ARCTIC
VOL. 74, NO. 1 (MARCH 2021) P. S1 – S3
https://doi.org/10.14430/arctic72208

Determinants of Gray Wolf (*Canis lupus)* Sightings in Denali National Park

Bridget L. Borg,[1,2,3] Stephen M. Arthur,[2,4] Jeffrey A. Falke[5] and Laura R. Prugh[6]

(*Received 19 June 2019; accepted in revised form 17 July 2020*)

WOLF PRESENCE MODEL

Methods

We used generalized linear mixed modeling to evaluate the effect of covariates on the proportion of wolf locations near the road. Covariates in the analysis included *DenDist* (the distance of the pack's den site to the closest point on the road), *PackSize* (size of packs in March), *WolfStatus* (classified as "breeder" or "non-breeder"), *Recruit* (factor that described the packs' denning success as either "yes" or "no" based on the presence of pups in fall. *Closure* was the presence (1) or absence (0) of a closure on wolf hunting and trapping outside of Denali National Park and Preserve in the northeast. We used fixed effects of pack size and distance of den site from the road to encompass pack level variation, and we included individual wolf identity as a random effect to address potential correlation due to individual wolf behavior patterns.

We used an information-theoretic approach to find the most parsimonious set of independent variables to estimate wolf presence near the road (wolf presence model). We used the glmm function in Program R (R Core Team, 2014) to create logistic regression models for wolf presence near the road as a function of covariates described above (n = 18 models). We did not include interactions or higher-level terms in our model set because of the limited sample size. We evaluated multicollinearity among covariates using a variance inflation factor statistic (VIF). All covariates included in the models had a VIF less than 10 (Kutner et al., 2004). The back-transformed parameter estimates are interpreted as odds ratios. We used the Akaike information criterion (AICc) to rank models (Burnham and Anderson, 2002). We calculated the marginal and conditional R^2, where the marginal R^2 indicates the proportion of variance explained by the fixed factors alone and the conditional R^2 indicates the proportion of variance explained by both the fixed and random factors (Nakagawa and Schielzeth, 2013).

TABLE S1. Candidate model set and model selection criteria evaluating factors affecting the proportion of summer wolf locations near the Denali Park Road in Denali National Park and Preserve, Alaska. Wolf ID was included as a random effect in all models. K is the number of parameters in the model, the marginal R^2 indicates the proportion of variance explained by the fixed factor alone, and the conditional R^2 indicates the proportion of variance explained by the fixed and random factor. *DenDist* is the log of the distance of the pack den site to the road, *PackSize* is the size of the pack, *WolfStatus* is the breeding status of the wolf (breeder or non-breeder), *Recruit* is a factor for success (yes) or failure (no) of denning.

Model	K	AICc	ΔAICc	Model likelihood	AICc Weight	Log likelihood	Marginal R^2	Conditional R^2
DenDist	3	136.02	0.00	1.00	0.27	−64.51	0.08	0.58
DenDist+PackSize	4	136.97	0.95	0.62	0.17	−63.62	0.11	0.56
DenDist+WolfStatus	4	137.91	1.90	0.39	0.10	−64.09	0.13	0.60
DenDist+Closure	4	138.21	2.19	0.33	0.09	−64.23	0.06	0.58
DenDist+Recruit	4	138.59	2.57	0.28	0.07	−64.43	0.08	0.58
Closure	3	138.70	2.69	0.26	0.07	−65.85	0.05	0.65
Closure+DenDist+PackSize	5	139.05	3.03	0.22	0.06	−63.16	0.08	0.55
DenDist+PackSize+WolfStatus	5	139.12	3.10	0.21	0.06	−63.20	0.16	0.57
DenDist+PackSize+Recruit	5	139.87	3.85	0.15	0.04	−63.57	0.10	0.56
Closure+DenDist+WolfStatus	5	140.31	4.29	0.12	0.03	−63.79	0.11	0.60
DenDist+WolfStatus+Recruit	5	140.72	4.70	0.10	0.03	−63.99	0.13	0.60
DenDist+PackSize+WolfStatus+Recruit	6	142.29	6.27	0.04	0.01	−63.14	0.15	0.57
PackSize+Recruit	4	155.21	19.19	0.00	0.00	−72.73	0.02	0.66
Recruit	3	156.68	20.66	0.00	0.00	−74.84	0.02	0.64
WolfStatus+Recruit	4	158.20	22.18	0.00	0.00	−74.23	0.08	0.65
PackSize	3	160.49	24.48	0.00	0.00	−76.75	0.01	0.68
PackSize+WolfStatus	4	162.19	26.17	0.00	0.00	−76.22	0.07	0.69
WolfStatus	3	169.57	33.56	0.00	0.00	−81.29		

[1] University of Alaska Fairbanks, Institute of Arctic Biology, 323 Murie Building, Fairbanks, Alaska 99775, USA
[2] National Park Service, Denali National Park and Preserve, PO Box 9, Denali Park, Alaska 99755, USA
[3] Corresponding author: bridget_borg@nps.gov
[4] Current address: U.S. Fish and Wildlife Service, Arctic National Wildlife Refuge, 101 12th Ave, Fairbanks, Alaska 99701, USA
[5] U.S. Geological Survey, Alaska Cooperative Fish and Wildlife Research Unit, PO Box 757020, Fairbanks, Alaska 99775, USA
[6] University of Washington, School of Environmental and Forest Sciences, Box 352100, Seattle, Washington 98195, USA

Results

According to AICc model selection criteria, the top-ranked single-parameter models were those that included *DenDist* and *Closure* (Table S1), although both had low marginal R^2, which indicates that the proportion of variance explained by the fixed effects was low and should be treated with caution. The proportion of locations near the road decreased with increasing distance of the den site from the road (*DenDist*: $\beta = -0.51 \pm 0.094$ SE, Table S2) and wolves were more likely to be near the road during the presence of a closure on trapping and hunting adjacent to the park than during its absence (*Closure*: Present: $\beta = 1.32 \pm 0.255$ SE). Models with *PackSize* and *WolfStatus* had ΔAICc values of 2 or less from the top-ranked model but differed by only one parameter, had similar maximized log-likelihood values as the top model, and the confidence intervals of the parameter estimates for the additional parameters overlapped zero. These more complex models were not supported by the data despite being close in AICc values owing to the addition of an uninformative parameter (Burnham and Anderson, 2002; Arnold, 2010; Leroux, 2019).

TABLE S2. Parameter estimates from single variable models evaluating factors affecting the probability of wolf presence near the Denali Park Road in Denali National Park and Preserve, Alaska. *DenDist* is the log of the distance of the pack den site to the road, and *Closure* is the presence or absence of a hunting and trapping closure adjacent to the park. β and odds ratio estimates for *Closure* (present) is relative to the absence of the harvest closure.

Parameter	β	SE	95% CL Lower	95% CL Upper	Odds ratio
(Intercept)	−0.57	0.993	−2.83	1.28	0.57
log(DenDist)	−0.51	0.094	−0.70	−0.33	0.60
(Intercept)	−5.34	0.801	−7.53	−3.95	0.00
Closure (present)	1.32	0.255	0.84	1.84	3.74

Wolf Sighting Model

For the wolf sighting model, we evaluated a suite of models including a global model that included all terms and 28 additional models that included reasonable and biologically relevant combinations of covariates (Table S3).

REFERENCES

Arnold, T.W. 2010. Uninformative parameters and model selection using Akaike's information criterion. Journal of Wildlife Management 74(6):1175–1178. https://doi.org/10.2193/2009-367

Burnham, K.P., and Anderson, D.R. 2002. Model selection and multimodel inference: A practical information-theoretic approach, 2nd ed. New York: Springer Verlag.

Kutner, M.H., Nachtsheim, C.J., and Neter, J. 2004. Applied linear regression models, 4th ed. New York: McGraw-Hill Irwin.

Leroux, S.J. 2019. On the prevalence of uninformative parameters in statistical models applying model selection in applied ecology. PLoS ONE 14(2): e0206711. https://doi.org/10.1371/journal.pone.0206711

Nakagawa, S., and Schielzeth, H. 2013. A general and simple method for obtaining R2 from generalized linear mixed-effects models. Methods in Ecology and Evolution 4(2):133–142. https://doi.org/10.1111/j.2041-210x.2012.00261.x

R Core Team. 2014. R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. http://www.r-project.org/

TABLE S3. Candidate model set evaluating covariates affecting the spatially explicit probability of wolf sightings along the Denali Park Road in Denali National Park and Preserve, Alaska, from 1997 to 2013. Collection Type and Offset were included in all models and are not explicitly listed in the covariate set below.

Model #	Model covariates by class	Full model covariates	Description
1	PHYS+BIO+HAR	Vis+Mask+PackSize+DenDist+DenStat+Wharv+Buffer+Bharv	Global model
2	PHYS+HARV	Vis+Mask+Wharv+Buffer+Bharv	Two-way combination of covariates by class
3	BIO+HARV	PackSize+DenDist+DenStat+Wharv+Buffer+Bharv	Two-way combination of covariates by class
4	PHYS+BIO	Vis+Mask+PackSize+DenDist+DenStat	Two-way combination of covariates by class
5	PHYS	Vis+Mask	Covariates class is most important
6	BIO	PackSize+DenDist+DenStat	Covariates class is most important
7	HARV	Wharv+Buffer+Bharv	Covariates class is most important
8	PHYS+BIO+Wharv	Vis+Mask+PackSize+DenDist+DenStat+Wharv	PHYS and/or BIO class of covariates and one harvest covariate most important
9	PHYS+Wharv	Vis+Mask+Wharv	PHYS and/or BIO class of covariates and one harvest covariate most important
10	BIO+Wharv	PackSize+DenDist+DenStat+Wharv	PHYS and/or BIO class of covariates and one harvest covariate most important
11	PHYS*+BIO*+Wharv	Mask+PackSize+DenDist+Wharv	Important PHYS and/or BIO covariates and one harvest covariate is most important
12	PHYS*+Wharv	Mask+Wharv	Important PHYS and/or BIO covariates and one harvest covariate is most important
13	BIO*+Wharv	PackSize+DenDist+Wharv	Important PHYS and/or BIO covariates and one harvest covariate is most important
14	PHYS+BIO+Buffer	Vis+Mask+PackSize+DenDist+DenStat+Buffer	PHYS and/or BIO class of covariates and one harvest covariate most important
15	PHYS+Buffer	Vis+Mask+Buffer	PHYS and/or BIO class of covariates and one harvest covariate most important
16	BIO+Buffer	PackSize+DenDist+DenStat+Buffer	PHYS and/or BIO class of covariates and one harvest covariate most important
17	PHYS*+BIO*+Buffer	Mask+PackSize+DenDist+Buffer	Important PHYS and/or BIO covariates and one harvest covariate is most important
18	PHYS*+Buffer	Mask+Buffer	Important PHYS and/or BIO covariates and one harvest covariate is most important
19	BIO*+Buffer	PackSize+DenDist+Buffer	Important PHYS and/or BIO covariates and one harvest covariate is most important
20	PHYS+BIO+BHarv	Vis+Mask+PackSize+DenDist+DenStat+BHarv	PHYS and/or BIO class of covariates and one harvest covariate most important
21	PHYS+BHarv	Vis+Mask+BHarv	PHYS and/or BIO class of covariates and one harvest covariate most important
22	BIO+BHarv	PackSize+DenDist+DenStat+BHarv	PHYS and/or BIO class of covariates and one harvest covariate most important
23	PHYS*+BIO*+BHarv	Mask+PackSize+DenDist+BHarv	Important PHYS and/or BIO covariates and one harvest covariate is most important
24	PHYS*+BHarv	Mask+BHarv	Important PHYS and/or BIO covariates and one harvest covariate is most important
25	BIO*+BHarv	PackSize+DenDist+BHarv	Important PHYS and/or BIO covariates and one harvest covariate is most important
26	PHYS*+BIO*	Mask+PackSize+DenDist	Important PHYS and BIO covariates
27	PHYS*	Mask	Important PHYS covariates only
28	BIO*	PackSize+DenDist	Important BIO covariates only
29	CT+OFF (ONLY)	Collection Type+Offset above.	Reduced model with CT only. All other models include CT and OFF (offset) although not explicitly listed