table 1. Differences in Design, Methods, and Raw Results between the Baseline and Current Studies. Values Are Annual Averages (minimum:maximum)

Topic	Metric	Baseline Study	Current Study
Design			
	Turbine addresses monitored	1133 (683:1390)	2596 (2210:2724)
	Nameplate capacity monitored (MW)	121 (86:134)	279 (246:290)
	Number of turbine types monitored	7 (4:9)	12 (12:12)
	Fraction of installed capacity monitored (%)	23 (15:26)	57 (50:60)
Level of Effort			
	Average searches per string	6.1 (5:9)	11.3 (7:12)
	Average searches per MW	7.3 (5:11)	13.4 (9:14)
	Average search interval (days)	67 (39:98)	38 (29:51)
Observations			
	Detections per year (all birds)	222 (165:248)	1070 (590:1435)
	Detections per search per year (all birds)	0.27 (0.18:0.35)	0.33 (0.24:0.40)

Several attempts have been made to address these issues by recalculating the baseline fatality estimate using different subsets of sampled turbines and other subsets of the data in an attempt to make the baseline and current study datasets more comparable (ICF Jones & Stokes 2009). This approach has been problematic because 1) it is unknown what scaling factors should be used in the two study periods; and 2) the way in which turbines were selected for sampling in combination with the differences in search interval, number of searches per turbines, and other sampling factors appear to be too great to overcome analytically.

For these and other reasons, the SRC and settling parties have been discussing alternatives to the baseline described in the settlement agreement. An approach centered on the concept of a 3-year rolling average of the estimated annual number of fatalities in the APWRA has been proposed. The purpose of this memo is to present and critically evaluate one such approach centered on the 3-year rolling average concept for establishing a “new” baseline and evaluating the effectiveness of management actions to achieve reductions in avian mortality. In addition, we provide preliminary estimates and results based on this approach to assist the SRC and settling parties in evaluating the efficacy of the proposed approach to a new baseline.

Methods

In order to evaluate change from the baseline conditions, the baseline fatality estimate should represent the long-term average APWRA-wide annual number of fatalities that would occur for a particular group of birds if the provisions of the settlement agreement were not implemented. This estimate represents the null-hypothesis that conditions have not changed in the APWRA since 2005, and that the total numbers of fatalities have not decreased. The test of this hypothesis is a one-tailed analysis of 3 or more years of expanded and adjusted fatality estimates using the same species or bird groups in both the baseline and subsequent years of data.

The basic concept of the baseline and the method presented here for tracking changes in the annual number of fatalities over time is to use a rolling 3-year average of the expanded and adjusted APWRA-wide number of fatalities for a distinct group of birds. To produce a fair estimate for the initial baseline, the estimate should be based on conditions as they existed in 2005, prior to initiation of any management actions to reduce fatalities.

We propose calculating an annual, turbine type-specific mortality rate for each bird group of interest and then taking the average to produce a 3-year average fatality rate. That rate would then be expanded to the installed capacity that existed in 2005. For each subsequent 3-year rolling average the average annual fatality rate would be expanded to the installed capacity in the last year of the average.

Assumptions

The analytical approach for estimating the APWRA-wide baseline annual focal species fatality rate outlined above is built on the following assumptions.

Assumption 1: Three- Year Average *Fatality Rates* (per MW) Are Predominantly Influenced by Turbine Type and Turbine Size

Older, smaller turbines present higher collision risks for most raptors when compared with newer larger turbines. Although larger rotor diameter and tip speed can increase collision risk (e.g., Tucker 1996), larger modern turbines have a variety of physical features and siting requirements that can reduce the overall potential collision risk in a turbine field. Although individual turbines present their own collision risk, it is difficult to estimate this risk for any given turbine in the APWRA. Because of the size and density of the APWRA in its current configuration, the number of fatalities detected at individual turbines is small and the number of turbines is relatively large. Although removals of an individual turbine will eliminate the risk presented by that turbine, the remaining risk in the APWRA may be large, uncertain, and/or variable. In developing the baseline estimate and evaluating change we will develop turbine-type specific fatality rate estimates by bird group. The assumption is that changes in the fatalities per MW associated with turbine removal within a 3-year period (Table 2) will be observable in the results for a turbine type and bird group.

Assumption 2: Three-Year Average APWRA-wide *Number of Fatalities* Is Predominantly Influenced by the Fatality Rate and Installed Capacity of Each Turbine Type/Size in the APWRA

The removal of hazardous turbines is a central element of the settlement agreement, and is a central theme of the management program and the work of the SRC. During the first 3 years of the current study, many turbines were removed based in part on hazardous ranking by the SRC (Table 2 and 3). However, turbine attrition has also occurred over time. The assumption is that reductions in nameplate capacity for specific turbine types in the APWRA will ultimately reduce the expanded fatality estimate, and/or will reduce the fatalities per MW observed over a 3-year period (Assumption 1).

Assumption 3: Fatalities per MW Have Been Sufficiently Monitored for Each Turbine Type in the Current Study to Estimate Turbine-Type Specific Fatality Rates

During the current study most turbine types were monitored. Two exceptions are the Danwin and Windmaster turbines, which were 1.4% of the installed nameplate capacity in 2005. We borrow fatality rates from similarly sized turbines for these two groups, assuming that there influence on the APWRA-wide estimate is relatively small. In addition the proportion of each turbine-type monitored was not constant across each group. All turbines of some turbine types were searched, while a sample of turbines from other turbine types were searched (Table 2 versus Table 3). We ignore these influences in this analysis. The assumption is that sample-size bias within a turbine type will have less influence on the baseline or comparative estimates than installed capacity (Assumption 2) and turbine type
(Assumption 1).

Table 2. Changes in APWRA Installed MW capacity during the Baseline (1998) and Current (2005–2008) Studies by Turbine Type and Monitoring Year

		Baseline				Current Study			
Turbine Type	**Turbine Size (average kilowatt [kW])**	**1998**	**1999**	**2000**	**2001**	**2005**	**2006**	**2007**	**2008**
250kW	250	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Bonus	113.75	55.7	55.7	55.7	55.7	55.7	55.7	55.7	55.0
Danwin	135	2.4	2.1	1.9	3.5	3.5	3.5	1.2	0.0
Enertech	53	7.3	7.3	7.3	7.3	5.8	5.7	5.7	5.7
Flowind	200	18.6	17.8	14.7	12.7	0.0	0.0	0.0	0.0
Howden	540	28.1	28.1	26.8	26.8	24.8	24.8	23.9	22.5
Kenetech 56-100	100	328.1	322.9	319.6	316.6	287.3	285.3	273.0	254.4
KVS 33	400	16.4	16.4	16.4	16.4	16.4	16.4	16.4	16.4
Micon	65	14.4	14.4	14.4	14.4	14.0	14.0	13.9	13.8
Mitsubishi	1000	0.0	0.0	0.0	0.0	0.0	0.0	38.0	38.0
Nordtank	93	20.2	20.2	23.5	29.2	29.2	29.2	20.2	20.2
Polenko	100	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.1
V-47	660	0.0	0.0	0.0	0.0	20.5	20.5	20.5	20.5

		Baseline				Current Study			
Turbine Type	**Turbine Size (average kilowatt [kW])**	**1998**	**1999**	**2000**	**2001**	**2005**	**2006**	**2007**	**2008**
Vestas	95	19.0	19.0	19.0	19.0	18.8	18.3	18.3	18.3
Windmaster	200	38.1	3.6	3.6	3.6	3.6	3.6	0.0	0.0
Windmatic	65	1.7	1.7	1.7	1.7	1.5	1.5	1.5	1.5

Table 3. Changes in APWRA Monitored MW Capacity during the Baseline (1998) and Current (2005–2008) Studies by Turbine Type

	Baseline	**Current Study**						
Turbine Type	1998	1999	2000	2001	2005	2006	2007	2008
250kW					5	5	5	5
Bonus	42.06	42.06	41.34	41.34	35.55	36.99	36.99	36.99
Danwin	2.09	1.32	0.44	0.33				
Enertech			7.32	7.32	5.76	5.76	5.76	5.76
Flowind	22.3	19.15						
Howden					26.16	14.61	14.61	14.61
Kenetech 56-100		42.4	39.3	42	100.1	153.8	153.8	153.8
KVS 33		6.4	6.4	6.4	14.8	14.8	14.8	14.8
Micon			14.365	14.365	14.365	14.365	14.365	14.365
Mitsubishi[1]							38	38
Nordtank					8.58	8.58	8.58	8.58
Polenko			0.6	0.6	0.6	0.6	0.6	0.6
V-47					20.46	20.46	20.46	20.46
Vestas	19.19	19.19	19.19	19.19	12.255	12.255	12.255	12.255
Windmatic			2.29	2.29	2.29	2.29	2.29	2.29

[1] Mitsubishi turbines are monitored at the Buena Vista project by Insignia, but are included in the APWRA-wide estimate.

Approach

The annual fatality estimate was expanded to the estimate of installed capacity for each turbine type/size in September 2005 (Table 2). These are the baseline conditions represented in the settlement condition from which reductions in fatalities were to be achieved. The APWRA-wide expansion is a function of:

Equation 1

$$AF = \sum_{y=1}^{F} (r \times C)_{y,t,b}$$

Where:

AF = total annual fatalities
F = number of fatalities
r = rate of fatalities in bird per MW
C = installed capacity in MW
y = monitoring year
t = turbine type
b = bird type

The current study provides 4 years of fatality rates from which this expansion can be made, allowing for the estimate of two 3-year averages by turbine type. The expansion to nonmonitored capacity was applied directly from the rates derived from the monitored capacity, without accounting for geographic variation in fatality rates. Annual variance in the fatality estimate was incorporated from the annual variance in the point estimate of expanded fatalities by turbine type.

The turbine type-specific fatality rate ("r") is a function of:

Equation 2

$$r = \left(\frac{\frac{Mu}{(Sv_i \times Se)}}{c} \right)_{y,t,b}$$

Where:
r = adjusted mortality rate reflecting scavenger removal and searcher efficiency
Mu = observed mortality numbers from carcass searches
Sv_i = estimate of the percent of fatalities remaining for the achieved search interval
Se = percent of carcasses found by searchers
c = monitored installed capacity
y = monitoring year

t = turbine type
b = bird group

Searcher efficiency and fatality removal rates were taken directly from the literature (Smallwood 2007). The estimate of monitored capacity is documented in the search data provided by the monitoring program. For any given year the search interval was calculated directly from the monitoring program as well. The current study is characterized by a relatively consistent search interval since 2005 (Table 4).

Table 4. Average Annual Search Interval by Turbine Type and Monitoring Year

Turbine Type	2005	2006	2007	2008	Grand Average
250kW	50.67	35.67	35.33	30.00	37.92
Bonus	52.04	36.20	34.89	29.84	38.16
Enertech	55.93	34.71	35.00	29.64	38.82
Howden	48.41	36.45	34.45	30.18	38.70
Kenetech 56-100	49.76	36.51	34.96	29.87	36.77
KVS 33	47.43	36.71	35.00	30.00	37.29
Micon	55.79	35.75	34.50	30.00	39.01
Nordtank	52.54	35.38	34.63	29.96	38.13
Polenko	49.00	37.00	35.00	30.00	37.75
V-47	33.62	36.00	32.46	30.00	33.02
Vestas	47.27	37.00	34.36	29.91	37.14
Windmatic	49.00	37.00	35.00	30.00	37.75
Annual Average	50.54	36.21	34.75	29.89	37.48

Table 5. Adjustment Factors by Monitoring Year and Turbine Type Based on the Search Intervals from Table 4, Percent Carcasses Remaining from Smallwood 2007, and a 75% Searcher Efficiency for Small Raptors from Smallwood 2007

Small Raptors					
Turbine Type	2005	2006	2007	2008	Average
250kW	0.1425	0.2025	0.2025	0.24	0.195
Bonus	0.135	0.2025	0.21	0.2475	0.1875
Enertech	0.1275	0.21	0.2025	0.2475	0.1875
Howden	0.15	0.2025	0.21	0.24	0.1875
Kenetech 56-100	0.15	0.2025	0.21	0.2475	0.2025
KVS 33	0.15	0.2025	0.2025	0.24	0.195
Micon	0.1275	0.2025	0.21	0.24	0.1875
Nordtank	0.135	0.2025	0.21	0.2475	0.1875
Polenko	0.15	0.195	0.2025	0.24	0.195
V-47	0.2175	0.2025	0.225	0.24	0.2175
Vestas	0.15	0.195	0.21	0.2475	0.195
Windmatic	0.15	0.195	0.2025	0.24	0.195

Large Raptors					
Turbine Type	2005	2006	2007	2008	Average
250kW	0.91	0.92	0.92	0.93	0.92
Bonus	0.91	0.92	0.92	0.93	0.92
Enertech	0.9	0.92	0.92	0.93	0.92
Howden	0.91	0.92	0.92	0.93	0.92
Kenetech 56-100	0.91	0.92	0.92	0.93	0.92
KVS 33	0.91	0.92	0.92	0.93	0.92
Micon	0.9	0.92	0.92	0.93	0.92
Nordtank	0.91	0.92	0.92	0.93	0.92
Polenko	0.91	0.92	0.92	0.93	0.92
V-47	0.93	0.92	0.93	0.93	0.93
Vestas	0.91	0.92	0.92	0.93	0.92
Windmatic	0.91	0.92	0.92	0.93	0.92

Results and Discussion

The number of fatalities detected each year is variable (Table 6). Low detections in 2005 may be due in part to a longer search interval and a smaller number of turbines included in the design. However, since the search interval and monitored capacity have stabilized variance between 2006 and 2008, results are more likely a function of variability in fatality rates, perhaps associated with changing bird use or changing environmental conditions. The equal number of small and large focal species fatalities observed in 2006 appears to be a complete anomaly, and is assumed to be unrelated to the sampling design or implementation.

The number of adjusted fatalities (Table 7) and adjusted fatalities per MW (Table 8) is variable by year and turbine type. The influence of unexplained variability in detection probability on variance in the fatality rates is unknown and not accounted for in these estimates. Similarly, hazardous turbine removal and winter shutdown occurred at monitored strings between 2005 and 2008 (Table 8). Notably, we do not see an absolute pattern in the reduction in the 3-year average fatality between periods. The 2006–2008 value is lower for some turbine types and higher for others. However the adjusted rate per MW is 6% lower for all focal species combined.

Table 6. Unadjusted Focal Species Fatalities by Monitoring Year and Turbine Type[2]

	American Kestrel and Burrowing Owl Combined				Golden Eagle and Red-Tailed Hawk Combined			
Row Labels	**2005**	**2006**	**2007**	**2008**	**2005**	**2006**	**2007**	**2008**
250kW	1	2	1	1	0	0	0	0
Bonus	4	30	17	11	24	42	26	5
Enertech	5	15	5	7	4	9	4	4
Howden	3	5	5	1	3	0	2	1
Kenetech 56-100	9	82	63	32	54	97	65	20
KVS 33	0	2	0	1	1	3	1	0
Micon	5	11	5	4	5	5	9	4
Nordtank	2	3	0	1	4	5	0	0
Polenko	0	2	0	0	0	1	0	0
V-47	4	9	2	4	4	3	8	7
Vestas	0	7	2	1	5	4	7	6
Windmatic	1	2	4	1	0	1	0	1
Total	34	170	104	64	104	170	122	48

[2] American kestrel and burrowing owl are combined, as are golden eagle and red-tailed hawk, because they are adjusted using the same adjustment factors in the previously published literature.

Table 7. Adjusted Fatalities by Monitoring Year and Turbine Type[3]

	American Kestrel and Burrowing Owl Combined				Golden Eagle and Red-Tailed Hawk Combined			
Turbine Type	**2005**	**2006**	**2007**	**2008**	**2005**	**2006**	**2007**	**2008**
250kW	7.0	9.9	4.9	4.2	0.0	0.0	0.0	0.0
Bonus	29.6	148.1	81.0	44.4	26.4	45.7	28.3	5.4
Enertech	39.2	71.4	24.7	28.3	4.4	9.8	4.3	4.3
Howden	20.0	24.7	23.8	4.2	3.3	0.0	2.2	1.1
Kenetech 56-100	60.0	404.9	300.0	129.3	59.3	105.4	70.7	21.5
KVS 33	0.0	9.9	0.0	4.2	1.1	3.3	1.1	0.0
Micon	39.2	54.3	23.8	16.7	5.6	5.4	9.8	4.3
Nordtank	14.8	14.8	0.0	4.0	4.4	5.4	0.0	0.0
Polenko	0.0	10.3	0.0	0.0	0.0	1.1	0.0	0.0
V-47	18.4	44.4	8.9	16.7	4.3	3.3	8.6	7.5
Vestas	0.0	35.9	9.5	4.0	5.5	4.3	7.6	6.5
Windmatic	6.7	10.3	19.8	4.2	0.0	1.1	0.0	1.1
Total	234.9	838.9	496.4	260.2	114.3	184.8	132.6	51.7

Table 8. Adjusted Fatalities per MW Based on the Adjusted Fatalities in Table 7 and the Monitored Capacity from Table 3

	American Kestrel and Burrowing Owl Combined						
Row Labels	**2005**	**2006**	**2007**	**2008**	**2005–2007 Average**	**2006–2008 Average**	**4 Year Average**
250kW	1.40	1.98	0.99	0.83	1.46	1.27	1.30
Bonus	0.83	4.01	2.19	1.20	2.34	2.47	2.06
Enertech	6.81	12.40	4.29	4.91	7.83	7.20	7.10
Howden	0.76	1.69	1.63	0.29	1.36	1.20	1.09
Kenetech 56-100	0.60	2.63	1.95	0.84	1.73	1.81	1.51
KVS 33	0.00	0.67	0.00	0.28	0.22	0.32	0.24
Micon	2.73	3.78	1.66	1.16	2.72	2.20	2.33
Nordtank	1.73	1.73	0.00	0.47	1.15	0.73	0.98
Polenko	0.00	17.09	0.00	0.00	5.70	5.70	4.27
V-47	0.90	2.17	0.43	0.81	1.17	1.14	1.08
Vestas	0.00	2.93	0.78	0.33	1.24	1.35	1.01
Windmatic	2.91	4.48	8.63	1.82	5.34	4.97	4.46
Average	1.56	4.63	1.88	1.08	2.69	2.53	2.29

[3] Adjusted using Equation 2 and the adjustment factors from Table 5.

	American Kestrel and Burrowing Owl Combined						
Row Labels	**2005**	**2006**	**2007**	**2008**	**2005–2007 Average**	**2006–2008 Average**	**4 Year Average**
	Golden Eagle and Red-Tailed Hawk Combined						
250kW	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bonus	0.74	1.23	0.76	0.15	0.91	0.71	0.72
Enertech	0.77	1.70	0.75	0.75	1.07	1.07	0.99
Howden	0.13	0.00	0.15	0.07	0.09	0.07	0.09
Kenetech 56-100	0.59	0.69	0.46	0.14	0.58	0.43	0.47
KVS 33	0.07	0.22	0.07	0.00	0.12	0.10	0.09
Micon	0.39	0.38	0.68	0.30	0.48	0.45	0.44
Nordtank	0.51	0.63	0.00	0.00	0.38	0.21	0.29
Polenko	0.00	1.81	0.00	0.00	0.60	0.60	0.45
V-47	0.21	0.16	0.42	0.37	0.26	0.32	0.29
Vestas	0.45	0.35	0.62	0.53	0.47	0.50	0.49
Windmatic	0.00	0.47	0.00	0.47	0.16	0.31	0.24
Average	0.32	0.64	0.33	0.23	0.43	0.40	0.38
Sum of Averages	1.88	5.27	2.21	1.31	3.12	2.93	2.67

The decline in fatalities per MW for the focal species is evident despite the fact that both monitoring periods include the relatively high fatality rates from 2006. The declining rate may be anomalous, or may be caused by management actions such as hazardous turbine removal within the monitored capacity and/or an effect of the winter shutdown of turbines. While the specific impacts of each management action may be difficult to detect, the ability to calculate a change through time supports the utility of evaluating change using this analytical approach.

The installed capacity decreased by 3% between 2005 and 2008. This reduction occurred at the same time that the 3-year average turbine-specific focal species fatality rate decreased by 6%. The 3-year rolling average for 2008 for focal species fatalities is therefore 13% lower than the point estimate for 2005 (Table 9). Although these results do not account for every influence discussed above (i.e., variability in detection probability, the influence of hazardous turbine removal, winter shutdown, etc.) they are seemingly useful in a management context. The basic assumptions regarding the influence of management actions are captured in the estimates of turbine-specific fatalities per MW and the turbine-specific expansion. The 2005 estimate supports the use of the baseline estimate within the analytical framework and common assumptions presented in this memo. The evaluation of differences between 2005 and 2008 APWRA-wide estimates provides a framework for evaluating change within a specific bird group.

Conclusions and Recommendations

The approach used to generate the point estimates in Table 9 was intentionally not probabilistic. In general the calculations can be equated to an accounting system. The only statistical elements in the approach are the use of averages, and the use of nonlinear estimates of detection probabilities from Smallwood (2007). Although the framework presented here provides context and an approach for deriving the baseline estimate and evaluating change, there is no confidence estimate associated with the evaluation.

To support adaptive management of the APWRA, a probabilistic approach should be applied to develop confidence intervals for the baseline estimate and when evaluating change through time. The turbine specific estimates of fatalities per MW were taken from multiple data points and multiple strings. This data can be subsampled using Bootstrap or Jackknife techniques to develop a 95% confidence interval to allow for a statistically defensible evaluation of the 50% reduction in fatalities (Manly 2006). This approach would help account for anomalous results in fatality rates regardless of whether they are biologically real (i.e., unexpected increases in bird use) or sampling problems (i.e., unexpected or unexplained variability in detection probability).

The evaluation of a 50% reduction in fatalities can only be successfully implemented if analytical assumptions, an analytical approach, and a monitoring program are consistently and scientifically implemented and applied (Holling 1978). Although the settlement agreement is a legal document, the baseline fatality estimate is a scientific product. Similarly, adaptive management of the APWRA is a natural resource problem that cannot be separated from the scientific method and the application of the best available scientific information. Baseline fatality estimates of any bird group must be adopted within an adaptive management context as performance metrics that are scientific in nature and have specific units and assumptions.

Changes in focal species fatalities may be sufficient for evaluating change in the APWRA. However, there is some evidence to suggest that management actions may have a positive influence on some species while negatively influencing others. This could result in Type 1 or 2 error when accepting or rejecting the hypothesis that management has been effective. For example, if long-term fatality rates increase for one or more of the focal species but decrease for all raptors or all birds, one might incorrectly conclude that management has failed. The converse is true as well. Adaptive management is robust to the use of multiple performance metrics and multiple models, and these could be easily derived for multiple bird groups and incorporated into an adaptive management program.

The baseline time period of 2005 cannot be revisited or resampled, and it is not possible to estimate baseline fatality rates or future fatalities with 100% certainty. However, the application of rigorous scientific principles will help decrease uncertainty in the evaluation of a 50% reduction in fatalities, and facilitate the implementation of adaptive management. Based on the information presented in this memo, the following recommendations seem reasonable and prudent.

1. Adopt an APWRA-wide baseline estimate for focal species, all raptors, and/or all native birds.
2. Evaluate the 50% reduction using all three of these metrics.

3. When evaluating the 50% reduction through time, utilize point estimates as well as probabilistic estimates of fatality rates.
4. Use the baseline estimate and corresponding analytical approach to design future monitoring so that changes in fatalities can be detected with a predictable level of confidence.

Table 9. Point Estimates of APWRA Fatalities for the Four Focal Species Using Adjusted Fatality Rates from Table 7 and the Corresponding Nameplate Capacity[4]

	2005	2005–2006 Rates			2008	2006–2008 Rates			
Turbine Type	Installed Capacity	American Kestrel and Burrowing Owl	Golden Eagle and Red-Tailed Hawk	Total	Installed Capacity	American Kestrel and Burrowing Owl	Golden Eagle and Red-Tailed Hawk	Total	% Decrease
250KW	5.0	7.3	0.0	7.3	5.0	6.3	0.0	6.3	13%
Bonus	55.7	130.5	50.9	181.4	54.995	135.6	39.3	174.9	4%
Danwin	3.5	6.0	2.0	8.0	0	0.0	0.0	0.0	100%
Enertech	5.8	45.1	6.2	51.3	5.72	41.2	6.1	47.3	8%
Howden	24.8	33.8	2.3	36.1	22.53	27.1	1.7	28.7	20%
Kenetech 56-100	287.3	496.3	166.4	662.8	254.4	460.0	108.9	568.9	14%
KVS 33	16.4	3.6	2.0	5.7	16.4	5.2	1.6	6.8	-20%
Micon	14.0	38.2	6.8	45.0	13.78	30.3	6.2	36.6	19%
Mitsubishi	0.0	0.0	0.0	0.0	38	2.3	12.9	15.2	NA
Nordtank	29.2	33.6	11.2	44.8	20.215	14.8	4.3	19.1	57%
Polenko	1.2	6.8	0.7	7.6	1.1	6.3	0.7	6.9	8%
V-47	20.5	23.9	5.4	29.3	20.46	23.3	6.5	29.8	-2%
Vestas	18.8	23.2	8.9	32.2	18.335	24.7	9.2	33.8	-5%
Windmaster	3.6	5.2	0.0	5.2	0	0.0	0.0	0.0	100%
Windmatic	1.5	8.0	0.2	8.2	1.495	7.4	0.5	7.9	4%
Total	487.3	861.7	263.0	1124.7	472.43	784.4	197.8	982.2	13%

[4] Danwin and Windmaster turbines are not monitored in the current study. Danwin fatalities were expanded using the Kenetech 56–100 rates. Similarly, the Windmaster turbines were expanded using the 250kW rates. Results for Mitsubishi turbines from the Buena Vista site were incorporated from Insignia (2009).

References Cited

Holling, C.S. (ed.) 1978. *Adaptive Environmental Assessment and Management.* John Wiley & Sons, Toronto. 377 pages.

ICF Jones & Stokes. 2009. *Altamont Pass Wind Resource Area Bird Fatality Study*. Draft. December. (ICF J&S 00904.08.) Sacramento, CA. Prepared for Alameda County Community Development Agency, Hayward, CA.

Insignia Environmental. 2009. *2008/2009 Annual Report for the Buena Vista Avian and Bat Monitoring Project.* Prepared for Contra Costa County. 95 Pages.

Manly, B.F.J. 2006. *Randomization, Bootstrap and Monte Carlo Methods in Biology.* 3rd Edition. Chapman & Hall, New York. 390 pages.

Smallwood, S.K. 2007. Estimating Wind Turbine-Caused Mortality. *The Journal of Wildlife Management* 71(8): 2781–2791.

Smallwood, K. S., and C. G. Thelander. 2004. *Developing Methods to Reduce Bird Fatalities in the Altamont Wind Resource Area*. Final Report by BioResource Consultants to the California Energy Commission, Public Interest Energy Research—Environmental Area. Contract No. 500-01-019 (L. Spiegel, Project Manager).

Smallwood, K. S., and C. G. Thelander. 2008. *Bird Mortality in the Altamont Pass Wind Resource Area, California*. Journal of Wildlife Management 72(1): 215-233.

Tucker, V.A. 1996. The Mathematical Model of Bird Collisions with Wind Turbine Rotors. *Journal of Solar Energy Engineering* 118(4).