**Introduction**

Congress has determined that herds of wild horses and burros are not only a part of the pioneer heritage but have become integral to the ecosystems in which they exist. Because of this, Congress has mandated that these animals be protected and properly managed to protect the numbers and well-being of the herds.

The herds are managed by the Bureau of Land Management, and managed to keep herd numbers at levels that will allow the animals to thrive, but prevent overgrazing. These levels have been termed Appropriate Management Levels (AMLs).

As part of these management efforts, animals are periodically gathered in an area to undergo various procedures such as sterilization, marking, treatments, and others. Excess numbers of animals are auctioned to the public for adoption.

Our intention is to explore the effect of various factors on the successful management of a herd area, and attempt to predict the magnitude of the effects of these chosen predictors. Data collected by the BLM for the fiscal year of 2009 was used for the analysis.

Cases considered were the herd areas managed by the BLM, and success was considered to have occurred when the number of animals was below the AML. Cases where zero animals resided in a managed area were thrown out when considering the years since an animal gathering as a predictor of success, as they would not be representative because they are not a true success because the herds were not preserved in that area, nor would a gather ever be conducted to round up zero animals.

**Methods**

Analysis was conducted using a simple chi-squared independence test, odds ratios to analyze conditional vs. marginal associations in partial tables, as well as logistic regression, both multiple and single. A “Hypothetical” situation with doctored data was also used to more easily demonstrate knowledge of the topics covered in this course. Analysis was performed using the open-ware R Statistical Analysis Package.

**The Data**

The data was taken from the Fiscal Year 2009 BLM Wild Horse and Burro Management Data. The data was actually displayed by state, but to simplify analysis, data for all states other than Nevada was grouped together as “Other Western States.” This generated two categories with respect to state, with similar numbers of observations in each.

The proportion of success displayed below was only calculated for the total numbers, and not the data as it is distributed by state. It should be noted that 50 was (somewhat) arbitrarily chosen to represent the number of years since the last gather in areas where a gather had not been recorded, implying that it has been a long time, if ever, since the last gather had been conducted.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | NV | | Other Western States | | Total | |  |
| Years Since Last Gather | Number of Areas | AML Success | Number of Areas | AML Success | Number of Areas | AML Success | Proportion |
| 4 | 5 | 2 | 11 | 6 | 16 | 8 | 0.50 |
| 5 | 13 | 6 | 23 | 14 | 36 | 20 | 0.56 |
| 6 | 15 | 5 | 15 | 6 | 30 | 11 | 0.37 |
| 7 | 13 | 3 | 12 | 4 | 25 | 7 | 0.28 |
| 8 | 11 | 2 | 11 | 0 | 22 | 2 | 0.09 |
| 9 | 3 | 2 | 10 | 0 | 13 | 2 | 0.15 |
| 10 | 2 | 1 | 1 | 1 | 3 | 2 | 0.67 |
| 11 | 1 | 1 | 2 | 0 | 3 | 1 | 0.33 |
| 12 | 0 | 0 | 2 | 1 | 2 | 1 | 0.50 |
| 13 | 2 | 1 | 0 | 0 | 2 | 1 | 0.50 |
| 14 | 1 | 0 | 0 | 0 | 1 | 0 | 0.00 |
| 16 | 4 | 2 | 0 | 0 | 4 | 2 | 0.50 |
| 17 | 0 | 0 | 1 | 1 | 1 | 1 | 1.00 |
| 24 | 0 | 0 | 2 | 0 | 2 | 0 | 0.00 |
| 28 | 0 | 0 | 1 | 1 | 1 | 1 | 1.00 |
| 31 | 1 | 1 | 0 | 0 | 1 | 1 | 1.00 |
| 50\* | 8 | 1 | 1 | 1 | 9 | 2 | 0.22 |
| Total | 79 | 27 | 92 | 35 | 171 | 62 |  |

Data Table 1

This is a three-way contingency table relating the data by state, whether or not the area recently experienced a gather, and whether or not the area is successfully managed:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  |  | Successful Management | Unsuccessful Management | Proportion Successful |
| Nevada | Recently Gather (4-6 years since) | 13 | 20 | 0.394 |
| Non- Recent ( >6 years since) | 14 | 22 | 0.389 |
| Other Western States | Recently Gather (4-6 years since) | 26 | 23 | 0.531 |
| Non- Recent ( >6 years since) | 9 | 34 | 0.209 |
| Total | Recently Gather (4-6 years since) | 39 | 43 | 0.476 |
| Non- Recent ( >6 years since) | 23 | 56 | 0.291 |

Data Table 2

Also included is a graphical summary of the data. In any following graphical representations, Nevada data points will appear in blue with silver fitted lines, and the Other Western State data points will appear in red with red fitted lines. Fitted lines applying to both state categories appear in green:



Graphical Data Summary 1

**Tests For Independence**

Using a chi-squared test, the hypothesis that the proportions of success and failure were equal was tested. This test was performed using the data from Data Table 1 to construct a 2x17 table that included total numbers of management successes and failures which can be extracted from the “Total” section of Data Table 1. The test was two tailed.

|  |  |  |  |
| --- | --- | --- | --- |
| H0: | = | HA: | ≠ |
| χ2 -test Statistic: | 26.937 | P-Value: | 0.042 |
| Degrees of Freedom: | 16 | Confidence level to reject H0: | 95% |

This test suggests that the data was likely dependent (there is some relationship between time since gathering and successful management), we can reject H0 with 95% confidence. We can continue with other methods of analysis, hopefully to define the relationship between successful area management and other factors.

To test the independence of which state an area was in, and the successful management of said area, a Fisher Exact Test was used. A 2x2 table was constructed for this:

**Odds Ratios**

To demonstrate the use of odds ratios, analysis to check for confounds and Simpson’s Paradox will be performed. From the 3-way contingency table shown in the data section, it would appear that the areas that have recently undergone gathers are more likely to be successfully managed. Using conditional odds ratios, conditional inference can be used to investigate the truth using the following partial tables.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Nevada | Other Western States | Total |
| Successfully Managed | 27 | 35 | 62 |
| Unsuccessfully Managed | 52 | 57 | 109 |
| Total | 79 | 92 | 171 |

The table above controls for how recently gatherings were conducted and summarize the data in terms of the state the area lies in and the success status of the management of the area. The odds ratio is:

This demonstrates to us that the odds of an area in Nevada being successfully managed are less that of those located in one of the other western states, when controlling for when gathers were conducted. This is not particularly novel because it was unclear whether or not higher rates of success were found in Nevada or not.

|  |  |  |  |
| --- | --- | --- | --- |
|  | 4-6 Years Since Gathering | >6 Years Since Gathering | Total |
| Successfully Managed | 39 | 55 | 94 |
| Unsuccessfully Managed | 43 | 34 | 77 |
| Total | 82 | 89 | 171 |

Above is a contingency table comparing areas that have “recently” undergone a gather and those that haven’t in terms of success or failure, which controls for the state the area is found in. We find that the odds ratio is calculated as follows:

demonstrating that the odds of an area being successfully managed for areas with a recent gathering are roughly half that of those who have not had a gathering for some time when controlling for the state the area is found in. This result contradicts our previous assumptions from the marginal inference of the 3-way table. Simpson’s Paradox has arisen. Further investigation is required.

When we compare the state an area is in with the time since the last gathering, the result is the following:

|  |  |  |  |
| --- | --- | --- | --- |
|  | Nevada | Other Western States | Total |
| 4-6 Years Since Last Gather | 33 | 49 | 82 |
| >6 Years Since Last Gather | 46 | 43 | 89 |
| Total | 79 | 92 | 171 |

We find that the odds of an area being subjected to a gathering recently are less for Nevada than in Other States when controlling for success. Using these conditional inferences, we can see that the truth can be summarized in the following way: Areas that have recently had the animals gathered and areas in Nevada are less likely to be successful, however, areas that have recently experienced a gather are less likely to appear in Nevada. Because of this, Nevada’s lack of success masks (or confounds) the reality that areas that have not recently experienced a gather are more likely to experience successful management.

**Logistic Regression**

*Simple Logistic Regression*

Time Since the Last Gather & The State an Area is Located In

Using logistic regression, it is possible to estimate the likelihood of an event using conditional probabilities. In general, the form of logistic regression is:

Often, when a predictor is binary, it is noted by including a second α parameter, rather than a βX term.

Probabilities can then be predicted for given values using:

The median effective level of a predictor variable in logistic regression, which would indicate the value of the predictor variable that results in a probability of success equal to that of failure (i.e. 0.5 and 0.5). This can be found by the following:

The Models

In these models, X will represent the number of years since the last gather, and different levels of state will be addressed with either the presence or absence of γ.

The First Model: Using only time since the last gather as a predictor



Figure 1: The first logistic model projected onto a plot of the data. While the data is plotted in a manner that differentiates Nevada areas from areas in other states, the model does not account for such a difference.

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Value | Std. Error | P-Value |
| α | -.42665 | .29077 | .155 |
| β | -.01457 | .02224 | .518 |
| AIC: | 89.30 | Model P-Value: | 0.8904 |

The second model attempted to predict area management success by whether or not the area was located in Nevada or another western state:

Nevada Areas:

Areas in Other States:



Figure 2: The second logistic model projected onto a plot of the data. This model only utilizes two intercept parameters and no slope coefficient. While this model does account for what state the area is located in, it does not account for the time since the last gathering. The silver line represents the effect of the area being located in Nevada; the red line indicates the effects of other states.

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Value | Std. Error | P-Value |
| α | -.6554 | .3050 | .042 |
| αOtherState (γ) | .1667 | .4115 | .687 |
| AIC: | 89.81 | Model P-Value: | 0.9259 |

*Multiple Logistic Regression*

The third model attempts to predict area management success by both the location of the area and the time in years since the last gathering:

Other States:

Nevada:



Figure 3: The third logistic model projected onto a plot of the data. This model accounts for both the different state levels and the effects of different amounts of time since the last gathering in an area. Two intercepts are used, and two slope coefficients are used. Again, the silver line is for areas in Nevada, red for other states.

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Estimate | Std. Error | P-Value |
| α | -0.43638 | .43221 | .324 |
| αOtherState (γ) | -0.09960 | .63501 | .877 |
| β | -0.01929 | .02745 | .490 |
| βOtherState | 0.02552 | .05464 | .645 |
| AIC: | 92.80 | Model P-Value: | 0.9988 |

Finally, for knowledge demonstration purposes, we will now consider a hypothetical situation that uses some manipulated data. It should be clear that these results are not valid, as the data is false. The data used was created by removing the 17, 28, and 31 year data points, making it so that “other” states have zero successes for the “no gather” areas and successes in Nevada for the 11 years since the last gather and for “other” states 10 years since the last gather data points were changed to failures. This was done to produce better fits for more easily understood models and computations:

Other States:

Nevada:



Figure 4: The “hypothetical” logistic model projected onto a plot of the manipulated data. This model accounts for both the different state levels and the effects of different amounts of time since the last gathering in an area. Two intercepts are used, and two slope coefficients are used. Again, the silver line is for areas in Nevada, red for other states.

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Value | Std. Error | P-Value |
| α | -0.45700 | 0.33688 | 0.175 |
| αOtherState (γ) | 3.4035 | 1.06943 | 1.46e-03 |
| β | -0.02736 | 0.02374 | 0.249 |
| βOtherState | -0.54483 | 0.16903 | 1.27e-03 |
| AIC: | 63.621 | Residual Deviance: | 20.135 |

The hypothetical model is good to make some sample predictions. For example if we wanted to predict the rates of successful management for each area, for performing gathers every five years:

Nevada: =

Other States:

Other predictions could be made as well.

This hypothetical model also presents us with an opportunity to evaluate a median effective level that would have some relevance to the data/problem. Using the model as it applies to “other” states, we can see that the median effective level for gathering might be. Remember, the model for this situation is:

Other States:

So the median effective level would be:

**Conclusions and Recommendations**

To re-iterate: many of these conclusions are not valid or not statistically significant. The methods applied were done so just for practice and to demonstrate understanding of topics covered in class.

In general, from the regression models, we might conclude that decreased time intervals between gathers and being managed by a western state other than Nevada result in a higher likelihood of being managed successfully.

Overall, for models that used the unaltered data, nothing was significant. But if we were to choose a model to be the best, the first model (that predicts success based on time since a gather) would be chosen based on the AIC, or we might choose the second model (which predicts based on the state) because it is the only model with a significant parameter (α). The hypothetical model could not be compared in this manner because the AIC can only be used to compare models that use the same data and the hypothetical model did not use that same data. For the same reason, it cannot be compared in terms of parameter significance, despite faring better in this respect as well.

Using the “hypothetical” model, in other western states, because the median effective level is 5.41 years since a gather, we might recommend that if the BLM wants to achieve its goal of properly managing these animals, gathers should be conducted more often than 5.14 years.

In general, our analysis leads us to recommend that other predictors of success be sought, as frequency of gathering operations, the state managing a given area, and the burden of the state (gross numbers of acres or animals) are poor predictors of successful management. Because there were several areas that seemed “resilient” and able to maintain success over extended periods of time, intuition tells us that perhaps the practices used or attitudes taken when undertaking a gathering may be more fruitful in producing sound models. Also, factors such as state funding for management operations or levels of enthusiasm for adopting wild horses or burros, or climate/environment patterns might be key to predicting successful management.