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To: Renee Culver
From: William Warren-Hicks
Subject: Summary of data analysis issues

The following narrative provides an overview of selected data analysis issues that should be addressed prior to selection of the final statistical and analytical methods used to infer species-specific Altamont-wide mortality. The following summary is brief, and it is intended to simply state the issue(s) without providing great detail on approaches that I would encourage and support.

Comments on the current statistical approach

1. The current approach used by the monitoring team (MT) is based on a single equation. As implemented, the method infers that each MW possibly produced (rated capacity) throughout the Altamont has the same probability of avian mortality (average mortality per MW times the maximum possible Altamont-wide MW produced), without consideration of the concept of sampling unit, sample size, inclusion probabilities for individual samples, covariables or weights, representative nature of the actual sampling units, or the assumptions inherent in the original survey design. The report provides no documentation or discussion of these issues.
2. The current approach assumes that the sampling error (a function of observer bias and scavenging efficiency) is consistent across the Altamont. No investigations of alternative statistical models and approaches leading to insights into the uncertainty in the number of found birds are presented (although, this may change with the publication of the new mortality study). The relative uncertainty associated with the adjusted mortality numbers is not addressed or presented.
3. The underlying assumptions of the estimating equation are not discussed, provided, or tested using data from the current study. In fact, equations for estimating the reported variance of the mortality estimates are not provided (although we have requested that they be included in the report). Note that the number of sampling units and the type of

survey (stratified block, completely random, cluster sampling, etc.) will impact the calculation of the variance and mean mortality.

4. Since the MT document does not address the representative nature of the data from which the inference is drawn, I am left to assume that the data were collected using a formal survey design. Since standard methods for estimating strata means were not addressed in the report, I can only assume that the survey design was a completely randomized design. In this case, sampling units would have been randomly drawn from a properly constructed list frame. The report does not explicitly address the sampling unit in the survey design, the representative nature of the sampling units, the construction of the list frame, and the relationship between the survey design and the selected analytical approach and equations. This confusion negates the credibility of the report.
5. Note that there is a lack of exploratory data analysis results in the MT report. Exploratory analyses and graphics could provide insights into methods and approaches for estimating the Altamont-wide mortality. For example, the current approach assumes that mortality is a function of the maximum possible MW generated by any turbine. An analysis of this assumption is required to provide credibility to the approach.
6. Note that I have repeatedly objected to the CEC estimating equation based on theoretical grounds (see NextEra comments on the MT report). And, please note that we were recently awarded a CEC grant to evaluate the merits of the equation used in the MT report, as well as other approaches for generating estimates of sampling error (of which many exist in the current literature, although not discussed in the MT report). At a minimum, alternative approaches for estimating the Altamont-wide mortality should be explored.

Going forward

In a very broad sense, one could analyze the current study data using the basic approaches and methods inherent in survey statistics, or one could generate a model which estimates mortality based on available covariables in the data set. Good practice in survey design dictates that the estimating equations follow from the survey design, and that the survey design itself be created and implemented properly. For example, if random samples were generated within-strata, and the selected sampling units are representative of the non-measured strata-specific sampling units, then classic estimating equations resulting in the strata mean could be implemented. There are standard methods for collapsing across strata, and standard methods for estimating the population mean. In all of these steps, the inclusion probability associated with each sampling unit must be known, and selected weighting approaches are used to adjust for issues that generally arise over the course of the survey.

In general, modelers are less tied to the structure of the survey design (although the concept of a representative sample still holds and is the basis for statistical inference). The data, if reasonably collected, provide an information basis for model building and developing methods for statistical inference.

Below I discuss some issues that must be addressed using either approach.

If we are to be survey statisticians:

Based on the formal documents I have been able to find¹ there is at best confusion concerning the approaches that were used to establish the current survey design. For example, while it has been claimed that the sampling unit is a turbine string, and that the turbine strings were randomly selected, yet there is no mention of this approach in the 2005 document. The 2005 document claims that blocks (which I believe are the same as our plots) were randomly selected within 2 strata; turbine size class (there are 3 size classes) and geographic location (North and South) [see Section 3 of the 2005 document]. A list frame (a list of all blocks in the Altamont) of blocks (plots) was created and a random sample of blocks was taken. Therefore, it seems that the originators of the survey design expected that the randomly selected blocks would be representative of strata-specific mortality, not a string or turbine. Strings and/or turbines would be sub-units, similar to a cluster survey design. Also, some strata were censused. If true, data from the censused strata should not influence estimates generated from other strata as part of the Altamont-wide estimation process.

The following issues should be addressed should the MT continue to analyze the data in a manner that is consistent with the survey design:

1. The concept of representative data must be addressed. This issue has implications for the estimation methods, as well as implications for deriving statistical inference. If indeed strata were censused, then this finding must be addressed in the final statistical methods.
2. The relationship between the survey design and estimation methods must be addressed (I list only a few of the underlying issues above).
3. Inclusion probabilities and/or weighting functions for the strata-specific estimation methods must be addressed.
4. I think there is general agreement that the sampling units (whatever they may be) are not replicates. Therefore, unless the strata were censused, approaches for weighting/scaling the sampling units must be addressed to ensure that the estimating equations result in a non-biased estimate of the Altamont-wide mortality.
5. Sampling effort is not addressed in the current MT report. Since the number of times a particular sampling unit was searched is variable, and changes between years, a method

¹ Draft Sample Design, Field Methods, and Statistical Methods For APWRA Management Plan Research and Monitoring. November 2005, Revised Draft.

for dealing with inconsistent sampling effort must be addressed.

6. Methods for dealing with zero finds on a search-level basis must be addressed. For example, suppose a block was searched 40 times over 4 years and no birds are found. How many times does the block need to be searched before the sampling error is minimal, and one begins to believe that the block represents a true zero over the course of the study? In the current MT method, the number of zero finds is not addressed or accounted for in the estimation methods. And, if the probability of a true zero for any sampling unit is high, how do the estimating equations take this into account when calculating the Altamont-wide mortality? The current approach disregards this obvious and practical issue.
7. There is a general lack of uncertainty analysis in the current approach. Going forward, variance components (sampling error, scavenging model error, error in observer bias rates, etc.) will need to be explicitly computed and documented. A comparison of the variance components is required to scientifically document those areas where additional information could lead to differing results.

If we are to be modelers:

8. For the above list, items 1 (representative data), 5 (sampling effort), 6 (zero finds), and 7 (uncertainty analysis) continue to be issues that must be addressed.
9. Representative data is a very important issue for model building and forecasting. For example, if indeed a particular turbine size class has been censused (or nearly so), then the population of interest (for which mortality predictions are generated) must be adjusted appropriately. Suppose mortality is a function of geographic area (or other variables) then these findings will have implications on which populations the model is used to generate mortality estimates. And, such associations may require that several models be generated, reflecting the variability in mortality and associated covariables in the Altamont-wide data set.
10. Relationships between mortality and characteristics of the sampling unit (number of sub-units or turbines, area searched, topographic features, search effort, etc.) must be addressed in order to build a model with good predictive ability.
11. Methods for adjusting the number of found birds using probability-based methods will need to be addressed. We have begun to create models in which the sampling error rate can be determined from the actual data. These models are directly tied to the approaches for adjusting the mortality estimates for zero finds.

In my recent conversations with experts in survey design, I have been advised that the survey design issues and associated approaches for data analysis may not be addressable. So, at this point, NextEra is planning the following near-term activities:

- Exploratory analysis of the final data set
- Evaluation of the possibility of using estimation techniques predicated on the underlying survey design
- Development of methods for estimating sampling error directly from the current study data set for selected species
- Development of probability-based approaches for dealing with zero finds.
- Development of models for estimating mortality at those sampling units yet to be surveyed
- Development of probability-based approaches for evaluating seasonal shutdown.