Importance of the Qinghai–Tibetan plateau for the Endangered Saker Falcon *Falco cherrug*

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Saker Falcons *Falco cherrug* are classified by IUCN as Endangered, with a large proportion of their global population existing in Mongolia and China. We conducted exploratory surveys for breeding Saker Falcons in June 2007 on the alpine grasslands of the Qinghai–Tibetan plateau. Our preliminary results indicate that Saker Falcons breed at relatively high density (0.52 ± 0.22 breeding pairs/100 km^2; 0.68 ± 0.21 territories/100 km^2), which suggests a total breeding population in this biogeographical region of several thousand pairs. Satellite telemetry has revealed that this large breeding population is augmented in winter by thousands of migrant Saker Falcons from Mongolia and adjacent regions of Russia. We have highlighted potential threats to the Saker Falcon population on the Qinghai–Tibetan plateau ranging from wide-scale environmental factors relating to socio-economic development, land use and climate change to more specific factors relating to small mammal eradication, electrocution and illegal trapping. Given the global importance of the large Saker Falcon populations occupying the high plateaus of Mongolia and China and their migratory connectivity, we argue that systematic surveys be conducted to better estimate the population dynamics of this species and that efforts be made to understand the impacts various anthropogenic activities in the region on both breeding and wintering populations of Saker Falcons.

INTRODUCTION

The Saker Falcon *Falco cherrug* (hereafter Saker) is the only member of its genus to be categorised as Endangered on the IUCN Red List, primarily because of large and rapid population declines in Central Asia, particularly in the states of the former USSR. Current estimates suggest that breeding pairs (bp) in Mongolia (2,000–5,000) and China (1,000–5,000) account for approximately 47–65% of the global Saker breeding population (BirdLife International 2015). However, published information on the species in these important range states is sparse, especially from China, where Sakers breed in desert and grassland landscapes in the west and north (MacKinnon & Phillipps 2000). In the western Gobi desert of Xinjiang, nesting density was found to be 0.12 bp/100 km^2 (Wu *et al*. 2008), comparable to 0.13 bp/100 km^2 in the eastern Gobi of Mongolia (Batbayar *et al*. 2010). However, as in neighbouring Mongolia, it is likely that grassland ecosystems support higher breeding densities. One such area which has the potential to support an expansive breeding population is the alpine grasslands of the Qinghai–Tibetan plateau, where Potapov & Ma (2004) reported a density of 0.28 bp/100km^2.

The Qinghai–Tibetan plateau is a unique biogeographic region extending over an area of 2.5 million km^2. This vast area encompasses the provinces of Qinghai and Tibet and includes the adjacent areas of Xinjiang, Gansu and Sichuan provinces (Zhang *et al*. 2002). High-altitude alpine grassland ranging from 2,300 to 5,300 m covers 59% of the plateau (Ding *et al*. 2013), and the distribution of the Plateau Pika *Ochotona curzoniae*, the principal prey for nearly all predators in the region (Smith & Foggin 1999), largely coincides with this habitat type (Lai & Smith 2003). There are nine Important Bird Areas (IBAs), covering about 45,000 km^2 on the Qinghai–Tibetan plateau, which list Sakers in their inventory of threatened species, although they are recorded as being present in only 7% of the IBAs in Qinghai and Tibet provinces (BirdLife International 2009).

The distribution of Saker records from the late nineteenth and early twentieth centuries collated by Vaurie (1972) indicate that the species bred and wintered primarily in the east and south of the plateau, although the apparent paucity of records from the Chang Tang, which covers a large part of west and north Tibet extending south-west to Ladakh, could also be a consequence of the remoteness of the region. Certainly, Kozlov (1899) recorded Sakers breeding in Chang Tang, whilst Schaller (1998) reported that Saker Falcons and Upland Buzzards *Buteo hemilasius* were the two commonest large raptors in the region. Elsewhere, King & Tai (1991) reported that Sakers were common where there was a large population of pikas in north-west Sichuan, and more recently Cui *et al*. (2008) reported that Sakers were common during the breeding season in north-east Qinghai.

Despite its remoteness a number of threats face the biodiversity of the Qinghai–Tibetan plateau. Global climate change is predicted to have major effects on the biomes of the region (Zhang *et al*.1996, Ni 2000, Zhao *et al*. 2011), which are already subject to change and degradation as a consequence of human land use (Fan *et al*. 1999, Wen *et al*. 2013) and infrastructure development (Ding *et al*. 2006). In addition to these wider ecological issues, local anthropogenic factors also threaten the stability of Saker populations. For example, management strategies to combat degradation of alpine grasslands include programmes to eradicate small burrowing mammals, an important food resource for Sakers (Lai & Smith 2003). A lack of suitable perches in the region makes electrical poles an attractive vantage point for Sakers, which are often electrocuted as a result (Dixon *et al*. 2013). Poaching for falconry is also known to occur in the region (Li *et al*. 2000) causing further stress to populations of Sakers.

In this paper we report the results of exploratory surveys and satellite telemetry studies that highlight the importance of the Qinghai–Tibetan plateau for both breeding and wintering Saker Falcons. Furthermore, we identify potential conservation threats facing the species in the region and provide tenable recommendations for their mitigation.

METHODS

We conducted exploratory breeding surveys between 17–20 June 2007 in Madoi county, Golog prefecture, and 25–30 June 2007 in the counties of Yushu, Zhiduo and Qumalai, Yushu prefecture (Figure 1). Surveys were restricted to areas adjacent to the main highways running through these four counties, and were chosen on the basis that they held potential nesting habitat for Sakers and were conveniently located to areas where we were based on our route through Qinghai. We undertook nest searches on foot, checking rock faces and outcrops in mountains, valleys, river courses and plains in areas adjacent to the road. We also surveyed a total length of 112 km of electricity transmission lines in Madoi county and

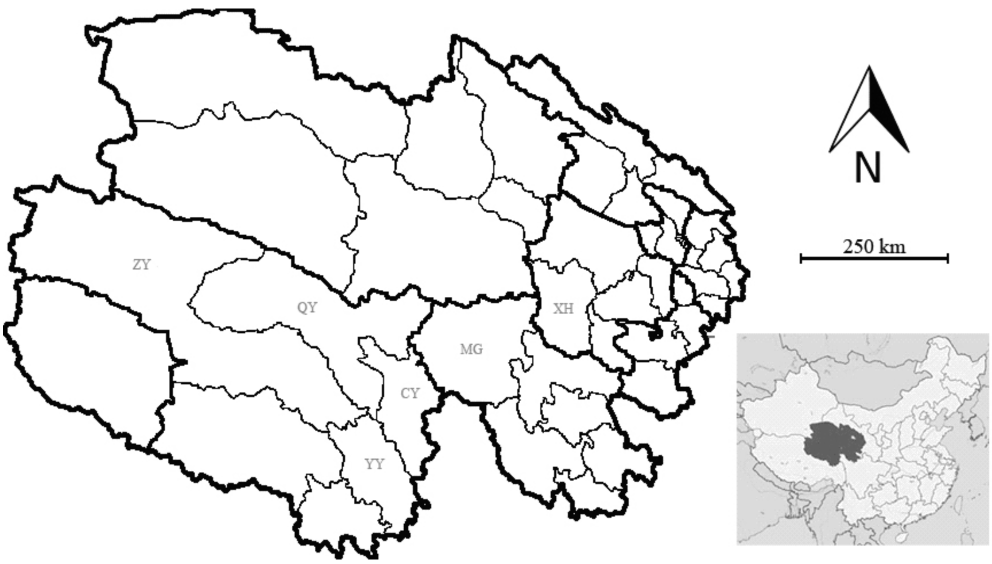

Figure 1. Location of counties in Qinghai province where breeding and wintering surveys were undertaken. MG = Maduo (Madoi), Guoluo (Golog) prefecture; CY = Chenduo (Chindu), QY = Qumalai (Qumerleb), YY = Yushu (Yulshul), ZY = Zhiduo (Zhidoi), Yushu prefecture; XH = Xinghai, Hainan prefecture. Inset shows location of Qinghai province in China.

checked all stick nests on poles and pylons for occupancy by Sakers. We plotted all active nest locations by GPS and recorded locations of occupied territories when no nests were found. We classified a territory as occupied if we detected a pair of adult Sakers in suitable nesting habitat or if we encountered evidence of recent activity at a known nest site (i.e. presence of fresh faeces, pellets and/or moulted feathers). Survey areas were subsequently defined by a minimum convex polygon (MCP) that included all active territories and nests found in each survey area. It should be noted that the entire MCP was not searched in each area and nests/active territories were probably under-recorded.

We recorded all Sakers seen in winter between 9–14 January 2008 in Maduo county, Guoluo prefecture, Xinghai county, Hainan prefecture, and Chenduo and Qumalai counties, Yushu prefecture (Figure 1). Birds were seen during road travel, the survey route following the main highway across these counties, and all sightings of Sakers were marked using GPS and their sex and age recorded when possible. Birds were assigned to two categories, i.e. hatched during previous calendar year (juvenile) and hatched before the previous calendar year, exact year unknown (adult). In addition, we plotted the GPS location of Sakers observed along a 76 km electricity distribution line running from Maduo to Huashixia, Maduo county, and subsequently measured nearest-neighbour distances between observations using Google Earth (treating observations of pairs as a single data points). We calculated an index of dispersion (I), where $I = \frac{s^2}{\bar{x}}$, which was compared to a Poisson distribution by a chi-square test.

Between May and July in the years 1997 to 2009, a total of 31 Sakers were captured in Mongolia and adjacent regions of Russia and fitted with satellite transmitters (platform terminal transmitter; PTT manufactured by Microwave Telemetry, Columbia, MD, USA and North Star Science and Technology, King George, VA, USA). We were able to use data from 20 of these transmitters, which provided locations until at least 1 December in the same or subsequent year (AD unpubl. data). We selected this cut-off date to define the wintering status of individuals because 26 November was the latest departure date for known migratory Sakers (Table 1). We defined a Saker as a migrant if it embarked on a long-distance (>350 km), directional movement from the breeding area where it was first fitted with a PTT.

RESULTS

The mean density of Sakers in our three surveyed areas was 0.52 ± 0.22 breeding pairs/100 km^2 and 0.68 ± 0.21 territories/100 km^2

Table 1. Timing of migration and duration of wintering period on the Qinghai–Tibetan plateau. Migration initiation refers to the date individuals left their breeding or natal regions, arrival refers to the date the individual arrived on the Qinghai–Tibetan plateau and departure the date that it left. Duration is the number of days spent in the wintering region. Four individuals stopped transmitting during migration and a further two stopped transmitting whilst wintering on the Qinghai–Tibetan plateau. †Exact date uncertain due to gaps in signal transmission. References for further satellite tracking information on individual Sakers: 1 (Eastham *et al.* 2000); 2 (Potapov *et al.* 2002); 3 (Karyakin *et al.* 2005); 4 (Batbayar *et al.* 2010).

Age, Sex	PTT	Migration initiation	Arrival	Departure	Duration (days)	Refs
Adult, female	3839	18 November 1997	04/09 January 1998†	01/07 March 1999†	57	1, 2
Adult, female	29040	11/14 September 2000†	18 September 2000	04 March 2001	167	2
Adult, female	35989	08/09 October 2002†	11/12 October 2002†	07 March 2003	147	
Adult, female	35991	17 November 2002	NA	NA	NA	
Adult, female	35993	26 November 2002	NA	NA	NA	
Juvenile, female	35990	30 August 2002	NA	NA	NA	3
Juvenile, male	56580	05 October 2006	NA	NA	NA	
Juvenile, female	56581	08 October 2006	11/12 October 2006†	08 April 2007	179	
Adult, female	90888	28/29 October 2009†	30/31 October 2009†	NA	NA	
Adult, female	90890	13 November 2009	20 November 2009	28 February 2010	100	
Adult, female	90893	11 October 2009	15 October 2009	24 February 2010	132	
Adult, female	93546	01 October 2010	04 October 2010	27 February 2011	146	4
Juvenile, female	93548	29 September 2009	02 October 2009	NA	NA	4
Mean ± SE		*16 October ± 7 days*	*24 October ± 11 days*	*07 March ± 6 days*	*132 ± 16 days*	

Table 2. The number of active nests and occupied territories found in three survey areas of Guoluo and Yushu prefectures. Breeding density is expressed as the number of nests and territories per 100 km².

County	Survey area (km²)	Nests	Nests/100 km²	Territories	Terr./100 km²
Maduo	735	7	0.95	8	1.09
Qumalai	1,435	4	0.28	7	0.49
Ziduo/Yushu	1,555	5	0.32	7	0.45

(Table 2). Nests were found on cliffs, rock outcrops and sandbanks on mountains, valley bottoms, plains and river valleys (Plates 1 and 2). We found no breeding Sakers nesting on 112 km of electricity power line in Madoi county, but did find a pair nesting on a river bridge of the Qinghai–Tibet highway outside our main survey areas.

Of the 20 individual Sakers which were tracked by satellite until at least 1 December, 11 (52%) were migratory—nine adults and two juveniles. Sample sizes were too small to identify any statistically significant difference in the migratory tendency between age classes; 50% of adults (n = 18) and 67% of juveniles (n = 3) were migrants. A further two migrants stopped transmitting before 1 December and all the migratory birds (n = 9) which were tracked to their wintering area went to the Qinghai–Tibetan plateau (Figure 2). One adult female was tracked over two winters and changed its status from resident in the first winter to migratory in the second.

On average, Sakers arrived at their wintering grounds on 22 October (± 12 days), with the earliest arrival recorded on 18 September and latest between 4–9 January—exact date uncertain due to gap in signal transmission from PTT (Table 1). All tagged Sakers spent the winter in regions of the Qinghai–Tibetan plateau (Figure 2). Birds spent 132 (± 16) days on the plateau, departing to their breeding or natal region on 7 March (± 6 days) (Table 1).

During our winter survey, we saw Sakers every day from 9–14 January. In total we saw 62 individuals, 52 of which we were able

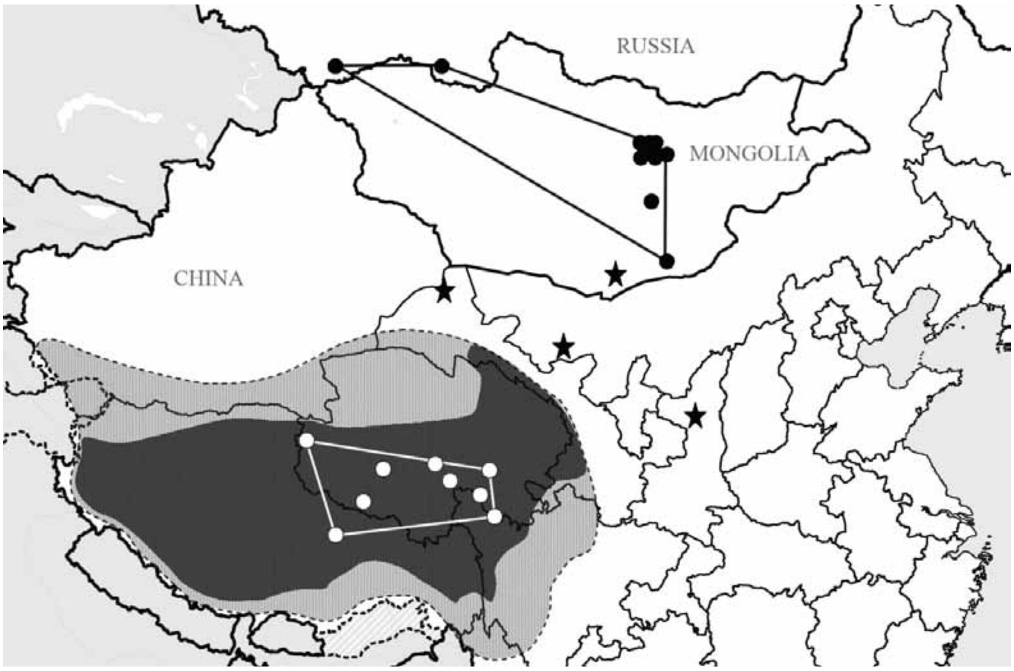

Figure 2. Map illustrating migratory connectivity between breeding (black dots) and wintering (white dots) areas of Sakers. The final locations of PTTs that stopped transmitting during migration are marked with stars. The Qinghai–Tibetan plateau is shown by the dashed line shaded grey and the darker shaded area represents the main region of alpine grassland (adapted from Zhang *et al*. 2013).

Plate 1. Saker Falcon *Falco cherrug* breeding habitat on rocky hillside of alpine grasslands, Maduo county.

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Plate 2. Saker Falcon breeding habitat on rocky sides of river valleys, Yangtse River, Qumalai county.

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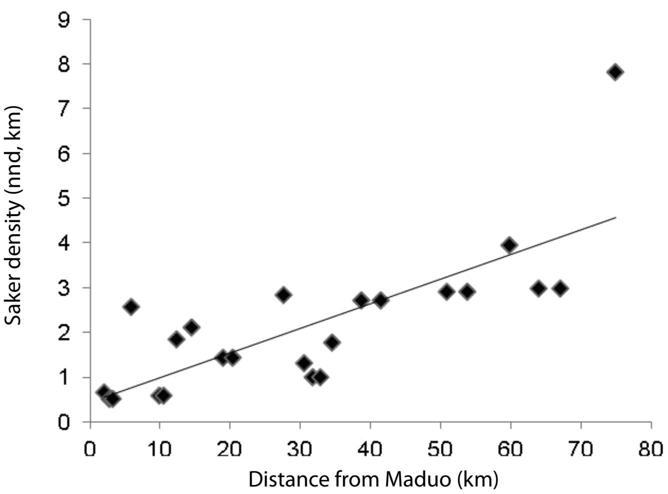

Figure 3. Density (expressed as nearest neighbour distance, nnd; km) of perched Sakers along a 76 km electricity distribution line running from Maduo to Huashixia, Maduo county. Observed Plateau Pika abundance was greatest nearer to Maduo (linear regression: y = 0.055x + 0.4479, $R^2 = 0.5935$).

to accurately age and sex; overall sex ratio was similar (26 of each sex) but adult birds (n = 32) outnumbered juveniles (n = 20) by a ratio of 1.6:1. Birds were usually observed singly, although we saw two together at four locations and at each of these there was an adult male and female present, suggesting that they were a pair. We recorded 27 Sakers (including four pairs) along the 76 km length of electricity transmission line survey during the winter count. The mean nearest-neighbour distance between perched birds was 2.14 ± 0.33 km. The dispersion of Sakers along the power line ($I = 3.05$, $\times^2 = 67.09$, df = 22, $p<0.05$), was aggregated with a higher density found nearer Maduo than Huashuxia (Figure 3).

DISCUSSION

The densities of nests and occupied territories reported here are minimum estimates as the areas were only partially surveyed and we undoubtedly missed other nests and territories. Potapov & Ma (2004) found Sakers breeding at a density of 0.28 pairs/100 km^2 in a 1,811 km^2 study area in Qumalai, which is the same density we found in a different area of this county. Extrapolating the mean density of 0.52 ± 0.22 breeding pairs/100 km^2 found during our study produces population estimates of 129 (75–184), 259 (150–368) and 405 (240–589) breeding pairs for Maduo, Qumalai, Zhiduo / Yushu counties respectively. The area of these four counties combined represents less than 12% of the high-altitude alpine grasslands on the Qinghai–Tibetan plateau. Given the widespread breeding distribution of the Saker across the plateau, it is clear that this vast biogeographic region holds a significant population that could possibly exceed the current estimate for the Saker population in China as whole. Nevertheless, more extensive, standardised surveys are required to obtain accurate breeding population estimates at county, prefecture, province and ecoregion scales. Interestingly, we found little evidence of widespread or frequent use of anthropogenic structures by nesting Sakers, whereas in Mongolia the habit is well established with many pairs nesting on powerline support structures (Dixon *et al*. 2013) and other human artefacts (Ellis *et al*. 1997, 2009).

Satellite telemetry has revealed that the Qinghai–Tibetan plateau not only supports a large breeding population, but also serves as an important wintering region for migratory Saker Falcons from breeding areas in Mongolia and adjacent regions of Russia. Formerly, Sakers were reported as being not uncommon during migration in 'Chihli' (approximating to modern Hebei province) and were believed to generally winter in northern China (La Touche 1931–1934). However, at present the Qinghai–Tibetan plateau is the only known wintering area for long-distance migratory Sakers from Mongolia. Given that 52% of the Mongolian Sakers we tagged migrated and the Mongolian breeding population is estimated to comprise 2,000–5,000 pairs, it is likely that thousands of migratory Sakers arrive on the Qinghai–Tibetan plateau each autumn.

The aggregated dispersion of Sakers along the surveyed powerline suggests that local densities on alpine grasslands are influenced by food availability, and although we did not collect quantitative data, the abundance of Plateau Pikas was observed to be highest closer to Maduo town where Sakers occurred at higher density. Our observations indicated that the wintering Saker population of the plateau is not sex-biased, although we did see more adults than juveniles, suggesting the possibility of spatial separation of wintering areas by age class or perhaps differential overwinter mortality rates. It would be useful to collect data to determine if there is any temporal variation in the age structure of the Saker population overwintering on the Qinghai–Tibetan plateau. Overwinter survival has the potential to be a major factor regulating the size of the Saker population in Mongolia as well as on the Qinghai–Tibetan plateau.

Despite its huge size and remoteness, the Qinghai–Tibetan plateau is still vulnerable to detrimental anthropogenic influences (Cui & Graf 2009, Harris 2010). Government policies to reduce grassland degradation and improve livestock productivity involve the management of grazing and rodent control (Xiang *et al*. 2009). Grazing management has involved reducing the density of grazing livestock and relocation of herders to settlements (Foggin & Smith 1996, Sheehy *et al*. 2006) in order to reduce grazing intensity, which is often regarded as the primary cause of pasture degradation. Changes in grassland land use could affect prey populations, particularly small mammals, through altering the structure of vegetation (Xin 2008).

It seems likely that the Qinghai-Tibetan plateau supports a large population of Sakers primarily because of the widespread and abundant supply of Plateau Pikas that are available throughout the year (Smith & Foggin 1999, Harris & Loggers 2004). However, other prey species are also likely to be important such as birds, Gansu Pikas *Ochotona cansus*, Plateau Zokers *Myospalax fontanierii*, Root Voles *Microtus oeconomus* and other small mammals (Zhang *et al*. 2003, Cui *et al*. 2008). Pest control programmes that set out to eradicate Plateau Pikas and other small mammals over large districts have the potential to reduce the area and carrying capacity of regions for Sakers (Lai & Smith 2003, Delibes-Mateos *et al*. 2011), although the efficacy of this strategy has been questioned (Pech *et al*. 2007). However, we currently do not know how breeding or wintering Sakers may respond, functionally and numerically, to a reduction in small mammal availability.

Increased infrastructure development on the Qinghai–Tibetan plateau may have a direct and indirect impact on Sakers. There is no evidence that the Qinghai–Tibet highway and railway impact on key prey species (Li 2012), and the physical structures associated with them can provide potential nest sites in areas where none existed previously. However, road and railway development increases accessibility in this remote region and can stimulate economic activity, which can lead to the creation of new settlements and the expansion of existing ones. While the potential benefit of increasing nest site availability through the development of electricity transmission infrastructure has only recently been recorded on the Qinghai–Tibetan plateau (Dixon 2015), the expanding electricity distribution network is responsible for the electrocution and death of large numbers of breeding and wintering Sakers (Dixon *et al*. 2013; Plate 3).

The large numbers of Sakers on the Qinghai–Tibetan plateau has not escaped the attention of falcon trappers and since 1994 the region has been targeted by illegal traders looking to export falcons

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Plate 3. Electrocuted Saker Falcon on an electricity distribution line, Maduo county.

to the lucrative Middle East falconry market (Li *et al.* 2000). The scale of 'harvesting' is reportedly very high, with at least 1,200 Sakers illegally trapped on average annually in Qinghai province according to the Qinghai Wildlife Management Bureau (Zhang *et al.* 2008). In the absence of accurate and reliable data on the 'harvest level', it is not possible to determine whether harvesting at this scale is sustainable, although it does provide further evidence for a substantial wintering population on the Qinghai–Tibetan plateau.

The impact of threats such as pika control, electrocution and falcon trapping on the breeding and/or wintering population of Sakers on the Qinghai-Tibetan plateau is not known, but precautionary measures could be adopted to minimise any potential detrimental effect. In several counties of Qinghai, rodent control departments have reduced pika poisoning efforts and have instead erected perches and artificial nesting platforms for raptors in order to facilitate and increase predation of pikas by birds of prey (Dixon 2015). The problem of electrocution at power distribution lines can be addressed by installing appropriate mitigation, such as cable insulation, particularly at the most dangerous anchor poles (Dixon *et al.* 2013). Studies in Mongolia have demonstrated that it is possible to manage Saker breeding populations using artificial nests, and such a managed and monitored population could potentially be used to support a sustainable harvest of falcons for falconry (Rahman *et al.* 2014), which in turn could have community benefits and undermine any illegal trade.

In conclusion, it is clear that the biogeographical region of the Qinghai–Tibetan plateau is hugely significant for the conservation of the Saker, holding a large breeding population and providing an important wintering area for a significant portion of the breeding Saker population of Mongolia and adjacent regions of Russia. It is likely, in winter at least, that 25–50% of the global Saker population resides on the Qinghai–Tibetan plateau. Priority should be given to developing targeted research and conservation projects aimed at obtaining a better understanding of and addressing the specific factors that potentially impact on the Saker population—pest control measures, electrocution and trapping.

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