

Analyses of Shutdown Effect
A reference guide to statistical output in M16 documents

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Guide to M16 – Analysis of shutdown effect

Analysis approach. Only the data related to winter shutdown was used. This includes just the months from November through March (March data can contain fatalities that occurred in February). The M16 document contains output to Poisson models fitted according to the description in document P55.

Page titles. There are 32 such models which vary by species or species group, basis of inference, scavenging rates, and sampling unit. The different models are indicated by the title on each page. For example, the first two pages have the title “Model AMKE fatalities per TURBINE, using SM raptor scavenging rates. Sampling unit is TURBINE”. All titles on every page are the same except for the words in capital letters. This particular title means that the tables on these two pages refer to analysis of mean fatalities of *American Kestrels*, per turbine, while accounting for scavenging rates on small raptors, using data records broken down by turbine-survey. Over the subsequent pages of this document, there are codes for 8 different sets of analyses categorized by raptor species or species groups: AMKE (American Kestrels), BUOW (Burrowing Owls), GOEA (Golden Eagles), RTHA (Red-tailed Hawks), AMKEBUOW (AMKE and BUOW combined, i.e., small raptors), GOEARTH (GOEA and RTHA combined, i.e. large raptors), and COMBINED (all four focal raptor species). The COMBINED analysis was repeated twice using two different formulas for scavenging rates – one for small raptors and one for large raptors. Each of the sets of analyses has four versions of models. There are two different bases of inferences: one on a per turbine basis and the other on a per MW capacity basis. And the data records were broken into two different sampling units: one as turbine and the other as string.

Output tables. Each model described in document M16 contains several tables, but the pertinent table in each analysis is the two-row table subtitled, for example, “*Mean Fatalities per TURBINE (or MW) per Year (extrapolated from wintertime rate) and Shutdown Effect in terms of percent change with t-test and p-value.*” The pertinent information in this table is the bottom row, where the 1st column (“parameter”) is listed as “Shutdown Effect.”¹ Columns are described as follows:

1. Estimate and StandardError: The estimated percent change in the rate of mean fatalities when the turbines are shutdown, and its standard error. Negative values of the estimate indicate percent reductions, and positive values indicate percent increases.

¹ The first row represents estimated mean fatalities per turbine per year. However, this was crudely derived by extrapolating the mean fatalities per turbine per day using just the winter data. See M16b for better estimates of the yearly rates using all seasons of data.

For example, in the first analysis on page 2 of M16, the estimated rate of kestrel fatalities per turbine is 76.0% less during shutdown compared to during operation, with a standard error of 15.7%. Whether the shutdown is one month or two months in winter, the percent reduction in fatalities is predicted to be 76% less.

2. DF, tValue, and Probt:

- DF. Degrees of freedom correspond to the sample size.
- tValue. T-test value. This value can be positive or negative. The more this value deviates from zero, then the more significant the effect.
- Probt. T-test p-value. This value ranges from 0 to 1. The smaller this value, then the more significant the effect. Values < 0.05 are widely considered significant. Values < 0.10 but > 0.05 are often considered significant depending on circumstances.

For the analysis on page 2 of M16, there were over 15000 turbine-survey visits, and the estimated reduction is highly significant (p -value < 0.0001).

3. Alpha, Lower, and Upper: These columns relate to the confidence interval.

- Alpha. This value sets the confidence level, which is defined as 1-alpha. By default, the software is set at 0.05, and calculates 95% confidence intervals.
- Lower and Upper. The bounds of the confidence interval. Confidence intervals that do not overlap zero (i.e., span a completely positive range or a completely negative range) are typically interpreted as statistically significant. Confidence intervals that widely flank zero are typically interpreted as inconclusive, as the effect could be positive, negative, or zero. Since confidence intervals are calculated from approximation formulas, then the lower and upper endpoints should be interpreted with caution, especially when one of the endpoints is near zero.

For the analysis on page 2 of M16, we are 95% confident that the fatality reduction based on the survey sample can be generalized to an Altamont-wide reduction that is actually between 45% and 100% reduction.²

² One of the interval endpoints is actually listed as a 106.71% reduction. Reductions of >100% are not possible, and the estimate should be regarded as an approximation of the confidence interval.

**M16a – Analysis of shutdown effect using filtered data
(12 Sep 2007)**

This was the M16 analysis repeated on filtered data provided by Brian Karas during the Sep 12-13 meeting. The filtered data was intended to include only fatalities that could reasonably be judged as to its cause of death and ability to classify time of death occurring in shutdown or operating period. This analysis was not informative as there were very few fatalities in the filtered data.

I proceeded with all other versions of M16 by including the use of all fatalities in the dataset. The reason for this is that the analysis can still test for a shutdown effect even in the presence of background fatality rates that are unrelated to wind turbines, and the model is designed to discern the shutdown effect even though individual fatalities are not classified to a particular shutdown or operating period.

**M16b – Analysis of shutdown effect including rates of annual change in fatalities
(20 Sep 2007 version)**

Analysis approach. Same as M16 except data for all seasons were used in order to further estimate yearly fatality rates, and impact of winter shutdown on these rates.

Page titles. Same as M16 except the four focal raptor species were integrated into one model. The integrated model still provides separate estimates for each species. There are four versions of the integrated model. Half of models estimate mean fatalities on a per turbine and half on a per MW basis. Half of models use turbine as sampling unit and half use turbine string as the sampling unit.

Output tables. The table columns are expanded from those in M16. This table has additional parameters (under the “Label” column). The current (20Sep2007) version has more estimates than the previous (13Sep2007) version. Estimates #1-48 are analogous to the estimates in the previous version. Estimates #49-62 are new to the 20Sep2007 version and represent the overall reduction across combined species, based on estimates from #1-48 in which the integrated model produced fatality rates and shutdown effects patterns separately for each species. A potentially useful feature of the integrated model is the capability to estimate standard errors and confidence intervals of the overall reduction across species.

See below for list of all estimates. All estimates labeled as “Mean” are fatality rates and all estimates labeled as “Shutdown Effect” (or “Shut Effect”) are proportion reductions (calculated as the difference between means with and without shutdown, divided by mean without shutdown). Estimates are grouped by species (AMKE, BUOW, GOEA, RTHA), subtotal of three species excluding BUOW (i.e., AMKE+GOEA+RTHA), and total of all four species:

List of estimates in 20 Sep 2007 version:

- 1) Mean AMKE/Turbine(or MW)/Day (Winter)
- 2) Mean AMKE/Turbine(or MW)/Day (Spring)
- 3) Mean AMKE/Turbine(or MW)/Day (Summer)
- 4) Mean AMKE/Turbine(or MW)/Day (Autumn)
- 5) Mean AMKE/Turbine(or MW)/Yr w/o Shutdown
- 6) Shutdown Effect for AMKE
- 7) Mean AMKE/Turbine(or MW)/Yr w/ 2-mo Shut
- 8) 2-mo Shutdown Effect on AMKE/Turbine(or MW)/Yr
- 9) Mean AMKE/Turbine(or MW)/Yr w/ 3-mo Shut
- 10) 3-mo Shutdown Effect on AMKE/Turbine(or MW)/Yr
- 11) Mean AMKE/Turbine(or MW)/Yr w/ 4-mo Shut
- 12) 4-mo Shutdown Effect on AMKE/Turbine(or MW)/Yr

- 13) Mean BUOW/Turbine(or MW)/Day (Winter)
- 14) Mean BUOW/Turbine(or MW)/Day (Spring)
- 15) Mean BUOW/Turbine(or MW)/Day (Summer)
- 16) Mean BUOW/Turbine(or MW)/Day (Autumn)
- 17) Mean BUOW/Turbine(or MW)/Yr w/o Shutdown
- 18) Shutdown Effect for BUOW
- 19) MeanBUOW/Turbine(or MW)/Yr w/ 2-mo Shut
- 20) 2-mo Shut.Effect on BUOW/Turbine(or MW)/Yr
- 21) MeanBUOW/Turbine(or MW)/Yr w/ 3-mo Shut
- 22) 3-mo Shut.Effect on BUOW/Turbine(or MW)/Yr
- 23) MeanBUOW/Turbine(or MW)/Yr w/ 4-mo Shut
- 24) 4-mo Shut.Effect on BUOW/Turbine(or MW)/Yr

- 25) Mean GOEA/Turbine(or MW)/Day (Winter)
- 26) Mean GOEA/Turbine(or MW)/Day (Spring)
- 27) Mean GOEA/Turbine(or MW)/Day (Summer)
- 28) Mean GOEA/Turbine(or MW)/Day (Autumn)
- 29) Mean GOEA/Turbine(or MW)/Yr w/o Shutdown
- 30) Shutdown Effect for GOEA
- 31) MeanGOEA/Turbine(or MW)/Yr w/ 2-mo Shut
- 32) 2-mo Shut.Effect on GOEA/Turbine(or MW)/Yr
- 33) MeanGOEA/Turbine(or MW)/Yr w/ 3-mo Shut
- 34) 3-mo Shut.Effect on GOEA/Turbine(or MW)/Yr
- 35) MeanGOEA/Turbine(or MW)/Yr w/ 4-mo Shut
- 36) 4-mo Shut.Effect on GOEA/Turbine(or MW)/Yr

- 37) Mean RTHA/Turbine(or MW)/Day (Winter)
- 38) Mean RTHA/Turbine(or MW)/Day (Spring)
- 39) Mean RTHA/Turbine(or MW)/Day (Summer)
- 40) Mean RTHA/Turbine(or MW)/Day (Autumn)
- 41) Mean RTHA/Turbine(or MW)/Yr w/o Shutdown

- 42) Shutdown Effect for RTHA
- 43) MeanRTHA/Turbine(or MW)/Yr w/ 2-mo Shut
- 44) 2-mo Shut.Effect on RTHA/Turbine(or MW)/Yr
- 45) MeanRTHA/Turbine(or MW)/Yr w/ 3-mo Shut
- 46) 3-mo Shut.Effect on RTHA/Turbine(or MW)/Yr
- 47) MeanRTHA/Turbine(or MW)/Yr w/ 4-mo Shut
- 48) 4-mo Shut.Effect on RTHA/Turbine(or MW)/Yr

- 49) Mean Subtotal(noBUOW)/Turbine(or MW)/Yr w/o Shutdown
- 50) Mean Subtotal(noBUOW)/Turbine(or MW)/Yr w/ 2-mo Shut
- 51) Mean Subtotal(noBUOW)/Turbine(or MW)/Yr w/ 3-mo Shut
- 52) Mean Subtotal(noBUOW)/Turbine(or MW)/Yr w/ 4-mo Shut
- 53) 2-mo Shut.Effect on Subtotal(noBUOW)/Turbine(or MW)/Yr
- 54) 3-mo Shut.Effect on Subtotal(noBUOW)/Turbine(or MW)/Yr
- 55) 4-mo Shut.Effect on Subtotal(noBUOW)/Turbine(or MW)/Yr

- 56) Mean Total4/Turbine(or MW)/Yr w/o Shutdown
- 57) Mean Total4/Turbine(or MW)/Yr w/ 2-mo Shut
- 58) Mean Total4/Turbine(or MW)/Yr w/ 3-mo Shut
- 59) Mean Total4/Turbine(or MW)/Yr w/ 4-mo Shut
- 60) 2-mo Shut.Effect on Total4/Turbine(or MW)/Yr
- 61) 3-mo Shut.Effect on Total4/Turbine(or MW)/Yr
- 62) 4-mo Shut.Effect on Total4/Turbine(or MW)/Yr

**M16b – Analysis of shutdown effect including rates of annual change in fatalities
(13 Sep 2007 version)**

This analysis has been superceded by M16b (20 Sep 2007), however most of the description below still applies and has been retained for reference.

Analysis approach. Same as M16 except data for all seasons were used in order to further estimate yearly fatality rates, and impact of winter shutdown on these rates.

Page titles. Same as M16 except only four models were analyzed, one for each of the four separate focal raptor species.

Output tables. The table columns are similar to those in M16. This table has additional parameters (under the “Label” column):

1. Mean/turbine/day (Winter, Spring, Autumn, Summer): Mean fatalities per turbine per day, for each of the four seasons.
2. Autumn vs. winter daily rate: Difference between autumn and winter.
3. Mean/turbine/yr without shutdown: Mean fatalities per turbine per year, for turbines operating all year.
4. Shutdown effect: Same meaning as in M16 (item #1 on previous page). Percent change in fatality rate per turbine when turbine is shutdown compared to operating.
5. Mean/turbine/yr with 4 month shutdown: Projected mean fatalities per turbine per year, for turbines shutdown 4 months in winter (Nov-Feb) and operating the remaining 8 months.
6. Proportion change in mean/turbine/yr with 4 month shutdown: The calculation using the means from #3 and #5 is: $(\#5 - \#3)/\#3$.
7. Mean/turbine/yr with 3 month shutdown: Projected mean fatalities per turbine per year, for turbines shutdown 3 months in winter (90 days) and operating the remaining 9 months.
8. Proportion change in mean/turbine/yr with 3 month shutdown: The calculation using the means from #3 and #7 is: $(\#7 - \#3)/\#3$.

**M16c – Analysis of separate shutdown and lockdown effects
(14 Sep 2007)**

This version attempted to advance the model of M16b by incorporating and estimating a lockdown effect in addition to a shutdown effect. This analysis is problematic, and the following versions M16d and M16e should be used instead. M16d is an analysis of shutdown effect for turbines with lockable blades, and M16e is an analysis of shutdown effect for turbines with feathering blades.

**M16d – Analysis of shutdown effect on lockable turbines
M16e – Analysis of shutdown effect on feathering turbines
(20 Sep 2007)**

For the feathering turbines (M16e), I applied the methods of M16b (20 Sep 2007) on the feathering data in order to integrate the analyses across all species. The seasonal fatality rates and shutdown effects are still estimated separately for each species, but the analysis is done in one integrated model so that an overall fatality rate and shutdown effect can be estimated with standard errors and confidence intervals. For the lockable turbines (M16d), there were problems using the integrated model to obtain estimates for species with low counts of fatalities. Therefore the M16d analysis on lockable turbines is still based on separate models for different species.

Both analyses have been updated to include per-MW, as well as per-turbine, estimates. Also, the analysis is repeated with turbine and turbine string as sampling units.

**M16d – Analysis of shutdown effect on lockable turbines
M16e – Analysis of shutdown effect on feathering turbines
(17 Sep 2007)**

This analysis has been superseded by M16d and M16e (21 Sep 2007).

I applied the methods of the M16b (13 Sep 2007) analysis of shutdown effect on only the lockable turbines and only the feathering turbines. These are based on estimates of fatalities modeled separately by species.