Multi-season occupancy models identify abiotic and biotic factors influencing a recovering Arctic Peregrine Falcon *Falco peregrinus tundrius* population

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SUPPORTING INFORMATION

Description of stepwise modeling procedure for nest-site occupancy analysis

Covariates are defined in Table 1 of the main text. First, we developed four suites of dynamic occupancy models (MacKenzie *et al*. 2003) with each suite consisting of additive combinations of covariates for one of ψ_{i1}, γ_{it}, ε_{it}, and p_{ijt}, while treating the other three parameters as constant (i.e. intercept only). Based on the predictions in Table S1, models for: (1) ψ_{i1} consisted of combinations of $aspect_i$, $height_i$, and $waterarea_i$; (2) γ_{it} consisted of combinations of $aspect_i$, $height_i$, $meltdate_t$, $peregrinedistance_{it}$, $waterarea_i$, and an $aspect_i$*$meltdate_t$ interaction; (3) ε_{it} consisted of combinations of $aspect_i$, $height_i$, $peregrinedistance_{it}$, $precip_t$, $productivity_{i,t-1}$, and $waterarea_i$; (4) p_{ijt} consisted of combinations of intercept only, $survey_{it}$, and *year*. We calculated variance inflation factors (VIF; Neter *et al*. 1996) while forming model lists to quantify multicollinearity among covariates and excluded those having a VIF > 5. We centered and scaled each covariate and used package UNMARKED (Fiske & Chandler 2011) in R 2.15.2 (R Core Team 2012) to fit models and estimate covariate coefficients for each parameter. We calculated an AIC value for each model, and ranked and selected the best-approximating models using ΔAIC values (Burnham & Anderson 2002). We retained models in each suite with ΔAIC < 2 for use in the second step of model selection. Second, we developed models using combinations of results from the first step, fitted models, and retained models with ΔAIC < 2 for use in the final step. Third, we built models consisting of time covariates (*year*, *yearlinear*, *yearthreshold*, *yearlog*) for γ_{it} and ε_{it}. We fitted models and retained those with ΔAIC < 2 for use in the final step. Our final model list consisted of 24 models using combinations of results from the second and third steps. We fitted models, and ranked and selected the best-approximating models as described in the Methods.

Description of stepwise modeling procedure for cliff occupancy analysis

Covariates are defined in Table 1 of the main text. First, we developed four suites of dynamic occupancy models (MacKenzie *et al*. 2003) with each suite consisting of additive combinations of covariates for one of ψ_{k1}, γ_{kt}, ε_{kt}, and p_{kjt}, while treating the other three parameters as constant (i.e., intercept only). Based on predictions in Table S1, models for: (1) ψ_{k1} consisted of combinations of $aspect_{k}$, $geology_{k}$, $height_{cliff,k}$, and $waterarea_{cliff,k}$; (2) γ_{kt} consisted of combinations of $aspect_{k}$, $geology_{k}$, $height_{cliff,k}$, $meltdate_{t}$, $waterarea_{cliff,k}$, and an $aspect_{k}$*$meltdate_{t}$ interaction; (3) ε_{kt} consisted of combinations of $aspect_{k}$, $height_{cliff,k}$, $precip_{t}$, $productivity_{cliff,k,t-1}$, and $waterarea_{cliff,k}$; (4) p_{kjt} consisted of combinations of intercept only, $survey_{kt}$, and *year*. We calculated VIFs (Neter *et al*. 1996) while forming model lists to quantify multicollinearity among covariates and excluded those having a VIF > 5. We centered and scaled each covariate and used package UNMARKED (Fiske & Chandler 2011) in R 2.15.2 (R Core Team 2012) to fit models and estimate covariate coefficients for each parameter. We calculated an AIC value for each model, and ranked and selected the best-approximating models using ΔAIC values (Burnham & Anderson 2002). We retained models in each suite with ΔAIC < 2 for use in the second step of model selection. Second, we developed models using combinations of results from the first step, fitted models, and retained models with ΔAIC < 2 for use in the final step.

Third, we built models consisting of time covariates (*year*, *yearlinear*, *yearthreshold*, *yearlog*) for γ_{kt} and ε_{kt}. We fitted models and retained those with ΔAIC < 2 for use in the final step. Our final model list consisted of 48 models using combinations of results from the second and third steps. We fitted models, and ranked and selected the best-approximating models as described in the Methods.

Table S1. Predictions for covariates evaluated in analyses examining factors related to occupancy dynamics of Arctic Peregrine Falcons on nest-sites and cliffs[a] along the Colville River, Alaska, USA during 1981-2002. Occupancy modeling parameters are: initial occupancy probability (ψ); colonization probability (γ); and local extinction probability (ε). Covariates are defined in Table 1.

Covariate	Prediction	Rationale
Nest-site or cliff height above river	$\psi > 0$ $\gamma > 0$ $\varepsilon < 0$	Nest-sites located higher above the Colville River may be of higher quality because they offer a better vantage of the surrounding area for hunting, territory defense, defense from predators, and updraft currents for flight (Jenkins 2000). We expected nest-site (or cliff) height to be positively correlated with initial occupancy and colonization, and negatively correlated with local extinction.
Date of snowmelt	$\gamma < 0$	Arctic Peregrines require a snow-free substrate on which to nest and earlier snowmelt provides a longer nesting season and higher probability of a successful nest (Olsen & Olsen 1989, Bradley *et al*. 1997). Therefore, nest-sites (cliffs) with later snowmelt would have lower colonization because potential nest-sites (cliffs) would not be snow-free and available to Arctic Peregrines arriving early in the spring.
Aspect	ψ - varies γ - varies ε - varies	Based on similar rationale to date of snowmelt, we expected initial occupancy and colonization would be higher, and local extinction lower, at southerly-facing compared to northerly-facing nest-sites (cliffs) because snowmelt would occur earlier on southerly aspects.
Distance to	$\gamma > 0$	Nest-sites located closer together results in greater competition for resources (Hakkarainen & Korpimäki

nearest nest	$\varepsilon < 0$	1996) and increased probability of Arctic Peregrines leaving the nest-site the following year. In contrast, greater distances between Arctic Peregrine nest-sites would result in reduced competition for resources, thereby leading to increased colonization probability.
Amount of precipitation	$\varepsilon > 0$	Effects of weather on raptor reproduction and occupancy are well documented (e.g. Fairhurst & Bechard 2005). Olsen and Olsen (1988) found Peregrine occupancy in Australia declined with average daily rainfall during the nesting period and duration of the egg-laying period was shorter during years with more days of rain. We expected local extinction would be positively correlated with total precipitation during the nesting period because years with wet weather may cause nest-sites to be flooded and unsuitable, thereby leading to nest failure and abandonment of the site in subsequent years.
Area of prey habitat	$\psi > 0$ $\gamma > 0$ $\varepsilon < 0$	Nest-sites (cliffs) with a greater amount of surrounding prey (waterbirds) habitat (wetlands, lakes, streams) may provide increased prey availability near the nest, which would be especially beneficial for survival of young (Dewey & Kennedy 2001). Greater resource availability would lead to higher initial occupancy and colonization, and lower local extinction.
Productivity	$\varepsilon < 0$	Nest success and more young fledged the previous year would make it more likely for Arctic Peregrines to return to the nest-site (cliff) the following year (Newton 1979), resulting in a lower probability of local extinction. Greater productivity is indicative of higher quality nesting habitat, which would be occupied

		earlier and more frequently than lower quality habitat (Sergio & Newton 2003).
Surficial geology	ψ - varies γ - varies ε - varies	We predicted initial occupancy, colonization, and local extinction would be influenced by cliff surficial geology because steeper sloping hills would provide better protection from predators and an improved vantage for hunting than gentle slopes (Urios & Martinez-Abrain 2006). Also, bedrock would provide a better nesting substrate than fine-grained deposits, which may erode with heavy rainfall or snowmelt.
Year	$\gamma > 0$ $\varepsilon < 0$	We expected colonization and local extinction would be positively and negatively associated, respectively, with year as linear, logarithmic, or threshold functions. We evaluated linear, logarithmic, and threshold functions for year because the population of Arctic Peregrines in the CRSA grew during the 1980s before stabilizing in the mid-1990s, suggesting increasing colonization probabilities in the 1980s and an attenuation in colonization as population growth rates slowed in the 1990s. We expected local extinction to decrease as the population grew and more nest-sites (cliffs) became occupied. Our year covariates can also be considered as an index of time since DDT was banned.

[a] We analyzed occupancy at two spatial scales (nest-site, nest cliff). See text for more details about our rationale for this approach.

Table S2. Range, mean, se, and sample size (*n*) for numerical covariates used in analyses examining nest-site and cliff occupancy dynamics of Arctic Peregrine Falcons along the Colville River, Alaska during 1981-2002. Covariates are defined in Table 1 of the main text.

Covariate	Range	Mean	se	*n*
$height_{i}$	0.85-86.7 m	31.9 m	2.1	108
$height_{cliff,k}$	0.85-86.5 m	26.2 m	2.1	74
$meltdate_{t}$	13 May-11 June	26 May	1.5 days	22
$peregrinedistance_{it}$	0.31-37.1 km	3.4 km	0.09	2268
$precip_{t}$	30.5-132 mm	63.0 mm	4.6	22
$productivity_{i,t-1}$	0-4 young	0.59 young	0.02	2268
$productivity_{cliff,k,t-1}$	0-4 young	0.58 young	0.03	1554
$waterarea_{i}$	1.1-10.0 km^2	3.7 km^2	0.20	108
$waterarea_{cliff,k}$	1.1-9.4 km^2	3.7 km^2	0.24	74

Table S3. Model results from the analysis examining factors related to nest-site occupancy dynamics of Arctic Peregrine Falcons along the Colville River, Alaska during 1981-2002. Provided for each model are the number of parameters (*K*), ΔAIC, and Akaike weight (*w*). The response variable was y_{ijt}, a binary variable denoting whether Arctic Peregrines were detected at nest-site *i* during survey *j* of year *t*. All models included detection probability with *year* and $survey_{it}$ covariates. Covariates are defined in Table 1; intercepts are not shown.

Initial occupancy probability	Colonization probability	Local extinction probability	*K*	ΔAIC	*w*
$height_i$	$height_i$ + $peregrinedistance_{it}$ + *yearthreshold*	$waterarea_i$ + $productivity_{i,t-1}$ + *yearthreshold*	32	0.00	0.112
$height_i$ + $waterarea_i$	$height_i$ + $peregrinedistance_{it}$ + *yearthreshold*	$waterarea_i$ + $productivity_{i,t-1}$ + *yearthreshold*	33	0.07	0.108
$height_i$	$height_i$ + $waterarea_i$ + $peregrinedistance_{it}$ + *yearthreshold*	$waterarea_i$ + $productivity_{i,t-1}$ + *yearthreshold*	33	0.57	0.084
$height_i$ + $waterarea_i$	$height_i$ + $waterarea_i$ + $peregrinedistance_{it}$ + *yearthreshold*	$waterarea_i$ + $productivity_{i,t-1}$ + *yearthreshold*	34	0.65	0.081
$height_i$	$height_i$ + $peregrinedistance_{it}$ +	$precip_t$ + $waterarea_i$ + $productivity_{i,t-1}$ +	33	0.86	0.073

	yearthreshold	*yearthreshold*			
$height_i + waterarea_i$	$height_i + peregrinedistance_{it} + yearthreshold$	$precip_t + waterarea_i + productivity_{i,t-1} + yearthreshold$	34	0.94	0.070
$height_i$	$height_i + peregrinedistance_{it} + yearlog$	$waterarea_i + productivity_{i,t-1} + yearlog$	32	1.04	0.067
$height_i + waterarea_i$	$height_i + peregrinedistance_{it} + yearlog$	$waterarea_i + productivity_{i,t-1} + yearlog$	33	1.15	0.063
$waterarea_i$	$height_i + peregrinedistance_{it} + yearthreshold$	$waterarea_i + productivity_{i,t-1} + yearthreshold$	32	1.57	0.051
$height_i$	$height_i + waterarea_i + peregrinedistance_{it} + yearlog$	$waterarea_i + productivity_{i,t-1} + yearlog$	33	1.58	0.051
$height_i$	$height_i + peregrinedistance_{it} + yearlog$	$precip_t + waterarea_i + productivity_{i,t-1} + yearlog$	33	1.63	0.050
$height_i + waterarea_i$	$height_i + waterarea_i + peregrinedistance_{it} + yearlog$	$waterarea_i + productivity_{i,t-1} + yearlog$	34	1.71	0.048
$height_i + waterarea_i$	$height_i + peregrinedistance_{it} + yearlog$	$precip_t + waterarea_i + productivity_{i,t-1} + yearlog$	34	1.75	0.047
$height_i$	$height_i + peregrinedistance_{it} +$	$height_i + waterarea_i + productivity_{i,t-1} +$	33	1.90	0.043

	yearthreshold	*yearthreshold*			
$waterarea_i$	$height_i + peregrinedistance_{it} + yearlog$	$waterarea_i + productivity_{i,t-1} + yearlog$	32	2.72	0.029
$height_i$	$height_i + peregrinedistance_{it} + yearlog$	$height_i + waterarea_i + productivity_{i,t-1} + yearlog$	33	2.92	0.026
$height_i$	$height_i + peregrinedistance_{it}$	$waterarea_i + productivity_{i,t-1}$	30	19.4	<0.001
$height_i + waterarea_i$	$height_i + peregrinedistance_{it}$	$waterarea_i + productivity_{i,t-1}$	31	19.5	<0.001
$height_i$	$height_i + peregrinedistance_{it}$	$precip_t + waterarea_i + productivity_{i,t-1}$	31	19.9	<0.001
$height_i + waterarea_i$	$height_i + peregrinedistance_{it}$	$precip_t + waterarea_i + productivity_{i,t-1}$	32	20.1	<0.001
$height_i$	$height_i + waterarea_i + peregrinedistance_{it}$	$waterarea_i + productivity_{i,t-1}$	31	20.9	<0.001
$height_i + waterarea_i$	$height_i + waterarea_i + peregrinedistance_{it}$	$waterarea_i + productivity_{i,t-1}$	32	21.0	<0.001
$waterarea_i$	$height_i + peregrinedistance_{it}$	$waterarea_i + productivity_{i,t-1}$	30	21.2	<0.001
$height_i$	$height_i + peregrinedistance_{it}$	$height_i + waterarea_i + productivity_{i,t-1}$	31	21.3	<0.001
•	•	•	4	90.8	<0.001

Table S4. Model results from the analysis examining factors related to cliff occupancy dynamics of Arctic Peregrine Falcons along the Colville River, Alaska during 1981 through 2002. Provided for each model are the number of parameters (*K*), ΔAIC, and Akaike weight (*w*). The response variable was y_{kjt}, a binary variable denoting whether Arctic Peregrines were detected at cliff *k* during survey *j* of year *t*. All models included detection probability with *year* and $survey_{it}$ covariates. Covariates are defined in Table 1; intercepts are not shown.

Initial occupancy probability	Colonization probability	Local extinction probability	*K*	ΔAIC	*w*
$waterarea_{cliff,k} + height_{cliff,k}$	$height_{cliff,k} + meltdate_t + yearlog$	$aspect_{cliff,k} + height_{cliff,k} + waterarea_{cliff,k} + productivity_{cliff,k,t-1} + yearlog$	41	0.00	0.078
$waterarea_{cliff,k} + height_{cliff,k}$	$waterarea_{cliff,k} + height_{cliff,k} + meltdate_t + yearlog$	$aspect_{cliff,k} + height_{cliff,k} + waterarea_{cliff,k} + productivity_{cliff,k,t-1} + yearlog$	42	0.78	0.052
$waterarea_{cliff,k} + height_{cliff,k}$	$height_{cliff,k} + meltdate_t + yearlog$	$height_{cliff,k} + waterarea_{cliff,k} + productivity_{cliff,k,t-1} + yearlog$	34	1.02	0.046
$waterarea_{cliff,k} + height_{cliff,k}$	$height_{cliff,k} + meltdate_t + yearlog$	$aspect_{cliff,k} + height_{cliff,k} + waterarea_{cliff,k} + productivity_{cliff,k,t-1} + precip_t + yearlog$	42	1.13	0.044
$waterarea_{cliff,k} +$	$height_{cliff,k} + meltdate_t + yearthreshold$	$aspect_{cliff,k} + height_{cliff,k} + waterarea_{cliff,k} +$	41	1.15	0.044

$height_{cliff,k}$		$productivity_{cliff,k,t-1} + yearthreshold$			
$waterarea_{cliff,k} + height_{cliff,k}$	$geology_{k} + height_{cliff,k} + meltdate_{t} + yearlog$	$height_{cliff,k} + waterarea_{cliff,k} + productivity_{cliff,k,t-1} + yearlog$	36	1.39	0.039
$waterarea_{cliff,k} + height_{cliff,k}$	$waterarea_{cliff,k} + height_{cliff,k} + meltdate_{t} + yearlog$	$height_{cliff,k} + waterarea_{cliff,k} + productivity_{cliff,k,t-1} + yearlog$	35	1.66	0.034
$waterarea_{cliff,k} + height_{cliff,k}$	$height_{cliff,k} + meltdate_{t} + yearlog$	$precip_{t} + height_{cliff,k} + waterarea_{cliff,k} + productivity_{cliff,k,t-1} + yearlog$	35	1.68	0.033
$waterarea_{cliff,k} + height_{cliff,k}$	$height_{cliff,k} + meltdate_{t} + yearthreshold$	$height_{cliff,k} + waterarea_{cliff,k} + productivity_{cliff,k,t-1} + yearthreshold$	34	1.87	0.030
$waterarea_{cliff,k} + height_{cliff,k}$	$waterarea_{cliff,k} + height_{cliff,k} + meltdate_{t} + yearthreshold$	$aspect_{cliff,k} + height_{cliff,k} + waterarea_{cliff,k} + productivity_{cliff,k,t-1} + yearthreshold$	42	2.05	0.028
$waterarea_{cliff,k} + height_{cliff,k}$	$geology_{k} + height_{cliff,k} + meltdate_{t} + yearthreshold$	$height_{cliff,k} + waterarea_{cliff,k} + productivity_{cliff,k,t-1} + yearthreshold$	36	2.11	0.027
$waterarea_{cliff,k} + height_{cliff,k}$	$height_{cliff,k} + meltdate_{t} + yearlog$	$aspect_{cliff,k} + height_{cliff,k} + waterarea_{cliff,k} + productivity_{cliff,k,t-1}$	40	2.11	0.027
$waterarea_{cliff,k} +$	$height_{cliff,k} + meltdate_{t} + yearlog$	$height_{cliff,k} + waterarea_{cliff,k} +$	33	2.14	0.027

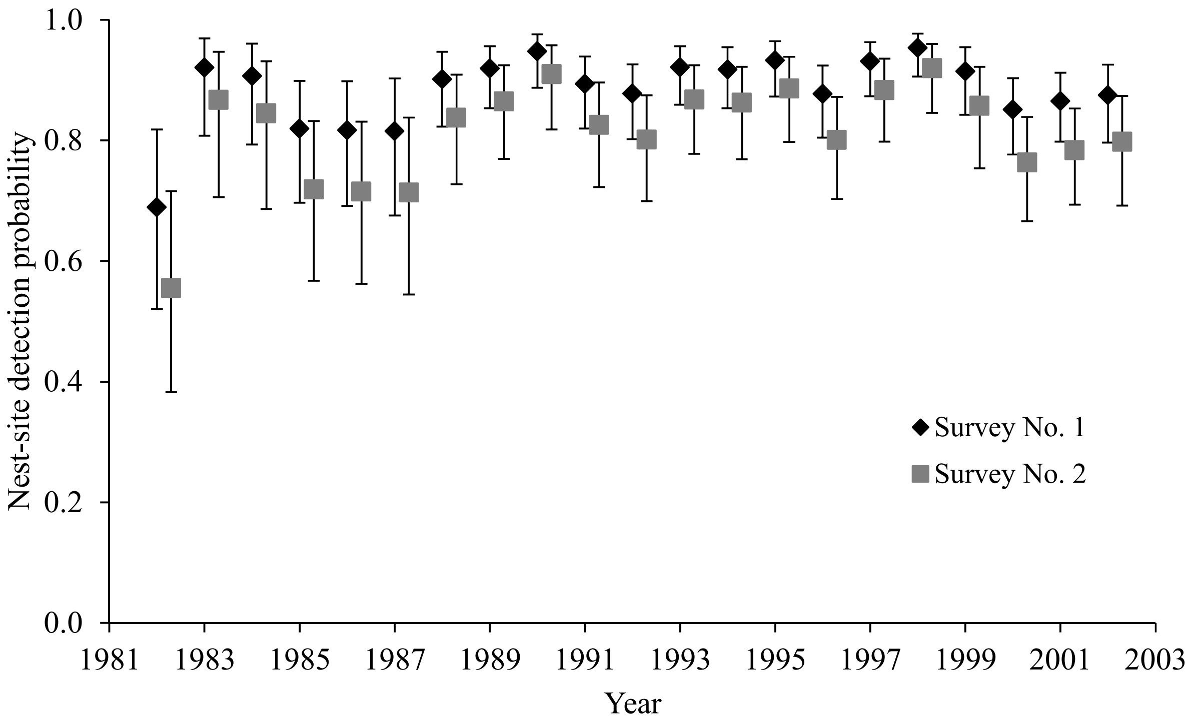
$height_{cliff,k}$		$productivity_{cliff,k,t-1}$			
$waterarea_{cliff,k}$ + $height_{cliff,k}$	$waterarea_{cliff,k}$ + $height_{cliff,k}$ + $meltdate_{t}$ + *yearlog*	$height_{cliff,k}$ + $waterarea_{cliff,k}$ + $precip_{t}$ + $productivity_{cliff,k,t-1}$ + *yearlog*	36	2.32	0.024
$waterarea_{cliff,k}$ + $height_{cliff,k}$	$height_{cliff,k}$ + $meltdate_{t}$ + *yearlinear*	$height_{cliff,k}$ + $waterarea_{cliff,k}$ + $productivity_{cliff,k,t-1}$	33	2.35	0.024
$waterarea_{cliff,k}$ + $height_{cliff,k}$	$height_{cliff,k}$ + $meltdate_{t}$ + *yearlinear*	$aspect_{cliff,k}$ + $height_{cliff,k}$ + $waterarea_{cliff,k}$ + $productivity_{cliff,k,t-1}$	40	2.36	0.024
$waterarea_{cliff,k}$ + $height_{cliff,k}$	$height_{cliff,k}$ + $meltdate_{t}$ + *yearthreshold*	$aspect_{cliff,k}$ + $height_{cliff,k}$ + $waterarea_{cliff,k}$ + $precip_{t}$ + $productivity_{cliff,k,t-1}$ + *yearthreshold*	42	2.37	0.024
$waterarea_{cliff,k}$ + $height_{cliff,k}$	$geology_{k}$ + $height_{cliff,k}$ + $meltdate_{t}$ + *yearlog*	$height_{cliff,k}$ + $waterarea_{cliff,k}$ + $productivity_{cliff,k,t-1}$	35	2.40	0.023
$waterarea_{cliff,k}$ + $height_{cliff,k}$	$height_{cliff,k}$ + $meltdate_{t}$ + *yearthreshold*	$aspect_{cliff,k}$ + $height_{cliff,k}$ + $waterarea_{cliff,k}$ + $productivity_{cliff,k,t-1}$	40	2.51	0.022
$waterarea_{cliff,k}$ + $height_{cliff,k}$	$height_{cliff,k}$ + $meltdate_{t}$ + *yearthreshold*	$height_{cliff,k}$ + $waterarea_{cliff,k}$ + $productivity_{cliff,k,t-1}$	33	2.56	0.022
$waterarea_{cliff,k}$ +	$waterarea_{cliff,k}$ + $height_{cliff,k}$ + $meltdate_{t}$	$height_{cliff,k}$ + $waterarea_{cliff,k}$ +	35	2.63	0.021

$height_{cliff,k}$	$+ yearthreshold$	$productivity_{cliff,k,t-1} + yearthreshold$			
$waterarea_{cliff,k} + height_{cliff,k}$	$height_{cliff,k} + meltdate_t + yearthreshold$	$height_{cliff,k} + waterarea_{cliff,k} + productivity_{cliff,k,t-1} + precip_t + yearthreshold$	35	2.65	0.021
$waterarea_{cliff,k} + height_{cliff,k}$	$geology_k + height_{cliff,k} + meltdate_t + yearthreshold$	$height_{cliff,k} + waterarea_{cliff,k} + productivity_{cliff,k,t-1}$	35	2.66	0.021
$waterarea_{cliff,k} + height_{cliff,k}$	$waterarea_{cliff,k} + height_{cliff,k} + meltdate_t + yearlog$	$height_{cliff,k} + waterarea_{cliff,k} + productivity_{cliff,k,t-1}$	34	2.81	0.019
$waterarea_{cliff,k} + height_{cliff,k}$	$waterarea_{cliff,k} + height_{cliff,k} + meltdate_t + yearlog$	$aspect_{cliff,k} + height_{cliff,k} + waterarea_{cliff,k} + productivity_{cliff,k,t-1}$	41	2.89	0.018
$waterarea_{cliff,k} + height_{cliff,k}$	$waterarea_{cliff,k} + height_{cliff,k} + meltdate_t + yearlinear$	$height_{cliff,k} + waterarea_{cliff,k} + productivity_{cliff,k,t-1}$	34	2.91	0.018
$waterarea_{cliff,k} + height_{cliff,k}$	$height_{cliff,k} + meltdate_t + yearlog$	$height_{cliff,k} + waterarea_{cliff,k} + productivity_{cliff,k,t-1} + precip_t$	34	2.94	0.018
$waterarea_{cliff,k} + height_{cliff,k}$	$geology_k + height_{cliff,k} + meltdate_t + yearlinear$	$height_{cliff,k} + waterarea_{cliff,k} + productivity_{cliff,k,t-1}$	35	3.00	0.017
$waterarea_{cliff,k} +$	$waterarea_{cliff,k} + height_{cliff,k} + meltdate_t$	$aspect_{cliff,k} + height_{cliff,k} + waterarea_{cliff,k} +$	41	3.04	0.017

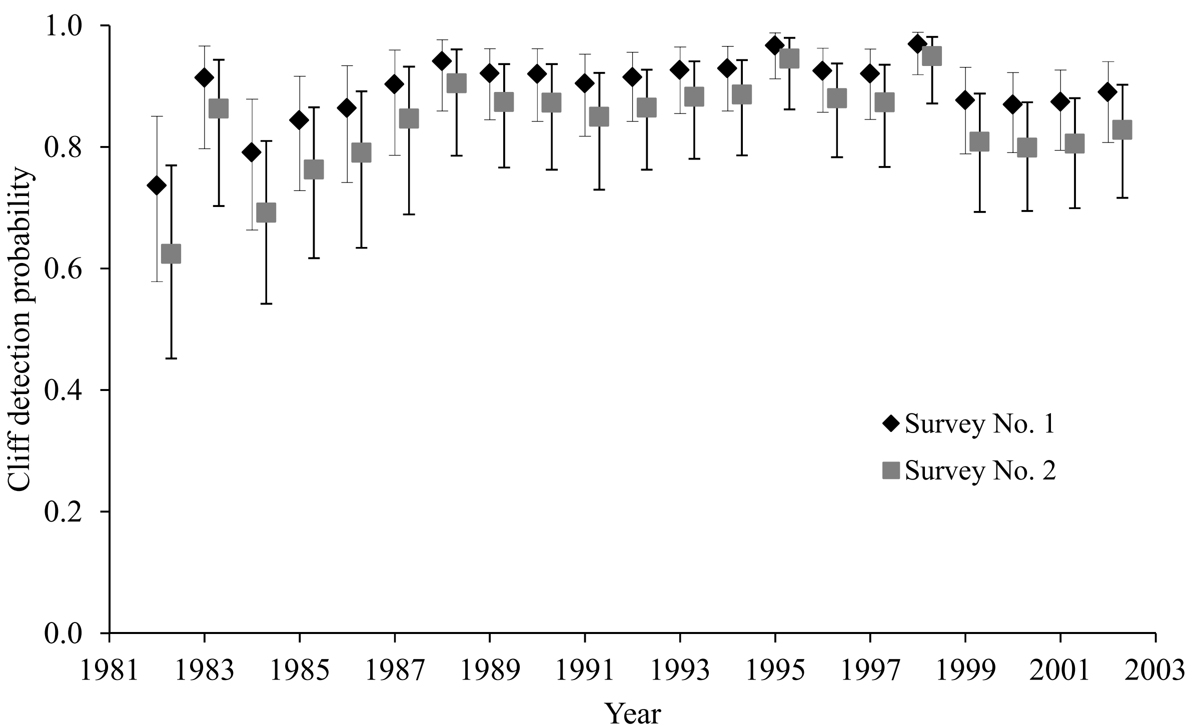
$height_{cliff,k}$	+ $yearlinear$	$productivity_{cliff,k,t-1}$			
$waterarea_{cliff,k}$ + $height_{cliff,k}$	$height_{cliff,k}$ + $meltdate_t$ + $yearlinear$	$height_{cliff,k}$ + $waterarea_{cliff,k}$ + $productivity_{cliff,k,t-1}$ + $precip_t$	34	3.16	0.016
$waterarea_{cliff,k}$ + $height_{cliff,k}$	$height_{cliff,k}$ + $meltdate_t$ + $yearthreshold$	$height_{cliff,k}$ + $waterarea_{cliff,k}$ + $productivity_{cliff,k,t-1}$ + $precip_t$	34	3.31	0.015
$waterarea_{cliff,k}$ + $height_{cliff,k}$	$height_{cliff,k}$ + $meltdate_t$ + $yearlog$	$aspect_{cliff,k}$ + $height_{cliff,k}$ + $waterarea_{cliff,k}$ + $productivity_{cliff,k,t-1}$ + $precip_t$	41	3.33	0.015
$waterarea_{cliff,k}$ + $height_{cliff,k}$	$waterarea_{cliff,k}$ + $height_{cliff,k}$ + $meltdate_t$ + $yearthreshold$	$height_{cliff,k}$ + $waterarea_{cliff,k}$ + $productivity_{cliff,k,t-1}$	34	3.34	0.015
$waterarea_{cliff,k}$ + $height_{cliff,k}$	$waterarea_{cliff,k}$ + $height_{cliff,k}$ + $meltdate_t$ + $yearthreshold$	$height_{cliff,k}$ + $waterarea_{cliff,k}$ + $productivity_{cliff,k,t-1}$ + $yearthreshold$	36	3.40	0.014
$waterarea_{cliff,k}$ + $height_{cliff,k}$	$waterarea_{cliff,k}$ + $height_{cliff,k}$ + $meltdate_t$ + $yearthreshold$	$aspect_{cliff,k}$ + $height_{cliff,k}$ + $waterarea_{cliff,k}$ + $productivity_{cliff,k,t-1}$	41	3.42	0.014
$waterarea_{cliff,k}$ + $height_{cliff,k}$	$height_{cliff,k}$ + $meltdate_t$ + $yearlinear$	$aspect_{cliff,k}$ + $height_{cliff,k}$ + $waterarea_{cliff,k}$ + $productivity_{cliff,k,t-1}$ + $precip_t$	41	3.60	0.013
$waterarea_{cliff,k}$ +	$waterarea_{cliff,k}$ + $height_{cliff,k}$ + $meltdate_t$	$height_{cliff,k}$ + $waterarea_{cliff,k}$ +	35	3.61	0.013

$height_{cliff,k}$	$+ yearlog$	$productivity_{cliff,k,t-1} + precip_t$			
$waterarea_{cliff,k} + height_{cliff,k}$	$height_{cliff,k} + meltdate_t + yearthreshold$	$aspect_{cliff,k} + height_{cliff,k} + waterarea_{cliff,k} + productivity_{cliff,k,t-1} + precip_t$	41	3.69	0.012
$waterarea_{cliff,k} + height_{cliff,k}$	$waterarea_{cliff,k} + height_{cliff,k} + meltdate_t + yearlinear$	$height_{cliff,k} + waterarea_{cliff,k} + productivity_{cliff,k,t-1} + precip_t$	35	3.74	0.012
$waterarea_{cliff,k} + height_{cliff,k}$	$waterarea_{cliff,k} + height_{cliff,k} + meltdate_t + yearthreshold$	$height_{cliff,k} + waterarea_{cliff,k} + productivity_{cliff,k,t-1} + precip_t$	35	4.09	0.010
$waterarea_{cliff,k} + height_{cliff,k}$	$height_{cliff,k} + meltdate_t$	$height_{cliff,k} + waterarea_{cliff,k} + productivity_{cliff,k,t-1}$	32	7.29	0.002
$waterarea_{cliff,k} + height_{cliff,k}$	$height_{cliff,k} + meltdate_t$	$aspect_{cliff,k} + height_{cliff,k} + waterarea_{cliff,k} + productivity_{cliff,k,t-1}$	39	7.43	0.002
$waterarea_{cliff,k} + height_{cliff,k}$	$height_{cliff,k} + meltdate_t$	$height_{cliff,k} + waterarea_{cliff,k} + productivity_{cliff,k,t-1} + precip_t$	33	7.78	0.002
$waterarea_{cliff,k} + height_{cliff,k}$	$waterarea_{cliff,k} + height_{cliff,k} + meltdate_t$	$height_{cliff,k} + waterarea_{cliff,k} + productivity_{cliff,k,t-1}$	33	8.31	0.001
$waterarea_{cliff,k} +$	$height_{cliff,k} + meltdate_t$	$aspect_{cliff,k} + height_{cliff,k} + waterarea_{cliff,k} +$	40	8.42	0.001

$height_{cliff,k}$		$productivity_{cliff,k,t\text{-}1} + precip_t$			
$waterarea_{cliff,k} + height_{cliff,k}$	$waterarea_{cliff,k} + height_{cliff,k} + meltdate_t$	$aspect_{cliff,k} + height_{cliff,k} + waterarea_{cliff,k} + productivity_{cliff,k,t\text{-}1}$	40	8.59	0.001
$waterarea_{cliff,k} + height_{cliff,k}$	$waterarea_{cliff,k} + height_{cliff,k} + meltdate_t$	$height_{cliff,k} + waterarea_{cliff,k} + productivity_{cliff,k,t\text{-}1} + precip_t$	34	8.79	0.001
$waterarea_{cliff,k} + height_{cliff,k}$	$geology_k + height_{cliff,k} + meltdate_t$	$height_{cliff,k} + waterarea_{cliff,k} + productivity_{cliff,k,t\text{-}1}$	34	9.07	0.001
•	•	•	4	77.5	<0.001


1.0
0.8
0.6
0.4
0.2
0.0
Nest-site detection probability
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
Year
Survey No. 1
Survey No. 2

(a)


1.0
0.8
0.6
0.4
0.2
0.0
Cliff detection probability
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
Year
Survey No. 1
Survey No. 2

(b)

Figure S1. Temporal trends in detection probability of nesting Arctic Peregrine Falcons for two surveys per summer of (a) individual nest sites, and (b) cliffs along the Colville River, Alaska in the Colville River Special Area between 1982-2002. Survey no. one was conducted during egg-laying and incubation in June, and survey no. two during the nestling period in late July through early August. Detection probability estimates are not provided for 1981 because data from year *t*-1 were used to parameterize models for year *t*.

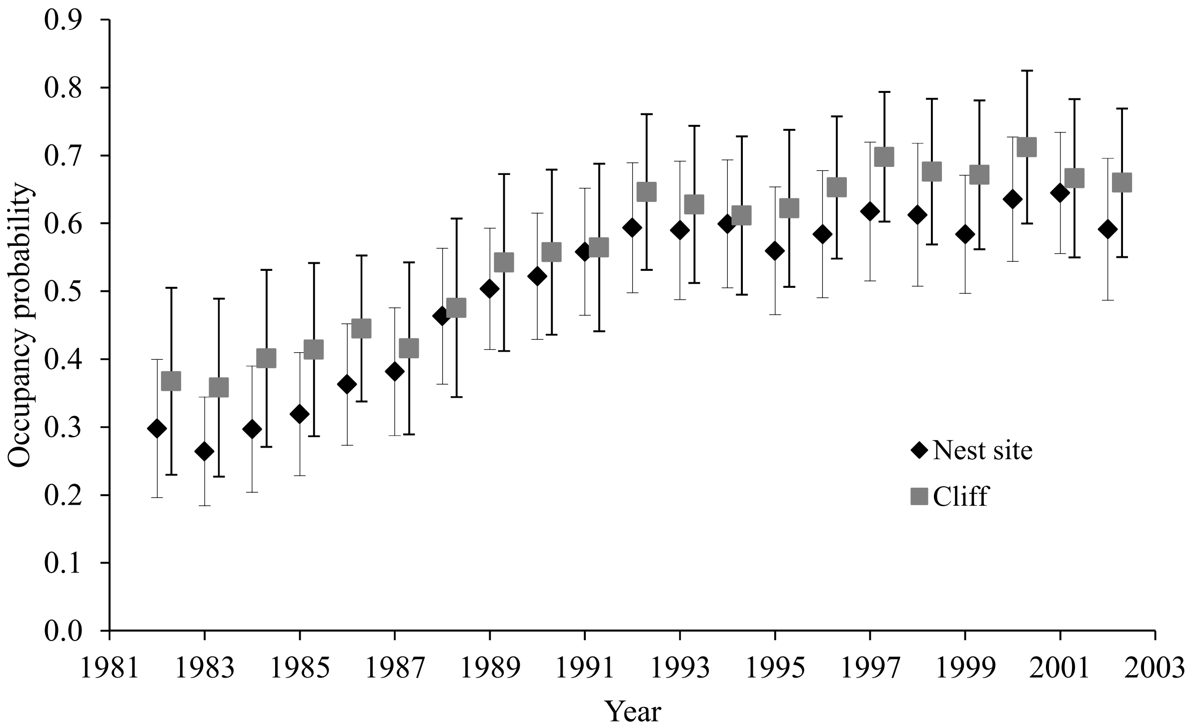


Figure S2. Temporal trends in the probability of Arctic Peregrine Falcon occupancy of individual nest-sites and cliffs along the Colville River, Alaska in the Colville River Special Area between 1982-2002. Error bars denote 95% CIs around model-averaged estimates. Because we used data from year *t*-1 to parameterize models for year *t*, occupancy is only estimated for 1982-2002.

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