DRAFT STUDY DESIGN FOR TESTING COLLISION RISK OF FLODESIGN WIND TURBINE IN FORMER AES SEAWEST WIND PROJECTS IN THE ALTAMONT PASS WIND RESOURCE AREA (APWRA)

K. Shawn Smallwood

23 April 2012

To test whether the FloDesign mixer-ejector wind turbine (MEWT) will cause bird fatalities due to collisions, FloDesign purchased the wind power assets in the Altamont Pass that were formerly owned by AES Seawest. FloDesign acquired these assets to perform a Before-After, Control-Impact (BACI) study (Anderson et al. 1999) at a larger number of wind turbines than originally planned (SRC P223). FloDesign took this step because in September 2011 the SRC recommended a BACI design, and agreed with me that the original trial-level study could serve as an indicator of avian safety, but would likely not generate conclusive results (SRC P226). Hence, FloDesign and I agreed to expand the study for the purpose of obtaining more conclusive results. I also prepared a grant proposal to support the study, and was recently awarded a grant by the California Energy Commission's Public Interest Energy Research (PIER) program.

Goals and objectives

In addition to testing the avian safety of the MEWT, we proposed a methodology to PIER that was intended to produce behavior data that will improve collision risk models (Tucker 1996a,b; Smales 2005; Band et al. 2005; Chamberlain et al. 2006; Podolsky 2005; Whitfield 2009; Nations and Erickson 2010) and map-based collision hazard models (Smallwood and Neher 2009; Smallwood and Neher 2010a,b), the former of which is increasingly being used to predict impacts and the latter of which is being used to more carefully site wind turbines. We wanted to ensure that, even if the MEWT fails to reduce bird fatalities, our study will nevertheless contribute useful information for wind turbine siting and impact assessments.

Our goals are to (1) test whether shrouded wind turbines are safer to birds than open-bladed turbines, and (2) develop the predictive tools needed to most safely and most quickly site both types of wind turbine in new projects. Our study objectives are the following:

(1) Compare avian interactions with wind turbines between MEWTs and conventional turbines at known high-fatality sites during day and night and various wind and terrain conditions;

(2) Compare avian fatality rates between MEWTs and conventional turbines at known high-fatality sites, using a short search interval and a BACI design;

(3) Explain variation in fatality rates by turbine design, flight patterns, and avian interactions with wind turbines, i.e., avoidance behaviors; and,

(4) Provide field-tested behavior survey methods and data that inform avoidance rates in collision risk models and map-based collision hazard models to guide wind turbine siting.

The study plan changed somewhat from the proposal the SRC reviewed in 2011. These changes were due principally to SRC comments and recommendations following its review of my 2011 study proposal. With FloDesign's support, I followed the SRC's recommendations and responded to comments and concerns. I prepared a study plan for a larger experiment, and subsequently transformed the study plan into a grant proposal, which I submitted to PIER. I won the PIER grant. At about the same time, FloDesign acquired the wind assets of AES SeaWest in the APWRA. The study increased in size from 10 MEWTs to 40 MEWTs. It shifted locations from Patterson Pass to four sites managed by AES SeaWest. It involves four types of old-generation wind turbines instead of one. It also includes both fatality searches and behavior surveys through the entire winter shutdown period, or year-round.

Recent Developments

Although the PIER funds will not be available until July 2012, FloDesign and I decided to begin the study prior to the availability of PIER funds. We had told the SRC in September 2011 that we intended to begin the trial-level study at the end of the winter shutdown, or on 15 February 2012. We believed the SRC expected us to begin by 15 February, so we decided to initiate the study as close to that date as possible. I began scouting for observation stations and working out logistical issues by late February, and we began fatality searches on 3 April 2012. We started with one searcher, and added two more a week later. We completed 3 rounds of searches as of 20 April 2012, but we had not begun behavior surveys as of 23 April. We decided to phase in the study elements as we develop proficiency, element by element.

Another advantage of beginning the study ahead of the PIER funds is to implement the methods and collect data for presentation at the May 2012 SRC meeting. We wanted to be able to inform the SRC about which study elements are working, and which might need some feedback from the SRC. At the end of this report, I make specific suggestions and queries to the SRC.

FATALITY STUDY DESIGN

I designed an experiment intended to maximize the likelihood of detecting an effect of the MEWT on avian collisions. To do this, I relied on four years of fatality monitoring data to identify the wind turbines associated with the highest rates of found bird carcasses. I then assigned the high-fatality turbines to a MEWT replacement treatment and a control treatment, and I replicated and interspersed the treatments.

The study area includes 403 wind turbines formerly owned by AES SeaWest (AES SeaWest continues to manage these turbines). These 403 turbines included 144 40-KW turbines in the Altech I project, 12 65-KW turbines in the Swamp (TV 11 & 12) project, 183 65-KW turbines in the Taxvest project at the Mountain House and Midway Road sites, 38 65-KW turbines in the Venture Winds project, and 26 65-KW turbines in the Viking project. The numbers of wind turbines in each project were derived from information gathered several years ago, but since then some wind turbines were removed due to attrition and due to the SRC's ratings of turbines as posing greater collision hazard to raptors.

Clusters of wind turbines can be replaced by MEWTs to provide reasonable buffer space between MEWTs and other wind turbines. The buffer space minimizes experimental contamination caused by bird carcasses being thrown by the blades of adjacent turbines onto the search area of MEWTs, and vice versa. In longer turbine rows, MEWTs can replace high-fatality turbines while adding a buffer space by removing and not replacing one or more of the 65-KW turbines between the MEWTs and the remainder of the older turbines in the row. This buffer can be achieved without loss of power generation because the replacement ratio of 100-KW MEWTs for 65-KW old turbines is 1 for 2.5 in the case of 40-KW turbines, and 1 for 1.5 in the case of 65-KW turbines.

I used four years of fatality monitoring data from the 2005 to 2009 period to calculate detected fatality rates per wind turbine. I did not adjust detected fatality rates for searcher detection error or scavenger removal rates, because I was attempting to characterize the numbers of bird carcasses actually found. I also omitted European starling and rock pigeon fatalities from fatality detection rates because these non-native species were killed in high numbers at AES SeaWest sites. Detected fatality rates represented the number of native birds found per MW per year. The four years of fatality monitoring I relied upon was based on an average of about 30 days between searches, but I would prefer to achieve two searches per week for the FloDesign study. A 48-hour search interval in an earlier study resulted in 2.4 times the detections of small bird fatalities than were expected by conventional scavenger removal rates applied to data concurrently collected at the same turbines using a 30 day search interval (Smallwood 2009b). Therefore, we can expect to find more fatalities per turbine with the proposed higher search interval.

I identified 60 high-fatality clusters among 403 wind turbines. From these 60, I randomly selected clusters to be assigned to the FloDesign replacement treatment. For each randomly selected high-fatality cluster, I assigned the nearest, similar-sized cluster to the control treatment. This approach ensured interspersion of treatments, and it facilitated the logistics of fatality monitoring. I assigned 40 FloDesign turbines to the high-fatality clusters randomly selected for the replacement treatment (Table 1). Some adjustments were necessary due to wind turbines having been removed per SRC recommendations. Where wind turbines were lost within a string, other turbines adjacent to the selected turbines were selected to replace the missing turbines. In one case, an entire string of wind turbines had been removed, so I selected the high-fatality cluster nearest to this string -- the next string to the west.

Based on a two day search interval, I estimated 88 native birds would be found in a year at the wind turbines assigned to replacement and control groups prior to replacement at the AES sites (Table 2). I estimated that 41.5 birds would be found at the control turbines, and 46.5 would be found at the replacement turbines. Of course, once the turbines are replaced, my research hypothesis is that many fewer birds would be found than 46.5 at the replacement sites during the ensuing year.

After 3 rounds of searches in April 2012, we found 28 fatalities (Table 3). Of these 28 fatalities, 20 were rock pigeons. Twelve of the 28 fatalities were sufficiently fresh for use in fatality rate estimates at the average search interval we hope to achieve. Four of the fatalities were recently dead native birds. However, 55% of the capacity of the study turbines was non-operational during April 2012 due to a malfunctioning circuit at the substation. All 12 of the freshly killed birds were found at operational wind turbines, and four of these were native species. Adjusting for the capacity of wind turbines offline, we already found 10% of our projected annual number of freshly killed, native birds. Once the circuit is repaired and all the wind turbines in our study are operational, I predict that our fatality projections will be met.

FATALITY SEARCH PROTOCOL

Some details of the fatality search protocol are included in the following list:

1) All fatality searches are recorded on a search schedule data sheet;

2) The ground is searched within 50 m of wind turbines selected for membership in our treatment groups;

3) Transects average about 6-7 m apart;

4) Found fatalities are recorded on data sheets, including date, species, initials of discoverer, whether a new or repeat find, whether standard search or incidental discovery, sex, age class, estimated days since death, checklist of possible causes of death, carcass condition, including a few diagnostics that can be used to support estimates of days since death, notes, and for each body part the nearest turbine, distance and bearing to turbine, and photo labels for photos taken of the carcass parts;

5) Known repeat fatality finds are recorded on data sheets, also, but including less information than new finds;

6) Found fatalities are not moved or removed by the fatality searchers in this study;

7) Eagles and endangered species are reported to GreenRidge Services without delay, and all other fatality finds are reported by spreadsheet to GreenRidge Services on a weekly basis;

8) Because 99 of the 157 wind turbines in our study are also searched by the Alameda County Avian Monitors, at the end of each month, I enquire with the Alameda County Avian Monitors about any fatalities they found and removed from wind turbines included in our study; and,

9) A detection trial is performed using placed bird carcasses and a specific study design yet to be determined.

BEHAVIOR SURVEYS

The standard survey methodology for avian impact assessment at wind projects has been utilization surveys, which are visual scans for birds performed by observers at prescribed stations and extending out to a certain maximum distance. Over a certain time period, the number of birds is divided by the session time to arrive at a utilization rate, or use rate. Use rates are then used to test hypotheses and predict impacts. However, use rates have not always related to fatality rates, and have led to highly inaccurate predictions of fatality rates in some cases. Also, use rates contribute little toward siting of wind turbines to minimize collision risk.

The rates at which certain behaviors are performed have been found to be more closely related to wind turbine collisions (Smallwood et al. 2009). In my experience, behavior patterns can be more stable than use rates, and they are not as vulnerable to biases in the calculation and comparison of use rates. To be comparable, for example, use rates should be adjusted for (1) changes in detection rates with changes in maximum survey distance, (2) variation in proportion of the airspace that is actually visible to the observer, i.e., not occluded by slopes or trees, and (3) overlap of surveyed airspace between observation stations. Behavior rate metrics, on the other hand, can be based on the birds that were detected, so long as the birds were near enough to the observer for pertinent behaviors to be observed carefully. Behavior rate metrics can include: Proportion of flights characterized as hovering, kiting, or contour-hunting within specific combinations of slope and wind conditions; Number of flights through the rotor zone during operating and non-operating periods; Flights within 20 m of rotors during operating and non-operating periods; Bird-minutes perched on wind turbines and specific parts of turbines; Proportion of approach vectors toward the turbine, e.g., from parallel or perpendicular to rotor plane, or from windward or leeward; Evasive behaviors exhibited by birds flying close to wind turbines; and, Reactions of birds flying across the rotor's intake or wake zones. Some of these behavior rates are useful for understanding how particular bird species interact with wind turbines in various conditions, and others are useful for predicting project impacts; all can help guide wind turbine siting in future projects.

In the following paragraphs, I list the specific objectives of the behavior survey protocol, followed by the general approach and specific data collection methods.

Specific Behavior Survey Objectives

(1) Characterize flight behaviors associated with slope and wind conditions where wind turbines have been located.

(2) Quantify reactions of flying and perched birds to wind turbines while rotors are not moving, feathering, operating, and starting up.

(3) Quantify flight behaviors during ecologically relevant times of day for various species of interest, such as during mornings and evenings, and during night.

(4) Further establish an empirical foundation of avoidance rates for use in collision risk models and map-based collision hazard models to guide wind turbine siting.

Survey Approach

First, this survey protocol is not intended for counting birds or for estimating relative abundance; it is not for estimating utilization rates. It should not be used to serve dual objectives of estimating use rates and characterizing behavior patterns, as has often been tried. This approach is purely for characterizing avian behaviors that are relevant to siting wind turbines in new projects. It is for estimating behavior rates, or the relative frequency of specific flight and perching behaviors as factors vary, such as wind turbine operations, avian-encountered slope conditions, wind conditions, and the presence of other conspecifics or members of other species.

Observation stations should be located where observers will hve excellent views of existing or planned wind turbines, including of the landscape where the turbines are situated. The maximum survey distance should be no more than 300 m, and it is alright for the visible area to be limited by slope or other occlusions. Any airspace that is hidden from the observer, due to terrain occlusions or for other reasons, should be excluded from subsequent analysis by a GIS analyst using a digital elevation model (DEM) of the survey area. Furthermore, for the purpose of hypothesis-testing, detection probabilities should be assigned to each grid cell of the DEM in order to weight bird observations associated with the grid cells. Detection probabilities should be based on detection rates that relate to distance from the observer and by degree of overlap of surveyed airspace from other observation stations (if any overlap occurs). Thus, observation stations should be located strategically, and the surveyed area should be prepared by a GIS analyst.

Whereas it is common practice in use surveys to locate observation stations on prominences such as hill peaks and ridge crests, stations used for behavior surveys should be located where the observer will least influence the behaviors of the birds, as well as where views are superior of the wind turbines at issue or of the landscape planned to support the wind turbines. Golden eagles, for example, are highly sensitive to human presence, and will often veer away from a human when they sense they are receiving focused attention. Stopping a vehicle to look at a golden eagle will cause the eagle to fly away. Standing on a hill peak will cause eagles to avoid the area surrounding the observer. Golden eagles are more likely to be observed performing natural behaviors when the observer is less exposed on the landscape, or contained within human infrastructure. For these reasons, when available, infrastructure or natural landscape features should be used as partial blinds, perhaps sometimes anticipating using a parked vehicle to augment the effectiveness of the blind. Examples can include clusters of utility poles, electrical collection boxes, under transmission towers, next to wind turbines, or amidst artificial rock piles or natural rock formations. During behavior surveys, the observers should also take care to minimize their reactions to eagle detections, because eagles can detect attention directed their way.

Observation sessions should last 30 min, because the observer's attention span begins to wane after about 22 min. However, it might be justifiable to add another 30 min session should activity levels of priority species prove to be unusually high. At the start and end of each session, the observer records wind direction, average and maximum wind speed, temperature, percentage overcast, and whether the air is smoky or foggy or rainy. Throughout the session, the observer should record the operating status of all turbines in the surveyed area, noting cut-ins and cut-outs of each turbine. The session start time should be recorded, along with the date and observation station number, and the initials of the observer. Once the session starts, decision rules should be used to decide which bird should be tracked at any given time.

Decision rules – Golden eagles should be given priority over other species. If golden eagles are not present, then visual tracking of birds should be directed in priority order to red-tailed hawks, other Buteo hawks, prairie falcon or peregrine falcon, American kestrel, burrowing owl, other owls, other native birds, non-native birds. Once a bird is being visually tracked, the observer should stay loyal to that bird as long as the bird is within the survey area, or unless a higher priority bird enters the survey area, such as a golden eagle. Priority should always be given to birds of special interest when those birds are flying within close proximity of wind turbines.

Visual tracking of birds requires writing onto an image of the survey area. Preferably, the image would be geo-referenced on a Trimble GeoXT GPS or on a notebook computer running ArcPad, but it can also be done onto paper copy. Recording onto images on paper is how we are starting our behavior surveys. Points can be added to the imaged maps where the observer sees the bird at regular, sequential time intervals (e.g., 5 or 10 sec), each point is numbered sequentially. Corresponding with the point labels, the observer records attributes of the observation into a handheld digital voice recorder: Point number, Height (above ground) and Behavior (e.g., flapping, hovering, kiting, contouring, soaring, column soaring, circling, gliding, diving, chasing, fleeing, fending off another bird, perching, displaying, carrying prey, eating, ground-hopping). When a bird is stationary, such as perching or hovering, then the observer should record the seconds into the observation when the stationary behavior begins and ends. These observations should be rote, minimizing time needed for the observer to look at the map and maximizing time for watching the bird. If a hardcopy map gets too busy with points added during a particular session (this would not be a problem using a GPS or notebook computer with ArcPad), then the observer should produce another copy of the same map for further recordings.

As birds approach wind turbines, additional attributes to record will include: Events (flying through rotor plane, landing on a turbine, taking off from a turbine, interacting with another bird within 50 m of a turbine) and Evasive actions (veering away; flapping hard to slow the approach or to gain lift over the turbine; flipping or banking or twisting to avoid blade collision; diving to duck under the rotor plane). If a bird is interacting with another bird, it is important to record how close the interaction puts the bird relative to the turbine, and whether the bird ever showed any awareness of the turbine's blades. If a bird is hovering or kiting near a wind turbine, it is important to record whether and how often the bird looks back toward the turbines, and how close the bird drifts with the wind towards the turbine. If a bird flies nearby or through the wind turbine, it is very important to record the angle of entry toward the rotor plane, ranging from perpendicular to parallel, and whether from the wake aspect or front aspect of the rotor. Distance from the turbine should be recorded as nearest distance from the center of the tower.

All observations should include sufficient description that an analyst can understand the observation and can extract additional information that might aid in hypothesis-testing. In other words, the observer should record into the voice recorder everything the observer feels is interesting or relevant about the observation. All voice recordings should be transcribed to an electronic spreadsheet within 24 to 48 hours. In this way, omissions and errors related to the voice and map recordings can be corrected by fresh recall.

Examples

Say a golden eagle crosses a ridge crest, entering the survey area. The observer starts the stopwatch on the observation and marks a point accompanied by a '1' at the location in the image corresponding with the eagle's entry point. The observer then activates the voice recorder while still visually tracking the bird. The observer talks into the recorder, "Golden eagle is bird A," and then "one, five meters, contouring, west; two, eight meters flapping, west; three, fifteen meters, circling, southwest; four, twenty-five meters, column soaring; five, three meters, gliding, south." The observer stops the stopwatch once the eagle glided over the other ridge crest, exiting the survey area on the south side. He can then mark the points 2 through 5 on the map. The time on the watch can be divided by the number of points and voice recorder entries to establish a time at each point. Assisted by the DEM data associated with the handheld image of the survey area, the information recorded would indicate the eagle flew in while contour hunting, hoping to surprise a ground squirrel or desert cottontail. It then flapped to maintain or gain lift, caught a deflection updraft or thermal and circled (soared) to gain additional lift over a north-facing slope, and then glided over another ridge crest bordering the southern aspect of the survey area. The entire observation lasted 20 seconds, so the regular data entries would indicate 5 sec per entry, or 5 sec between points on the map. Also, the analyst learns where and under what wind conditions this eagle chose to contour hunt, and where it used the landscape and wind/temperature to gain lift to exit the watershed basin it had just briefly visited. In time, other eagle visits to this same basin should reveal where and under what conditions the eagles typically fly low and where they use the landscape to gain lift. Both of these locations are not where wind companies will want to place wind turbines due to the vulnerability of golden eagles to collide with wind turbines at these locations, and as more of these types of locations are found, predictive models can be more effectively developed to guide wind turbine siting.

In another example, a red-tailed hawk glides into the survey area, prompting the observer to add the first point on the map, start the stopwatch, and tell the voice recorder which letter was assigned to the bird. Because the bird glided to near the top of a concave slope facing the wind and began to kite, the observer tells the recorder the stopwatch time when the new behavior began, he adds a point on the image where the red-tailed hawk is kiting, and he records the direction the bird is facing. He then watches it, noting any drift with the wind, until the red-tailed hawk breaks away from the kiting site, turning with the wind and narrowly missing the outer sweep of the blades of an operating wind turbine as it leaves the survey plot. This event must be recorded into the voice recorder, and the bird's flight path subsequently noted on the map image. Hopefully, the observer would have also noted whether the red-tailed hawk displayed any awareness of the wind turbine, such as by veering from the turbine's blades at the last second, or by even looking in the direction of the turbine. The observer also should have recorded the bird's height above ground, distance from the turbine's tower when this event occurred, and angle of flight relative to the turbine's rotor plane. Later, and with a sufficient sample of similar observations, the analyst should be able to detect a pattern of where and under what wind conditions red-tailed hawks typically kite or hover, where and to which direction the red-tailed hawk is likely to break away from the kiting or hovering behavior, and how often the hawks took evasive action to avoid a collision with the wind turbines.

Behavior Variables

Perched	See perch types listed below
Landing	See perch types listed below
Taking off	Taking off without being flushed; See perch types listed below
Fly-through	Directed flight powered by active wing flaps
Flapping	Wing flaps to maintain lift at slow speeds
Gliding	Directional flight with no wing beats
Surfing	Wind-powered flights usually perpendicular to the wind direction
Soaring	Gradual turning with few wing beats, often powered by thermals
Column soaring	Gradual turning with few wing beats, using thermals or deflection updrafts to gain altitude
Circling	Tight circles with some wing beats, usually looking at something on ground
Contouring	Flights close to terrain, changing direction and height with terrain
Kiting	Stationary position maintained using wind currents. Wings are partially closed with little movement. Tail closed.
Hovering	Stationary position maintained using frequent wing beats. Tail widely fanned.
Fly-catching	Short flights to and from perch in pursuit of volant prey items
Diving	Wings recessed or folded for rapid downward flight, usually to attack prey or competitor
Attacking	Attacking a potential prey item or competitor, not involving a dive
Chasing/Mobbing	Harassing a larger bird
Fleeing attacker	Evading predatory or competitive attack
Mobbed/Chased	Evading harassment by smaller birds
Flushed	Chased off perch
Ground-hopping	Hops along the ground while foraging
Running/walking	Often exhibited by burrowing owls

Carry prey
Carry nest material
Eating
Displaying
Copulating
Interacting
Flocking

Perching Variables

Wind turbine
Tower
Catwalk
Anemometer
Ladder
Turbine housing
Blade
Blade tip
Transformer box
Electric distribution line
Electric distribution pole

Pole top
Pole crossarm
Pole equipment, e.g., jumpers, transformer, capacitor box
Transmission line
Transmission tower
Meteorological tower
Communication tower
Guy wire
Ground
Water
Rock pile
Rock outcrop
Low vegetation
Tree
Post
Fence
Sign
Artificial wooden perch (two occur in the APWRA)
Building
Other landscape feature

SUGGESTIONS AND QUERIES TO SRC

The following list includes my suggestions and some specific queries to the SRC.

I request that the SRC recommend that the Alameda County Avian Monitors leave in the field all fatalities they find at wind turbines included in our study. Exceptions would be eagles and endangered species. Leaving carcasses in the field is not without precedent, and should not lead to confusion over possible double counting. If there is confusion, then one of the possible double counts can always be summarily omitted from fatality rate estimation. Not leaving carcasses in the field requires me to request the information from the Monitors, which creates more work for all of us. Furthermore, leaving carcasses in the field can serve as a built-in detection trial between the overlapping search teams.

The time it is taking our searchers to complete one search rotation is about 60 person-hours. At this rate, we will not achieve all of our objectives, because this amount of time does not include behavior surveys and data entry. The time to complete a search rotation might diminish with experience on the project, but probably not by much because our searchers are experienced. I think there are two options at this point. One option is to reduce the number of wind turbines we are searching. The second option is to reduce the number of searches per month from 8 to 6. I would like to obtain the SRC's opinion on these options.

REFERENCES CITED

Anderson, R., M., Morrison, K. Sinclair, D. Strickland. 1999. Studying wind energy and bird interactions: a guidance document. National Wind Coordinating Committee. Washington, D.C.

Band, W., M. Madders, and D. P. Whitfield. 2005. Developing field and analytical methods to assess avian collision risk at wind farms. In De Lucas, M., G. Janss, and M. Ferrer, eds. Birds and Wind Power. Barcelona., Spain: Lynx Edicions.

Chamberlain, D. E., M. R. Fehfisch, A. D. Fox, M. Desholm, and S. J. Anthony. 2006. The effects of avoidance rates on bird mortality predictions made by wind turbine collision risk models. Ibis 148:198-202.

Nations, C. S., and W. P. Erickson. 2010. Marbled Murrelet – Wind Turbine Collision Model for the Radar Ridge Wind Resource Area. Report prepared for Energy Northwest, Richland, Washington.

Podolsky, R. 2005. Application of Risk Assessment Tools: Avian Risk of Collision Model. Pages 86-87 *in* Schwartz, S. S. (RESOLVE, Inc.), ed. Proceedings of the Onshore Wildlife Interactions with Wind Developments: Research Meeting V. Lansdowne, VA. Wildlife Subcommittee of the National Wind Coordinating Committee, Washington, D.C.

Smales, I. 2005. Modelled Cumulative Impacts on the White-Bellied Sea Eagle across the Species' Australian Range. Report for the Department of Environment and Heritage. Project No. 5238. Biosis Research Pty Ltd., Melbourne.

Smallwood, K. S. 2010. Review of American Kestrel-Burrowing owl (KB) Scavenger Removal Adjustments Reported in Alameda County Avian Monitoring Team's M21 for the Altamont Pass Wind Resource Area. http://www.altamontsrc.org/alt_doc/p154_smallwood_ kb_removal_ rates_041610.pdf

Smallwood, K. S. and L. Neher. 2010a. Siting Repowered Wind Turbines to Minimize Raptor Collisions at the Tres Vaqueros Wind Project, Contra Costa County, California. Draft Report to the East Bay Regional Park District, Oakland, California.

Smallwood, K. S. and L. Neher. 2010b. Siting Repowered Wind Turbines to Minimize Raptor Collisions at Vasco Winds. Unpublished report to NextEra, Inc., Livermore, California.

Smallwood, K. S., L. Rugge, and M. L. Morrison. 2009a. Influence of Behavior on Bird Mortality in Wind Energy Developments: The Altamont Pass Wind Resource Area, California. Journal of Wildlife Management 73:1082-1098.

Smallwood, K. S., L. Neher, D. Bell, J. DiDonato, B. Karas, S. Snyder, and S. Lopez. 2009b. Range Management Practices to Reduce Wind Turbine Impacts on Burrowing Owls and Other Raptors in the Altamont Pass Wind Resource Area, California. Final Report to the California Energy Commission, Public Interest Energy Research – Environmental Area, Contract No. CEC-500-2008-080. Sacramento, California. http://www.energy.ca.gov/2008publications/ CEC-500-2008-080/CEC-500-2008-080.PDF

Tucker, V.A, 1996a. A mathematical model of bird collisions with wind turbine rotors. J. Solar Energy & Engineer. 118: 253-262.

Tucker, V.A, 1996b. Using a collision model to design safer turbine rotors for birds. J. Solar Energy & Engineer. 118: 263-269.

Whitfield, D. P. 2009. Collision Avoidance of Golden Eagles at Wind Farms under the 'Band' Collision Risk Model. Report to Scottish Natural Heritage, Natural Research Ltd, Banchory, UK.

Table 1. Original experimental treatment design among the wind energy projects composing the AES SeaWest sites. The first 22 groups selected in random order would total 40 MEWT replacements, and the next 8 groups selected would total 50 MEWT replacements. We are planning to use 40 MEWTs.

Random order	Treatment	String	Turbine addresses	MW	MEWTs	Notes
1	Replace	191	GE-1, GE-2	0.130	1	
2	Replace	204	WM-26, PO-33 to PO-38	0.455	5	
3	Replace	165	H-5, H-6	0.080	1	
4	Replace	199	WM-1, WM-2	0.130	1	
5	Replace	164	F-5, F-6	0.080	1	
6	Replace	182.2	CD-9 to CD-12	0.130	1	
7	Replace	170	K-3 to K-6	0.160	2	
8	Replace	201	WM-14 to WM-21	0.325	3	3 turbines removed
9	Replace	188	GD-6 to GD-8	0.195	2	
10	Replace	178.2	CA-6 to CA-8	0.195		2 turbines removed
10A	Replace	178.2	CA-3 to CA-8	0.260	3	Replaced group 10
11	Replace	182.1	AD-10 to AD-13	0.260	2	
12	Replace	168	J-3	0.040	1	
13	Replace	184	CF-6 and CF-7	0.130		Turbines removed
13A	Replace	183.2	CE-6 to CE-8	0.195	1	Replaced group 13
14	Replace	153	VK-15	0.065	1	
15	Replace	156	TV-1 to TV-5	0.325	3	
16	Replace	174	O-5, O-6, N-1 to N-3	0.160	2	1 turbine removed
17	Replace	161	D-1 to D-3	0.080	1	1 turbine removed
18	Replace	181.1	AC-17 to AC-20	0.260	3	
19	Replace	159	D-9 to D-12	0.160	2	
20	Replace	187	GC-17 to GC-18	0.130	1	
21	Replace	168	J-5 to J-6	0.080	1	
22	Replace	178.2	AA-1, CA-1, CA-2	0.195	2	
23	Replace	170	M-8 to M-10	0.120	1	
24	Replace	170	L-10 to L-12	0.120	1	
25	Replace	205	VK-1 to VK-2	0.130	1	
26	Replace	181.2	CC-11 to CC-13	0.195	2	
27	Replace	183.2	CE-1 to CE-3	0.195	2	
28	Replace	157	VTR-10 to VTR-11	0.130	1	
29	Replace	161	E-4 and E-5	0.080	1	
30	Replace	171	M-6, L-1, L-2	0.120	1	
1	Control	189	GB-2 to GB-5			
2	Control	203	WM-25, PO-27 to PO-32			1 turbine removed
3	Control	162	G-2 to G-6			
4	Control	162	F-7			
5	Control	162	G-11, G-12, F-12			
6	Control	182.2	CD-14, CD-15			
7	Control	171	N-9 to N-12			

8	Control	200	WM-3 to WM-10			1 turbine removed
9	Control	186	GB-9 to GB-14			1 turbine removed
10	Control	179	CA-12			
11	Control	182.1	AD-20 to AD-24			
12	Control	172	O-9 to O-12			
13	Control	181.2	CC-7 and CC-8			
14	Control	153	VK-7			
15	Control	175	O-1 and O-2			
16	Control	155	VK-24 to VK-26			
17	Control	161	D-6 to D-8, E-1			
18	Control	182.1	AD-15 to AD-17			
19	Control	171	N-4 to N-6			
20	Control	185	GA-1 and GA-2			
21	Control	164	F-1 and F-2			
22	Control	180.1	CB-1, AB-1, AB-2			
23	Control	169	I-1 to I-3			
24	Control	170	L-7 to L-9			
25	Control	153	VK-5 and VK-6			
26	Control	183.2	CE-6 to CE-8			
27	Control	183.2	CC-15 and CC-16			
28	Control	154	VK-22 and VK-23			
29	Control	160	E-6 and E-7			
30	Control	157	VTR-6			

Table 2. Comparison of rates of found fatalities projected to a two day search interval, based on four years of fatality monitoring at three sites composing the FloDesign study area.

		Detection rate, birds/MW/year		Detected birds predicted over 1 year	
Treatments	**MW**	**Mean**	**SE**	**Total**	**90% CI**
Non-study turbines	14.250	2.45	0.32		
Reference turbines	4.305	9.74	1.01	41.5	34.8-49.1
MEWT replacement	4.040	11.52	1.34	46.5	37.7-55.4

Table 3. Distribution of found fatalities AES SeaWest sites from April 1998 through September 2009, and compared to fatalities found after the first three rounds of searches in April 2012 at 8.78 MW of the same turbines, only 3.965 MW of which were operational during the recent searches. Fresh bird carcasses of native species found at sampled turbines have already numbered 10% of my annual projection, even though more than half the capacity of turbines was non-operational.

Species	Fatalities found at AES Seawest sites, 22.595 MW	Fatalities found at sampled SeaWest sites, 3.965 - 8.78 MW for operational and total sample, respectively	
	After 48 rounds over 8 years, 1998-2009	After 3 rounds of surveys in April 2012	After 3 rounds in April 2012, and dead within 10 days
Brown pelican	1		
Great blue heron	1		
Great egret	1		
Mallard	8		
Turkey vulture	2		
Golden eagle	5		
Red-tailed hawk	51	1	
Buteo	1		
Northern harrier	1		
Small raptor	1		
American kestrel	22		
Burrowing owl	58	1	
Barn owl	18	1	1
Great horned owl	5		
American avocet	2		
Killdeer	1		
Gull	1	1	1
California gull	1		
Common poorwill	1		
Northern flicker	1		
Rock pigeon	556	20	8
Mourning dove	44		
American crow	5		
Common raven	12		
Horned lark	6		
Loggerhead shrike	7		
European starling	68		
Pacific-slope flycatcher	1		
Say’s phoebe	1		
Northern mockingbird	1		
Mountain bluebird	1		
Cliff swallow	4		
Barn swallow	2		

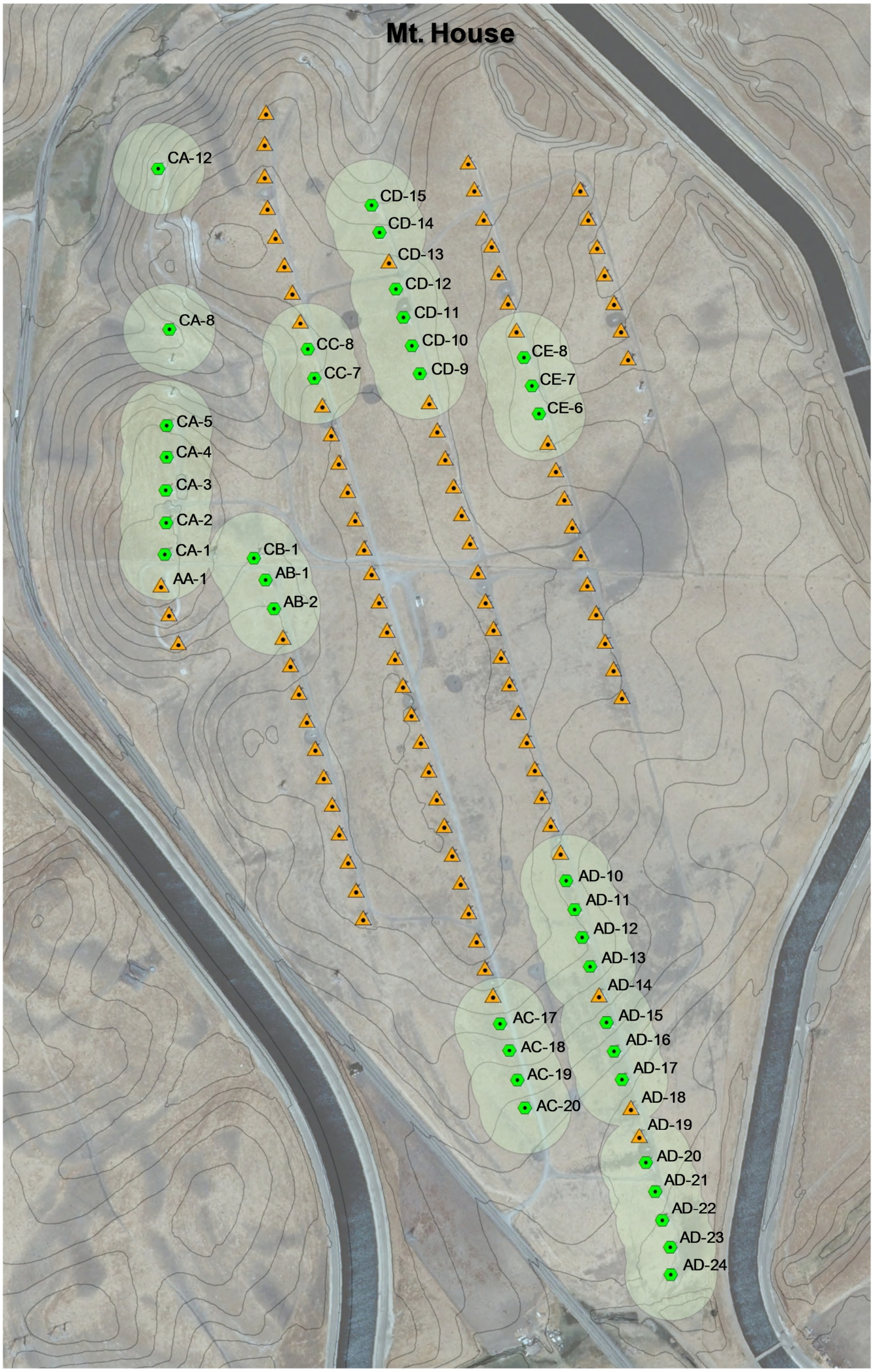
Blackbird	5		
Brewer's blackbird	5		
Brown-headed cowbird	1		
Tricolored blackbird	1		
Red-winged blackbird	8		
Western meadowlark	36	1	1
Golden-crowned sparrow	1		
Savanna sparrow	1		
Sparrow	1	1	1
House sparrow	1		
House finch	6		
Cockatiel	1		
Small bird	45	1	
Large bird	2		
Medium bird	24	1	
Mexican free-tail bat	2		
Western red bat	1		
Total birds	1,028	28	12
Total birds/MW/search	0.95/MW	1.06 to 2.35	---

Appendix 1. List of 157 wind turbines included in the avian safety test of the MEWT. An X under M-team identifies 99 turbines searched by both the M-team and Smallwood team.

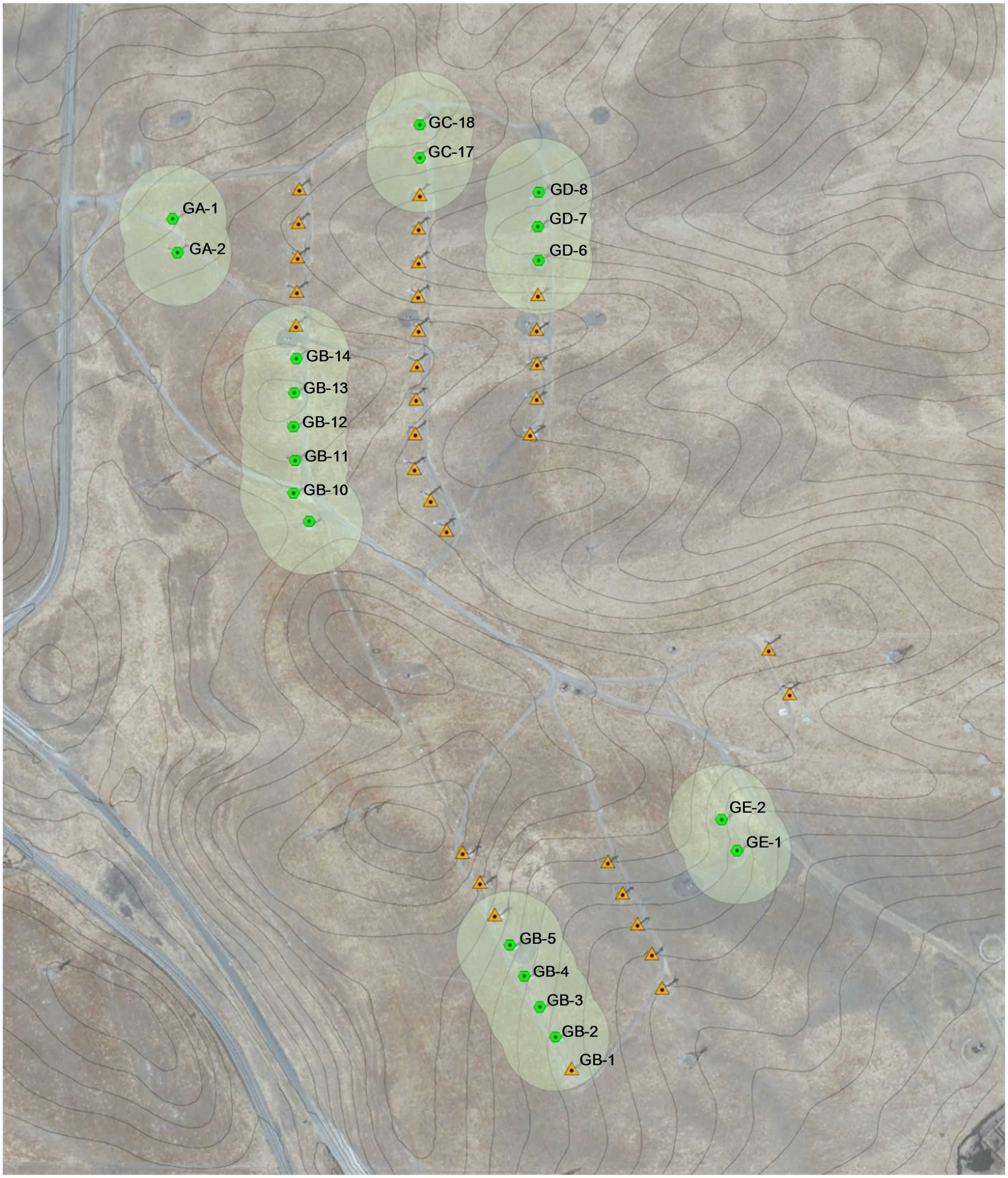
Taxvest at Mt House		Taxvest at Midway		Venture		Altech at Gate 11			
65 KW	**M-team**	**65 KW**	**M-team**	**65 KW**	**M-team**	**40 KW**	**M-team**	**40 KW**	**M-team**
CE-8		GE-1	X	WM-26		O-1	X	J-3	X
CE-7		GE-2	X	PO-33		O-6	X	J-5	X
CE-6		GB-1	X	PO-34		O-5	X	J-6	X
CD-15	X	GB-2	X	PO-35		N-1	X	F-1	X
CD-14	X	GB-3	X	PO-36		N-2	X	F-2	X
CD-13	X	GB-4	X	PO-37		N-3	X	F-3	X
CD-12	X	GB-5	X	PO-38		O-9	X	F-4	X
CD-11	X	GD-8	X	PO-27		O-10	X	F-5	X
CD-10	X	GD-7	X	PO-28		O-11	X	F-6	X
CD-9	X	GD-6	X	PO-29		O-12	X	G-11	
CC-8	X	GC-18	X	PO-31		N-4	X	G-12	
CC-7	X	GC-17	X	PO-32		N-5	X	F-12	
CA-12	X	GB-14	X	WM-14		N-6	X	F-11	
CA-8	X	GB-13	X	WM-15		N-8	X	F-10	
CA-5	X	GB-12	X	WM-17		N-9	X	F-9	
CA-4	X	GB-11	X	WM-19		N-10	X	F-8	
CA-3	X	GB-10	X	WM-21		N-11	X	F-7	
CA-2	X	GA-1	X	WM-3		N-12	X		
CA-1	X	GA-2	X	WM-5		K-3	X		
CB-1	X			WM-6		K-4	X		
AA-1		**Swamp**		WM-7		K-5	X		
AB-1		TV-1		WM-8		K-6	X		
AB-2		TV-2		WM-9		H-6	X		
AD-10	X	TV-3		WM-10		H-5	X		
AD-11	X	TV-4		WM-11		G-2			
AD-12	X	TV-5		WM-1		G-3			
AD-13	X			WM-2		G-4			
AD-14	X	**Viking**				G-5			
AD-15	X	VK-24				G-6			
AD-16	X	VK-25				D-2	X		
AD-17	X	VK-26				D-3	X		
AD-18	X	VK-7				D-4	X		
AD-19	X	VK-8				D-5	X		
AD-20	X	VK-14				D-6	X		
AD-21	X	VK-15				D-7	X		
AD-22	X					D-8	X		
AD-23	X					D-9	X		
AD-24	X					D-10	X		
AC-17	X					D-11	X		
AC-18	X					D-12	X		

AC-19	X								
AC-20	X								

Appendix 2. Layout of the existing old-generation wind turbines in the study.


Mt. House
CA-12
CD-15
CD-14
CD-13
CD-12
CD-11
CD-10
CD-9
CA-8
CC-8
CC-7
CE-8
CE-7
CE-6
CA-5
CA-4
CA-3
CA-2
CA-1
AA-1
CB-1
AB-1
AB-2
AD-10
AD-11
AD-12
AD-13
AD-14
AD-15
AD-16
AD-17
AD-18
AD-19
AD-20
AD-21
AD-22
AD-23
AD-24
AC-17
AC-18
AC-19
AC-20

Midway


GC-18
GC-17
GD-8
GD-7
GD-6
GA-1
GA-2
GB-14
GB-13
GB-12
GB-11
GB-10
GE-2
GE-1
GB-5
GB-4
GB-3
GB-2
GB-1

Gate 11 and Venture

Appendix 3. Example behavior survey data sheet.

Date ________ Start time ________ Investigator _______

1

	Temperature	Max wind speed	Avg wind speed	Wind direction	% overcast	Note
Start						
End						

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z