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Prairie Falcon (*Falco mexicanus*) Abundance in a National Conservation Area in Idaho Has Increased since the 1970s–1990s

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ABSTRACT.—The Morley Nelson Snake River Birds of Prey National Conservation Area (NCA), in southwestern Idaho, USA supports a large population of breeding Prairie Falcons (*Falco mexicanus*). Abundance of Prairie Falcons in the NCA was previously monitored in 1976–1978 and 1990–1994. That research indicated maximum counts for each period in 1976 and 1992 and a possible population decline across that time span. We assessed the abundance and nesting success of Prairie Falcons in the NCA in 2002–2003 and 2019–2021, and we compared results to data from before 2000 to assess possible population change. Number of nesting pairs increased over 45 years from peak counts of 206, 193, and 217 in the 1970s, 1990s, and early 2000s, respectively, to 257 in 2021. Increases were not concentrated in one region, but widely distributed across the study area. Rates of nesting success in 2002–2003 and 2019–2021 averaged 57 ± 11.8% (SD) at 49.8 ± 3.3 nests observed each year and did not differ from pre-2000 rates. Finally, our analysis showed that in all 10 years in which a full census was conducted, a sampling approach to surveys would have been effective at estimating the number of falcons nesting within the NCA. Prairie Falcons are of conservation concern because of possible population declines in parts of their range. These results illustrate an area with apparently increasing numbers of this important species and highlight the importance of long-term surveys for tracking population fluctuations and the value of a national conservation area for providing raptor breeding habitat.

KEY WORDS: *abundance*; *long-term monitoring*; *nesting success*; *population trends*; *Snake River Birds of Prey*.

LOS INDIVIDUOS DE *FALCO MEXICANUS* QUE ANIDAN EN UN ÁREA NACIONAL DE CONSERVACIÓN EN IDAHO SON MÁS ABUNDANTES AHORA QUE EN LAS DÉCADAS DE 1970 A 1990

RESUMEN.—El Área Nacional de Conservación (ANC) de Aves de Presa Morley Nelson Snake River, en el suroeste de Idaho, EEUU, sostiene una gran población de individuos reproductores de *Falco mexicanus*. La abundancia de *F. mexicanus* en el ANC fue evaluada previamente en 1976–1978 y 1990–1994. Esa investigación indicó conteos máximos para cada período en 1976 y 1992, y un posible declive de la población a lo largo de ese lapso de tiempo. Evaluamos la abundancia y el éxito reproductivo de *F. mexicanus* en el ANC en 2002–2003 y 2019–2021, y comparamos los resultados con datos anteriores al 2000 para evaluar un posible cambio poblacional. El número de parejas reproductoras aumentó en 45 años, desde máximos de 206, 193 y 217 en las décadas de 1970, 1990 y principios de 2000, respectivamente, hasta 257 en 2021. Los aumentos no se concentraron en una sola región, sino que se distribuyeron

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ampliamente por toda el área de estudio. Las tasas de éxito reproductivo en 2002–2003 y 2019–2021 promediaron 57 ± 11.8% (DE) en 49.8 ± 3.3 nidos observados cada año, y no difirieron de las tasas anteriores al 2000. Finalmente, nuestro análisis mostró que en los 10 años en los que se realizó un censo completo, un enfoque de muestreo para los censos habría sido efectivo para estimar el número de halcones anidando dentro del ANC. *F. mexicanus* es una especie de preocupación para la conservación debido a posibles declives poblacionales en partes de su distribución. Estos resultados ilustran un área con un aparente aumento en los números de esta importante especie y destacan la importancia de estudios a largo plazo para determinar las fluctuaciones poblacionales y el valor de un área nacional de conservación para proporcionar hábitat de reproducción para aves rapaces.

[Traducción del equipo editorial]

INTRODUCTION

Populations of many North American raptors have fluctuated dramatically in the recent past (Dumandan et al. 2021). For example, Peregrine Falcon (*Falco peregrinus*) populations declined to the point of becoming federally listed as endangered in the United States and Canada (White et al. 2020). Conservation efforts, including captive rearing, reintroductions, and a ban on the use of organochlorine pesticides ultimately helped remove this species (50 Code of Federal Regulations Part 17) from listing under the US Endangered Species Act. More recently concern has been raised about apparent large-scale declines of populations of American Kestrels (*Falco sparverius*; McClure et al. 2021). The reasons for declines of American Kestrels are not well understood but may relate to reductions in important prey, increases in numbers of other avian predators, loss of suitable habitat, effects of environmental toxicants or climate change, or even cascade effects from rebounds in populations of other raptors (Farmer and Smith 2009, Smallwood et al. 2009, McClure et al. 2017, Newton 2017, Freddie-Jeanne et al. 2021, Bird and Smallwood 2023). Thus, as frequent apex predators, like other raptors, members of the genus *Falco* can be indicators of ecosystem stress and function (Sergio et al. 2005).

Prairie Falcons (*Falco mexicanus*) are large falcons that range from southern Canada to northern Mexico, where they inhabit shrub steppes, grasslands, and canyon lands in western North America (Steenhof 2020). Prairie Falcons in some regions defend nesting territories at cliffs where they breed, but they do not defend foraging areas (Marzluff et al. 1997, Steenhof 2020). Because of this strategy, dense nesting aggregations sometimes occur. The Prairie Falcon diet includes rodents, passerines, and lizards; ground squirrels are a key prey item during the breeding season in most areas (Steenhof and Kochert 1988, Steenhof 2020). Their reliance on mammals may have allowed Prairie Falcons to avoid major population effects experienced by bird- and fish-eating raptors from pesticide use during the 1940s–1970s (Mineau et al. 1999, Henny et al. 2010, Steenhof 2020). However, despite their widespread distribution in western North America, there has been recent concern about declines in nesting populations (Iknayan and Beissinger 2018, Gail Garber, Hawks Aloft, Inc., pers. comm.) and in counts in parts of their winter range (McClure et al. 2023).

The Snake River Canyon of the Morley Nelson Snake River Birds of Prey National Conservation Area (NCA) in southwestern Idaho, USA supports a dense nesting concentration of several species of birds of prey, including Prairie Falcons (Steenhof et al. 1999, US Department of Interior 2008). Long-term monitoring of Prairie Falcons in the NCA suggested that between 1976 and 1994 nesting success fluctuated and the number of pairs declined (Steenhof et al. 1999).

We surveyed the NCA during 2002–2003 and 2019–2021 and compared our findings with data from 1974–1997 to understand possible changes in abundance and nesting success of this species. Specifically, our objectives were to (1) census or estimate the number of nesting pairs of Prairie Falcons in the NCA, (2) estimate annual rates of nesting success, and (3) compare these demographic indicators to pre-2000 data in Steenhof et al. (1999) to assess potential changes in number of nesting pairs and rates of success. Our comparisons were at two spatial scales—that of the entire NCA and that of specific stretches of the canyon. Finally, by evaluating post-2000 data in the context of prior work, we highlight the value of long-term monitoring for this species.

METHODS

Study Area. The NCA study area (43°50′N, 115°50′W; Fig. 1) included 2430 km^2 of public and private lands within Canyon, Ada, Elmore, and Owyhee Counties, Idaho, USA. We focused surveys on 130 km of both sides of the Snake River Canyon and

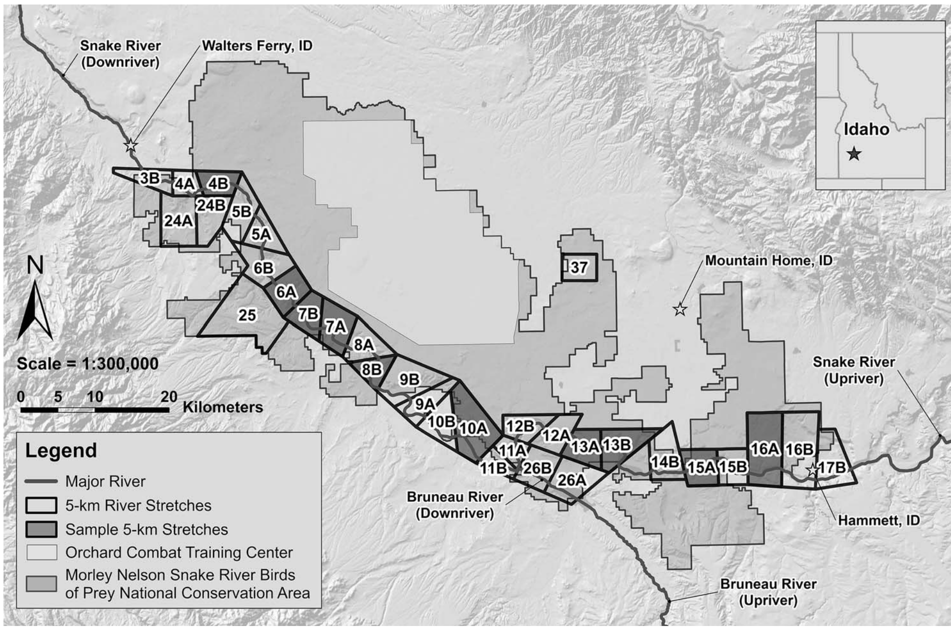

Figure 1. The southwestern Idaho study area where Prairie Falcons were surveyed. Study area includes Morley Nelson Snake River Birds of Prey National Conservation Area, including parts of the Snake and Bruneau Rivers and 33 5-km stretches surveyed for Prairie Falcon nesting pairs. All 5-km stretches were surveyed as part of full-canyon counts in 2002 and 2021. A stratified random sample of stretches ($n = 10$, shown darkened on the map) was surveyed in 2003, 2019, and 2020.

adjacent suitable cliffs between Walters Ferry and Hammett, Idaho (Fig. 1). Elevation of the canyon ranges from approximately 700 m above sea level (masl) at the lowest points of the valley floor to approximately 900 masl at the highest points of the canyon rim, and its basalt cliffs are up to approximately 125 m in height (US Department of Interior 2008). Above the canyon, topography is generally flat with a few isolated buttes. The area is dry with 15–25 cm of precipitation per year occurring mainly in winter and early spring (US Department of Interior 1996). Native and historically dominant vegetation includes associations of big sagebrush (*Artemisia tridentata*), shadscale (*Atriplex confertifolia*), and winterfat (*Krascheninnikovia lanata*). Invasive plants such as cheatgrass (*Bromus tectorum*), Russian thistle (*Salsola kali*), and tall tumblemustard (*Sisymbrium altissimum*) are now common in areas where disturbances (e.g., fire, grazing, off-highway vehicle traffic) have converted perennial shrublands to annual grasslands (Knick and Rotenberry 2000, Pilliod et al. 2017). Livestock grazing is widespread in the NCA, and the Idaho Army National Guard also conducts training activities (e.g., artillery and small arms fire; armored vehicle, tank, and helicopter training; and bivouacking) in the Orchard Combat Training Center (OCTC), which is entirely within the boundaries of the NCA (Fig. 1; US Department of Interior 2008). Major habitat changes have occurred within the NCA since the 1980s (US Department of the Interior 1996, 2008, Boise District, Bureau of Land Management unpubl. data). By 1994 wildfires had converted a large proportion of the native shrub communities in the NCA to extensive stands of cheatgrass and other annual, nonnative plants. Shrub loss due to wildfire has continued to the present.

Field Surveys. Previous surveys assessed the total number of Prairie Falcon pairs in the NCA from 1976–1978 and in 1990–1994 (Steenhof et al. 1999), based on full-canyon counts. In 15 yr from 1974–1997, researchers also estimated nesting success (percentage of occupied focal territories that produced at least one young that reached 30 d of age). Detailed descriptions of survey methods and nesting success evaluations are in Steenhof et al. (1999).

We designed post-2000 field survey methods to replicate, as closely as possible, approaches used by Steenhof et al. (1999). Ultimately, we conducted two types of surveys to document numbers of nesting pairs of falcons in the NCA: (1) full-canyon counts in 2002 and 2021, during which the entire study area was censused by visiting 33 stretches, each one 5-km in river length, and (2) stratified random surveys in 2003, 2019, and 2020, during which a subset of ten of the 5-km river stretches was surveyed (Supplemental Material Table S1). We implemented this sampling approach during years when funding limitations prevented surveying the full canyon, and we included the same 10 5-km stretches of river canyon in each of those years. These stretches were selected based on a stratified sampling procedure (Table S1) that considered six strata: three NCA management areas in which falcon pairs were most likely to forage (US Department of Interior 2008) across two levels of historical falcon abundance (low or high; Kochert and Steenhof 2004). Ultimately, we used results from each stratified random survey to calculate an estimate of full-canyon abundance (±95% CI) of nesting pairs for a given year.

We conducted surveys from one or more observation points in ~1-km segments of the canyon situated within each 5-km river stretch. We positioned observation points on the canyon rim or floor at locations that provided the best available viewpoint to assess presence or absence of Prairie Falcons for each 1-km segment of suitable cliff. Observation points were usually, but not always, similar among years. The number of 1-km segments within 5-km river stretches varied from 1 to 17 ($\bar{x} = 8.0 \pm 4.8$, $n = 33$ 5-km river stretches, Table S2). The number of segments per 5-km stretch varied because the river canyon was not linear, surveys included side canyons and isolated buttes, and the amount of cliff suitable for falcon nesting was not always present on both sides of the canyon.

In 2002, we used field survey methods developed by Steenhof et al. (1999) to detect nesting pairs, and we conducted three 2-hr survey sessions along each 1-km segment. These visits occurred in mid-March to early April, late April to late May, and in early to mid-June. Thereafter (2003–2021), we surveyed in two 2-hr periods per 1-km segment, once in mid-March to mid-April and once again in May to mid-June, based on recommendation of Kochert and Steenhof (2003). Their recommendation was based on observations that Prairie Falcons are most detectable during these two time periods (Lehman et al. 1990, Kochert and Steenhof 2003), as the first corresponds to the period of territory establishment and courtship, and the second to when nestlings are conspicuous, typically with frequent parental feeding visits.

Surveyors navigated to observation points using hard copy topographic maps and aerial or satellite imagery (2002–2003), and later with use of commercially available GPS enabled data loggers (2019–2021; CP3; Juniper Systems and Harvest Manager, Inc., Logan, UT, USA) with pre-loaded digital spatial information (e.g., topographic, aerial imagery, 1-km boundary, 5-km boundary, roads, land management). We considered evidence for occupancy as an observation of eggs, young, an incubating bird, a mated pair on or near the nest, a pair copulating, or at least one bird engaged in nesting territory defense (Franke et al. 2017, Steenhof et al. 2017).

We assessed nesting success at 46–55 occupied Prairie Falcon territories in 2002–2003 and 2019–2021 (Table S3). We selected territories for this monitoring using a stratified random approach similar to that used by Steenhof et al. (1999) with proportional allocation according to falcon abundance to ensure representation across the study area. As a consequence, we monitored 0–11 occupied territories within a 5-km stretch (Table S3). We visited these 46–55 territories approximately once per week. We considered a pair successful if it raised at least one young to 30 d of age (aging based on Moritsch 1983), which is 80% of typical fledging age (Steenhof 1987).

Statistical Analysis. We quantified the number of occupied territories for each 5-km stretch for each survey year. We summed counts of occupied territories in stretches to represent the number of nesting pairs occupying the NCA during full-canyon survey years (2002, 2021). We estimated the total number of occupied territories (±95% CI) in the NCA for years when we did not survey all 5-km stretches. To do this, we calculated an abundance estimate following Lohr (2010; pages 99–101; calculations shown in Table S4a–S4c) and weighted the mean and variance in numbers of pairs counted in each of the six strata surveyed. When there was only one 5-km stretch sampled in a stratum, we calculated our abundance estimate using the variance in the stratum during the most recent previous full-canyon count. We assessed the potential accuracy of this approach for estimating full-canyon number of pairs by comparing full-canyon counts of all 33 5-km stretches with estimates derived from only the 10 5-km stretches for 2002 and 2021, as well as for all eight previous years with full-canyon counts (1976–1978, 1990–1994 as reported in Steenhof et al. 1999; calculations shown in Table S5a–S5j). When assessing accuracy, we calculated the difference between the actual and estimated count and evaluated whether the 95% CI of the estimated

Table 1. Number of Prairie Falcon nesting pairs per 5-km river stretch, by year, and total number of nesting pairs counted in each year of survey within the Morley Nelson Snake River Birds of Prey NCA in southwestern Idaho, USA (see also Table S8 for data organized by stretch, including all years of surveys). Years are organized by the type of survey conducted, either a full-canyon survey (all 33 5-km stretches) or a sample (10 5-km stretches). Data from 1976 and 1992 are years with previous peak abundance for comparison.

	Full-canyon Survey (33 Stretches)				Sampling Survey (10 Stretches)		
Pairs/Stretch	1976	1992	2002	2021	2003	2019	2020
0	5	5	5	3	0	0	0
1	5	5	3	7	1	1	0
2	4	5	4	3	0	1	2
3	2	0	4	1	1	0	0
4	2	3	0	0	1	0	0
5	1	1	0	1	0	0	0
6–10	8	9	10	8	5	3	4
11–15	2	1	3	6	1	4	2
16–20	2	2	3	1	1	0	1
21–25	2	2	1	1	0	0	0
>25	0	0	0	2	0	1	1
Total Pairs	206[a]	193	217	257	75	113	107

[a] Steenhof et al. (1999) originally reported number of pairs as 205 for 1976. Subsequent re-evaluations corrected this value to 206.

count included the actual count. We reasoned that if the 95% CI surrounding the point estimate captured the actual count, then the stratified random survey approach was an acceptable alternative for quantifying abundance of Prairie Falcons in the NCA and suitable for use in trend analysis.

We assessed long-term variation in number of pairs in the NCA using two different analytical approaches. First, we used a generalized linear regression to examine number of pairs as a function of year to evaluate if there was a change in the long-term trend of abundance between 1976 and 2021. For this analysis, we used maximum likelihood estimation and Akaike information criterion (AIC_c; Burnham and Anderson 2002) to select a response distribution (Table S6a). We also evaluated if fit was improved by adding second- and third-order polynomials for the year term (Table S6b). We explored the relationship between number of pairs and year in two ways: initially, using full-canyon counts and point estimates of abundance from stratified random sampling years, and subsequently only including full-canyon counts (i.e., without estimates of 2003, 2019, 2020 abundance). Inferences were similar, so we present results of the first analysis only.

Second, we compared our most recent count from 2021 to peak counts in three previous time periods with full-canyon counts, given that peak counts in the late 1970s, early 1990s, and early 2000s were likely the “maxima” from each time period. We used nonparametric Wilcoxon signed rank tests to compare mean number of pairs per 5-km stretch between 2021 and each of the previous peak years separately. We also evaluated changes in number of nesting pairs in each 5-km stretch between 2021 and each of the previous peak years to assess if any changes in abundance were distributed evenly or concentrated in certain stretches.

We compared mean nesting success (% of pairs successful) in post-2000 surveys (2002–2021) to that of earlier years (1974–1997) using a nonparametric Wilcoxon test. We also used generalized linear regression to evaluate possible trends in nesting success from 1974 to 2021. Once again, we used maximum likelihood estimation and compared several different response distributions using AIC_c (Table S6c).

Means $\pm$ SD are reported throughout unless indicated otherwise, and results of statistical tests were considered significant if $P < 0.05$. We used JMP Pro v.17.2 (SAS Institute, Inc., Cary, NC, USA) for all statistical analyses. Pre-2000 data were reported in Steenhof et al. (1999), but the data used in this analysis differ slightly from those reported there because of re-evaluation of data and adjustment for minor differences in survey areas (USGS unpubl. data; Table S7a, S7b).

RESULTS

Number of Pairs. We counted 217 and 257 pairs of Prairie Falcons during full-canyon surveys in 2002 and 2021, respectively (Table 1). Number of pairs

Table 2. Number of Prairie Falcon nesting pairs in the Morley Nelson Snake River Birds of Prey NCA in southwestern Idaho, USA (1976–2021). Shown are actual counts from full-canyon surveys and estimates (±95% CI) based on sampling only 10 5-km stretches. In three years (2003, 2019, and 2020) only the sample was surveyed, in other years the full canyon was surveyed. Difference is estimate minus actual count. Data from pre-2002 are USGS, unpublished data.

Year	Full-canyon Survey	Estimate from 10 5-km Stretches	Lower 95% CI	Upper 95% CI	Difference	Estimate Within CI?
1976	206[a]	218	192	244	12	Yes
1977	205[a]	222	193	251	17	Yes
1978	183[a]	207	181	235	25	Yes
1990	184[a]	191	163	221	8	Yes
1991	184[a]	178	144	212	−6	Yes
1992	193[a]	195	164	226	2	Yes
1993	187	193	165	221	6	Yes
1994	159[a]	155	131	179	−4	Yes
2002	217	225	194	256	8	Yes
2003	—	204	169	239	—	—
2019	—	308	248	368	—	—
2020	—	304	237	371	—	—
2021	257	271	214	328	14	Yes

[a] Values differ by one nesting pair from those reported in Steenhof et al. (1999) because of subsequent re-evaluation of data.

per 5-km stretch averaged 6.6 ± 6.3 (range: 0–22) in 2002 and 7.8 ± 8.0 (range: 0–28) in 2021. In 2002, there were five stretches with 0 pairs, seven with >10 pairs and none with > 25 pairs (Table 1). In 2021 there were three stretches with 0 pairs, 10 with >10 pairs and two with >25 pairs (Table 1).

In the 10 randomly selected 5-km stretches surveyed in 2003, 2019, and 2020, we identified 75, 113 and 107 Prairie Falcon pairs, respectively (Table 1). None of the 10 5-km stretches lacked a nesting pair in these years. Number of pairs per 5-km stretch averaged 7.5 ± 4.7 (range: 1–17) in 2003, 11.3 ± 8.1 (range: 1–30) in 2019, and 10.7 ± 8.4 (range: 2–31) in 2020. In 2003 there were two stretches with >10 pairs and none with >25 pairs (Table 1). In 2019 and 2020, there were five and four stretches with >10 pairs, respectively, and one stretch in each year contained >25 pairs (Table 1). Extrapolating from the sample of 10 5-km stretches to obtain estimates of full-canyon abundance, the number of Prairie Falcon pairs in the NCA was 204 ± 35 (95% CI), 308 ± 60, and 304 ± 67 in 2003, 2019, and 2020, respectively (Table 2, Table S4a–S4c).

For the two years in which we conducted full-canyon counts of Prairie Falcon pairs in the NCA (2002 and 2021), there were 85 and 97 pairs, respectively, in the 10 randomly selected 5-km stretches (2002: 8.5 ± 5.0 per 5-km stretch; 2021: 9.7 ± 7.6). When we used only counts in these 10 5-km stretches to estimate total number, i.e., to assess potential accuracy of the stratified random sampling, there were an estimated 225 ± 31 (95% CI) in 2002 and 271 ± 57 pairs in 2021 (Table 2; Table S5a, S5b). For both 2002 and 2021, these respective 95% CIs captured the actual number detected in the full-canyon count (217 and 257, respectively; Table 2). Using the same approach for all pre-2000 full-canyon surveys (1976–1978 and 1990–1994), 95% CIs encompassed the actual count in all years (Table 2, Table S5c–S5j). The absolute value of abundance estimates based on the 10 randomly selected 5-km stretches differed from the full-canyon counts by only 10.2 ± 6.9 pairs/yr ($n = 10$; range of absolute value of differences: 2–25; Table 2).

Long-term Variation in Number of Pairs. There was a significant positive relationship in Prairie Falcon abundance as a function of year from 1976–2021 (Fig. 2). The relationship fit best when including a polynomial term for year (year^2) and indicated positive and significant regression parameters (generalized regression with lognormal response distribution: year: $B = 0.007$, 95% CI = 0.0043–0.0101, $\chi^2 = 24.01$, $P < 0.001$; year^2: $B = 0.0005$, 95% CI = 0.0003–0.0007, $\chi^2 = 22.76$, $P < 0.001$; Fig. 2, Table S7a, S7b).

For the three years with stratified random surveys (2003, 2019, and 2020), mean number of Prairie Falcon pairs in the 10 5-km stretches was significantly greater in 2019 (11.3 ± 8.1, range: 1–30) than in 2003 (7.5 ± 4.7, range: 1–17; Wilcoxon signed rank test: S = 23.5, $P = 0.014$). Number of pairs in 2020 (10.7 ± 8.4, range: 2–31) was greater in 6 of 10 (60%) 5-km stretches but, on average, did not differ significantly from 2003 (Wilcoxon signed rank test: S = 17.0, $P = 0.094$).

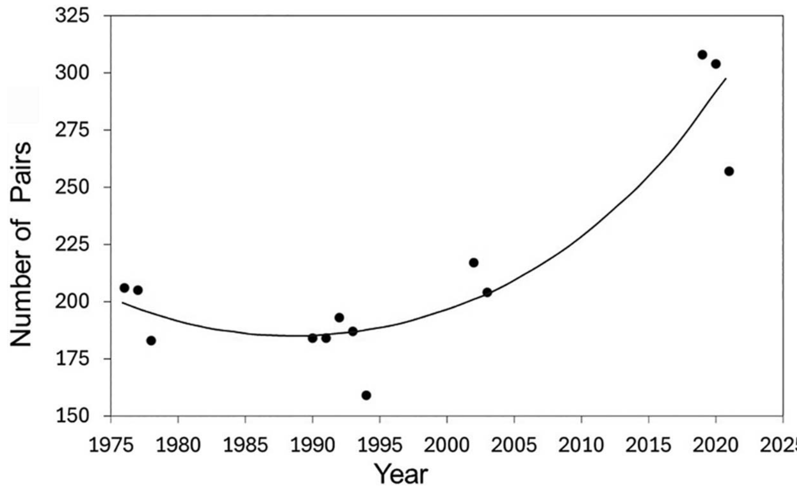

Figure 2. Number of Prairie Falcon nesting pairs in the Morley Nelson Snake River Birds of Prey National Conservation Area, southwestern Idaho, USA based on full-canyon counts in 1976–1978, 1990–1994, 2002, and 2021 and point estimates generated from sampling 10 5-km stretches in 2003, 2019, and 2020. Results for years before 2002 are from USGS, unpublished data. Regression line is estimated based on polynomial regression using lognormal response distribution (see text).

Peak numbers of Prairie Falcons were detected during full-canyon surveys in 1976, 1992, and 2002 (data for 1976 and 1992 from Steenhof et al. 1999). Number of pairs of Prairie Falcons in the 33 5-km stretches was greater in 2021 (257) than during previous peak count years in 2002 (217, a 15.6% increase), in 1992 (193, 24.9%), and in 1976 (206, 19.8%). Moreover, mean number of pairs per 5-km stretch was significantly greater in 2021 (7.8 ± 8.0, range: 0–28) than in 2002 (6.6 ± 6.3, range 0–22; Wilcoxon signed rank test: S = 116.5, $P = 0.03$), 1992 (5.8 ± 6.4, range: 0–23; S = 176.5, $P < 0.001$), and 1976 (6.2 ± 6.7, range: 0–23; S = 149, $P = 0.005$).

The number of Prairie Falcon pairs increased in 19 (58%) of the 33 5-km stretches from the peak from the earliest time period (1976) to 2021 (increase = 3.3 ± 2.2, range: 1–8), it decreased in 8 (24%, decrease = −1.5 ± 0.8, range: −1 to −3), and it did not change in 6 (18%, Fig. 3a, Table S8). When compared to 1992, number of pairs in 2021 was greater in 18 of the 5-km stretches (55%, mean increase = 4.0 ± 2.6, range: 1–10), lower in 4 (12%, −2.0 ± 1.4, range: −1 to −4), and not different in 11 (33%; Fig. 3b, Table S8). Finally, compared to data from the full-canyon count in 2002, there were more pairs in 15 (46%) of the 5-km stretches in 2021 (increase = 3.3 ± 2.9, range: 1–9), fewer in 6 (18%, decrease = −1.7 ± 0.8, range: −1 to −3), and no change in number in 12 (36%; Fig. 3c, Table S8).

The 5-km stretches with higher counts in 2021 than in previous years were broadly distributed among upper (eastern), middle, and lower (western) reaches of the Snake River canyon system within the NCA (Fig. 3). However, larger increases tended to occur in the lower sections of the study area. Stretches where counts declined in 2021 compared to earlier time periods were not restricted to any single portion of the study area (Fig. 3).

Nesting Success. From 2002 through 2021, the percentage of nesting falcon pairs that successfully produced at least one offspring averaged 57.0 ± 11.8% and ranged from a low of 42% in 2003 to a high of 75% in 2020 ($n = 5$ yr and 49.8 ± 3.3 nesting attempts/yr). Mean nesting success in post-2000 surveys did not differ from mean nesting success from 1974–1997 (62.9 ± 14.7; Wilcoxon two-sample test, normal approximation: S = 44, $z = -0.698$, $P = 0.485$), and the range of success estimates for 2002–2021 was similar to that observed prior to 2000. A Weibull response distribution best fit the data, and there was no significant trend in nesting success from 1974 to 2021 (Fig. 4; $B = -0.002$, 95% CI = −0.0075–0.0030, $P = 0.404$, Table S6c).

DISCUSSION

Prairie Falcons are of conservation concern throughout their range. Our evaluation of the

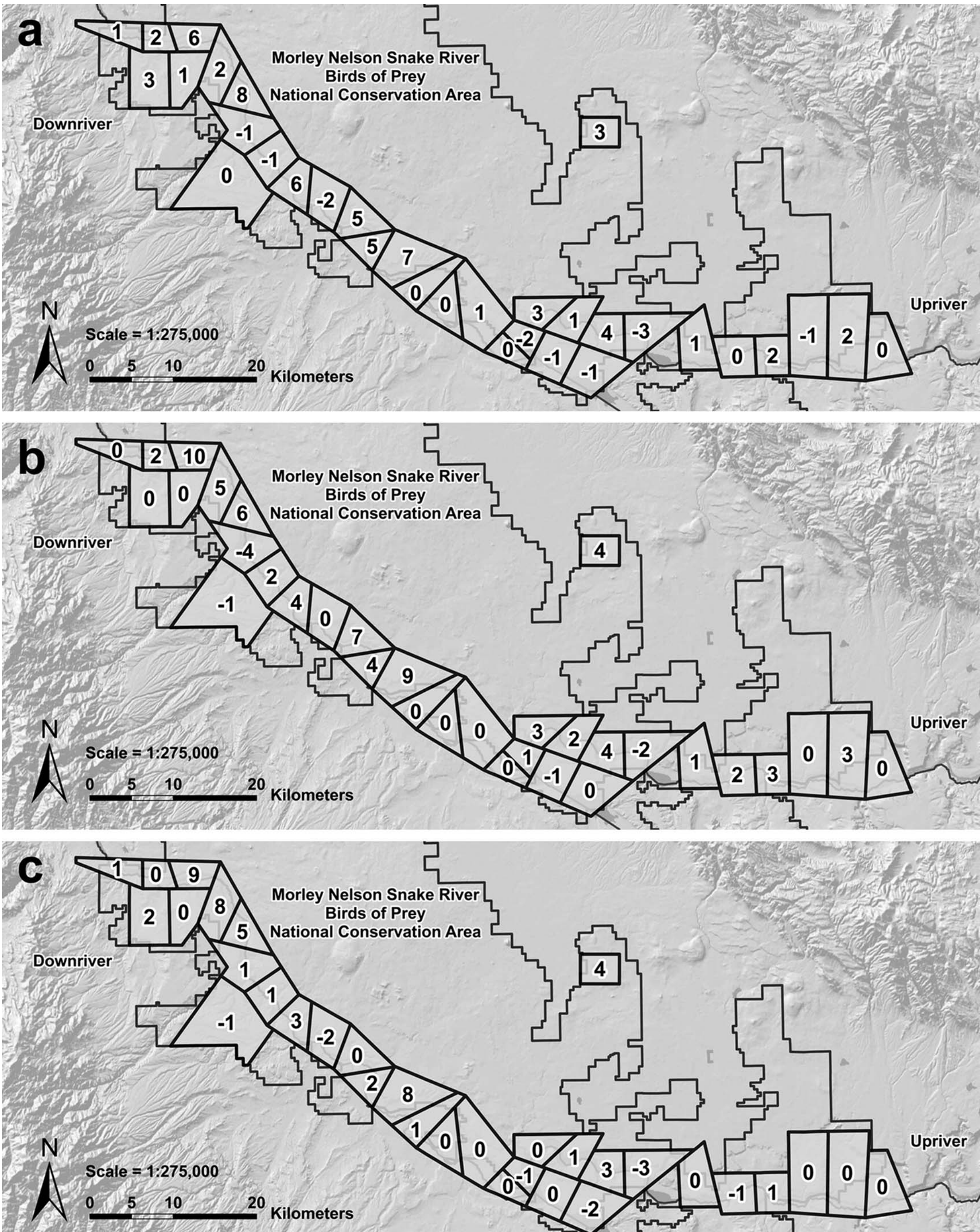

Figure 3. Difference in number of Prairie Falcon nesting pairs in 2021 from (a) 1976, (b) 1992, and (c) 2002 in 33 5-km stretches surveyed in the Morley Nelson Snake River Birds of Prey National Conservation Area, Idaho, USA. Data for 1976 and 1992 are from USGS, unpublished data.

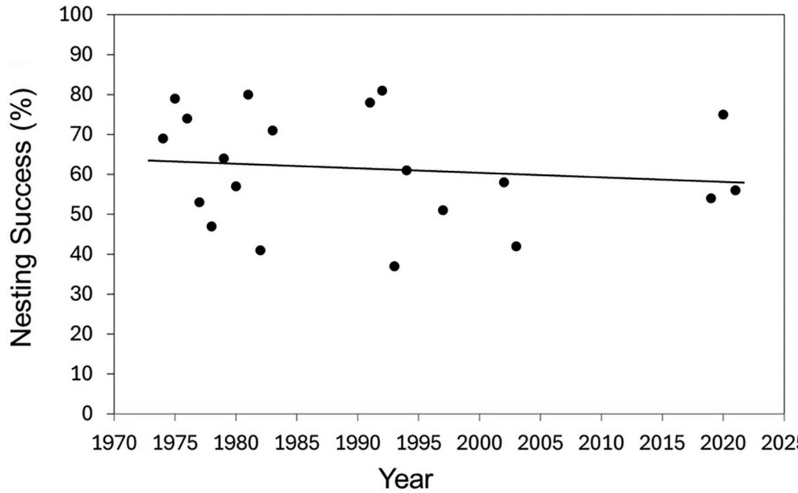

Figure 4. Nesting success (% of pairs that raised ≥1 nestling reaching 30 d of age) for Prairie Falcons in the Morley Nelson Snake River Birds of Prey National Conservation Area, Idaho, USA in 2002–2021 (this study) and from 1974–1997 (USGS, unpublished data) based on 46.5 ± 21.8 (SD) pairs per year (range: 16–91). There was no significant relationship between % success and year (regression line based on generalized regression and Weibull error distribution, shown for illustration rather than statistical significance).

nesting Prairie Falcon population in the NCA indicated that this population has increased in abundance and maintained nesting success over 45 years. Despite differing objectives over 45 years of surveys, long-term monitoring data like ours allow a unique assessment of population change and trajectory.

Steenhof et al. (1999) reported declines in Prairie Falcon numbers throughout the NCA from 1976 to 1997, but this trend has not continued. Our results show that Prairie Falcon abundance was greater from 2019 to 2021 than during the 1970s, 1990s, and early 2000s. We have no reason to believe that the difference in number we detected was caused by change in survey techniques between pre- and post-2000 surveys, or because of variation in detection rates among years or observers. Our most recent surveys followed protocols established in prior work. Differences in methodology and in observer training, experience, and performance were minor. For example, observation points sometimes differed, and data collection was computerized in later surveys, but the fundamentals of each survey remained the same. Furthermore, our conclusions about increases in abundance likely are conservative in that statistical analyses compared abundance in 2021 and peak abundance during earlier timeframes. Had the comparisons been made with averages of earlier time periods, they would have suggested even larger increases in number of pairs.

Abundance of Prairie Falcon pairs in 5-km river stretches generally stayed the same or increased from 2003 to 2021. Why increases occurred in some stretches and not in others may be related to variation in cliff height and structure that resulted in different amounts of suitable nesting habitat in each stretch (US Department of Interior 1979, Steenhof et al. 1999). Stretches with taller cliffs sometimes allowed pairs to separate their nests vertically as well as horizontally. Thus, Prairie Falcons are able to nest in dense concentrations where they do not defend foraging territories. Tracking data suggest that adults have large home ranges (~300 km^2) and sometimes travel more than 20 km from nest sites to forage (Marzluff et al. 1997) in areas devoid of nesting sites. This wide-ranging behavior was one reason boundaries of the NCA were established well beyond the Snake River Canyon to encompass and protect these large foraging areas (US Department of Interior 1979). Thus, changes in numbers of nesting pairs in a particular stretch may reflect factors that are difficult to measure because they occur well outside of the canyon.

Nesting success of Prairie Falcons varied annually in the NCA. Despite this, on average, more than half of all Prairie Falcon pairs monitored in the NCA in 2019–2021 were successful, a pattern that also mirrored earlier data from the 1970s–2000s (Steenhof et al. 1999, Kochert and Steenhof 2003, 2004). Weather, prey populations, disease or parasites, and predators all can affect nesting success rates (McFadzen and Marzluff 1996, Steenhof et al. 1999), but the extent to which each affected annual success in our study is not completely known. We therefore have no indication that current threats to successful reproduction are adversely affecting the population. Furthermore, we saw no evidence that the greater density of falcons in recent years negatively influenced rates of nesting success, i.e., nesting success does not appear, at the scale of the study area, to be density dependent (Fig. 4).

An important outcome from our work is that we were able to assess the relative accuracy of population estimates for ten years of surveys (1976–1978, 1990–1994, 2002, 2021) based on a stratified random sample of 5-km stretches rather than completing full-canyon counts. Full-canyon surveys are substantially more labor intensive and expensive, and thus sampling would optimize use of time, people, and money. Our data indicate that the stratified random sample of stretches provided a reasonably accurate estimate of the number of nesting pairs in the entire canyon. Therefore, a raptor monitoring strategy for the NCA proposed in 2008 (Kochert et al. 2009), which included the recommendation that two sampling surveys and one full-canyon count be completed every five years, remains reasonable to monitor Prairie Falcon numbers in the study area.

The high density of Prairie Falcons is unique to our study area, and few areas will require the type of subsampling that we developed for the NCA. However, there are some lessons drawn from our work that can apply to other settings. For example, it was highly effective for us to survey for 2-hr intervals from appropriate observation points at least twice each year: early in the nesting season when falcons are detectable during courtship and territory establishment and late in the nesting season when parental feeding visits are frequent. It would facilitate comparison throughout the species' range if others collected similar evidence for occupancy (i.e., eggs, young, an incubating bird, a mated pair on or near the nest, a pair copulating, or at least one bird engaged in nesting territory defense) and used similar standards to assess when pairs are successful (at least one nestling 30 d of age).

Our findings that Prairie Falcon nesting populations increased from 1976 to 2021 stand in contrast to reports of widespread declines in bird populations throughout North America from 1970 to 2017 (Rosenberg et al. 2019). Even within the NCA, for example, Golden Eagle (*Aquila chrysaetos*) abundance has declined since 1979 (Kochert et al. 2018). Investigators have suggested that the decline in Golden Eagles in southwestern Idaho could be related to local climate changes (Kochert et al. 2019), increasing recreation (Steenhof et al. 2014), shrub loss (Kochert et al. 1999), declining prey populations (Heath et al. 2021), disease (Dudek et al. 2018), parasites (Dudek et al. 2021), or some combination of these factors. Why Prairie Falcons may have responded differently to these influences is not fully understood.

One possibility is that, unlike many other regional species, Prairie Falcons typically are associated with grasslands (Pandolfino et al. 2011, DeLong and Steenhof 2020, Steenhof 2020). Thus, shrub loss in the NCA may also have increased the NCA's carrying capacity for Prairie Falcons, benefiting the local population. Given the panmictic structure of the western USA population of this species (Doyle et al. 2018), the NCA might be attracting birds from other regions.

The NCA has long been considered the area with the globally highest density of nesting Prairie Falcons, and this was one of the main reasons the protected area was established (US Department of Interior 1979, Steenhof 2020). In this regard, the NCA seems to be serving its conservation purpose, at least to the extent that Prairie Falcon numbers have not decreased over 45 years. This population trend therefore provides evidence of the value and importance of conservation lands for the conservation of raptors.

Prairie Falcons are of conservation concern throughout their range (Steenhof 2020). Long-term data about Prairie Falcon population trends in many states and provinces are only sometimes published, and those that are available can be inconclusive and sometimes conflicting due to inconsistent survey effort among years and relatively small survey areas. Recent increases in the number of Prairie Falcons nesting in the NCA do not mean that the species is immune to emerging threats or novel population pressures. Coordinated long-term monitoring throughout the range may contribute to understanding aspects of the ecology and population dynamics of Prairie Falcons across the species' range. To this end, a Prairie Falcon working group has been formed recently to identify knowledge gaps, develop a range-wide monitoring strategy, and evaluate patterns in the context of the rapidly changing environment that these falcons experience.

SUPPLEMENTAL MATERIAL (available online). Table S1: We used a stratified random sampling approach to identify 10 5-km stretches for surveys for nesting Prairie Falcons. Table S2: Approximate linear length of cliff habitat for nesting Prairie Falcons within 5-km river stretches ($n = 33$) within the Morley Nelson Snake River Birds of Prey National

Conservation Area, Idaho, USA. Table S3: Nesting success of Prairie Falcons (number of successful territories/number of territories under observation; percentage in parentheses) within 5-km stretches of the Snake River Canyon in the NCA selected for monitoring in 2002, 2003, 2019, 2020, and 2021. Table S4: Estimation of the number of nesting pairs of Prairie Falcons in the Morley Nelson Snake River Birds of Prey National Conservation Area for years in which a full-canyon count was not conducted. Table S5: Estimation of the number of nesting pairs of Prairie Falcons in the Morley Nelson Snake River Birds of Prey National Conservation Area for years in which a full-canyon count was conducted. Table S6a: AIC_c information used to identify (a) the best response distribution for evaluating trends in the number of pairs of Prairie Falcons nesting in the Morley Nelson Snake River Birds of Prey National Conservation Area, Idaho, USA in 1976–2021; (b) if fit of the best model from (a) was improved by addition of a second- or third-order polynomial for the year term; and (c) the best response distribution for evaluating potential changes in time in nesting success of these same Prairie Falcons. Table S7: Sample sizes and nesting success reported in Steenhof et al. 1999 and calculated from the USGS Snake River Field Station database. Table S7b: Number of Prairie Falcon nesting pairs in the Morley Nelson Snake River Birds of Prey NCA in southwestern Idaho, USA (1976–1994), based on full-canyon surveys. Table S8: Number of Prairie Falcon pairs counted in 5-km river stretches within the Morley Nelson Snake River Birds of Prey National Conservation Area, Idaho, USA, in study years 2002, 2003, 2019–2021 in comparison to previous peak abundance years (1976 and 1992) from USGS unpublished data.

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LITERATURE CITED

Bird, D. M., and J. A. Smallwood (2023). Evidence of continuing downward trends in American Kestrel population and recommendations for research into causal factors. Journal of Raptor Research 57:131–145. doi:10.3356/JRR-22-35.

Burnham, K., and D. Anderson (2002). Model Selection and Multimodel Inference. Second ed. Springer-Verlag, New York, NY, USA.

DeLong, J. P., and K. Steenhof (2020). The effects of management practices on grassland birds—Prairie Falcon (*Falco mexicanus*). In The Effects of Management Practices on Grassland Birds (D. H. Johnson, L. D. Igl, J. A. Shaffer, and J. P. DeLong, Editors). US Geological Survey Professional Paper 1842. doi:10.3133/pp1842.

Doyle, J. M., D. A. Bell, P. H. Bloom, G. Emmons, A. Fesnock, T. E. Katzner, L. LaPré, K. Leonard, P. SanMiguel, R. Westerman, and J. A. DeWoody (2018). New insights into the phylogenetics and population structure of the Prairie Falcon (*Falco mexicanus*). BMC Genomics 19:233. doi:10.1186/s12864-018-4615-z.

Dudek, B. M., M. T. Henderson, S. F. Hudon, E. J. Hayden, and J. A. Heath (2021). Haematophagous ectoparasites lower survival of and have detrimental physiological effects on Golden Eagle nestlings. Conservation Physiology 9:coab060. doi:10.1093/conphys/coab060.

Dudek, B. M., M. N. Kochert, J. R. Barnes, P. H. Bloom, J. M. Papp, R. W. Gerhold, K. E. Purple, K. V. Jacobson, C. R. Preston, C. R. Vennum, J. W. Watson, et al. (2018). Prevalence and risk factors of *Trichomonas gallinae* and trichomonosis in Golden Eagle (*Aquila chrysaetos*) nestlings in western North America. Journal of Wildlife Diseases 54:755–764.

Dumandan, P. K. T., K. L. Bildstein, L. J. Goodrich, A. Zaiats, T. T. Caughlin, and T. E. Katzner (2021). Shared functional traits explain synchronous changes in long-term count trends of migratory raptors. Global Ecology and Biogeography 30:640–650.

Farmer, C. J., and J. P. Smith (2009). Migration monitoring indicates widespread declines of American Kestrels (*Falco sparverius*) in North America. Journal of Raptor Research 43:163–273. doi:10.3356/JRR-08-14.1.

Franke, A., C. L. McIntyre, and K. Steenhof (2017). Terminology. In Applied Raptor Ecology: Essentials from

Gyrfalcon Research (D. L. Anderson, C. J. W. McClure, and A. Franke, Editors). The Peregrine Fund, Boise, ID, USA. pp. 33–42.

Freddie-Jeanne, R., I. Southern, M. Gigauri, G. Bellini, O. Rojas, and A. Runde (2021). Warning on nine pollutants and their effects on avian communities. Global Ecology and Conservation 32:e01898. doi:10.1016/j.gecco.2021.e01898.

Heath, J. A., M. N. Kochert, and K. Steenhof (2021). Golden Eagle dietary shifts following wildfire and shrub loss have negative consequences for nestling survivorship. Ornithological Applications 123:1-14. doi:10.1093/ornithapp/duab034.

Henny, C. J., R. A. Grove, J. L. Kaiser, and B. L. Johnson (2010). North American Osprey populations and contaminants: Historic and contemporary perspectives, Journal of Toxicology and Environmental Health, Part B 13:7–8, 579–603.

Iknayan, K. J., and S. R. Beissinger (2018). Collapse of a desert bird community over the past century driven by climate change. Proceedings of the National Academy of Sciences, 115:8597–8602.

Kochert, M. N., and K. Steenhof (2003). Long-term Nesting Population and Productivity Changes of Prairie Falcons and Golden Eagles in the Snake River NCA: 2002 Report. US Geological Survey Forest and Rangeland Ecosystem Science Center, Snake River Field Station, Boise, ID, USA.

Kochert, M. N., and K. Steenhof (2004). Abundance and productivity of Prairie Falcons and Golden Eagles in the Snake River Birds of Prey National Conservation Area, 2003 Report. US Geological Survey Forest and Rangeland Ecosystem Science Center, Snake River Field Station, Boise, ID, USA.

Kochert, M. N., K. Steenhof, and J. L. Brown (2019). Effects of nest exposure and spring temperatures on Golden Eagle brood survival: An opportunity for mitigation. Journal of Raptor Research 53:91–97. doi:10.3356/JRR-17-100.

Kochert, M. N., K. Steenhof, L. B. Carpenter, and J. M. Marzluff (1999). Effects of fire on Golden Eagle territory occupancy and reproductive success. Journal of Wildlife Management 63:773–780.

Kochert, M. N., K. Steenhof, C. Pozzanghera, and J. H. Heath (2018). Monitoring of Golden Eagle Nesting Territory Occupancy and Reproduction in the Morley Nelson Snake River Birds of Prey National Conservation Area, Owyhee Survey Area, and Comparison Survey Areas, Idaho, 2011–16. US Geological Survey, Reston, VA, USA.

Kochert, M. N., M. A. Yates, M. R. Fuller, J. Sullivan, M. O'Donnell, and K. Kitchell (2009). Conservation of Raptor Populations and Habitats in the Snake River Birds of Prey National Conservation Area. Report of the Raptor Monitoring Workshop, 27 June 2008. US Geological Survey Forest and Rangeland Ecosystem Science Center, Snake River Field Station, Boise, ID, USA.

Knick, S. T., and J. R. Rotenberry (2000). Ghosts of habitats past: Contribution of landscape change to current habitats used by shrubland birds. Ecology 81:220–227.

Lehman, R. N., M. N. Kochert, and K. Steenhof (1990). Raptor nesting densities and reproductive success in the Snake River Birds of Prey Area, 1990. In Snake River Birds of Prey Research Project Annual Report, 1990 (K. Steenhof, Editor). US Department of Interior, Bureau of Land Management, Boise, ID, USA. pp. 22–23.

Lohr, S. L. (2010). Sampling: Design and Analysis. Second Ed. Brooks/Cole, Cenage Learning, Boston, MA, USA.

Marzluff, J. M., B. A Kimsey, L. S. Schueck, M. E. McFadzen, M. S. Vekasy, and J. C. Bednarz (1997). The influence of habitat, prey abundance, sex, and breeding success on the ranging behavior of prairie falcons. The Condor 99:567–584.

McClure, C. J. W., J. L. Brown, S. E. Schulwitz, J. Smallwood, K. E. Farley, J. Therrien, K. E. Miller, K. Steenhof, and J. A. Heath (2021). Demography of a widespread raptor across disparate regions. Ibis 163:658–670.

McClure, C. J. W., B. W. Rolek, and J. Fleischer (2023). Composite population trends reveal status of wintering diurnal raptors in the northwestern USA. Biological Conservation 277:109861. doi:10.1016/j.biocon.2022.109861.

McClure, C. J. W., S. E. Schulwitz, R. Van Buskirk, B. P. Pauli, and J. A. Heath (2017). Commentary: Research recommendations for understanding the decline of American Kestrels (*Falco sparverius*) across much of North America. Journal of Raptor Research 51:455–464. doi:10.3356/JRR-16-73.1.

McFadzen, M. E., and J. M. Marzluff (1996). Mortality of Prairie Falcons during the fledging-dependence period. The Condor 98:791–800.

Mineau, P., M. R. Fletcher, L. C. Glaser, N. J. Thomas, C. Brassard, L. K. Wilson, J. E. Elliott, L. A. Lyon, C. J. Henny, T. Bollinger, and S. L. Porter (1999). Poisoning of raptors with organophosphorus and carbamate pesticides with emphasis on Canada, U.S. and U.K. Journal of Raptor Research 33:1–37.

Moritsch, M. Q. (1983). Photographic Guide for Aging Nestling Prairie Falcons. US Department of the Interior, Bureau of Land Management, Boise, ID, USA.

Newton, I. (2017). Invited commentary: Fifty years of raptor research. Journal of Raptor Research 51:95–106. doi:10.3356/0892-1016-51.2.95.

Pandolfino, E. R., M. P. Herzog, S. L. Hooper, and Z. Smith (2011). Winter habitat associations of diurnal raptors in California's Central Valley. Western Birds 42:62–84.

Pilliod, D. S., J. L. Welty, and R. S. Arkle (2017). Refining the cheatgrass–fire cycle in the Great Basin: Precipitation timing and fine fuel composition predict wildfire trends. Ecology and Evolution 7:8126–8151.

Rosenberg, K. V., A. M. Dokter, P. J. Blancher, J. R. Sauer, A. C. Smith, P. A. Smith, J. C. Stanton, A. Panjabi, L. Helft, M. Parr, and P. P. Marra (2019). Decline of the North American avifauna. Science 366:120–124.

Sergio, F., I. Newton, and L. Marchesi (2005). Top predators and biodiversity. Nature 436:192–192.

Smallwood, J. A., M. F. Causey, D. H. Mossop, J. R. Klucsarits, B. Robertson, S. Robertson, J. Mason, M. J. Maurer, R. J. Melvin, R. D. Dawson, G. R. Bortolotti, et al. (2009). Why are American Kestrel (*Falco sparverius*) populations declining in North America? Evidence from nest-box programs. Journal of Raptor Research 43:274–282. doi:10.3356/JRR-08-83.1.

Steenhof, K. (1987). Assessing raptor reproductive success and productivity. In Raptor Management Techniques Manual (B. A. Giron Pendleton, B. A. Millsap, K. W. Cline, and D. M. Bird, Editors). National Wildlife Federation, Washington, DC, USA. pp. 157–170.

Steenhof, K. (2020). Prairie Falcon (*Falco mexicanus*), version 1.0. In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. doi:10.2173/bow.prafal.01.

Steenhof, K., J. L. Brown, and M. N. Kochert (2014). Temporal and spatial changes in Golden Eagle reproduction in relation to increased off highway vehicle activity. Wildlife Society Bulletin 38:682–686.

Steenhof, K., and M. N. Kochert (1988). Dietary responses of three raptor species to changing prey densities in a natural environment. Journal of Animal Ecology 57:37–48.

Steenhof, K., M. N. Kochert, L. B. Carpenter, and R. N. Lehman (1999). Long-term Prairie Falcon population changes in relation to prey abundance, weather, land uses and habitat conditions. The Condor 101:28–42.

Steenhof, K., M. N. Kochert, C. L. McIntyre, and J. L. Brown (2017). Coming to terms about describing Golden Eagle reproduction. Journal of Raptor Research 51:378–390. doi:10.3356/JRR-16-46.1.

US Department of the Interior (1979). Snake River Birds of Prey Special Research Report to the Secretary of the Interior. US Department of Interior, Bureau of Land Management, Boise District, Boise, ID, USA.

US Department of the Interior (1996). Effects of military training and fire in the Snake River Birds of Prey National Conservation Area. BLM/IDARNG Research Project Final Report. US Geological Survey, Snake River Field Station, Boise, ID, USA.

US Department of the Interior (2008). Snake River Birds of Prey National Conservation Area Resource Management Plan. Chapter 2. Affected environment. Bureau of Land Management, Boise District, Boise, ID, USA. https://eplanning.blm.gov/public_projects/lup/35553/41906/44406/Snake_River_Birds_of_Prey_RMP_RoD_2008_508.pdf.

White, C. M., N. J. Clum, T. J. Cade, and W. G. Hunt (2020). Peregrine Falcon (*Falco peregrinus*), version 1.0. In Birds of the World (S. M. Billerman, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. doi:10.2173/bow.perfal.01.

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