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Population trends in Himalayan Griffon in Upper Mustang, Nepal, before and after the ban on diclofenac

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Summary

The Upper Mustang region of Nepal holds important breeding populations of Himalayan Griffon *Gyps himalayensis.* Despite this species being considered 'Least Concern' on the IUCN Red List, the population in Upper Mustang had declined substantially in the early to mid-2000s. During that period, the non-steroidal anti-inflammatory drug diclofenac was commonly used to treat illness and injury in domesticated ungulates throughout Nepal. The timing and magnitude of declines in Himalayan Griffon in Upper Mustang resemble the declines in resident populations of the 'Critically Endangered' White-rumped Vulture *Gyps bengalensis* and Slender-billed Vulture *Gyps tenuirostris* in Nepal, both of which are also known to be highly sensitive to diclofenac. Since 2006, the veterinary use of diclofenac has been banned in Nepal to prevent further vulture declines. In this paper, we analyse the population trend in Himalayan Griffon in Upper Mustang between 2002 and 2014 and show a partial recovery. We conclude that the decline is now occurring at a slower rate than previously observed and immigration from areas where diclofenac was either not or rarely used the probable explanation for the recovery observed.

Introduction

Vultures play an important role in natural and anthropogenic systems by disposing of carcasses (Houston 1979, 1983, De Vault *et al.* 2003, Moleón *et al.* 2014). This is especially important in South Asian countries, like Nepal, where large numbers of cattle (*Bos indicus, B. taurus* and hybrids) are kept for milk and as draught animals, but not for meat, resulting in a large number of carcasses that require disposal (Prakash *et al.* 2003, Markandya *et al.* 2008).

Nationwide road transect surveys in the lowlands of Nepal between 1995 and 2011 showed 91% and 96% declines in populations of White-rumped Vulture *Gyps bengalensis* and Slender-billed Vultures *Gyps tenuirostris*, respectively (Chaudhary *et al.* 2012). Declines of similar magnitude and timing in up to five species of vulture have been observed in India (Prakash *et al.* 2007), Pakistan (Gilbert *et al.* 2006) and Bangladesh (Khan 2013). Due to the declines, four species have been up-listed to 'Critically Endangered' (IUCN 2014).

All species of vulture tested so far are highly sensitive to the non-steroidal anti-inflammatory drug (NSAID) diclofenac (Oaks *et al.* 2004, Swan *et al.* 2006), which was commonly used to treat a variety of ailments in domestic ungulates in South Asia during the 1990s and early 2000s. Vultures are exposed to diclofenac residue if they feed upon tissues of domestic ungulates treated with the drug within a day or two before death (Green *et al.* 2006). Green *et al.* (2007) showed the prevalence and concentration of diclofenac measured in liver samples from carcasses of domestic ungulates available to vultures in India were sufficient to have caused the declines in White-rumped Vultures observed there.

In 2006, the Governments of India, Nepal and Pakistan banned the manufacture, sale and use of diclofenac for veterinary purposes. Bangladesh banned diclofenac in 2010. Since then, monitoring of domestic ungulate carcasses in India has shown a reduction in the prevalence and concentration of diclofenac (Taggart *et al.* 2007, 2009, Cuthbert *et al.* 2011, 2014); and the most recent analysis of surveys in India, Pakistan and Nepal show that the previous rapid declines in vulture populations are now slowing and possibly recovering (Chaudhary *et al.* 2012, Prakash *et al.* 2012).

The Himalayan Griffon is a resident species in the Himalayas of Nepal (Grimmett *et al.* 2000). In addition, large numbers of immature Himalayan Griffons seasonally migrate between Central and South Asia, mixing with the resident population in the Himalayas (RSPB unpubl. data). This species is listed as 'Near Threatened' in the IUCN Red List (IUCN 2014). However, in the Upper Mustang region of Nepal, the population of Himalayan Griffon declined by 70% between 2002 and 2005 (Acharya *et al.* 2009). Further, this species has been shown to be intolerant to diclofenac; more specifically, a wild individual treated with diclofenac for a broken leg died of acute visceral gout (Das *et al.* 2010). Surveys of pharmacies in the Upper Mustang, coinciding with surveys of vultures, revealed that diclofenac was readily available to veterinarians and livestock owners, even in this remote part of Nepal (Acharya *et al.* 2009).

In this study, we undertook four annual surveys of Himalayan Griffon in Upper Mustang. Combining these new data with those published by Acharya *et al.* (2009), we measure the population trend over a longer period spanning the 2006 ban on veterinary diclofenac.

Methods

Field methods

Upper Mustang represents the northern half of Mustang District. In this area, Acharya *et al.* (2009) counted Himalayan Griffon along four walked transects totalling 188 km in 2002, 2004 and 2005. These transects followed the main trails used by local people to travel between settlements. We walked nine transects totalling 91.2 km within the same network of trails, but our transects differed from those of Acharya *et al.* (2009) by being similar to one another in length and the number of days required to walk each one (Table S1 in the online supplementary material). For this reason, there exists a discrepancy in the number of vultures counted in Acharya *et al.* (2009) and our study.

Six of the nine transects were surveyed in 2002 and all nine were surveyed in 2004, 2005, 2008, 2010, 2012 and 2014. All vultures seen within 500 m of each side of transect routes were counted, but the distance to each sighting was not estimated for practical reasons. Surveys were conducted between 08h00 and 17h30, over a 17–24 day period between 13 July and 18 September. This period was at the end of the breeding season. Variation in the number of days and the dates surveyed was the result of not starting or continuing surveys on days affected by adverse weather conditions, but the total survey effort (days) and distance walked were comparable across all surveys.

Statistical analysis

The data used in this study include many zero counts as well as a few large value counts (Table S1). Our analysis closely followed that of Galligan *et al.* (2014), including running multiple models with different link functions and error distributions and using an information-theoretical approach for selecting the best model to describe the population trend (Table S2). For brevity, we focus on the methods associated with only the best model here.

We fitted a GLM with a log link and a negative binomial error distribution (NB) to account for overdispersion (Crawley 2007). Year was treated as a fixed factor; as was Transect, to allow for transects that were not surveyed every year. The model was $c_{ij} = \exp(g_i + h_j)$, where c_{ij} is the

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expected value of the count at the ith transect in the jth year, g_i is the transect effect for the ith transect, and h_j is the year effect for the jth year. Population indices in the jth year, scaled relative to the first year of the series, were calculated as $index_j = \exp(h_j)/\exp(h_1)$. We calculated 95% confidence intervals by 999 bootstrap iterations of all data (Fewster *et al.* 2000).

To determine population trends between two consecutive years, we estimated the average rate of annual population change, as a percentage, in the period between two consecutive surveys in year i and j, as $100 \cdot ((index_j / index_i)^{(1/(j - i))} - 1)$ and obtained 95% confidence limits of these rates from the bootstrap samples. To determine possible changes between two consecutive trends, we calculated the difference in two consecutive estimates of the average rate of annual population change and its 95% confidence limits, using the same bootstrap samples, to test whether the annual rate of population change had itself changed over time. All models were implemented using R (R Development Core Team 2013) and the package 'MASS' (Ripley *et al.* 2013) for NB GLMs.

Results

The Himalayan Griffon population in Upper Mustang underwent a rapid and substantial decline of 72% between 2002 and 2005 (Figure 1). However, by 2008 the population had recovered by 51% and then remained approximately stable for the next two surveys. In 2014, the population index was 25% smaller than it was in 2002.

The annual rate of population change was negative and statistically significant between 2004 and 2005 (Figure 2). Population change was positive in the periods 2005–2008 and 2008–2010; however, these changes were not statistically significant (i.e. 95% confidence intervals for estimates overlapped zero). The population showed a non-significant negative change in the last three periods (Figure 2). Ninety-seven percent of bootstrapped samples showed a positive increase between 2005 and 2008.

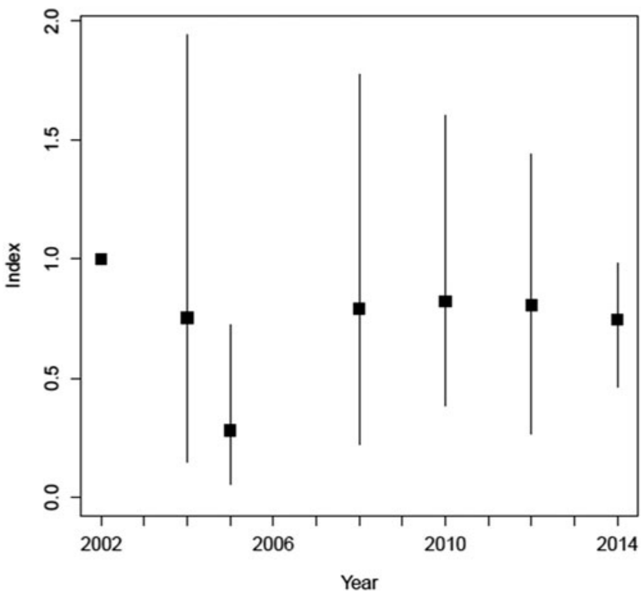

Figure 1. Population index values for Himalayan Griffon surveyed in the Upper Mustang region of Nepal between 2002 and 2014. Indices are population density in a given year relative to that in the 2002, estimated by a negative binomial model (see Methods for more detail). Vertical lines show estimated 95% bootstrap confidence limits.

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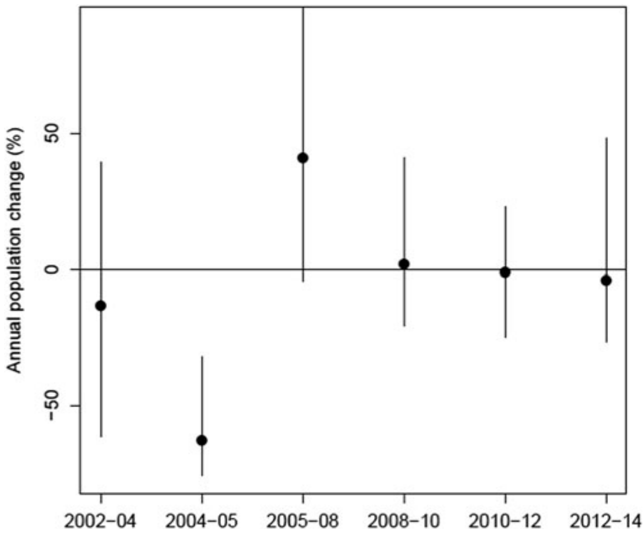

Figure 2. The average rate of annual population change (%) of Himalayan Griffon surveyed in the Upper Mustang region of Nepal between 2002 and 2014. Circles show average annual rates between each pair of consecutive surveys with 95% bootstrap confidence intervals (vertical lines).

The difference in the rates of annual population change between 2004–2005 and 2005–2008 was positive and statistically significant (Figure 3). In the three subsequent periods, the differences in population change were negative, but statistically non-significant (Figure 3).

Discussion

The Himalayan Griffon population in Upper Mustang underwent sudden and substantial decline in the early to mid-2000s. However, between 2005 and 2008, the population made an almost complete recovery relative to the population in 2002 and has remained at a similar size up to 2014.

This evidence begins to build a case that the cause of the rapid decline in Himalayan Griffon was the veterinary use of diclofenac. We know that diclofenac was available in Upper Mustang before the ban (Acharya *et al.* 2009, 2010) and that Himalayan Griffons are highly sensitive to diclofenac (Das *et al.* 2010). In 2006, when the Government of Nepal banned veterinary diclofenac, cessation of its sale and use largely occurred immediately throughout the country. While we did not repeat surveys of drug availability in pharmacies in Upper Mustang after 2008, we have no reason to think that the almost nationwide cessation of diclofenac sales recorded elsewhere in Nepal (BCN unpubl. data) did not occur there as well. Therefore, we suggest that the observed recovery in the Himalayan Griffon population in the Upper Mustang may well have been a response to this conservation action.

The Upper Mustang region of Nepal is small in comparison to the Asian range of Himalayan Griffon and we have no information on trends elsewhere. Hence, our results may not be typical of the whole of the species' range. In addition, our survey method meant data were collected from single short periods within each year. Without repeated surveys within years, we cannot control for unmeasured variables that affect distribution, such as food availability, weather conditions and even ranging behaviour. Vultures move vast distances in search of food and cluster at feeding sites; therefore, it is possible that our data reveal only natural fluctuations in population size. Despite these caveats, the population trend of Himalayan Griffon we present here mirrors that of

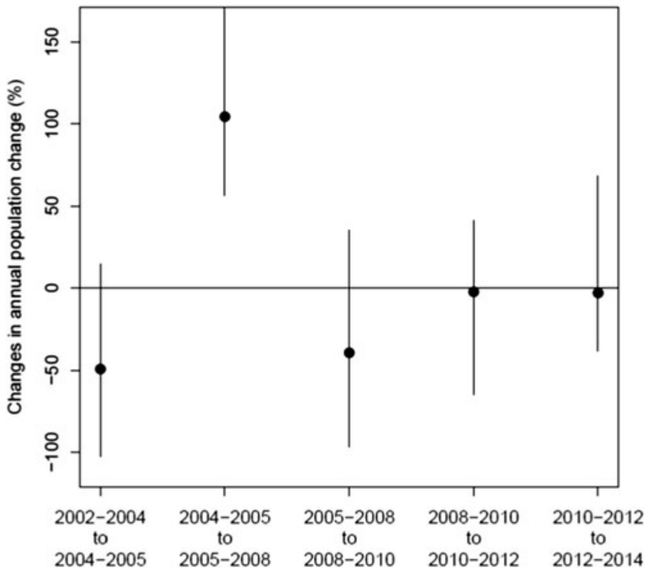

Figure 3. The average rate of change in annual population change (%) of Himalayan Griffon surveyed in the Upper Mustang region of Nepal between 2002 and 2014. Circles show differences in the average annual rates between each pair of consecutive periods, consisting of two consecutive surveys, with 95% bootstrap confidence intervals (vertical lines).

the six other populations of vultures presently being monitored in South Asia (Prakash *et al.* 2012, Galligan *et al.* 2014). Indeed, the Himalayan Griffon population in Upper Mustang appears to have recovered more than any other population.

The rapid rate of the recovery of Himalayan Griffon population makes it unlikely that local reproduction was an important demographic mechanism of the recovery. The maximum rate of increase in a closed population of long-lived, late-maturing birds, like vultures, is 5–10% per year (Niel and Lebreton 2005, Prakash et al. 2012). Therefore, immigration from areas where diclofenac was either not or rarely used is the most probable explanation for the recovery observed. The Himalayan Griffon is a gregarious species and immature individuals are seasonal migrants. Each boreal winter, immature individuals move from breeding grounds in Central Asia and the Tibetan Plateau to Nepal and northern India and Pakistan (RSPB unpubl. data). Such behaviour makes it likely that this species could easily recolonise suitable habitat in Upper Mustang and thereby account for the rapid recovery observed.

Supplementary material

The supplementary materials for this article can be found at journals.cambridge.org/bci

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