EVALUATING WILDLIFE RESPONSES TO WINTER HUMAN USE IN YELLOWSTONE NATIONAL PARK

A Statistical Analysis of the Bison, Elk, and Trumpeter Swan Winter Use Wildlife Road Survey Data: December 2002 to April 2003

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1. Introduction

In this report, a summary of a statistical analysis of the winter use road survey data collected during the 2002-2003 winter will be presented. Models will be developed to determine if variables related to winter recreation are associated with changes in animal behavior. The focus of this analysis will be on addressing two specific management-related questions posed by the YNP's Division of Planning and Compliance:

1. Do the responses of wildlife to snowmobiles and snowcoaches differ?
2. Are the levels of human activities and behavioral responses of wildlife different between commercially guided and unguided groups of snowmobiles?

A companion report entitled 'Recommendations for the 2003 Sampling Design and Protocol' will contain recommendations regarding quantitative sampling objectives and changes to the 2003 sampling design/protocol that are based on a critical review of the existing survey form and the results of the statistical analyses presented in this report.

The statistical analyses and the subsequent recommendations will be instrumental in the development of a long-term monitoring program for quantitatively evaluating the effects of human winter use on wildlife in Yellowstone National Park in collaboration with the Yellowstone Center for Resources.

2. The Survey Data

Winter use survey data was collected from December 26, 2002 through April 19, 2003. The observational data are based on information extracted from the Winter Use Wildlife Road Survey Form (WUWRSF). Table 1 contains a list of the variables for which information was recorded and which were considered in the statistical analyses. The 'Wildlife response category' is the response variable to be studied in the statistical model. The other variables are potential regression variables whose levels may be associated with certain wildlife responses (e.g., is increased distance from the road associated with a lower likelihood of a particular wildlife response?). Several other variables were incorporated into the statistical analysis and are also included in Table 1. These include:

- The daily number of OSVs entering through the west and south gates of YNP.
- The number of animals for each species. This is the sum of the observed numbers of adult females, adult males, young, and unknown (af + am + yng + unk).
- The total number of snowmobiles = sb2 + sb4.
- An variable indicating whether or not the species was on the road during the human wildlife encounter. This variable was only applicable for the bison data because of the relatively high occurrence of bison encounters occurring on the road.

Table 1: The Survey and Model Variables

Survey and Model Variables	Coded Name
Wildlife response category	wresp
Temperature	temp
Cloud cover category	ccover
Precipitation category	prcp
Visibility category	vsbl
Habitat type	habitat
Direction of wildlife travel	dir
Perpendicular distance of the nearest animal to the road	distance
Number of adult females	af
Number of adult males	am
Number of young	yng
Number of unknown age class	unk
Predominant wildlife activity	actv
Number of 2-stroke snowmobiles involved in a wildlife interaction	sb2
Number of 4-stroke snowmobiles involved in a wildlife interaction	sb4
Number of snowcoaches involved in a wildlife interaction	coach
Number of wheeled vehicles involved in a wildlife interaction	whld
Type of guidance associated with the human group	guide
Type of human response during a wildlife interaction	hresp
Duration of the human/wildlife interaction	intxn

Other Model Variables	Coded Name
Total number for the species	sppnum
Total number of snowmobiles involved in a wildlife interaction	sb24
Daily west gate OSV count	west
Daily south gate OSV count	south

Because of the sparsity of data collected for the majority of the animal species observed, the current analysis will be restricted to the three most commonly-observed species: bison, elk, and trumpeter swans. The Table 2 contains the number of observations used in the final statistical models.

Table 2

Species	Observations
Bison	1652
Elk	583
Swan	335

Although numerous other animal species were observed (e.g., coyotes, wolves, bald eagles), the numbers of observations are much lower. Although not part of this report, a more limited analysis (with respect to the number of variables that can be considered) will be conducted in the future for these additional species. Once survey data has been collected over several winter seasons, a more comprehensive analysis that uses data pooled over multiple winters should be performed on these other animal species.

The survey variable to be modeled is 'wildlife response'. Wildlife response represents the predominant response behavior of the majority of the animals in the wildlife group to the OSVs and human behavior. There were six categorical responses on the WUWRSF. These responses, their coded levels on the survey, the coded levels used in the statistical analysis, and the frequencies across animals species are presented in Table 3. The N (no apparent response) and LR (look-and-resume) categories account for 91%, 74%, and 81% of the bison, elk, and swan observations, respectively. Because of the relatively low frequencies for the T, AA, F, and D responses, the response categories were combined into a single category for each animal species. The category is called AC (for an active response). Also, the T, AA, F, and D categories represent responses requiring a greater energy expenditure than either an N or LR response. Hence, the coded response levels of 2, 1, and 0 represent ordered categories corresponding to activities requiring a increasing amount of energy expenditure.

This coding was used for two reasons:

1. Two comparisons will be performed in the statistical analysis.

   - The first comparison will be to see if any of the WUWRSF variables are associated with a significant increase or decrease in a look-and-resume (LR) response relative to no apparent response (N). Thus, we are comparing a wildlife response of '1' with a wildlife response of '2'.
   - The second comparison will be to see if any of the WUWRSF variables are associated with a significant increase or decrease in an active (AC) response relative to no apparent response (N). Thus, we are comparing a wildlife response of '0' with a wildlife response of '2'.

   For each comparison, we are especially interested if determining if there are significant effects associated with guided versus unguided OSVs and with snowmobiles versus snowcoaches.

2. *SAS*, the statistical package used to perform the statistical analysis, uses the highest coded level as the baseline level in comparisons. Because we want N to be the baseline level, it needs to be assigned the highest coded level of 2.

Table 3: The Wildlife Response Code Summary

Survey code	Description of response	Model code	Frequency of bison	elk	swans
N	No apparent wildlife response	2	1288	220	194
LR	Look-and-resume	1	220	212	78
AC	Combining T, AA, F, and D	0	144	151	63
T	Travel (walk or swim) away from OSVs and humans	—	80	58	47
AA	Alarm, attention, or agitation	—	41	85	11
F	Flight	—	22	8	5
D	Defensive attack or charge	—	1	0	0

3. Statistical Methods for Data Analysis

In this section, a detailed explanation of the statistical methods for analysis of the data described in Section 2 of this report. The details include information regarding model assumptions and parameter descriptions.

In studies when there are only two response categories (e.g, presence vs. absence, responded vs. did not respond), logistic regression is the most commonly-used statistical method of data analysis. When there are more than two response categories, known as a **polytomous response**, a logistic regression model is not an option for a simultaneous analysis of all responses. Because there are three response categories in this study (No wildlife response (N), a look-and-resume response (LR), and an active response (AC)), a polytomous response model will be fitted. Specifically, a **generalized logits regression model** will be fitted to the data.

A generalized logits model is similar to a logistic regression model in the sense that we are modeling response probabilities given a set of conditions for other variables. Let

$$\mathbf{x}_i = (x_{i1}, x_{i2}, \ldots, x_{ip})$$

represent the i^{th} set of conditions that contain the levels of the p variables appearing in the model. Variables can be either categorical or quantitative, e.g., one of the quantitative x's could be distance from road, while another of the x's could be the categorical habitat type. In the winter use study there are three response probabilities in the model:

$$\pi_{i0} = \text{Probability of a active (AC) response given condition } \mathbf{x}_i.$$

$$\pi_{i1} = \text{Probability of a look-and-resume (LR) response given condition } \mathbf{x}_i.$$

$$\pi_{i2} = \text{Probability of no (N) response given condition } \mathbf{x}_i.$$

In a generalized logits regression, the probabilities themselves are not modeled. Like logistic regression, **logits** (or log odds ratios) are modeled. The number of logits to be modeled is one less than the number of response levels. Thus, we will be modeling two logits, L_{i0} and L_{i1}, where:

$$L_{i0} = \log\left(\frac{\pi_{i0}}{\pi_{i2}}\right) \qquad \text{and} \qquad L_{i1} = \log\left(\frac{\pi_{i1}}{\pi_{i2}}\right).$$

The ratios $\frac{\pi_{i0}}{\pi_{i2}}$ and $\frac{\pi_{i1}}{\pi_{i2}}$ are known as **odds ratios**. For example, if $\frac{\pi_{i0}}{\pi_{i2}} = 2$, then response 0 (or AC) is twice as likely to occur than response 2 (or N) given condition $\mathbf{x}_i$. We model the logarithm of the odds ratio (i.e., the logit) instead of the ratio itself because the parameter estimates are approximately normally distributed for large samples. This is not the case using the odds ratios. By selecting π_{i2} to be in the denominator of each odds ratio, these two logits can be used to model

- the odds of a wildlife response requiring a low energy expenditure (LR) to a wildlife response requiring a negligible or no energy (N), and
- the odds of a wildlife response requiring a higher energy expenditure (AC) to a wildlife response requiring a negligible or no energy expenditure (N).

Thus, when interpreting results from the statistical analysis, we will be assessing whether or not the odds of a response requiring some energy expenditure relative to a no response probability is associated with changing levels of the study variables.

Model and Data Assumptions

Like all statistical regression methods, there are certain assumptions when using generalized logits regression. For a large population, let π_0, π_1, and π_2 correspond to the proportion of population units that have responses of 0, 1, and 2 respectively. If a sample of size n is obtained by independently sampling units from this large population, then the sampled frequencies f_0, f_1, and f_2 of response categories 0, 1, and 2, respectively, follow a multinomial distribution with expected frequencies $F_0 = n\pi_0$, $F_1 = n\pi_1$, and $F_2 = n\pi_1$. With respect to the winter use study, these assumptions (and their validity) are discussed in the following items:

- For each species, the population consists of all OSV human/wildlife encounters with that species along established roads used by snowmobiles and snowcoaches. The sampling unit is the wildlife group involved in an encounter (not the individuals within each group). For a winter season, the size of these populations can be considered large for bison, elk, and trumpeter swans.

- The sample collected in YNP should be random, but was not for two reasons. First, you do not know when or where human/wildlife encounter will occur. Hence, you have no control to randomly select which encounters will be observed. Second, the established roads used by snowmobiles and snowcoaches were stratified into three road segments that were repeatedly sampled across the winter. The effects of this deviation from strict random sampling (which often is infeasible in a wildlife study) should be negligible given equal effort in sampling each road segment. That is, given equal sampling effort in each road segment across time, we expect the observed numbers and types of human/wildlife encounters in each segment to be close to the numbers and types of encounters that would be expected under pure random sampling during the winter.

- Hypothetically, a predetermined sample of size n is to be collected. The sample size, however, is not predetermined. It is random. Like other statistical procedures where a fixed sample size is assumed but is not for a particular study, the fact that it is random should not seriously affect the conclusions drawn.

- The sampling units should be sampled independently. Because sampling units are groups of animals, we are assuming that each sampled group is independent of every other sampled group. It is quite likely, however, that the same groups or groups containing subsets of the same animals were sampled. Thus, when modeling the logits, we are assuming the effect of this lack of independence on data-based inferences is minimal. Assessment of the impact on the model due to of dependencies among the groups would involve costly monitoring of individuals.

<u>Fitting the Generalized Logits Model</u>

The generalized logits model was fitted using the CATMOD procedure of the *SAS* statistical analysis computing package. Two sets of parameter estimates will be produced – one for each of the two logits L_{i0} and L_{i1}. The estimated logits based on the fitted model will be labeled $\widehat{L}_{i0}$ and $\widehat{L}_{i1}$. Specifically, we generate two fitted functions

$$\widehat{L}_{i0} = \text{estimated } \log\left(\frac{\pi_{i0}}{\pi_{i2}}\right) = b_{00} + b_{10}x_{i1} + b_{20}x_{i2} + b_{30}x_{i3} + \cdots + b_{m0}x_{im}$$

$$\widehat{L}_{i1} = \text{estimated } \log\left(\frac{\pi_{i1}}{\pi_{i2}}\right) = b_{01} + b_{11}x_{i1} + b_{21}x_{i2} + b_{31}x_{i3} + \cdots + b_{m1}x_{im}$$

which can be evaluated at any combination $\mathbf{x}_i = (x_{i1}, x_{i2}, \ldots, x_{ip})$ of the p variables in the model. The total number of parameters m for each estimated logit is dependent on the number of levels of the categorical variables. For each categorical variable the number of estimated parameters is one less than the number of levels. For each quantitative variable there is only one estimated parameter. These numbers are analogous to degrees of freedom in an ANOVA for a classical linear regression model containing quantitative and categorical factors.

Table 4 contains the categorical variables that appear in the models for the bison, elk, or trumpeter swans, as well as their levels. Estimated model parameters for categorical variables are expressed relative to a baseline or reference level. The level indicated with an asterisk corresponds to the baseline level for that variable.

Table 5 contains the quantitative variables corresponding the model terms and the unit of measurement used when fitting the generalized logits model. It will be important to know the units of measurement when interpreting parameter estimates for quantitative variables. It also aids the interpretation by having a scale that prevents parameter estimates from very small on the original scale. Note that the interaction time (intxn) was converted from seconds to minutes, distance was converted to 100-meter units by dividing the original distance by 100 (e.g., a distance of 350 meters is 3.5 100-meter units), the total number for the species was converted to 10-animal units by dividing the original number by 10 (e.g., 46 elk is 4.6 10-elk units), and the daily number of vehicles recorded at the west and south gates were converted by dividing the original counts by 100.

The modeling process began with a complete model, i.e., a model that incorporated all of the variables contained in Table 1. As in any multiple variable regression, if strong correlations exist among pairs or subsets of variables (known as multicollinearity) then the results of a fitted model are suspect. Variance inflation factors were calculated to determine if multicollinearity amongst these variables was a potential concern. No multicollinearity problems were detected.

Table 4: Categorical Model Variables and Their Levels

Habitat (habitat)
A = aquatic
F = forest
BF = burned forest
M = meadow
TH = thermal *

Precipitation (prcp)
0 = none
1 = light or intermittent rain
2 = constant rain
3 = light snow
4 = heavy snow *

Human response (hresp)
SR = stop $<$ 15 seconds, remain on OSV, drive away
W = stop $>$ 15 seconds, remain on OSV, drive away
D = dismount OSV but remain near machine
AA = attempt to attract or disturb wildlife
AP = approach wildlife
IH = impede or hasten movement of wildlife
N = no apparent response *

Visibility (vsbl)
1 = good
2 = fair
3 = poor *

Wildlife activity (actv)
S = standing/feeding
R = resting/bedded/floating
T = traveling *

Guide status (guide)
A = administrative traffic
G = guided by a commercial operator
N = not guided by a commercial operator *

On or off road (onroad)
0 = some animals on road
1 = all animals off road *

An asterisk indicates the baseline category for that variable.

Table 5: Quantitative Model Variables

Variable	Coded	Units of measurement in model
Temperature	temp	degrees Fahrenheit
Distance of the nearest animal to the road	distance	100 meters
Number of snowcoaches	coach	individual snowcoaches
Number of wheeled vehicles	whld	individual vehicles
Duration of the human/wildlife interaction	intxn	minutes
Total number for the species	sppnum	10 animals
Total number of snowmobiles	sb24	individual snowmobiles
Daily west gate OSV count	west	100 vehicles
Daily south gate OSV count	south	100 vehicles

After the complete model was fitted, the variable having the largest p-value was removed from the model. This model reduction process continued until all remaining variables had p-values less than .15. The only exception to this rule was for (i) the number of snowmobiles (sb24), (ii) the number of snowcoaches (coach), and (iii) the guide status (guide). These were retained in the model so that the two specific management concerns stated in the Introduction are addressed explicitly in the final model. A maximum likelihood analysis of variance (ML ANOVA) was run to determine if a variable's effect was statistically significant in the generalized logit model. The results of these ML ANOVAs for the bison, elk, and swan data are summarized in Table 6. In Table 6, 'df' is the degrees of freedom associated with the χ^2 statistic.

Table 6: Maximum Likelihood Analysis of Variance Results

For Bison

Model Terms	df	χ^2	p-value
Intercept	2	9.24	0.0099
temp	2	3.99	0.1357
distance	2	58.36	<.0001
intxn	2	21.90	<.0001
sppnum	2	8.11	0.0174
sb24	2	6.64	0.0362
coach	2	1.54	0.4635
habitat	6	16.70	0.0104
hresp	10	61.50	<.0001
prcp	8	15.31	0.0533
vsbl	4	8.16	0.0859
guide	4	19.53	0.0006
actv	4	15.85	0.0032
onroad	2	53.70	<.0001
south	2	9.45	0.0089
west	2	7.88	0.0195

For Elk

Model Terms	df	χ^2	p-value
Intercept	2	13.83	0.0010
distance	2	41.71	<.0001
intxn	2	4.87	0.0877
sppnum	2	8.25	0.0162
sb24	2	2.75	0.2531
coach	2	4.81	0.0903
whld	2	5.47	0.0650
habitat	8	39.19	<.0001
hresp	8	21.39	0.0062
prcp	8	15.29	0.0537
guide	4	42.99	<.0001
actv	4	24.00	<.0001

For Swans

Model Terms	df	χ^2	p-value
Intercept	2	14.96	0.0006
distance	2	14.58	0.0007
intxn	2	10.30	0.0058
sb24	2	3.97	0.1372
coach	2	7.12	0.0284
hresp	8	57.61	<.0001
vsbl	4	7.67	0.1044
guide	4	4.68	0.3222
actv	4	11.20	0.0244

Now that we know which variables were significant in the ML ANOVA, the next step is to examine the maximum likelihood estimates associated with the model parameters for the two logit functions. Tables 7 and 8 contain the maximum likelihood estimate summaries for the categorical and quantitative variables, respectively, in the final model of the bison data.

<u>The Maximum Likelihood Estimate Tables</u>

A brief description of the information contained in Tables 7 and 8 will be provided before an indepth interpretation of the maximum likelihood estimates is given.

- For each categorical variable level, results are presented relative to a baseline level (which were initially indicated in Table 4). In the 'Level' column in Table 7, the specific comparisons to the baseline are indicated. For example, 'BF v TH' for habitat indicates that we are comparing the burned forest habitat to the baseline thermal habitat.

- The two comparisons in the 'Comparison' column represent the two logits in a form for ease of interpretation. 'AC v N' represents L_{i0} and 'LR v N' represents L_{i1}.

- The 'Estimate' column contains the maximum likelihood estimates of the generalized logits model parameters.

- The 'χ^2' column contains the chi-squared test statistics. The p-values associated with the χ^2 statistics are included.

- Statistically significant parameter estimates are indicated in the 'p-code' column. One or more plus signs indicate a statistically significant positive parameter estimate while one or more minus signs indicate a statistically significant negative estimate. The number of plus or minus signs indicates the level of the p-value: (i) for 4 symbols, the p-value is $< .001$, (ii) for 3 symbols, the p-value is between .001 and .01, (iii) for 2 symbols, the p-value is between .01 and .05, and (iv) for 1 symbol, the p-value is between .05 and .10. Hence, the stronger the evidence of statistical significance, the more plus or minus signs will appear.

- The odds ratio associated with each estimate is given in the 'Odds Ratio' column. For categorical variable estimates (Table 7), the odds ratio is found by exponentiation of twice the parameter estimate. That is,

  $$\text{odds ratio } = e^{2\times(\text{estimate})}.$$

  The factor of two in the exponent occurs because of the way *SAS* codes categorical variables. For quantitative variable estimates (Table 8), the odds ratio is found by exponentiation of the parameter estimate. That is,

  $$\text{odds ratio } = e^{(\text{estimate})}.$$

Interpretation of the results for the bison, the elk, and the swan models will be given in Sections 5, 6, and 7, respectively. In each of these sections, results for the two primary management questions stated in the Introduction will be addressed as well as significant results for other survey variables.

Table 7: Maximum Likelihood Estimates for the Categorical Variables in the Generalized Logits Model for the Bison Data

Parameter	Level	Comparison	Estimate	χ^2	p-value	p-code	Odds Ratio
Intercept	.	AC v N	1.340	5.37	0.0205	++	
		LR v N	1.269	7.21	0.0073	+++	
habitat	BF v TH	AC v N	0.294	1.39	0.2385		1.80
		LR v N	−0.086	0.20	0.6521		0.84
habitat	F v TH	AC v N	0.328	2.05	0.1519		1.93
		LR v N	0.389	5.65	0.0175	++	2.18
habitat	M v TH	AC v N	−0.702	11.87	0.0006	−−−−	0.25
		LR v N	−0.179	1.86	0.1730		0.70
hresp	AP v N	AC v N	0.263	0.22	0.6382		1.69
		LR v N	0.055	0.01	0.9105		1.12
hresp	D v N	AC v N	0.288	0.55	0.4603		1.78
		LR v N	0.522	2.43	0.1192		2.84
hresp	IH v N	AC v N	0.652	0.52	0.4709		3.68
		LR v N	−0.507	0.20	0.6570		0.36
hresp	SR v N	AC v N	0.225	0.31	0.5772		1.57
		LR v N	0.310	0.70	0.4024		1.86
hresp	W v N	AC v N	−0.005	0.00	0.9869		0.99
		LR v N	0.630	4.09	0.0431	++	3.52
prcp	0 v 4	AC v N	0.441	2.78	0.0955	+	2.41
		LR v N	−0.082	0.22	0.6407		0.85
prcp	1 v 4	AC v N	−0.801	2.17	0.1410		0.20
		LR v N	0.313	1.19	0.2758		1.87
prcp	2 v 4	AC v N	1.159	5.30	0.0213	++	10.16
		LR v N	0.200	0.29	0.5876		1.49
prcp	3 v 4	AC v N	−0.127	0.13	0.7187		0.78
		LR v N	0.162	0.59	0.4437		1.38
vsbl	1 v 3	AC v N	−0.325	1.50	0.2205		0.52
		LR v N	−0.449	6.30	0.0120	−−	0.41
vsbl	2 v 3	AC v N	−0.288	1.12	0.2890		0.56
		LR v N	−0.240	1.84	0.1752		0.62
guide	A v N	AC v N	−0.305	1.03	0.3112		0.54
		LR v N	0.555	7.10	0.0077	+++	3.03
guide	G v N	AC v N	0.760	4.56	0.0327	++	4.57
		LR v N	−0.134	0.24	0.6226		0.77
actv	R v T	AC v N	−0.491	3.12	0.0774	−	0.37
		LR v N	−0.173	0.96	0.3273		0.71
actv	S v T	AC v N	−0.401	4.11	0.0427	−−	0.45
		LR v N	0.040	0.08	0.7739		1.08
onroad	On v Off	AC v N	−1.536	53.46	0.0001	−−−−	0.05
		LR v N	−0.664	13.16	0.0003	−−−−	0.27

Table 8: Maximum Likelihood Estimates for the Quantitative Variables in the Generalized Logits Model for the Bison Data

Parameter	Comparison	Estimate	χ^2	p-value	p-code	Odds Ratio
temp	AC v N	−0.022	3.74	0.0531	−	0.98
	LR v N	−0.009	1.02	0.3120		0.99
distance	AC v N	−0.545	8.82	0.0030	−−−	0.58
	LR v N	−0.932	52.33	0.0001	−−−−	0.39
intxn	AC v N	−0.022	0.39	0.5305		0.98
	LR v N	−0.155	21.38	0.0001	−−−−	0.86
sppnum	AC v N	−0.075	1.75	0.1864		0.93
	LR v N	−0.116	7.65	0.0057	−−−	0.89
sb24	AC v N	0.042	3.11	0.0780	+	1.04
	LR v N	0.050	5.98	0.0144	++	1.05
coach	AC v N	−0.123	0.13	0.7168		0.88
	LR v N	0.245	1.15	0.2836		1.28
south	AC v N	−0.082	0.06	0.8036		0.92
	LR v N	−0.683	8.95	0.0028	−−−	0.50
west	AC v N	−0.156	0.79	0.3731		0.86
	LR v N	0.259	5.14	0.0234	++	1.30

5. Results from the Bison Model

(1) Do the responses of bison to snowmobiles and snowcoaches differ?

The results in Table 8 regarding snowmobiles (sb24) indicate that the parameter estimates for the two comparisons are positive and statistically significant. Thus, after adjusting for the other model effects, we conclude that the odds of a look-and-resume (LR) bison response or an active (AC) bison response increase with increasing numbers of snowmobiles in a group. The odds ratio of 1.04 indicates that we estimate a that the odds of observing an AC bison response (relative to no response) are 4% greater for each additional snowmobile in the group. Similarly, the odds ratio of 1.05 indicates that we estimate a that the odds of observing an LR bison response (relative to no response) are 5% greater for each additional snowmobile in the group.

- Example: Under identical conditions, we would expect the odds of an active bison response (relative to no response) would, on average, be 16% higher for a group of

8 snowmobiles than for a group of 4 snowmobiles. Also, we expect the odds of a look-and-resume bison response would, on average, be 20% higher for a group of 8 snowmobiles than for a group of 4 snowmobiles (under identical conditions).

The fact that these parameter estimates are statistically significant indicates that in the presence of variability, we still have strong evidence that the odds ratios are both greater than 1. Hence, we expect some increase in AC and LR responses for bison relative to N responses for bison as the number of snowmobiles increases.

These results are supported by Figure 1A. The heights of the bars correspond to the percentages in the raw data for the three bison responses across three categories representing increasing numbers of snowmobiles (0, 1, 2 or more). We can look at the raw odds ratios of AC to N and LR to N by comparing the heights of the AC and LR bars to the N bar across the snowmobile count categories. Figure 1A indicates that the two raw odds ratios increase across the snowmobile count categories which is consistent with the positive estimates in the fitted model.

The results in Table 8 regarding snowcoaches (coach) indicate that the parameter estimates for the two comparisons are not statistically significant. Thus, after adjusting for the other model effects, there is not enough evidence conclude the odds of a look-and-resume (LR) bison response or an active (AC) bison response change with increasing numbers of snowcoaches in a group. Note that although the odds ratio is 1.28 for the LR v N comparison, the variability associated with this estimate was much larger than the variability for the snowmobile estimates.

The fact that these parameter estimates are not statistically significant indicates as the number of snowcoaches increased we did not observe significant changes across the three response categories. This implies either (i) there is no positive or negative association between the number of snowcoaches and the bison response or (ii) any association between the number of snowcoaches and the bison response cannot be detected given the current sample size. By collecting data over several winter seasons, this issue can be readdressed with the increased sample size.

In Figure 1B, the heights of the bars correspond to the percentages in the raw data for the three bison responses across three categories representing increasing numbers of snowcoaches (0, 1, 2 or more). Like the snowmobile case, we can look at the raw odds ratios of AC to N and LR to N by comparing the heights of the AC and LR bars to the N bar across the snowcoach count categories. Figure 1B indicates that the two raw odds ratios increase across the snowmobile count categories. This is consistent for the LR vs N comparison yielding a positive estimate in the fitted model.

The pattern for the AC v N raw data odds ratios, however, may seem inconsistent with the negative estimate for AC vs N comparison in the fitted model. It is important to stress two points. First, the raw odds ratios are unadjusted for the influence of other model variables. Second, the negative estimate in Table 8 was not statistically significant.

Figures of raw percentages have been included for thoroughness. Therefore, use of the bar charts in all of the figures associated with the bison data analysis, as well as the elk and swan data analyses, should be treated with caution. The raw percentage plots are, however, consistent in almost every case with the significance test and the odds ratio results from the fitted generalized logits models.

(2) Are the levels of human activities and behavioral responses of bison different between commercially guided and unguided groups of snowmobiles?

The results in Table 7 indicate that in a comparison of guided to unguided groups, there is a statistically significant parameter estimate associated with the AC v N comparison. The odds ratio of 4.57 indicates that we estimate that the odds of observing an active bison response (relative to no response) is 4.57 times higher for a guided group than for an unguided group (under identical conditions). These results are supported by Figure 1C. The raw odds ratios of AC to N for the guided groups is larger than the raw odds ratios of AC to N for the unguided groups.

In a related comparison of administrative traffic to unguided groups, there is a statistically significant parameter estimate associated with the LR v N comparison. The odds ratio of 3.03 indicates that we estimate that the odds of observing a look-and-resume bison response (relative to no response) for administrative traffic are 3.03 times higher than for an unguided group (under identical conditions). These results are also supported by Figure 1C. The raw odds ratios of LR to N for the administrative traffic are larger than the raw odds ratios of LR to N for the unguided groups.

(3) What other categorical factors are significantly related to the behavioral responses of bison?

Based on the results in Table 7, the behavioral responses of bison are associated with certain comparisons of categorical variable levels with the baseline level. In the subsequent discussion of the bison results, comparisons are assumed to be under identical conditions. The following discussion involves only statistically significant parameter estimates.

1. The estimated odds of observing a look-and-resume response (relative to no response) are 2.18 times higher for a forested habitat than for a thermal habitat.

2. The estimated odds of observing an active response (relative to no response) are .25 times or one-fourth for a meadow habitat than for a thermal habitat.

3. The estimated odds of observing a look-and-resume response (relative to no response) are 3.52 times higher for a stop-and-watch human response than for no human response. See Figure 1D for raw data percentages.

4. The estimated odds of observing an active response (relative to no response) are 2.41 times higher when there is no precipitation than when it is snowing heavily.

5. The estimated odds of observing an active response (relative to no response) are .37 times (or, approximately one-third) when the predominant bison activity is resting/bedded than when the predominant activity is traveling.

6. The estimated odds of observing an active response (relative to no response) are .45 times (or, approximately one-half) when the predominant bison activity is standing/feeding than when the predominant activity is traveling.

7. The estimated odds of observing an active response (relative to no response) are .05 times (or, one-twentieth) when the bison are off the road than when the bison are on the road.

8. The estimated odds of observing an look-and-resume response (relative to no response) are .27 times (or, approximately one-fourth) when the bison are off the road than when the bison are on the road.

Note that some odds ratios may appear large, but because of large variability in the data, the parameter estimates were not significant. As stated earlier, with data from additional winter seasons, we will improve the likelihood of detecting any potential effects that truly exist, but currently cannot be detected from a single season's data.

(4) What other quantitative factors are significantly related to the behavioral responses of bison?

Based on the results in Table 8, the behavioral responses of bison are associated with certain quantitative variables. The discussion involves only statistically significant parameter estimates. For odds ratios less than one for quantitative variables, we look at the reciprocal of the odds and reverse the order of the comparison.

1. The estimated odds of observing an active response (relative to no response) are .98 for each one degree temperature increase. Or, the estimated odds of observing no response relative to an active response is $(1/.98) = 1.02$. Thus, for each one degree temperature increase, the estimated odds of observing no response relative to an active response are 2% higher. Thus, for a 10 degree temperature increase, the estimated odds of observing no response (relative to active response) are 20% higher.

2. For distance from road, the estimated odds of observing an active response (relative to no response) are .58., or, equivalently, the estimated odds of observing no response relative to an active response are $(1/.58) = 1.72$. Note that 100 meters is the distance unit of measurement. Thus, for each 100 meters increase in distance from the road, the estimated odds of observing no bison response relative to an active bison response are 72% higher. See Figure 1F for the raw percentages.

3. Analogously, the estimated odds of observing no response relative to a look-and-resume response are $(1/.39) = 2.56$ for distance. Thus, for each 100 meters increase

in distance from the road, the estimated odds of observing no bison response relative to a look-and-resume bison response 2.56 times higher.

4. For the interaction time (in minutes), the estimated odds of observing no response relative to a look-and-resume response are $(1/.86) = 1.16$. Thus, for each minute increase in interaction time, the estimated odds of observing no bison response relative to a look-and-resume bison response 16% higher.

5. For the number of bison (sppnum), the estimated odds of observing no response relative to a look-and-resume response relative are $(1/.89) = 1.12$. Note that 10 animals is the unit of measurement. Thus, for a 10 bison increase in group size, the estimated odds of observing no bison response relative to a look-and-resume bison response are 5% higher. See Figure 1E for the raw percentages.

6. For the daily west gate OSV numbers, the estimated odds of observing a look-and-resume response relative to no response relative are 1.3. Thus, for a 100 vehicle increase, the estimated odds of observing a look-and-resume bison response relative to no bison response are 30 % higher.

7. For the daily south gate OSV numbers, the estimated odds of observing no response relative to a look-and-resume response are $(1/.5) = 2$. Thus, for a 100 vehicle increase, the estimated odds of observing no response relative to a look-and-resume bison response is twice as large. This may seem counterintuitive until you that the south gate has smaller daily gate totals than the west gate and a 100-unit change at the south gate is unlikely. Also, note that if traffic increases through both gates, the south and west gate effects will essentially negate each other given the large west gate totals. However, a more indepth study of temporal patterns and possibly using a single combined daily gate total should be considered. The daily gate numbers, as seen in Sections 6 and 7, did not appear in the final models for the elk and swans.

6. Results from the Elk Model

(1) Do the responses of elk to snowmobiles and snowcoaches differ?

The results in Table 9 regarding snowmobiles (sb24) indicate that neither of the parameter estimates for the two comparisons are statistically significant (although the p-value of .1014 is marginal for the LR v N comparison). See Figure 2A for the raw percentages for each category.

The fact that these parameter estimates are not statistically significant indicates either as the number of snowmobiles increased we did not observe significant changes across the three response categories. This implies either (i) there is no positive or negative association between the number of snowmobiles and the elk response or (ii) any association between the number of snowmobiles and the elk response cannot be detected given the current sample size. By collecting data over several winter seasons, this issue can be reexamined.

The results in Table 9 regarding snowcoaches (coach) indicate that the parameter estimate for the AC v N comparison is statistically significant. Thus, after adjusting for model effects, we conclude that the odds of an active (ACC) elk response increase with increasing numbers of snowcoaches in a group. The odds ratio of 5.37 indicates that we estimate the odds of observing an AC elk response (relative to no response) are 5.37 times greater for each additional snowcoach in the group.

The fact that this parameter estimate is statistically significant indicates that in the presence of variability and a sample size that is smaller than for the bison, we still have strong evidence that the odds ratios is greater than 1. Hence, we expect some increase in AC responses for elk relative to N responses for elk as the number of snowcoaches increases.

These results are supported by Figure 2B. The heights of the bars correspond to the percentages in the raw data for the three elk responses across three categories representing increasing numbers of snowcoaches (0 and 1 or more). We can look at the raw odds ratios of AC to N by comparing the heights of the AC bars to the N bar across the snowcoach count categories. Figure 2B indicates that the two raw odds ratios increase across the snowcoach categories which is consistent with the positive estimates in the fitted model.

(2) Are the levels of human activities and behavioral responses of elk different between commercially guided and unguided groups of snowmobiles?

The results in Table 9 indicate that in a comparison of guided to unguided groups, there are statistically significant parameter estimates associated with both the AC v N and the LR v N comparisons. The odds ratios of .09 and .19 for the AC v N and LR v N comparisons, respectively, indicates that we estimate that (i) the odds of observing no elk response relative to an active response are (1/.09) or 11.1 times higher for a guided group than for an unguided group and (ii) the odds of observing no elk response relative to a look-and-resume response are (1/.19) or 5.3 times higher for a guided group than for an unguided group. Despite these large values, I recommend that they be viewed cautiously. Only 8% of the data (48 of 583 cases) corresponds to guided groups. Additional data from one or more winter seasons will help to establish the validity of this negative effect of guided groups on LR and AC responses. Also, when unadjusted for the effects of other variables in the model, the raw percentages shown in Table 2C suggest an increase in the odds ratio for both AC and LR relative to N for the guided groups. Once again it is important to note that the percentages corresponding to the three bars in Figure 2C having the same height for the guided groups are based on only 16 observations per bar. The percentages for the unguided groups, however, are based on 180, 106, and 50 observations, respectively.

In a comparison of administrative traffic to unguided groups, there are statistically significant parameter estimates associated with both the AC v N and the LR v N comparisons. The odds ratios of 31.80 and 11.69 indicate that we estimate that the odds of observing an active elk response or a look-and-resume elk response (relative to no response) for administrative traffic are 31.80 and 11.69 times higher, respectively, than for an unguided group. These results are also supported by Figure 2C. The raw odds ratios of AC to N and LR to N for the administrative traffic are larger than the raw odds ratios of AC to N and LR to N for the unguided groups.

(3) What other categorical factors are significantly related to the behavioral responses of elk?

Based on the results in Table 9, the behavioral responses of elk are associated with certain comparisons of categorical variable levels with the baseline level. The following discussion involves only statistically significant parameter estimates.

1. The estimated odds of observing an active response or a look-and-resume response (relative to no response) are 16.6 and 3.6 times higher, respectively, for a forested habitat than for a thermal habitat.

2. The estimated odds of observing an active response (relative to no response) are .21 times or approximately one-fifth for a meadow habitat than for a thermal habitat.

3. The estimated odds of observing an active response (relative to no response) are 3.13 times higher for a burned forest habitat than for a thermal habitat.

4. The estimated odds of observing an active response (relative to no response) are 7 times higher for an approach-wildlife (AP) human response than for no human response. See Figure 2D for raw data percentages.

5. The estimated odds of observing an active response or a look-and-resume response (relative to no response) are 4.13 and 3.33 times higher, respectively, for a watch-wildlife (W) human response than for no human response. See Figure 2D for raw data percentages.

6. The estimated odds of observing an active response or a look-and-resume response (relative to no response) are .27 and .13 (or, approximately, one-fourth and one-eighth) when there is light snow than when it is snowing heavily.

7. The estimated odds of observing an active response (relative to no response) are .03 times when the predominant elk activity is resting/bedded than when the predominant activity is traveling.

Again, note that some odds ratios may appear large, but because of large variability in the data, the parameter estimates were not significant. As stated earlier, with data from additional winter seasons, we will improve the likelihood of detecting any potential effects that truly exist, but currently cannot be detected from a single season's data.

(4) What other quantitative factors are significantly related to the behavioral responses of elk?

Based on the results in Table 9, the behavioral responses of elk are associated with certain quantitative variables. The following discussion involves only statistically significant parameter estimates. When the odds ratios are less than one for quantitative variables, we will again look at the reciprocal of the odds and reverse the order of the comparison.

1. For distance from the road, the estimated odds of observing no response relative to an active response are (1/.33) or 3. Thus, for each 100 meters increase in distance from the road, the estimated odds of observing no elk response relative to an active elk response are 3 times higher. See Figure 2E for the raw percentages.

2. Analogously, the estimated odds of observing no response relative to a look-and-resume response are $(1/.65) = 1.5$ for distance. Thus, for each 100 meters increase in distance from the road, the estimated odds of observing no elk response relative to a look-and-resume elk response are 1.5 times higher.

3. For the interaction time (in minutes), the estimated odds of observing an active response or a look-and-resume response relative to no response are 1.14 and 1.09, respectively. Thus, for each minute increase in interaction time, the estimated odds of observing an active response or a look-and-resume response relative to no elk response are 14% and 9% higher. See Figure 2F for the raw percentages.

4. For the number of elk (sppnum), the estimated odds of observing no response relative to a look-and-resume response relative are $(1/.82) = 1.22$. Thus, for a 10 elk increase in group size, the estimated odds of observing no elk response relative to a look-and-resume elk response are 22% higher.

Table 9: Maximum Likelihood Estimates for All Variables in the Generalized Logits Model for the Elk Data

Parameter	Level	Comparison	Estimate	χ^2	p-value	p-code	Odds Ratio
Intercept	.	AC v N	1.318	5.75	0.0165	++	
		LR v N	1.821	13.82	0.0002	++++	
distance	.	AC v N	−1.115	40.95	0.0001	−−−−	0.33
		LR v N	−0.436	13.63	0.0002	−−−−	0.65
intxn	.	AC v N	0.131	4.84	0.0277	++	1.14
		LR v N	0.089	2.85	0.0916	+	1.09
sppnum	.	AC v N	0.049	1.48	0.2232		1.05
		LR v N	−0.193	5.65	0.0175	−−	0.82
sb24	.	AC v N	−0.029	1.23	0.2665		0.97
		LR v N	−0.043	2.68	0.1014		0.96
coach	.	AC v N	1.680	4.50	0.0340	++	5.37
		LR v N	0.651	0.92	0.3385		1.92
whld	.	AC v N	0.226	2.64	0.1040		1.57
		LR v N	−0.053	0.19	0.6600		0.90
habitat	A v TH	AC v N	−0.097	0.07	0.7937		0.82
		LR v N	0.477	2.26	0.1328		2.60
habitat	BF v TH	AC v N	0.570	3.78	0.0519	+	3.13
		LR v N	−0.169	0.44	0.5061		0.71
habitat	F v TH	AC v N	1.406	14.64	0.0001	++++	16.63
		LR v N	0.641	3.93	0.0473	++	3.61
habitat	M v TH	AC v N	−0.771	6.67	0.0098	−−−	0.21
		LR v N	−0.115	0.25	0.6154		0.79
hresp	AP v N	AC v N	0.972	3.92	0.0476	++	6.99
		LR v N	0.578	1.65	0.1986		3.18
hresp	D v N	AC v N	0.246	0.31	0.5769		1.64
		LR v N	0.525	2.03	0.1547		2.86
hresp	SR v N	AC v N	−0.824	2.21	0.1372		0.19
		LR v N	−0.840	3.45	0.0631	−	0.19
hresp	W v N	AC v N	0.709	3.34	0.0676	+	4.13
		LR v N	0.602	2.94	0.0864	+	3.33
prcp	0 v 4	AC v N	0.105	0.15	0.6998		1.23
		LR v N	0.036	0.02	0.8754		1.07
prcp	1 v 4	AC v N	−0.126	0.07	0.7868		0.78
		LR v N	0.533	2.46	0.1171		2.90
prcp	2 v 4	AC v N	0.276	0.24	0.6214		1.74
		LR v N	0.064	0.02	0.8921		1.14
prcp	3 v 4	AC v N	−0.650	3.24	0.0719	−	0.27
		LR v N	−1.024	10.93	0.0009	−−−−	0.13
guide	A v N	AC v N	1.730	26.65	0.0001	++++	31.80
		LR v N	1.230	20.55	0.0001	++++	11.69
guide	G v N	AC v N	−1.193	5.39	0.0202	−−	0.09
		LR v N	−0.824	4.34	0.0371	−−	0.19
actv	R v T	AC v N	−1.812	19.79	0.0001	−−−−	0.03
		LR v N	−0.509	2.28	0.1312		0.36
actv	S v T	AC v N	−0.411	1.39	0.2380		0.44
		LR v N	−0.500	2.47	0.1162		0.37

7. Results from the Swan Model

(1) Do the responses of swans to snowmobiles and snowcoaches differ?

The results in Table 10 regarding snowmobiles (sb24) indicate that the parameter estimate for the LR v N comparison is (marginally) statistically significant. Thus, after adjusting for model effects, we conclude that the odds of a look-and-resume (LR) swans response increase with increasing numbers of snowmobiles in a group. The odds ratio of 1.07 indicates that we estimate the odds of observing an AC swans response (relative to no response) are 7% greater for each additional snowmobile in the group.

These snowmobile results are supported by Figure 3A. The heights of the bars correspond to the percentages in the raw data for the three swan responses across three categories representing increasing numbers of snowmobiles (0, 1, and 2 or more). We can look at the raw odds ratios of LR to N by comparing the heights of the LR bars to the N bar across the snowmobile count categories. Figure 3B indicates that the raw odds ratios increase across the snowmobile categories which is consistent with the positive estimates in the fitted model.

The results in Table 10 regarding snowcoaches (coach) indicate that the parameter estimate for the AC v N comparison is statistically significant. Thus, after adjusting for model effects, we conclude that the odds of an active (AC) swan response increases if snowcoaches are present (P) than when they are not present (P). The odds ratio of 10.70 indicates that we estimate the odds of observing an AC swan response (relative to no response) are 10.7 times greater when snowcoaches are present.

These snowcoach results are supported by Figure 3B. The heights of the bars correspond to the percentages in the raw data for the three swan responses across three categories representing the absence of snowcoaches (0) or the presence of snowcoaches (1+). We can look at the raw odds ratios of AC to N by comparing the heights of the AC bars to the N bar across the two snowcoach categories. Figure 3B indicates that the raw odds ratios increase across the snowcoach categories which is consistent with the positive estimates in the fitted model.

(2) Are the levels of human activities and behavioral responses of swans different between commercially guided and unguided groups of snowcoaches?

The results in Table 10 indicate no statistically significant results in comparisons of guided to unguided groups and of administrative traffic to unguided groups.

The fact that these parameter estimates are not statistically significant indicates for guided groups we did not observe significant changes in the odds ratios across the three response categories. This implies either (i) there is no positive or negative association the elk response and whether a group was guided or unguided or (ii) any association between the guided and unguided groups and the elk response cannot be detected given the current sample size. By collecting data over several winter seasons, this issue can be reexamined with the increased sample size.

(3) What other categorical factors are significantly related to the behavioral responses of swans?

Based on the results in Table 10, the behavioral responses of swans are associated with certain comparisons of categorical variable levels with the baseline level. The following discussion involves only statistically significant parameter estimates.

1. The estimated odds of observing an active response (relative to no response) are 14.5 times higher for an approach-wildlife (AP) human response than for no human response. See Figure 3D for raw data percentages.

2. The estimated odds of observing an active response (relative to no response) are 14.4 times higher for a dismount OSV (D) human response than for no human response. See Figure 3D for raw data percentages.

3. The estimated odds of observing an look-and-resume response (relative to no response) are 17.2 times higher for a stop and remain-on-OSV (SR) human response than for no human response. See Figure 3D for raw data percentages.

4. The estimated odds of observing an active response (relative to no response) are .21 (or, approximately, one-fifth) when the visibility is good that when visibility is

poor.

5. The estimated odds of observing an active response (relative to no response) are .17 (or, approximately one-sixth) when the predominant swans activity is standing or feeding than when the predominant activity is traveling.

(4) What other quantitative factors are significantly related to the behavioral responses of swans?

Based on the results in Table 10, the behavioral responses of swans are associated with certain quantitative variables. The following discussion involves only statistically significant parameter estimates. When the odds ratios are less than one for quantitative variables, we will again look at the reciprocal of the odds and reverse the order of the comparison.

1. For distance from the road, the estimated odds of observing no response relative to a look-and-resume response are $(1/.33)$ or 3. Thus, for each 100 meters increase in distance from the road, the estimated odds of observing no swan response relative to a look-and-resume swan response are 3 times higher. See Figure 3F for the raw percentages.

2. For the interaction time (in minutes), the estimated odds of observing no response relative to an active response are $(1/.77) = 1.3$. Thus, for each minute increase in interaction time, the estimated odds of observing no response relative to an active response are 30% higher.

Table 10: Maximum Likelihood Estimates for All Variables in the Generalized Logits Model for the Swan Data

Parameter	Level	Comparison	Estimate	χ^2	p-value	p-code	Odds Ratio
Intercept	.	AC v N	2.736	13.97	0.0002	++++	
		LR v N	0.361	0.23	0.6322		
distance	.	AC v N	−0.332	1.84	0.1744		0.72
		LR v N	−1.110	13.81	0.0002	−−−−	0.33
intxn	.	AC v N	−0.266	9.66	0.0019	−−−	0.77
		LR v N	−0.022	0.05	0.8155		0.98
sb24	.	AC v N	0.073	2.37	0.1236		1.08
		LR v N	0.071	3.14	0.0766	+	1.07
coach	P v A	AC v N	1.185	7.07	0.0079	+++	10.70
		LR v N	0.442	1.03	0.3103		2.42
hresp	AP v N	AC v N	1.338	3.68	0.0551	+	14.52
		LR v N	−0.713	0.70	0.4031		0.24
hresp	D v N	AC v N	1.335	9.55	0.0020	+++	14.44
		LR v N	0.066	0.01	0.9035		1.14
hresp	SR v N	AC v N	0.517	0.60	0.4393		2.81
		LR v N	1.422	4.21	0.0402	++	17.20
hresp	W v N	AC v N	−0.547	1.82	0.1768		0.33
		LR v N	−0.359	0.62	0.4314		0.49
vsbl	1 v 3	AC v N	−0.792	6.07	0.0137	−−	0.21
		LR v N	−0.160	0.36	0.5460		0.73
vsbl	2 v 3	AC v N	0.136	0.17	0.6828		1.31
		LR v N	−0.207	0.51	0.4767		0.66
guide	A v N	AC v N	0.823	2.69	0.1012		5.18
		LR v N	−0.173	0.10	0.7493		0.71
guide	G v N	AC v N	−0.809	2.48	0.1153		0.20
		LR v N	−0.161	0.12	0.7262		0.73
actv	R v T	AC v N	−0.341	0.95	0.3297		0.51
		LR v N	−0.268	0.57	0.4499		0.59
actv	S v T	AC v N	−0.878	6.23	0.0125	−−	0.17
		LR v N	0.266	0.62	0.4294		1.70

8. Summary Comments

Although results were presented for all significant survey variables, the focus of the analysis was to address the two specific management-related questions:

1. Do the responses of wildlife to snowmobiles and snowcoaches differ?
2. Are the levels of human activities and behavioral responses of wildlife different between commercially guided and unguided groups of snowmobiles?

Table 11 summarizes the odds ratio results from Sections 5, 6, and 7 that are directly related to these two questions. Odds ratios associated with significant parameter estimates are in boldface. The results in Table 11 suggest that the relationship of wildlife responses to winter use in Yellowstone National Park along the surveyed road segments is species dependent. For example, for bison and trumpeter swans, the odds ratios are greater than one for the AC v N and for the LR v N comparisons while the odds ratios are less than one for elk.

Eight of the 18 odds ratios were statistically significant. By collecting data over several winter seasons, we can validate the statistically significant results observed during this winter season. Similarly, for the ten odds ratios that were not statistically significant, additional data can be used to assess if the effects truly do not exist or if there was not enough data from one season to detect several effects that do exist.

Because a baseline level was required for each categorical variable, only comparisons with the baseline level were generated. If there is interest in other odds ratios for other pairs of categorical variable levels, the estimation process is simple. Just double the difference between two estimates and then exponentiate. For example, if a person wanted to estimate the odds ratio of burned forest (BF) to meadows (M) for bison for the AC v N comparison, first take the difference of the estimates in Table 7 (which is $.294 - (-.702) = .996$. Then exponentiate twice this difference (1.992) yielding an odds ratio of $e^{1.992} = 7.33$.

Table 11: Estimated Odds Ratios

Snowmobile Comparisons

	For Bison	For Elk	For Swans
AC v N	**1.04**	0.97	1.08
LR v N	**1.05**	0.96	**1.07**

Snowcoach Comparisons

	For Bison	For Elk	For Swans
AC v N	0.88	**5.37**	**10.70**
LR v N	1.28	1.92	2.42

Guided vs Unguided Group Comparisons

	For Bison	For Elk	For Swans
AC v N	**4.57**	**0.09**	0.20
LR v N	0.77	**0.19**	0.73

Boldface values are statistically significant.

References

Agresti, A. (1990), *Categorical Data Analysis*, Chapter 9, New York: John Wiley & Sons.

Clogg, C.C., and Shihadeh, E.S. (1994), *Statistical Models for Ordinal Variables*, Chapter 7, Thousand Oaks, CA: SAGE Publications.

Friendly, M. (2001), *Visualizing Categorical Data*, Chapter 6, Cary, NC: SAS Institute Inc..

Stokes, M.E., Davis, C.S. and Koch, G.G. (1996), *Categorical Data Analysis*, Chapter 9, Cary, NC: SAS Institute Inc..