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Population and Productivity of the Critically Endangered White-rumped Vulture (*Gyps bengalensis*) in the Argha Important Bird and Biodiversity Area, Nepal

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ABSTRACT.—The White-rumped Vulture (*Gyps bengalensis*) is an accipitrid vulture native to Asia. Once known as the world's most abundant large bird of prey, its population declined dramatically across its range during the 1990s. As a result, it is listed on the International Union for the Conservation of Nature (IUCN) Red List as critically endangered. From 2010 to 2021, we monitored two breeding colonies of White-rumped Vultures in the Argha Important Bird and Biodiversity Area, Arghakhanchi District, in the western mid-hill region of Nepal. We visited the colonies at least three times in each breeding season during November, February, and April and calculated nesting success. We estimated annual trends in number of occupied nests (i.e., nesting activity, egg, nestling, or adult in incubation posture), number of fledglings, and productivity (i.e., young fledged per occupied nest). The number of occupied nests, fledglings, and productivity were analyzed separately using identical models. Although the number of occupied nests appeared to increase, the credible interval of the growth rate (r) overlapped zero (r = 0.05, 95% CRI = –0.06–0.16). The number of fledglings (r = 0.04, 95% CRI = –0.04–0.16) and productivity (r < 0.01, 95% CRI = –0.08–0.09) appeared stable. Our findings are encouraging because they suggest stable population and productivity levels in the two breeding colonies of this critically endangered bird. However, our survey covered a small portion of the global population over a single generation of the species. We recommend coordinated, widespread, and long-term monitoring of vultures across South Asia.

KEY WORDS: *diclofenac*; *occupied nests*; *population*; *productivity*; *vulture*.

POBLACIÓN Y PRODUCTIVIDAD DE LA ESPECIE EN PELIGRO CRÍTICO *GYPS BENGALENSIS* EN EL ÁREA IMPORTANTE PARA LAS AVES Y LA BIODIVERSIDAD DE ARGHA, NEPAL

RESUMEN.—*Gyps bengalensis* es un buitre accipítrido originario de Asia. Considerada en su tiempo como el ave rapaz grande más abundante del mundo, su población disminuyó drásticamente en toda su área de distribución durante la década de 1990. Como resultado, se encuentra catalogada como en peligro crítico en la Lista Roja de la Unión Internacional para la Conservación de la Naturaleza (UICN). De 2010 a 2021, seguimos dos colonias de cría de *G. bengalensis* en el Área Importante para las Aves y la Biodiversidad de Argha, distrito de Arghakhanchi, en la región occidental de colinas medias de Nepal. Visitamos las colonias al menos tres veces en cada temporada reproductiva durante noviembre, febrero y abril y calculamos el éxito de nidificación. Estimamos las tendencias anuales en el número de nidos ocupados (i.e., actividad de cría, huevo, polluelo o adulto en postura de incubación), el número de volantones y la productividad (i.e.,

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polluelos emplumados por nido ocupado). El número de nidos ocupados, el número de volantones y la productividad se analizaron por separado usando modelos idénticos. Aunque el número de nidos ocupados pareció aumentar, el intervalo de credibilidad de la tasa de crecimiento (r) incluyó al cero (r = 0.05, 95% ICR = −0.06 – 0.16). El número de volantones (r = 0.04, 95% ICR = −0.04 – 0.16) y la productividad (r < 0.01, 95% ICR = −0.08 – 0.09) parecieron estables. Nuestros hallazgos son alentadores porque sugieren niveles estables de población y de productividad en las dos colonias de cría de este ave en peligro crítico. Sin embargo, nuestro muestreo cubrió una pequeña porción de la población mundial durante una sola generación de la especie. Recomendamos un seguimiento coordinado, generalizado y a largo plazo de los buitres en el sur de Asia.

[Traducción del equipo editorial]

INTRODUCTION

Vultures are obligate scavengers that play an important ecological role in natural and anthropogenic systems by disposing of animal carcasses (Houston 1979, Buechley and Şekercioğlu 2016). Carcass removal is especially important in South Asian countries, like Nepal, where many cattle are kept for milk but not for meat, resulting in a large number of carcasses that require disposal (Prakash et al. 2003, Markandya et al. 2008). Vultures are also culturally important for the sky burial practices in the trans-Himalayan region of Nepal (Acharya et al. 2009, Bhusal et al. 2020).

Vultures of the family Accipitridae native to Asia, Europe, and Africa are among the most threatened bird species in the world (Buechley and Şekercioğlu 2016, McClure et al. 2018, McClure and Rolek 2020). These imperiled birds face crises in Africa and Asia (Pain et al. 2008, Ogada et al. 2016) due to rapid population declines, and 75% of these species are listed as either endangered or critically endangered by the International Union for the Conservation of Nature (IUCN; McClure et al. 2018).

The White-rumped Vulture (*Gyps bengalensis*) was formerly described as the most abundant large bird of prey in the world, with a global population of tens of millions (Houston 1985). However, this species declined between 1992 and 2007 in India, with rates about 50% per year (Prakash et al. 2007) resulting in a total loss of >99%. Road transect surveys in Nepal during 2002–2011 revealed population declines of 14% per year (Chaudhary et al. 2012) with an overall population decline of 91%. Declines of similar magnitude, rate, and timing also occurred in the formerly large White-rumped Vulture populations in Pakistan (Gilbert et al. 2002) and Bangladesh (Khan 2013).

In Nepal, the White-rumped Vulture is now a patchily distributed resident, rare in the central part of the country, rare and very local in the east, and locally frequent in the western part of Nepal (Inskipp et al. 2016). White-rumped Vultures are monogamous and pairs generally use the same nest yearly. Nests are built in tall trees and the birds generally form a loose colony. Breeding is usually during winter from October to April. A single white egg is laid, usually in December, and the incubation period is approximately 45–52 d. Both sexes participate in incubation and care of the nestling. Fledglings stay with the adults for approximately 3 mo until independence.

Galligan et al. (2020a) examined the long term population trend of White-rumped Vultures along road transects in Nepal. Bird Conservation Nepal (BCN) has also monitored the nesting colonies of White-rumped Vultures in Nepal and recorded approximately 400 nests (BCN, unpubl. data). However, these data were not collected in a consistent manner that would allow for robust statistical analysis of trends. There is also a data gap in some details of nest site characteristics of White-rumped Vultures in Nepal (e.g., tree height, nest height, aspect, and elevation preferences).

We monitored two breeding colonies of White-rumped Vultures within the Argha Important Bird and Biodiversity Area (IBA), Arghakhanchi District of the western mid-hill region of Nepal from 2010 to 2021. To understand nest site characteristics of White-rumped Vultures, we recorded aspect, tree species, tree height, and nest height. We also report trends in the number of occupied nests, number of fledglings, and overall productivity in the breeding colonies to understand population trends of White-rumped Vultures at the Argha IBA.

METHODS

Study Area. The Argha IBA (approximate center at 28°01′12″N, 83°07′12″E) lies in the northern part of the Arghakhanchi District, western mid hill of Nepal (Fig. 1), covering an area of 155.92 km^2. The Argha IBA was designated because of the nesting

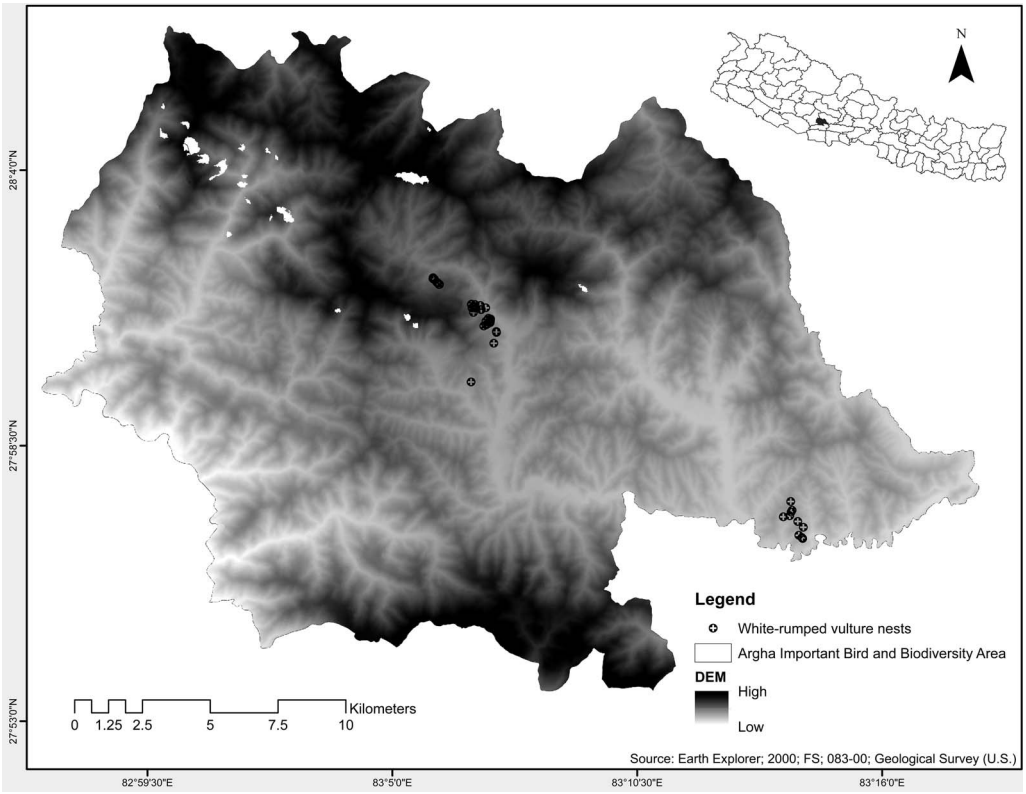

Figure 1. White-rumped Vulture nesting locations and the Argha Important Bird and Biodiversity Area in Nepal. DEM = Digital Elevation Model.

area for critically endangered White-rumped Vultures (Bhusal et al. 2020). The area also contains nesting areas of other globally threatened birds such as Red-headed Vultures (*Sarcogyps calvus*), Egyptian Vultures (*Neophron percnopterus)*, and Cheer Pheasants (*Catreus wallichii*). The Argha IBA is an important foraging site of the critically endangered Slender-billed Vulture (*Gyps tenuirostris*) and wintering grounds of the endangered Steppe Eagle (*Aquila nipalensis*). Including the vulnerable Grey-crowned Prinias (*Prinia cinereocapilla*), there are 239 total species of birds recorded in the IBA (Bhusal et al. 2020). The forest area is dominated by chir pine (*Pinus roxburghii*), which is used by White-rumped Vultures for nesting.

Field Surveys. We monitored the breeding status of White-rumped Vultures in the Argha IBA, Arghakhanchi District, Nepal, from 2010 to 2021. We visited the two 2.5–3-km^2 colonies during the months November, February, and April, for a total of three visits per breeding season. We observed the nests during periods when the vultures were most active: mornings from 0800–1100 H and afternoons from 1500–1700 H, local time. We recorded the nesting tree species, tree height, and nest height from the ground along with coordinates of the each nesting tree. If there was nest reuse over the course of multiple years, we only took a single measurement for analysis. During the first visit we determined whether there was nest building and during the second visit we recorded whether there was an egg or nestling in the nests. We recorded incubation behavior and we considered that this incubation posture indicated that an egg had been laid. In the third visit, we monitored fledgling status. Nests were classified as occupied if there were signs of reproduction (copulation, courtship behaviors, refurbished nest, or two adults; Steenhof et al. 2017). We considered nests successful if the nestling fledged. We defined productivity as the number of young fledged per occupied nest (Franke et al. 2017).

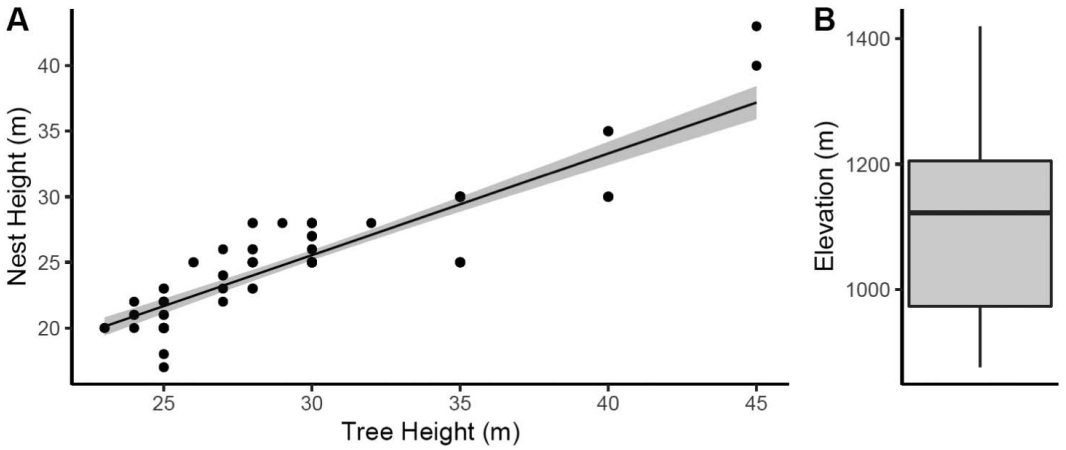

Figure 2. (A) Correlation between nest height and tree height of White-rumped Vulture nests in Arghakhanchi, Nepal. Points indicated the observed values, the solid bold line depicts the predicted average, and the shading depicts the 95% CI. (B) Boxplot of the elevation (in masl) of White-rumped Vulture nests in Arghakhanchi, Nepal.

Statistical Analysis. We performed linear regression to estimate the relationship between nest height and tree height. We used a digital elevation map (DEM) in ArcGIS 10.3, to estimate the elevation and aspect of the nests. We followed oft-used methodology (e.g., Benson and McClure 2020, Bhusal et al. 2021, McClure et al. 2022) to estimate trends in yearly values of the number of occupied nests, number of fledglings, and productivity. We used state-space models under a Bayesian framework, which analyzed counts using the formula: $\log(N_{t+1}) = \log(N_t) + r_t$, where N_t was abundance in a given year, N_{t+1} was abundance in the next year, and r_t was the growth rate from t to $t + 1$. The number of occupied nests, the number of fledglings, and productivity were analyzed separately using identical models following the code provided by Kéry and Schaub (2012:127).

We used JAGS (Plummer 2003) and the R (R Core Team 2021) package *jagsUI* (Kellner 2016) to run three chains at 50,000 iterations with a burn-in of 10,000 and thinning rate of one. We calculated the Gelman–Rubin statistic (Gelman and Rubin 1992) and considered chains to have converged when parameters had a value of $\hat{R}$ of <1.1. We used vague priors for all parameters (Kéry and Schaub 2012). We considered there to be trends in the number of occupied nests, number of fledglings, or productivity if the 95% credible interval (CRI) of their r parameters excluded zero (Benson and McClure 2020, Bhusal et al. 2021, McClure et al. 2022).

RESULTS

Almost all White-rumped Vulture nests were made in chir pine trees, which are the dominant tree in the mid-hill area. The nests were mostly built at the trunk of the tree, with only a few observed in the branches away from the main trunk. We recorded the nests at elevations from 887 masl to 1420 masl with the majority of them located between 984 masl and 1267 masl (Fig. 2). White-rumped Vultures nested primarily on slopes facing the east (13 nests), southeast (13 nests), and southwest (13 nests), with some nests also observed on slopes facing the northeast (nine nests) and northwest (five nests). The shortest nest tree was 23 m tall and the lowest height of a nest was 17 m, and the tallest nest tree was 45 m and the highest nest 43 m above the ground ($n = 100$). Mean heights of nest trees and nests were 30.0 m and 25.6 m, respectively, and were correlated ($\beta = 0.78$, SE = 0.04, $P < 0.01$, $R^2 = 0.785$, Fig. 2).

The greatest number of occupied White-rumped Vulture nests was 24 (in 2021), while the smallest number was 13 (in 2010). The lowest productivity was 0.50 young fledged per occupied nest (in 2019), with 11 successful nests out of 22 occupied, and the greatest productivity was 0.67 young fledged per occupied nest (in 2012), with 10 successful nests of 15 occupied nests (Table 1).

Although the number of occupied nests appeared to increase (Fig. 3), the credible interval of r overlapped zero (r = 0.05, 95% CRI = –0.06–0.16). The number of fledglings (r = 0.04, 95% CRI =

Table 1. Monitoring results from White-rumped Vulture nest surveys in the Argha Important Bird and Biodiversity Area in Nepal.

Year	Number of Occupied Nests	Number of Fledglings	Productivity (Young per Occupied Nest)
2010	13	7	0.54
2011	21	12	0.57
2012	15	10	0.67
2013	17	11	0.65
2014	18	10	0.56
2015	14	9	0.64
2016	16	12	0.75
2017	20	13	0.65
2018	19	10	0.53
2019	22	11	0.50
2020	23	13	0.57
2021	24	14	0.58

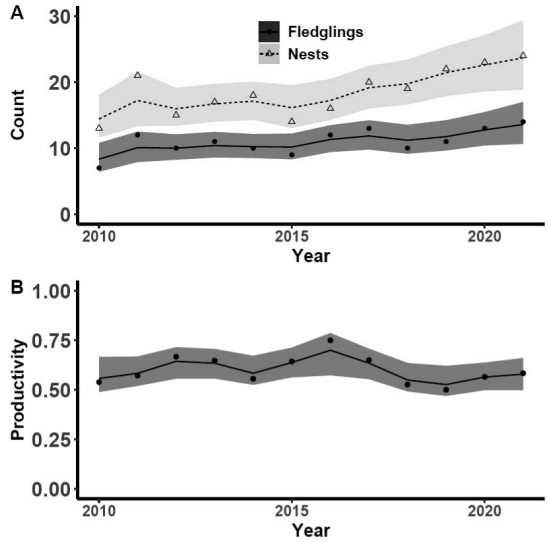

Figure 3. (A) Observed (points) and estimated (solid and dotted lines; shaded areas = 95% credible interval [CRI]) counts of occupied nests and fledglings in a breeding colony of White-rumped Vultures from 2010 through 2021. (B) Observed (points) and estimated (line; shaded area = 95% CRI) number of fledglings per occupied nest (productivity) in a breeding colony of White-rumped Vultures from 2010 through 2021.

–0.04–0.16) and productivity ($r < 0.01$, 95% CRI = –0.08–0.09) appeared stable (Fig. 3).

DISCUSSION

We monitored a White-rumped Vulture colony for over a decade in the Arghakanchi District of Nepal and documented a relatively stable population and reproductive rate. In contrast, many previous studies in Nepal suggested rapid population declines. For example, the population across Nepal declined by 91% between 2002 and 2011 along road transects (Chaudhary et al. 2012). Similarly, the number of occupied nests declined by 78.5% from 2000 to 2003 in the Koshi area of eastern Nepal (Baral et al. 2004). The number of occupied nests of White-rumped Vultures declined by 37.1% in Rampur, Palpa, and 56% in Synja and Tanahu from 2002 to 2014 (Gautam and Baral 2014). However, road counts indicated that the rapid decline from 2002 until about 2013 gave way to a partial recovery between about 2013 and 2018 (Galligan et al. 2020).

Several conservation programs have been implemented by various organizations and communities with the aim of conserving the remaining vulture population in our study region. Arghakhanchi was declared a diclofenac-free district in 2011 due to the removal of diclofenac use as a livestock treatment and the Argha IBA was designated in 2015 to preserve vulture habitat. However, the populations of White-rumped Vultures at our focal colonies have not increased as we expected. Because our focal colonies are outside of protected areas, there are several anthropogenic pressures in the nesting area including logging and road construction, which may disturb the vultures. These colonies are two of the few remaining known breeding sites of White-rumped Vultures in Nepal.

Our study examined only two colonies and for only a single generation of White-rumped Vultures (11.3 yr; BirdLife International 2022). Coordinated, long-term, and range-wide monitoring is needed for this and other vulture species across South Asia (McClure et al. 2022). Initiatives such as the Global Raptor Impact Network (McClure et al. 2021) should aid researchers in standardizing surveys, pooling data, and conducting analyses. We hope that other researchers will join us in monitoring White-rumped Vultures and other vulture species across South Asia.

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