

## SUPPLEMENTARY INFORMATION

### Climate impacts on bird and plant communities from altered animal-plant interactions

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#### Study area and Methods

##### *Study area*

Study drainages are 8-14 ha each (most are approximately 10 ha) and relatively shallow, with a width from bottoms to ridge tops of about 75 - 150 m. We have placed permanently marked sampling stations at 25 m intervals down the center of each drainage. Drainages support a mix of deciduous and coniferous vegetation; canopy trees are quaking aspen (*Populus tremuloides*), Douglas-fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), ponderosa pine (*Pinus ponderosa*), and white pine (*Pinus monticola*). The understory and subcanopy includes canyon maple (*Acer grandidentatum*), New Mexican locust (*Robinia neomexicana*), ramets and saplings of over- and understory tree species, golden pea (*Thermopsis pinetorum*), and various grasses. The surrounding forest is characterized by open ponderosa pine (*Pinus ponderosa*) with Gambel's oak (*Quercus gambeli*) in the subcanopy and little understory vegetation<sup>1-3</sup>. A cross-section of each drainage varies predictably in plant species composition with those requiring mesic habitat (maple, aspen, forbs) being more abundant in the drainage bottoms and those requiring xeric conditions (locust, oak) being more abundant at the ridgetops<sup>1,2</sup>. This gradient is replicated in every drainage and annual changes in vegetation have been carefully measured since 1989<sup>3</sup>.

To examine the effects of elk herbivory, we selected paired treatment and control drainages (generally separated by approximately 300 – 500 m) and erected an elk enclosure around one randomly selected drainage of each pair in autumn 2004. Drainage pairs were replicated across three canyons (roughly 2-5 km apart). The enclosures consisted of a 3 m tall game fence that started 0.3 m above ground level to allow entry and exit of all animals except elk (see Fig. S1). Two high tension wires were strung above the game fence. The fence inhibited mule deer (*Odocoileus hemionus*) movement, but did not completely exclude them because they used the 0.3 ground-level opening to crawl in and out.

##### *Climate variation*

Climate data were obtained from the National Ocean and Atmospheric Administration weather station at the Blue Ridge Ranger Station, Coconino National Forest. Winter snowfall was estimated as total snowfall from October through March rather than snowpack, since large accumulations of snow, even if they wax and wane, can cause elk to move out of the area<sup>4,5</sup>.

##### *Plant sampling*

We sampled the gradient in plants up the sides of drainages (see *Study area*) via a stratified random sampling design. We placed five 5 m-radius sampling circles at equi-distant points up a transect running from the drainage bottom to the ridge tops. Transects were deployed at every other station (50 m intervals) on alternating sides of the drainage to capture any effects of differing aspect and exposure on plant populations<sup>1,2</sup>.

On the paired control and enclosure drainages, we sampled in a similar manner as above, starting in the first 50 m of the drainage bottom and ending approximately 500 m from these

initial points. At some locations, drainage sides were too short to allow 5 sampling circles for the transect while allowing a 12 m buffer between sampling circles to eliminate any overlap, so the transect was reduced to 3 sampling points (bottom, middle, ridge). As a result, a total of 131 sampling circles were established and sampled per treatment. Note that these transects and circles were paired between treatments; for each replicate pair of drainages, transects were started at the same distance from the beginning of the drainage and on the same side of the drainage on both drainages. This ensured that the distance from start of the drainage, orientation, and topographic location of sampling circles were paired between treatments.

### ***Bird species and sampling***

Thirty-two species of birds occur regularly on our study drainages<sup>1</sup>. Study species were the ground-nesting orange-crowned warbler (*Oreothlypis celata*), Virginia's warbler (*Oreothlypis virginiae*), red-faced warbler (*Cardellina rubrifrons*), and gray-headed junco (*Junco hyemalis*) and the shrub-nesting green-tailed towhee (*Pipilo chlorurus*) and hermit thrush (*Catharus guttatus*). These species differ in nest site selection along the vegetation gradient<sup>2</sup>.

T. Martin conducted censuses in all years, except 2000, to control for potential observer differences. Censuses were supplemented with territory maps made by each nest-searcher who visited the drainages every other day for the entire field season<sup>3</sup>. Most drainages are 25 stations in length (625 m) and 10 ha in area, but 3 drainages are shorter and smaller. We standardized bird abundance to numbers of pairs per 10 ha across all drainages.

### ***Elk population sizes***

Elk population sizes come from annual roadside and aerial surveys conducted each August by Arizona Game and Fish Department<sup>6</sup>. These survey estimates are further verified by population estimates derived from modeling annual elk take by sex and age classes<sup>6</sup>. Elk population sizes are the total number of elk for Management Unit 5A, which is defined geographically by Arizona Game and Fish Department. Management Unit 5A is a large area that encompasses both summer range (our study area and surrounding areas) and winter range (our study area and lower elevations). Population size in this entire region does not reflect the number of elk overwintering on our study area but instead is best thought of as the number of animals that are *potentially* available to create overwinter browsing impacts. The *actual* overwinter browsing impact, however, depends on the influence of snow on overwinter presence of elk. Put another way, the number of elk that spend the winter at our study area depends on snowfall<sup>4</sup>, whereas the elk survey data represent elk numbers over a much broader region and is not determined by snow. So, even when elk population sizes for this region are high, overwinter browsing impact is low during high snowfall years because high snow causes elk to move to lower elevations in both our study area<sup>4</sup> and in other geographic areas<sup>5</sup>. This is the reason that elk population sizes do not explain variation in plant densities – browsing impacts are determined by snow levels rather than population size. Even a few animals can have a large effect if low snowfall allows them to stay the entire winter, as reflected by the lack of recovery of plants in the last 11 years when elk population sizes are a fraction of earlier years. Finally, we also note that elk population sizes in this management unit are closely correlated with elk population sizes in adjacent management units and for the state as a whole<sup>6</sup>, again showing that overall population size is not the predictor of overwinter browsing impact.

## Supplementary statistical analyses

### *Snowfall and deciduous woody stem correlations*

Correlated annual changes in snowfall (October through March) and average density of deciduous woody stems (stems per 5-m radius sampling circle) were tested using simple and multiple regression analysis based on snowfall in the three prior winters. Snowfall in the three winters were independent because snowfall was not correlated among the three years (prior year vs two years prior:  $r = -0.02$ ,  $P = 0.9$ ; prior year vs three years prior:  $r = 0.05$ ,  $P = 0.8$ ; two years prior vs three years prior:  $r = 0.26$ ,  $P = 0.3$ ). Densities of deciduous woody stems were averaged across all non-treatment drainages and sampling circles each year, based on 313 – 535 sampling circles per year<sup>3</sup>. The multiple regression analysis of density of deciduous stems showed significant independent and additive effects of snowfall in all three winters: snowfall in the winter prior to vegetation sampling ( $r_p = 0.72$ ,  $P < 0.001$ ,  $N = 20$ ), snowfall two years prior ( $r_p = 0.84$ ,  $P < 0.001$ ) and snowfall three years prior ( $r_p = 0.74$ ,  $P < 0.001$ ) that together explained substantial long-term variation in numbers of woody stems ( $R^2_{3,16} = 0.854$  when including all three years). *The likelihood of three uncorrelated variables (i.e., 3 years of snowfall) each correlating with, and additively explaining, variation in plant density cannot be explained by chance.*

We also conducted detrending time series correlation analyses. This analysis estimates deviations of each of deciduous stem densities and snowfall from the time trend and then tests for correlations of these deviations. Because of the curvilinear nature of the stem density decline with time (i.e., Fig. 1b), we log transformed time (year). We conducted a partial correlation analysis, where both the dependent variable and the independent variables were corrected for time (the basis of detrending), while properly accounting for the  $df$  for estimating and correcting the trend. This is most appropriate when the trends are intrinsically fitted monotonic functions, such as the log-linear functions observed here. We found that deviations in stem density remained correlated with deviations in snowfall in the prior winter ( $r_p = 0.59$ ,  $P = 0.012$ ,  $df = 1,15$ ), two years prior ( $r_p = 0.73$ ,  $P = 0.001$ ,  $df = 1,15$ ) and three years prior ( $r_p = 0.64$ ,  $P = 0.005$ ,  $df = 1,15$ ), after correcting for time ( $r_p = -0.79$ ,  $P < 0.001$ ,  $df = 1,15$ ).

The lag effect of snow makes biological sense: plant density in one year is influenced by plant density in prior years. A lag effect is clearly demonstrated in the plant responses to exclusion of elk (Fig. 3); plants show a small response in the first year following cessation of browsing and increasing responses that build on previous density in subsequent years (Fig. 3). Indeed, plant density (log-transformed) increased with year in exclosures ( $r = 0.80$ ,  $P = 0.03$ ,  $n = 7$ ) reflecting the influence of plant density in the prior year on plant density in the current year. In contrast, plant density did not increase with year on control plots ( $r = -0.24$ ,  $P = 0.6$ ) where elk browsing continued to reduce plant densities. The exclosure result reflects a well-known and common population response where plant density is influenced by the number of recruits and stems in the prior year. Yet, when recruits are browsed to the ground, as occurs in this system on non-exclosure drainages, it reduces recruitment and plant density in subsequent years. Such responses yield the significant lag effects of snow through elk herbivory on plant densities. Thus, all of this evidence shows a very strong influence of snowfall on plant densities.

### *Bird abundances and deciduous woody stem densities*

Correlated changes in bird abundances with vegetation across years were tested using linear regression between mean density of deciduous woody stems per 5 m radius sampling circle and average numbers of breeding pairs per 10 ha for each bird species, where bird densities were averaged across the same 10 drainages sampled every year. We used linear regression rather

than trying to fit curves because we were simply interested in the long-term linear change in bird abundances relative to overall changes in plant stem densities (Fig. 2a).

We also conducted detrending time series analyses. Detrending has to be applied with careful attention to the questions being asked because of the variance that is being removed. The general trend over time represents the primary and major source of variation in the data and removal of this trend leaves only secondary minor variation that is the deviations from the trend. When asking the question, as here, whether bird abundances are changing in response to changes in deciduous stems, the overall response to changes in deciduous stems (i.e., Fig. 2a, which addresses changes in birds to both the trend and deviations from the trend) is important. Focus on only the secondary variation (deviations from the trend), as provided by detrended analyses, addresses only one smaller component of the response by birds to vegetation. The latter can provide additional inference on sensitivity of birds to changes in vegetation, but the overall response of birds to change in vegetation (both the primary variation and the secondary deviations) remains the question being asked in this study. Detrending analyses (Table S1) showed that 4 of the 6 bird species were sensitive to deviations of vegetation beyond the major trend over time. The importance of the overall response to vegetation (both primary trend and deviations from the trend) is further emphasized by the fact that time (year) only explained variation beyond vegetation in two species (Table S1). The four species where time (year) is not significant (Table S1) shows that time trends in bird abundance are not important once we account for variation in vegetation, and detrending analyses are not appropriate in these cases. Instead, the overall relationships between annual bird abundance and vegetation density (as in Fig. 2a) is most appropriate. In the case of Red-faced Warblers and Gray-headed Juncos, where the time trend remains significant even after accounting for vegetation changes, detrended analyses are appropriate as secondary analyses, but note that the effect of vegetation remains significant in both cases (Table S1). Thus, all species showed strong correlations with vegetation density either when detrending was appropriate (Red-faced Warblers and Gray-headed Juncos) and when based on the overall response (all remaining species).

To test whether any larger spatial effects may explain the population changes of birds that we observed, we queried the Breeding Bird Survey data of USGS for population trends of our species for the region in which our study system exists (defined by the Breeding Bird Survey as southern Rockies and Colorado Plateau - <http://www.mbr-pwrc.usgs.gov/bbs/bbs.html>). These trend data for both the long-term and the last decade (Table S2) show that the trends on our study sites are not reflected in regional population trends. Indeed, we found 5 of the 6 species showed significant population declines on our study sites, whereas only Virginia's Warbler showed any tendency for a regional decline, but the trend is essentially flat and not significant (see Table S2). Gray-headed Junco was the only species we examined that increased on our study sites over time (Fig. 2a), and the regional analyses show positive trends, but note that the trend was flat and non-significant for the last 10 years when juncos increased most strongly on our sites (Table S2). Thus, the trends we observed in birds associated with changes in vegetation (Fig. 2a) do not reflect larger spatial scale effects. Moreover, if larger spatial issues were important in the long-term declines, we would not have seen the strong responses of birds to our experimental treatment (i.e., Fig. 2b).

### ***Exclosure treatment effects on birds***

Differences in abundances of birds between treatments were analyzed in two ways, where both ways were based on the difference in numbers of breeding birds between exclosure minus control drainages for each of the three pairs of treatment drainages. First, we examined whether

differences were statistically significant in each year of the study starting from the pre-treatment year (2004) through the last year (2010). We conducted a general GLM to account for experiment-wise error and examined whether mean differences between treatments were significantly different from 0 in each year, where 0 represents no difference between treatments. This was achieved by not including an overall model intercept to examine the significance of the individual intercepts for each year while accounting for variance among the paired replicates and across years. This approach has low power for each year given an  $N$  of 3 for each year. As a result, we were also interested in whether there was a consistent change from the pre-treatment period to post-treatment period. We defined the pre-treatment period as the first two years of the study (2004-2005) when total woody plant densities did not differ between treatments (see Fig. 3a). We compared this pre-treatment period to the subsequent post-treatment years (Period) using a GLM while also accounting for any variation among pairs of treatment drainages, period by treatment pair interaction, and differences among years nested within each period (Table S3).

### ***Treatment differences in plant densities***

Differences between treatments (exclosure minus control) in densities of deciduous woody plants (numbers of stems per 5-m radius samples) were calculated for the three paired replicate sets of drainages. Sampling circles were established in a design that paired them between treatment drainages relative to sampling station and topographic location for all replicates (see *Plant sampling* above). Differences in stem densities were calculated as the difference between these paired sampling circles. We examined whether differences in numbers of stems between treatments were different from 0, which reflects no difference between treatments. This was achieved by using a GLM with no overall model intercept to examine the significance of the intercept in each year while accounting for variance among the replicates, topographic location of the sampling circles, and the interaction of topographic location and replicate identity (Table S4).

Differences between treatments in height of the three main deciduous woody plant species were tested in a two-step process. First, GLM models were used to estimate vegetation height of marked plants in the first (2005) and last (2010) years of the study for each of the 6 drainages while accounting for topographic location and the interaction of topographic location with drainage identity (Table S5). Mean vegetation height was obtained as the least squares mean for each drainage obtained from this analysis. In the second step, these least squares mean vegetation heights for each drainage were used to test for differences between treatments in the first (2005) and final (2010) year of measurements for plants marked in 2005 (Table S6).

### ***Nest predation***

Nest predation rates of birds were estimated using the logistic exposure method<sup>8,9</sup> based on R v2.11.1 for Windows (R Foundation for Statistical Computing, Vienna, Austria). We initially examined all years and included treatment (exclosure vs non-exclosure), bird species, and year as factors. Results showed that an additive model with all three factors was the most parsimonious model explaining the most variation (Table S7a). However, nest predation rates were plotted in Fig. 4 based on the interactive model (Treatment + Species + Year + Treatment\*Species + Treatment\*Year) because this model allows the real variation among years and species to be expressed and does not differ significantly from the additive model based on analysis of deviance ( $P = 0.18$ ).

A second set of models was tested to examine whether pre- and post-treatment periods differed by including period as an additional factor, while nesting year within period. Period was

defined as pre-treatment (2004 and 2005) and post-treatment (2006 – 2010) periods. Results showed that a model including period and interactions with period was the best model (lowest AIC – Table S7b) and this model was better than models without period (Table S7a). Given the significant interaction of period in the best model, we analysed the two periods separately.

For the pre-treatment period, we examined treatment, species and year as factors. Treatment was not included in the best model and was not significant when included ( $P = 0.85$ ; Table S8). This seems clear in that in 2004, most species did not show a strong difference between treatments, and in 2005, species showed no consistent direction of differences (Fig. 4). For the post-treatment period, we examined the same variables, but treatment was highly significant and it was consistent among species as indicated by the lack of interactions between species and treatment (Table S9). Indeed, all species showed significantly lower predation on exclosures than control drainages (see Fig. 4).

## Supplementary Figures



Figure S1. Photo of the game fence surrounding exclosures, shortly after it was erected. Note that the fence has a 0.3 m opening at the bottom to allow movement of animals in and out of the exclosures.

## Supplementary Tables

**Table S1.** Detrended time series analyses of vegetation densities and bird abundances. The dependent variable (abundance of a bird species) and the potential causal independent variable (total deciduous stem density) were corrected for time (year) using log-linear analysis using partial correlation analysis. Time (year) and bird abundance were also corrected for effects of vegetation density. In each column of the table, the first number is  $r_p$  (*partial correlation coefficient*) and the second number is the  $P$ -value. Significant results are bolded.

Bird Species	Ln (Year)	Deciduous Stems
Hermit Thrush	0.322, 0.18	<b>0.523, .022</b>
Orange-crowned Warbler	-0.029, 0.91	<b>0.457, .049</b>
Virginia's Warbler	-0.216, .37	0.062, 0.80
Red-faced Warbler	<b>0.581, 0.009</b>	<b>0.649, 0.003</b>
Green-tailed Towhee	0.037, 0.88	0.318, 0.18
Gray-headed Junco	<b>0.869, &lt;0.001</b>	<b>0.717, 0.001</b>



**Table S2.** Regional population trends of study species. Slopes of the mean trends (lower, upper 95% confidence intervals) for the study species over the long-term (1966-2009) and the past decade (1999-2009) as estimated by the Breeding Bird Survey<sup>10</sup> for the southern Rockies and Colorado Plateau region. When the confidence intervals include 0, the trend is not significant. Note that no data are available for Red-faced Warblers because of its limited distribution. Significant trends are bolded.

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Bird species	1966-2009	1999-2009
Hermit Thrush	0.3 (-0.7, 1.3)	<b>2.3 ( 0.6, 4.1)</b>
Orange-crowned Warbler	1.4 (-0.5, 3.1)	1.4 (-1.1, 3.9)
Virginia's Warbler	-0.5 (-1.9, 0.9)	-0.4 (-2.5, 1.6)
Green-tailed Towhee	0.6 (-0.1, 1.5)	<b>1.5 ( 0.3, 3.3)</b>
Gray-headed Junco	<b>1.2 ( 0.1, 2.2)</b>	0.3 (-1.7, 2.3)

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**Table S3.** GLM analysis of treatment differences (exclosure minus control) in numbers of breeding birds per 10 ha drainage for three paired replicates. We compared the pre-treatment period (first two years when vegetation did not differ – Fig. 3a) to the post-treatment period (subsequent years), while accounting for variance among the paired replicates, and their interaction with period, plus year nested within period. Period was significant for all species, indicating a general change in abundance from pre-treatment to post-treatment.

<u>Variable</u>	<u>df</u>	<u>F-value</u>	<u>P-value</u>
a) Hermit Thrush			
Intercept	1	14.41	0.004
Period	1	53.52	0.000
Replicate Identity	2	4.00	0.053
Period x Replicate Identity	2	0.14	0.87
Period (Year)	5	5.38	0.012
Error	10		
b) Orange-crowned Warbler			
Intercept	1	41.61	0.000
Period	1	67.22	0.000
Replicate Identity	2	1.01	0.40
Period x Replicate Identity	2	1.01	0.40
Period (Year)	5	1.10	0.42
Error	10		
c) Virginia's Warbler			
Intercept	1	55.68	0.000
Period	1	11.19	0.007
Replicate Identity	2	4.17	0.048
Period x Replicate Identity	2	1.13	0.36
Period (Year)	5	4.92	0.016
Error	10		
d) Red-faced Warbler			
Intercept	1	1.58	0.24
Period	1	6.84	0.026
Replicate Identity	2	1.14	0.36
Period x Replicate Identity	2	0.21	0.82
Period (Year)	5	1.76	0.21
Error	10		
e) Green-tailed Towhee			
Intercept	1	31.29	0.000
Period	1	9.45	0.012
Replicate Identity	2	17.69	0.001
Period x Replicate Identity	2	4.66	0.037
Period (Year)	5	2.94	0.069
Error	10		
f) Gray-headed Junco			
Intercept	1	6.39	0.030
Period	1	11.12	0.008
Replicate Identity	2	5.19	0.028
Period x Replicate Identity	2	3.57	0.067
Period (Year)	5	1.35	0.32
Error	10		

**Table S4.** GLM analysis of annual differences between treatments (exclosure minus control) in numbers of stems of deciduous woody plants per 5 m radius sampling circles for three paired sets of replicate drainages. We examined whether differences in numbers of stems between treatments were different from 0, which reflects no difference between treatments. This was achieved by examining the significance of the intercept in each year while accounting for variance among the replicates, topographic location of the sampling circles, and the interaction of topographic location by replicate identity; other interactions were not significant and dropped from the models.

<u>Variable</u>	<u>df</u>	<u>F-value</u>	<u>P-value</u>
a) Total deciduous woody stems			
Year	6	19.09	0.000
Replicate Identity	2	8.09	0.000
Topographic location	4	7.75	0.000
Replicate identity x topographic location	8	3.52	0.000
Error	896		
b) Aspen			
Year	6	7.28	0.000
Replicate Identity	2	3.21	0.041
Topographic location	4	21.23	0.000
Replicate identity x topographic location	8	7.09	0.000
Error	896		
c) Maple			
Year	6	11.16	0.000
Replicate Identity	2	24.81	0.000
Topographic location	4	5.55	0.000
Replicate identity x topographic location	8	7.62	0.000
Error	896		
d) Locust			
Year	6	3.51	0.001
Replicate Identity	2	20.64	0.000
Topographic location	4	6.65	0.000
Replicate identity x topographic location	8	4.95	0.000
Error	896		

**Table S5.** GLM models to estimate vegetation height of marked plants in the first (2005) and last (2010) years of the study for each of the 6 drainages while accounting for topographic location. Least squares mean vegetation heights for each drainage obtained from this analysis were then used to test for differences between treatments.

<u>Variable</u>	<u>df</u>	<u>F-value</u>	<u>P-value</u>
<b>2005</b>			
a) Aspen			
Intercept	1	1254.27	0.000
Drainage	5	7.97	0.000
Topographic location	4	0.89	0.47
Drainage x topographic location	16	2.81	0.000
Error	451		
b) Maple			
Intercept	1	1720.16	0.000
Drainage	5	5.72	0.000
Topographic location	4	1.76	0.14
Plot x topographic location	16	1.38	0.15
Error	449		
c) Locust			
Intercept	1	1494.08	0.000
Drainage	5	2.72	0.019
Topographic location	4	4.43	0.002
Drainage x topographic location	20	1.76	0.023
Error	489		
<b>2010</b>			
d) Aspen			
Intercept	1	37.66	0.000
Drainage	5	3.54	0.008
Topographic location	4	0.24	0.917
Drainage x topographic location	9	0.66	0.740
Error	55		
e) Maple			
Intercept	1	326.40	0.000
Drainage	5	24.72	0.000
Topographic location	4	1.35	0.25
Drainage x topographic location	15	2.08	0.015
Error	131		
f) Locust			
Intercept	1	179.61	0.000
Drainage	5	6.56	0.000
Topographic location	4	0.31	0.87
Drainage x topographic location	17	0.76	0.74
Error	136		

**Table S6.** GLM analysis of differences in plant height between treatments in the first year of marking (2005) and last year of measurement (2010) based on comparing means on the 6 drainages obtained from GLM analyses summarized in Table S5.

<u>Variable</u>	<u>df</u>	<u>F-value</u>	<u>P-value</u>
<b>2005</b>			
Treatment	a) Aspen	0.55	0.50
	1		
Error	4		
	b) Maple	0.30	0.61
1			
Error	4		
	c) Locust	0.06	0.82
1			
Error	4		
	<b>2010</b>		
Treatment	d) Aspen	17.60	0.014
	1		
Error	4		
	e) Maple	15.18	0.018
1			
Error	4		
	f) Locust	12.24	0.025
1			
Error	4		

**Table S7.** Logistic exposure models<sup>8,9</sup> for analyzing nest predation rates on exclosure versus all (i.e., 20) non-exclosure drainages. a) Models were tested for all years as a continuous factor. The best models (i.e., lowest AIC) included treatment, species, and year as factors. b) A second set of models were tested including period as a factor to test for differences between pre- and post-treatment periods. The best model was better than the best model without period (from a) and demonstrated that the two periods differed in the between-treatment differences in nest predation rates (see Fig. 4).

Variable <sup>1</sup>	<i>AIC</i>
a) Tests of all variables with year as a continuous factor	
Treatment + Species + Year †	7262.8
Treatment + Species + Year + Treatment*Species	7266.8
Treatment + Species + Year + Treatment*Year	7267.6
Treatment + Species + Year + Treatment*Species + Treatment*Year	7271.7
Treatment + Species	7277.0
Treatment + Species + Treatment*Species	7280.3
Species + Year	7282.5
Treatment + Species + Year + Species*Year	7296.7
Species	7296.8
Treatment + Species + Year + Species*Year + Treatment*Year	7301.3
Treatment + Species + Year + Treatment*Year + Species*Year + Treatment*Year	7304.7
Species + Year + Species*Year	7314.7
Treatment + Year	7338.0
Treatment + Year + Treatment*Year	7342.5
Year	7350.4
Treatment	7352.5
Null (intercept only)	7365.0
b) Tests with year nested within pre- versus post-treatment periods	
Treatment + Species + Period + Period(Year) + Treatment*Period	7258.7
Treatment + Species + Period + Period(Year)	7262.8
Treatment + Species + Period	7277.5

<sup>1</sup>Treatment = treatment (control, exclosure), species = bird species, period = pre- vs post-treatment; Period(Year) reflects that year was nested within period.

†Treatment:  $P < 0.0001$ ; Species:  $P < 0.0001$ ; Year:  $P < 0.0001$

**Table S8.** Logistic exposure models<sup>8,9</sup> for analyzing nest predation rates for the pre-treatment years (2004-2005) of the study.

<u>Variable<sup>1</sup></u>	<u>AIC</u>
Species + Year	1913.4
Treatment + Species + Year <sup>†</sup>	1915.4
Treatment + Species + Year + Treatment*Year	1916.9
Species + Year + Species*Year	1918.4
Treatment + Species + Year + Species*Year	1920.4
Treatment + Species + Year + Treatment*Species	1921.6
Treatment + Species + Year + Treatment*Year + Species*Year	1921.9
Species	1922.9
Treatment + Species + Year + Treatment*Year + Treatment*Species	1923.1
Treatment + Species	1924.9
Treatment + Species + Year + Species*Year + Treatment*Species	1926.4
Treatment + Species + Year + Treatment*Year + Species*Year + Treatment*Species	1927.7
Year	1928.3
Treatment + Species + Treatment*Species	1930.8
Treatment + Year	1930.0
Treatment + Year + Treatment*Year	1931.4
Null (intercept only)	1938.8
Treatment	1940.6

<sup>1</sup>Treatment = treatment (control, enclosure), species = bird species, Year = year.

<sup>†</sup>Treatment:  $P = 0.85$ ; Species:  $P < 0.0001$ ; Year:  $P < 0.0001$

**Table S9.** Logistic exposure models<sup>8,9</sup> for analyzing nest predation rates for the post-treatment years (2006-2010) of the study.

<u>Variable<sup>1</sup></u>	<u>AIC</u>
Treatment + Species + Year †	5353.2
Treatment + Species + Year + Treatment*Species	5359.1
Treatment + Species	5359.4
Treatment + Species + Year + Treatment*Year	5360.6
Treatment + Species + Treatment*Species	5363.9
Treatment + Species + Year + Treatment*Year + Treatment*Species	5366.4
Treatment + Species + Year + Species*Year	5373.6
Treatment + Species + Year + Species*Year + Treatment*Species	5378.9
Species + Year	5379.2
Treatment + Species + Year + Treatment*Year + Species*Year	5380.9
Species	5382.7
Treatment + Species + Year + Treatment*Year + Species*Year + Treatment*Species	5386.1
Species + Year + Species*Year	5397.7
Treatment + Year	5405.3
Treatment	5409.7
Treatment + Year + Treatment*Year	5412.5
Year	5423.5
Null (intercept only)	5426.5

<sup>1</sup>Treatment = treatment (control, enclosure), species = bird species, Year = year.

†Treatment:  $P < 0.0001$ ; Species:  $P < 0.0001$ ; Year:  $P = 0.0003$



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