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 2003 to April 2004

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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 2003-2004 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 OSVs, administrative OSVs, and vehicles that were not guided?

The statistical analyses in this report 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 12, 2003 through March 31, 2004. The observational data are based on information extracted from the current Winter Use Wildlife Road Survey Form (WUWRSF). For this winter season, numerous variables were recorded. From these recorded variables, other variables were created. A list of these variables is contained in Table 1. Any variable for which information was recorded was labeled as R in the Type column. Any variable that was created from other recorded variables was labeled as C in the Type column. Table 1 is also partitioned in groups of related variables. Brief descriptions will now be given as to how each 'C' Type variable in each group was generated.

Among the 'Wildlife Activity Variables' in Table 1, the 'Most extreme wildlife response category' (wresp1) and the 'Most common wildlife response category' (wresp2) were the two potential response variables considered in the statistical models. They were created from the six percentage variables pctN, pctLR, pctT, pctAA, pctF, and pctD. These variables are ordered based on activities requiring an increasing amount of energy expenditure from 'no apparent response' to 'defensive attack/charge'.

- Let 'wresp1' be the last response category having a non-zero percentage in the ordered list pctN, pctLR, pctT, pctAA, pctF, and pctD. Thus, 'wresp1' represents the most extreme response exhibited by at least one animal in the wildlife group.

- Let 'wresp2' be the response category having the highest percentage in the ordered list pctN, pctLR, pctT, pctAA, pctF, and pctD. In case of a tie, the activity associated with the greater energy expenditure was selected. Thus, 'wresp2' represents the most commonly exhibited response by the animals in the wildlife group.

- The response categories for both 'wresp1' and 'wresp2' were coded 'N' for no apparent response, 'LR' for a look/resume response, 'T' for traveling, 'AA' for alarm/attention, 'F' for flight, and 'D' for a defensive attack/charge. Because 'wresp1' and 'wresp2' often agreed for recorded encounters between humans/OSVs and wildlife groups, 'wresp1' was selected as the response to be modeled.

The predominant undisturbed wildlife activity variable 'actv' was created using a procedure similar to the one used to generate 'wresp2'.

- Let 'actv' be the category having the highest percentage in the ordered list R, S, FD, T, AA, FL, and D. In case of a tie, the activity associated with the greater energy expenditure was selected. Thus, 'actv' represents the most commonly exhibited activity by undisturbed animals in the wildlife group.

- The response categories for 'actv' were coded 'R' for resting , 'S' for standing, perching, or floating, 'FD' for feeding, 'T' for traveling, 'AA' for alarm/attention, 'FL' for flight, and 'D' for a defensive reaction.

Table 1: The Survey and Model Variables

Wildlife Activity Variables

Variable	Coded Name	Type
Percentage of wildlife group that exhibited no apparent response	pctN	R
Percentage of wildlife group that exhibited a look-and-resume response	pctLR	R
Percentage of wildlife group that traveled slowly away	pctT	R
Percentage of wildlife group that exhibited an alarm/attention response	pctAA	R
Percentage of wildlife group engaged in flight	pctF	R
Percentage of wildlife group engaged a defensive attack/charge response	pctD	R
Percentage of undisturbed animals that were resting	pctUR	R
Percentage of undisturbed animals that were standing/perching/floating	pctUS	R
Percentage of undisturbed animals that were feeding	pctUFD	R
Percentage of undisturbed animals that were traveling	pctUT	R
Percentage of undisturbed animals that exhibited alarm/attention	pctAA	R
Percentage of undisturbed animals that were fleeing	pctUFL	R
Percentage of undisturbed animals that exhibited a defensive action	pctUD	R
Most extreme Wildlife response category	wresp1	C
Most common Wildlife response category	wresp2	C
Predominant wildlife activity	actv	C

Table 1: The Survey and Model Variables (continued)

Other Wildlife-Related Variables

Variable	Coded Name	Type
Number of adult females	af	R
Number of adult males	am	R
Number of young/juvenile	juv	R
Number of unknown age class	unk	R
Direction of wildlife travel	dir	R
Perpendicular distance of the nearest animal to the road	distance	R
Total number for the species	sppnum	C
Total number of adult females or juvenile for the species	af_juv	C
Onroad indicator	onroad	C

Human Activity Variables

Variable	Coded Name	Type
Number of snowmobiles involved in a wildlife interaction	sb	R
Number of snowcoaches involved in a wildlife interaction	coach	R
Number of wheeled vehicles involved in a wildlife interaction	whld	R
Type of guidance associated with the human group	guide	R
Duration of the human/wildlife interaction	intxn	R
Number of people that did not stop or react to wildlife	N	R
Number of people that stopped to observe wildlife	S	R
Number of people that dismounted their OSVs to observe wildlife	D	R
Number of people that approached wildlife	AP	R
Number of people that impeded or hindered or chased wildlife	IH	R
Reaction to observer	RTO	R
Distance from closest person to an animal	OSVdist	R
Most common human response during a wildlife interaction	hresp	C

Environmental Variables

Variable	Coded Name	Type
Temperature	temp	R
Cloud cover category	ccover	R
Precipitation category	prcp	R
Visibility category	vsbl	R
Habitat type	habitat	R

Traffic-Related Variables

Variable	Coded Name	Type
Daily west gate OSV count	west	R
Daily south gate OSV count	south	R
Daily east gate OVSV count	east	R
Cumulative daily west gate OSV count	cumwest	R
Cumulative daily south gate OSV count	cumsouth	R
Cumulative daily east gate OSV count	cumseast	R
Daily OSV count (any gate)	gate	C
Cumulative daily OSV count (any gate)	cum	C
Cumulative gate indicator	gateid	C

For the 'Other Wildlife-Related Variables' in Table 1:

- 'sppnum' is the total number of animals observed during a human/wildlife interaction. It is the sum of the observed numbers of adult females, adult males, juveniles, and unknown (af + am + juv + unk).
- 'af_juv' is the total number of adult females or juvenile animals observed during a human/wildlife interaction (af + juv).
- 'onroad' indicates whether or not any of the animals in the wildlife group were 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 or near a road.

For the 'Human Activity Variables' in Table 1, 'hresp' (the most extreme human response during a wildlife interaction) was determined from the human response variables that were ordered from least to most aggressive. Specifically, stopping, not stopping, dismounting, approaching wildlife, and impeding/hindering/blocking wildlife.

- Let 'hresp' be the last response category having a non-zero count in the ordered list N, S, D, AP, and IH. Thus, 'hresp' represents the most extreme response exhibited by at least one animal in the wildlife group.
- The response categories for 'hresp' were coded 'N' for not stopping, 'S' for stopping, 'D' for dismounting, 'AP' for approaching wildlife, and 'IH' for impeding or hindering or blocking wildlife.

For the 'Traffic-Related Variables' in Table 1:

- The daily number ('gate') and the cumulative daily number ('cum') of OSVs entering through the west, south, or east gates of YNP. Thus, 'gate' is the sum of 'west', 'south', and 'east' and 'cum' is the sum of 'cumwest', 'cumsouth', and 'cumeast'.
- The variable 'gateid' indicates whether or not the cumulative number of OSVs for each day in the study is > 7500 or < 7500.

The Wildlife Species:

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. Table 2 contains the number of observations used in the final statistical models.

Although numerous other animal species were observed, the numbers of observations are much lower. Once survey data has been collected over several winter seasons, analyses

that use data pooled over multiple winters should be performed on these other animal species. Preliminary analyses may be feasible for both coyotes and bald eagles with one or two more seasons of data.

Table 2

Species	Observations
Bison	1485
Elk	766
Swan	382

The Response to be Modeled:

The survey variable to be modeled is 'wresp1', the most extreme wildlife response that was observed during a human/wildlife encounter. 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.

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	1064	291	141
LR	Look-and-resume	1	187	170	75
AC	Combining T, AA, F, and D	0	234	305	166
T	Travel away from OSVs and humans	—	111	47	53
AA	Alarm, attention, or agitation	—	74	220	104
F	Flight	—	43	37	9
D	Defensive attack or charge	—	6	1	0

The N (no apparent response) and LR (look-and-resume) categories account for 84%, 60%, and 56% of the bison, elk, and swan observations, respectively. Because of the relatively low frequencies for both the F and D responses, and either the T or AA responses, these four response categories were combined into a single category for each 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.

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.

Because we have a **polytomous response** (i.e., more than two response categories), 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 a function of 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:

π_{i0} = Probability of an active (AC) response given condition $\mathbf{x}_i$.

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

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

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

Fitting the Generalized Logits Model

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

$$\begin{aligned}
\widehat{L}_{i0} &= \text{estimated log}\left(\frac{\pi_{i0}}{\pi_{i2}}\right) = b_{00} + b_{10}x_{i1} + b_{20}x_{i2} + b_{30}x_{i3} + \cdots + b_{m0}x_{im} \\
\widehat{L}_{i1} &= \text{estimated log}\left(\frac{\pi_{i1}}{\pi_{i2}}\right) = b_{01} + b_{11}x_{i1} + b_{21}x_{i2} + b_{31}x_{i3} + \cdots + b_{m1}x_{im}
\end{aligned}$$

which can be evaluated at any combination $\mathbf{x}_i = (x_{i1}, x_{i2}, \ldots, x_{ip})$ of the p variables in the model. 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.

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. 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 each of the gates was 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. The only serious multicollinearity problem was between 'distance' and 'OSVdist'. Thus, only one of these two highly correlated variables should be in the model at any time.

Because of low counts, similar categories were combined or, if a category was not similar to any other category, the data were deleted from the data set. The following summarize the adjustments to the categorical data:

- Because of very few cases of 'prcp' = fog, these observations were not included.
- Because of very few cases of 'prcp' = 1 and 'prcp' = 2, the light and intermittent rain and constant rain categories were combined into a single 'prcp' = 1 category
- For the numerous cases of missing data for 'actv', a category labeled 'unknown' was created for these cases.

Because of the relatively large ranges of values for certain quantitative variables, large values were transformed to a maximum permissible value to improve the fit of the linear model.

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)
S = stop and remain on OSV
D = dismount OSV but remain near machine
AP = approach wildlife
IH = impede or hasten movement of wildlife
N = no apparent response *

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

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

Cloud cover (ccover)
0 = clear
1 = up to 25%
2 = 25% to 50%
3 = 50% to 75%
4 = 75% to 100% *

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

Wildlife activity (actv)
R = resting *
S = standing/perching/floating
FD = feeding
T = traveling
AA = attention/alarm
FL = flight
D = defensive

Reaction to Observer (RTO)
0 = No reaction to observers
1 = Some reaction to observers *

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 snowmobiles	sb	individual snowmobiles
Number of snowcoaches	coach	individual snowcoaches
Number of wheeled vehicles	whld	individual vehicles
Duration of the human/wildlife interaction	intxn	minutes
Total number in wildlife group	sppnum	10 animals
Total number of adult males	am	10 animals
Total number of females and juvenile	af_juv	10 animals
Total number of unknown age/gender	unk	10 animals
Daily gate OSV count	gate	100 vehicles

The following summarize the adjustments to the quantitative variables:

- For bison: (i) if 'distance' > 200m, then 'distance' = 200m, (ii) if 'sb' > 12, then 'sb' = 12, (iii) if 'intxn' > 20 minutes, then 'intxn' = 20 minutes, and (iv) if 'sb' > 12, then 'sb' = 12.
- For elk: (i) if 'distance' > 200m, then 'distance' = 200m, (ii) if 'sb' > 2, then 'sb' = 2, (iii) if 'coach' > 0 then 'coach' = 1, (iv) if 'intxn' > 20 minutes, then 'intxn' = 20 minutes, (v) if 'af_juv' > 30 then 'af_juv' = 30, (vi) if 'am' > 5 then 'am' = 5, and (vii) if 'unk' > 100, then 'unk' = 100.
- For swans: (i) if 'distance' > 75m, then 'distance' = 75m, (ii) if 'sb' > 8, then 'sb' = 8, and (iii) if 'sppnum' > 12, then 'sppnum' = 12.

These maximum cutoff values act as thresholds. That is, once exceeded, we no longer expect to observe the effect on the response associated with changing that variable.

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 (sb) and the number of snowcoaches (coach) for bison, elk, and swans, and (ii) the guide status (guide) for bison and elk only. These were retained in the model so that the two specific management concerns stated in the Introduction are addressed explicitly in the final model. With only 3 cases of with a 'no guide' status for the OSVs, it was not feasible to keep these 3 observations when model building. Once removed, the presence of coaches and the presence of a guide were confounded (i.e., if a coach was present it was guided). Thus, only 'coach' was retained in the swan 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.

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. The maximum likelihood estimate summaries for the categorical and quantitative variables, respectively, in the final model of the bison data will now be examined.

Table 6: Maximum Likelihood Analysis of Variance Results

For Bison

Model Terms	df	χ^2	p-value
Intercept	2	3.61	0.1647
distance	2	62.51	<.0001
sb	2	14.03	0.0009
coach	2	10.81	0.0045
guide	4	24.76	<.0001
intxn	2	4.16	0.1252
am	2	7.22	0.0271
af_juv	2	5.70	0.0580
habitat	6	14.41	0.0254
hresp	8	42.93	<.0001
onroad	2	31.71	<.0001
ccover	8	15.89	0.0440
RTO	2	43.95	<.0001
actv	8	14.63	0.0667
gate	2	7.90	0.0193

For Elk

Model Terms	df	χ^2	p-value
Intercept	2	6.68	0.0355
distance	2	8.42	0.0149
sb	2	28.37	<.0001
coach	2	24.75	<.0001
guide	4	23.72	<.0001
intxn	2	4.21	0.1221
am	2	15.48	0.0004
af_juv	2	19.02	<.0001
unk	2	4.41	0.1101
habitat	8	12.28	0.1393
hresp	6	27.98	<.0001
prcp	6	19.53	0.0034
RTO	2	16.91	0.0002
actv	8	17.21	0.0280
gate	2	16.19	0.0003

For Swans

Model Terms	df	χ^2	p-value
Intercept	2	20.29	<.0001
distance	2	23.21	<.0001
sb	2	6.81	0.0332
coach	2	7.72	0.0211
temp	2	4.49	0.1061
sppnum	2	5.47	0.0650
hresp	6	2.26	0.8943
prcp	6	17.66	0.0072
RTO	2	14.81	0.0006

The Maximum Likelihood Estimate Tables

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

- For each categorical variable level, results are presented relative to a baseline level (which is indicated in Table 4). In the 'Level' column in Table 7, the specific comparisons to the baseline are indicated. For example, 'BF v M' for habitat indicates that we are comparing the burned forest habitat to the baseline meadow 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:
  - For 4 symbols ($++++$ or $----$), the p-value is $< .001$.
  - For 3 symbols ($+++$ or $---$), the p-value is between .001 and .01.
  - For 2 symbols ($++$ or $--$), the p-value is between .01 and .05.
  - For 1 symbol ($+$ or $-$), 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	0.860	3.06	0.0805	+	2.36
		LR v N	0.629	1.85	0.1735		1.88
guide	N v G	AC v N	-0.694	5.40	0.0202	−−	0.25
		LR v N	-1.373	20.29	<.0001	−−−−	0.06
guide	A v G	AC v N	0.341	2.80	0.0943	+	1.98
		LR v N	0.631	11.26	0.0008	++++	3.53
RTO	No v Yes	AC v N	-1.419	31.30	<.0001	−−−−	0.06
		LR v N	-1.455	38.62	<.0001	−−−−	0.05
habitat	BF v M	AC v N	-0.302	1.18	0.2778		0.55
		LR v N	0.021	0.01	0.9304		1.04
habitat	F v M	AC v N	-0.056	0.08	0.7789		0.89
		LR v N	-0.330	2.69	0.1007		0.52
habitat	TH v M	AC v N	0.600	8.67	0.0032	+++	3.32
		LR v N	0.405	5.27	0.0217	++	2.25
hresp	IH v N	AC v N	2.678	25.28	<.0001	++++	212
		LR v N	0.159	0.04	0.8371		1.37
hresp	AP v N	AC v N	-0.842	3.25	0.0714	−	0.19
		LR v N	0.300	0.45	0.5007		1.82
hresp	D v N	AC v N	-0.603	3.27	0.0706	−	0.30
		LR v N	-0.260	0.49	0.4861		0.59
hresp	S v N	AC v N	-0.389	2.34	0.1258		0.46
		LR v N	0.049	0.03	0.8651		1.10
onroad	On v Off	AC v N	-0.726	21.25	<.0001	−−−−	0.23
		LR v N	0.243	2.01	0.1560		1.63
ccover	1 v 0	AC v N	-0.155	0.47	0.4911		0.73
		LR v N	0.096	0.29	0.5890		1.21
ccover	2 v 0	AC v N	-0.518	2.51	0.1131		0.36
		LR v N	0.359	2.65	0.1037		2.05
ccover	3 v 0	AC v N	0.333	2.44	0.1185		1.95
		LR v N	-0.472	4.65	0.0310	−−	0.39
ccover	4 v 0	AC v N	0.001	0.00	0.9936		1.00
		LR v N	-0.195	1.52	0.2180		0.68
actv	U v R	AC v N	0.188	0.78	0.3760		1.46
		LR v N	-0.389	4.47	0.0345	−−	0.46
actv	T v R	AC v N	0.642	3.92	0.0477	++	3.61
		LR v N	0.750	5.40	0.0201	++	4.48
actv	FD v R	AC v N	-0.185	0.61	0.4335		0.69
		LR v N	-0.139	0.58	0.4455		0.76
actv	S v R	AC v N	0.073	0.04	0.8448		1.16
		LR v N	0.288	0.84	0.3597		1.78

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
distance	AC v N	-1.149	30.63	<.0001	$----$	0.32
	LR v N	-1.024	42.43	<.0001	$----$	0.36
sb	AC v N	0.131	11.39	0.0007	+++	1.14
	LR v N	0.090	6.15	0.0131	++	1.09
coach	AC v N	0.847	10.63	0.0011	+++	2.33
	LR v N	0.410	2.45	0.1176		1.51
intxn	AC v N	0.051	3.99	0.0457	++	1.05
	LR v N	0.004	0.01	0.9059		1.00
am	AC v N	0.030	1.04	0.3078		1.03
	LR v N	-0.072	4.84	0.0278	$--$	0.93
af_juv	AC v N	-0.012	0.90	0.3419		0.99
	LR v N	0.020	3.63	0.0569	+	1.02
gate	AC v N	-0.213	3.10	0.0783	$-$	0.81
	LR v N	-0.261	6.47	0.0110	$--$	0.77

5. Results from the Bison Model

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

The results in Table 8 regarding snowmobiles (sb) 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 ratio of a look-and-resume (LR) bison response or an active (AC) bison response (relative to the odds of no response) increases with increasing numbers of snowmobiles in a group. The odds ratio of 1.14 indicates that we estimate that the odds of observing an AC bison response (relative to the odds of no response) are 14% greater for each additional snowmobile in the group (up to sb=12 (see page 12)). Similarly, the odds ratio of 1.09 indicates that we estimate a that the odds of observing an LR bison response (relative to the odds of no response) are 9% greater for each additional snowmobile in the group.

- Example: Under identical conditions, we would expect the odds of an active bison response (relative to the odds of no response) would, on average, be 28% higher for a group of 4 snowmobiles than for a group of 2 snowmobiles. Also, we expect the odds of a look-and-resume bison response would, on average, be 18% higher for a group of 4 snowmobiles than for a group of 2 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.

If the human/wildlife encounter occurred between the observers and the wildlife group (RTO=yes), then the effects of the number snowmobiles needs to be adjusted. The adjustments are given by the reaction-to-observers (RTO) estimates. The odds of a look-and-resume (LR) bison response or an active (AC) bison response (relative to the odds of no response) decreases if the interaction was between the observers and the bison group (RTO=yes) rather than if the interaction was between the park visitors and the bison group (RTO=no). We estimate that the odds of observing an AC bison response is approximately 1/17 (.06) the odds of no response when the reaction was to the observers rather than to the park visitors. Similarly, we estimate that the odds of observing a LR bison response is approximately 1/20 (.05) the odds of no response when the reaction was to the observers rather than to the park visitors. Thus, although bison on occasion react to the observers, the odds of it being a LR or AC response is much less likely than if the reaction was to a park visitor.

The results in Table 8 regarding snowcoaches (coach) indicate that the parameter estimate for the AC v N comparison is statistically significant. Thus, after adjusting for the other model effects, we conclude the odds of an active (AC) bison response (relative to the odds of no response) change with increasing numbers of snowcoaches in a group. The odds ratio of 2.33 indicates that we estimate that the odds of observing an AC bison response (relative to the odds of no response) are 2.33 times greater for each additional snowcoach in the group.

Note that although the odds ratio is 1.51 for the LR v N comparison suggesting that the odds of observing an LR bison response (relative to the odds of no response) is increasing with the number of snowcoaches, the variability associated with this estimate was much larger than the variability for the snowmobile estimates. The fact that this parameter estimate was (marginally) not statistically significant ($p = .1176$) indicates that any association between the number of snowcoaches and the LR 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.

(2) Are the levels of human activities and behavioral responses of bison different between commercially guided OSVs and other vehicles?

The results in Table 7 indicate that in a comparison of administrative traffic to guided groups, there are statistically significant parameter estimates associated with both the LR v N and the AC v N comparisons. The odds ratio of 3.53 indicates that we estimate that the odds of observing a look-and-resume bison response (relative to the odds of no response) for administrative traffic are 3.53 times higher than for an guided OSV group (under identical conditions). Similarly, the odds ratio of 1.98 indicates that we estimate that the odds of observing an active response (relative to the odds of no response) for administrative traffic is approximately twice that for a guided group (under identical conditions).

In a comparison of guided to not guided status groups, there is a statistically significant parameter estimate associated with both the LR v N and AC v N comparisons. The odds ratios of 0.06 and 0.25 indicate that we estimate that the odds of observing an look-and-resume or active bison response (relative to the odds of no response) are, respectively, about 1/17 and 1/4 for a not-guided group than for an guided group (under identical conditions). The statistical significance of the not-guided group effects are due to the fact that all 359 cases correspond to wheeled vehicles. Thus, the results suggest that a wheeled vehicle is less likely to be associated with LR and AC wildlife responses.

(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 and the baseline level. In the subsequent discussion of the bison results, comparisons are assumed to be under identical conditions. The discussion involves only statistically significant parameter estimates.

1. The estimated odds of observing a look-and-resume response (relative to the odds of no response) are 2.25 times higher for a thermal habitat than for a meadow habitat.
2. The estimated odds of observing an active response (relative to the odds of no response) are 3.32 times higher for a thermal habitat than for a meadow habitat.
3. The estimated odds of observing an active bison response (relative to the odds of no bison response) are 212 times higher for an impede/hasten human response than for no human response.

4. When the human response comparisons are, respectively, AP v N and D v N, the estimated odds of observing an active bison response (relative to the odds of no bison response) are not significant at the .05 level (p=.0714 and p=.0706) but are marginally significant at the .10 level. The fact that the odds ratios are < 1 (0.19 and 0.30) makes these results difficult to interpret. By comparing these results over several seasons, we will be able to determine if these effects are spurious or are consistent across multiple seasons.

5. The effects of cloud cover on the odds ratio appear to be minor. The only moderately significant (p=.0310) odds ratio of 0.39 was for the LR v N comparison and between the 50-75% (ccover=3) and clear (ccover=0) categories.

6. The estimated odds of observing an active response or look-and-resume response (relative to the odds of no response) are, respectively, 3.61 and 4.48 times greater when the predominant undisturbed bison activity is traveling (T) than when the predominant undisturbed activity is resting (R).

Note that some odds ratios may appear large (much greater than 1) or small (close to 0), but because of large variability in the data, the parameter estimates were not significant. As stated earlier, when data is pooled from multiple winter seasons, we will (i) improve the likelihood of detecting any potential effects that truly exist, but currently cannot be detected from a single season's data, (ii) strengthen the evidence for those effects already statistically significant, and (iii) hopefully eliminate any spurious effects that may be marginally significant in any particular season.

(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. For distance from road, the estimated odds of observing an active response (relative to the odds of no response) are .32., or, equivalently, the estimated odds of observing no response relative to an active response are $(1/.32) = 3.12$. Note that 100 meters is the distance unit of measurement. Thus, for each 100 meters increase in distance from the road (up to 200 meters (see page 12)), the estimated odds of observing no bison response relative to the odds of an active bison response are approximately 3 times higher.

2. Analogously, the estimated odds of observing no response relative to a look-and-resume response are $(1/.36) = 2.78$ 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 2.78 times higher.

3. For the interaction time (in minutes), the estimated odds of observing an active response to the odds of no response are 1.05. Thus, for each minute increase in interaction time (up to 20 minutes (see page 12)), the estimated odds of observing an active bison response relative to odds of no response are 5% higher.

4. The effect of the number of bison on the odds ratio depends on the combination of sex and age class. For the number of adult male bison (am), the estimated odds of observing no response relative to the odds of a look-and-resume response relative are $(1/.93) = 1.08$. On the other hand, for the number of adult female or juvenile bison (af_juv), the estimated odds of observing a look-and-resume response relative to the odds of no response are 1.02. Thus, there is a tradeoff between the number of males present and the number of females or juveniles present. Also, note that 10 animals is the unit of measurement.

5. For the daily gate OSV numbers, the estimated odds of observing no response relative to the odds of a look-and-resume response are $(1/.77) = 1.30$. Thus, for a 100 vehicle increase, the estimated odds of observing no response relative to the odds of a look-and-resume response are 30 % higher.

6. For the daily gate OSV numbers, the estimated odds of observing no response relative to the odds of an active response are $(1/.81) = 1.23$. Thus, for a 100 vehicle increase, the estimated odds of observing no response relative to the odds of an active response are 23 % higher. These results suggest bison are less likely to respond on days with higher traffic.

6. Results from the Elk Model

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

The results in Table 10 regarding snowmobiles (sb) 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 ratio of a look-and-resume (LR) elk response or an active (AC) elk response (relative to the odds of no response) increases with increasing numbers of snowmobiles in a group. The odds ratio of 4.40 indicates that we estimate that the odds of observing an AC elk response (relative to the odds of no response) are 4.4 times greater for each additional snowmobile

in the group (up to sb=2 (see page 12). Similarly, the odds ratio of 1.99 indicates that we estimate a that the odds of observing an LR elk response (relative to the odds of no response) are twice as great for each additional snowmobile in the group. Hence, we expect some increase in AC or LR responses for relative to N responses for elk as the number of snowmobiles increases.

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

Parameter	Level	Comparison	Estimate	χ^2	p-value	p-code	Odds Ratio
guide	N v G	AC v N	-1.421	3.60	0.0577	$-$	0.06
		LR v N	-0.914	4.77	0.0290	$--$	0.16
guide	A v G	AC v N	1.175	9.63	0.0019	$+++$	10.5
		LR v N	0.892	16.57	<.0001	$++++$	5.96
RTO	H v M	AC v N	-2.172	15.96	<.0001	$----$	0.01
		LR v N	-1.845	11.47	0.0007	$----$	0.02
habitat	A v M	AC v N	0.447	2.89	0.0889	$+$	2.44
		LR v N	0.749	7.87	0.0050	$+++$	4.48
habitat	BF v M	AC v N	0.010	0.00	0.9622		1.02
		LR v N	-0.124	0.29	0.5877		0.78
habitat	F v M	AC v N	0.221	0.90	0.3426		1.56
		LR v N	0.165	0.45	0.5023		1.39
habitat	TH v M	AC v N	-0.453	2.10	0.1476		0.40
		LR v N	-0.858	4.92	0.0266	$--$	0.18
hresp	AP v R	AC v N	0.903	4.57	0.0326	$++$	6.09
		LR v N	0.508	1.01	0.3140		2.76
hresp	D v R	AC v N	0.541	1.78	0.1822		2.95
		LR v N	-1.093	2.88	0.0898	$-$	0.11
hresp	S v R	AC v N	-0.616	4.86	0.0275	$--$	0.29
		LR v N	0.207	0.38	0.5393		1.51
prcp	0 v 4	AC v N	-0.052	0.05	0.8216		0.90
		LR v N	0.269	0.70	0.4018		1.71
prcp	1 v 4	AC v N	-1.185	6.37	0.0116	$--$	0.09
		LR v N	-2.395	8.55	0.0035	$---$	0.01
prcp	3 v 4	AC v N	0.123	0.22	0.6394		1.28
		LR v N	0.839	6.03	0.0141	$++$	5.35
actv	U v R	AC v N	0.045	0.03	0.8650		1.09
		LR v N	0.075	0.07	0.7909		1.16
actv	T v R	AC v N	-0.559	0.77	0.3807		0.33
		LR v N	0.133	0.05	0.8236		1.31
actv	FD v R	AC v N	-0.544	3.79	0.0517	$-$	0.34
		LR v N	-0.155	0.29	0.5928		0.73
actv	S v R	AC v N	1.468	5.79	0.0162	$++$	18.8
		LR v N	-0.340	0.19	0.6594		0.51

Table 10: Maximum Likelihood Estimates for the Quantitative Variables in the Generalized Logits Model for the Elk Data

Parameter	Comparison	Estimate	χ^2	p-value	p-code	Odds Ratio
Intercept	AC v N	1.713	4.42	0.0355	++	5.54
	LR v N	0.140	0.03	0.8652		1.15
distance	AC v N	-0.355	8.17	0.0042	− − −	0.70
	LR v N	-0.194	2.73	0.0986	−	0.82
sb	AC v N	1.481	25.33	<.0001	+ + ++	4.40
	LR v N	0.690	5.69	0.0170	++	1.99
coach	AC v N	2.914	22.78	<.0001	+ + ++	18.4
	LR v N	1.327	4.79	0.0286	++	3.77
intxn	AC v N	0.053	1.61	0.2051		1.05
	LR v N	0.085	4.20	0.0404	++	1.09
am	AC v N	-0.868	14.16	0.0002	− − −−	0.42
	LR v N	-0.452	5.23	0.0223	−−	0.64
af_juv	AC v N	0.070	11.99	0.0005	+ + ++	1.07
	LR v N	-0.019	0.61	0.4361		0.98
unk	AC v N	-0.095	4.18	0.0408	−−	0.91
	LR v N	-0.024	0.78	0.3786		0.98
gate	AC v N	-0.576	15.71	<.0001	− − −−	0.56
	LR v N	-0.204	2.26	0.1326		0.82

If the human/wildlife encounter occurred between the observers and the wildlife group (RTO=yes), then the effects of the number snowmobiles needs to be adjusted. The odds of a look-and-resume (LR) elk response or an active (AC) elk response (relative to the odds of no response) decreases if the interaction was between the observers and the elk group (RTO=yes) than if the interaction was between the park visitors and the elk group (RTO=no) . We estimate that the odds of observing an AC elk response is approximately 1/100 (.01) the odds of no response when the reaction was to the observers rather than to the park visitors. Similarly, we estimate that the odds of observing a LR elk response is approximately 1/50 (.02) the odds of no response when the reaction was to the observers rather than to the park visitors. Thus, although elk on occasion react to the observers, the odds of it being a LR or AC response is much less likely than if the reaction was to a park visitor.

The results in Table 10 regarding snowcoaches (coach) indicate that the parameter estimates for the two comparisons are positive and statistically significant. Recall that if at least one snowcoach was present, then we set coach=1 (see page 12). Thus, we are treating 'coach' as a presence/absence variable. After adjusting for the other model

effects, we conclude that the odds ratio of a look-and-resume (LR) elk response or an active (AC) elk response (relative to the odds of no response) increases with the presence of a snowcoach. The odds ratio of 18.4 indicates that we estimate that the odds of observing an AC elk response (relative to the odds of no response) are 18.4 times greater when at least one snowcoach is present than when none are present. Similarly, the odds ratio of 3.77 indicates that we estimate a that the odds of observing an LR elk response (relative to the odds of no response) are 3.77 times greater when at least one snowcoach is present. Hence, we expect some increase in AC or LR responses for relative to N responses for elk given the presence of a snowcoach.

(2) Are the levels of human activities and behavioral responses of elk different between commercially guided OSVs and other vehicles?

The results in Table 9 indicate that in a comparison of administrative traffic to guided groups, there are statistically significant parameter estimates associated with both the LR v N and the AC v N comparisons. The odds ratio of 5.96 indicates that we estimate that the odds of observing a look-and-resume elk response (relative to the odds of no response) for administrative traffic are approximately six times higher than for a guided OSV group (under identical conditions). Similarly, the odds ratio of 10.48 indicates that we estimate that the odds of observing an active response (relative to the odds of no response) for administrative traffic is 10.48 times higher than for a guided group (under identical conditions).

In a comparison of guided to not-guided groups, there is a statistically significant parameter estimate associated with both the LR v N and AC v N comparisons. The odds ratios of 0.16 and 0.06 indicate that we estimate that the odds of observing an look-and-resume or active elk response (relative to the odds of no response) are, respectively, about 1/6 and 1/17 for a not-guided group than for an guided group (under identical conditions). The statistical significance of the not-guided group effects are due to the fact that all 107 cases correspond to wheeled vehicles. Thus, the results suggest that a wheeled vehicle is less likely to be associated with LR and AC wildlife responses.

(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.

1. The estimated odds of observing an active response or a look-and-resume response (relative to the odds of no response) are 2.4 and 4.5 times higher, respectively, for an aquatic habitat than for a meadow habitat.

2. The estimated odds of observing a look-and-resume response (relative to the odds of no response) are .18 times or approximately one-fifth for a thermal habitat than for a meadow habitat.

3. The estimated odds of observing an active response (relative to the odds of no response) are 6 times higher for an approach-wildlife (AP) human response than for no human response.

4. The estimated odds of observing a look-and-resume response (relative to the odds of no response) are .11 or approximately one-ninth for a dismount (D) human response than for no human response.

5. The estimated odds of observing an active response (relative to the odds of no response) are .29 or approximately three-tenths for a stop vehicle (S) human response than for no human response.

6. The estimated odds of observing an active response or a look-and-resume response (relative to the odds of no response) are .09 and .01 when it is raining than when it is snowing heavily.

7. The estimated odds of observing a look-and-resume response (relative to the odds of no response) are 5.35 when it is snowing lightly than when it is snowing heavily.

8. The estimated odds of observing an active response (relative to the odds of no response) are 18.8 times greater when the predominant undisturbed elk activity is standing (S) than when the predominant activity is resting (R).

9. The estimated odds of observing an active response (relative to the odds of no response) are .34 or approximately 1/3 times when the predominant undisturbed elk activity is feeding than when the predominant activity is resting (R).

Again, note that some odds ratios may appear large (much greater than 1) or small (close to 0), but because of large variability in the data, the parameter estimates were not significant. As stated earlier, with data pooled from multiple winter seasons, we will improve the likelihood of detecting any potential effects that truly exist, but were not detected from a this season's data.

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

Based on the results in Table 10, the behavioral responses of elk are associated with certain quantitative variables. 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 the odds of an active response are (1/.70) or 1.43. Thus, for each 100 meters increase in distance from the road (up to 200 meters (see page 12)), the estimated odds of observing no elk response relative to the odds of an active elk response are 1.43 times higher.

2. Analogously, the estimated odds of observing no response relative to a look-and-resume response are (1/.82) = 1.22 for distance. Thus, for each 100 meters increase in distance from the road, the estimated odds of observing no elk response relative to the odds of a look-and-resume elk response are 1.22 times higher.

3. For the interaction time (in minutes), the estimated odds of observing a look-and-resume response relative to the odds of no response are 1.09. Thus, for each minute increase in interaction time (up to 20 minutes (see page 12)), the estimated odds of observing a look-and-resume response relative to the odds of no elk response are 9% higher.

4. The effect of the number of elk on the odds ratio depends (like for bison) on the combination of sex and age class. For the number of adult male elk (am), the estimated odds of observing no response relative to the odds of an active response are (1/.42) = 2.38. Similarly, the estimated odds of observing no response relative to the odds of a look-and-resume response are (1/.64) = 1.56. On the other hand, for the number of adult female or juvenile elk (af_juv), the estimated odds of observing an active response relative to the odds of no response are 1.07. Thus, there is a tradeoff between the number of males present and the number of females or juveniles present. Also, note that 10 animals is the unit of measurement.

5. For the daily gate OSV numbers, the estimated odds of observing no response relative to the odds of an active response are (1/.56) = 1.79. Thus, for a 100 vehicle increase, the estimated odds of observing no response relative to the odds of a look-and-resume response are 79 % higher.

6. For the daily gate OSV numbers, the estimated odds of observing no response relative to the odds of an active response are (1/.81) = 1.23. Thus, for a 100 vehicle increase, the estimated odds of observing no response relative to the odds of an active response are 23 % higher. These results suggest elk are less likely to respond on days with higher traffic.

7. Results from the Swan Model

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

The results in Table 11 regarding snowmobiles (sb) 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) swans response increase with increasing numbers of snowmobiles in a group. The odds ratio of 1.13 indicates that we estimate the odds of observing an AC swans response (relative to the odds of no response) are 13% greater for each additional snowmobile in the group (up to sb=8 (see page 12)).

Table 11: 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	3.698	19.98	<.0001	++++	40.4
		LR v N	2.422	7.14	0.0075	+++	11.3
distance		AC v N	-3.698	23.06	<.0001	----	0.02
		LR v N	-2.085	5.69	0.0170	--	0.12
sb		AC v N	0.122	5.99	0.0144	++	1.13
		LR v N	0.016	0.07	0.7898		1.02
coach		AC v N	0.800	7.64	0.0057	+++	2.23
		LR v N	0.419	1.66	0.1979		1.52
temp		AC v N	-0.023	4.28	0.0386	--	0.98
		LR v N	-0.018	1.97	0.1606		0.98
sppnum		AC v N	0.062	2.48	0.1155		1.06
		LR v N	-0.036	0.55	0.4597		0.96
RTO	No v Yes	AC v N	-1.959	13.22	0.0003	----	0.02
		LR v N	-1.470	6.86	0.0088	---	0.05
hresp	AP v N	AC v N	0.244	0.39	0.5305		1.63
		LR v N	0.237	0.24	0.6266		1.61
hresp	D v N	AC v N	0.086	0.04	0.8379		1.19
		LR v N	-0.420	0.56	0.4537		0.43
hresp	S v N	AC v N	-0.097	0.10	0.7473		0.82
		LR v N	0.195	0.31	0.5783		1.48
prcp	0 v 4	AC v N	-0.285	0.95	0.3288		0.57
		LR v N	-0.482	2.51	0.1130		0.38
prcp	1 v 4	AC v N	-1.295	3.77	0.0522	-	0.08
		LR v N	-0.707	1.21	0.2709		0.24
prcp	3 v 4	AC v N	0.398	1.46	0.2266		2.21
		LR v N	0.571	2.77	0.0960	+	3.13

If the human/wildlife encounter occurred between the observers and the wildlife group (RTO=yes), then the effects of the number snowmobiles needs to be adjusted. The odds

of a look-and-resume (LR) swan response or an active (AC) swan response (relative to the odds of no response) decreases if the interaction was between the observers and the swan group (RTO=yes) than if the interaction was between the park visitors and the swan group (RTO=no). We estimate that the odds of observing an AC swan response is approximately 1/50 (.02) the odds of no response when the reaction was to the observers rather than to the park visitors. Similarly, we estimate that the odds of observing a LR swan response is approximately 1/20 (.05) the odds of no response when the reaction was to the observers rather than to the park visitors. Thus, although swans on occasion react to the observers, the odds of it being a LR or AC response is much less likely than if the reaction was to a park visitor.

The results in Table 11 regarding snowcoaches (coach) indicate that the parameter estimate for the AC v N comparison is also statistically significant. Thus, after adjusting for model effects, we conclude that the odds of an active (AC) swan response increases with increasing numbers of snowcoaches in a group. The odds ratio of 2.23 indicates that we estimate the odds of observing an AC swans response (relative to the odds of no response) are 2.23 times greater for each additional snowcoach in the group.

(2) Are the levels of human activities and behavioral responses of swans different between commercially guided OSVs and other vehicles?

As stated earlier, the guide status was not retained in the swan model because there were only 3 cases of OSVs with an not-guided group status. With so few cases, it was not feasible to keep these 3 observations when model building. Also, the presence of coaches and the presence of a guide were confounded (i.e., if a coach was present it was guided). Thus, only 'coach' was retained in the swan model, and no test for the guide status was performed.

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

Based on the results in Table 11, the behavioral responses of swans are associated with certain comparisons of categorical variable levels with the baseline level.

1. The estimated odds of observing an active response (relative to the odds of no response) are 1/(.08) = 12.5 times greater when it snowing heavily than when there is no precipitation.

2. The estimated odds of observing a look-and-resume response (relative to the odds of no response) are 3.13 times greater when it is snowing lightly than when it is snowing heavily.

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

Based on the results in Table 11, the behavioral responses of swans are associated with certain quantitative variables. For an odds ratio less than one for a quantitative variable, we will again use 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 the odds of an active response are (1/.02) or 50. Thus, for each 100 meters increase in distance from the road, the estimated odds of observing no swan response relative to the odds of an active swan response are 50 times higher.

2. For distance from the road, the estimated odds of observing no response relative to the odds of a look-and-resume response are (1/.12) or 8.33. Thus, for each 100 meters increase in distance from the road, the estimated odds of observing no swan response relative to the odds of a look-and-resume swan response are 8.33 times higher.

3. For temperature, the estimated odds of observing no response relative to an active response are (1/.98) = 1.02. Thus, for each degree increase in temperature, the estimated odds of observing no response relative to an active response are 2% higher.

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 OSVs and other vehicles?

Table 12 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 12 suggest that the odds of an active or look-and-resume wildlife responses relative to the odds of no response to winter use in Yellowstone National Park along the surveyed road segments is consistent across species. It is the magnitude of the odds that varies considerably across species.

- For bison and trumpeter swans, the snowmobile odds ratios are similar for both the AC v N and for the LR v N comparisons while the odds ratios are larger for the elk. The same is true for the snowcoach odds ratios.
- The administrative vs guided OSV odds ratios are larger for both the AC v N and for the LR v N comparisons for the elk than for the bison.
- The not-guided vehicles vs guided OSV odds ratio for AC v N comparison is smaller for the elk than for bison, while the odds ratio for the LR v N comparison is larger for the elk than for the bison. In either case, both AC and LR responses are less likely with the not-guided (wheeled) vehicle groups than for the guided groups.

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 forest (F) for bison for the AC v N comparison, first take the difference of the estimates in Table 7 (which is $-.302 - (-.056) = -.246$. Then exponentiate twice this difference ($-.492$) yielding an odds ratio of $e^{-.492} = 0.611$.

Table 12: Estimated Odds Ratios

Snowmobile Comparisons

	For Bison	For Elk	For Swans
AC v N	**1.14**	**4.40**	**1.13**
LR v N	**1.09**	**1.99**	1.02

Snowcoach Comparisons

	For Bison	For Elk	For Swans
AC v N	**2.33**	**18.43**	**2.23**
LR v N	1.51	**3.77**	1.52

Administrative vs Guided Group Comparisons

	For Bison	For Elk	For Swans
AC v N	**1.98**	**10.48**	—
LR v N	**3.53**	**5.96**	—

Not Guided vs Guided Group Comparisons

	For Bison	For Elk	For Swans
AC v N	**0.25**	**0.06**	—
LR v N	**0.06**	**0.16**	—

Boldface values are statistically significant.