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 km²; 0.68 ± 0.21 territories/100 km²), 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 widespread 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.

**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...
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 Haashixia, Maduo county, and subsequently measured nearest-neighbour distances between observations using Google Earth (treating observations of pairs as a single data point). We calculated an index of dispersion ($I$), where $I = \frac{2}{N} \sum_{i=1}^{N} d_{ij}^2$, 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 $0.52 \pm 0.22$ breeding pairs/100 km$^2$ and $0.68 \pm 0.21$ 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).

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

**Mean ± SE**

| 16 October ± 7 days | 24 October ± 11 days | 07 March ± 6 days | 132 ± 16 days |

**Figure 1.** Location of counties in Qinghai province where breeding and wintering surveys were undertaken. MG = Maduo (Madol; 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.
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.

<table>
<thead>
<tr>
<th>County</th>
<th>Survey area (km²)</th>
<th>Nests</th>
<th>Nests/100 km²</th>
<th>Territories</th>
<th>Terr./100 km²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maduo</td>
<td>735</td>
<td>7</td>
<td>0.95</td>
<td>8</td>
<td>1.09</td>
</tr>
<tr>
<td>Qumalai</td>
<td>1,435</td>
<td>4</td>
<td>0.28</td>
<td>7</td>
<td>0.49</td>
</tr>
<tr>
<td>Ziduo/Yushu</td>
<td>1,555</td>
<td>5</td>
<td>0.32</td>
<td>7</td>
<td>0.45</td>
</tr>
</tbody>
</table>

(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 to track.

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.

Plate 2. Saker Falcon breeding habitat on rocky sides of river valleys, Yangtze River, Qumalai county.
we found in a different area of this county. Extrapolating the we undoubtedly missed other nests and territories. Potapov & Ma could possibly exceed the current estimate for the Saker population combined represents less than 12% of the high-altitude alpine Zhiduo / Yushu counties respectively. The area of these four counties mean density of 0.52 ± 0.22 breeding pairs/100 km² found 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, x² = 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 km² in a 1.81 km² 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 km² 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 habitat 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

Figure 3. Density (expressed as nearest neighbour distance, nnd; km) of perched Sakers along a 76 km electricity distribution line running from Maduo to Huashuxia, Maduo county. Observed Plateau Pika abundance was greatest nearer to Maduo (linear regression: y = 0.055x + 0.4479, R² = 0.5953)
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.

ACKNOWLEDGEMENTS

This project was funded by the Environment Agency-Abu Dhabi (EAD; formerly Environmental Research and Wildlife Development Agency, ERWDA), The World Bank (Netherlands-Mongolia Trust Fund for Environmental Reform) and BirdLife International (the Rio Tinto-BirdLife Programme) funded the purchase and deployment of two PTTs used in this study. In addition to PTTs deployed by the authors (2006–2009) we have included data from PTs deployed by Christopher Eastham (1997); Igor Karyakin, Eugene Potapov and Gombobazar Sundev (2000–2002). We thank Carl Ashford, Hu Baowen, Ryan Dixon, Gankhuyag Purev-Ochir, Dimitar Ragirov and Paul Stafford for their assistance.

REFERENCES


Ding M., Zhang Y., Shen Z., Liu L., Zhang W., Bai W. & Zheng D. (2006) The paradox 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.

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.

ACKNOWLEDGEMENTS

This project was funded by the Environment Agency-Abu Dhabi (EAD; formerly Environmental Research and Wildlife Development Agency, ERWDA). The World Bank (Netherlands-Mongolia Trust Fund for Environmental Reform) and BirdLife International (the Rio Tinto-BirdLife Programme) funded the purchase and deployment of two PTs used in this study. In addition to PTs deployed by the authors (2006–2009) we have included data from PTs deployed by Christopher Eastham (1997); Igor Karyakin, Eugene Potapov and Gombobazar Sundev (2000–2002). We thank Carl Ashford, Hu Baowen, Ryan Dixon, Gankhuyag Purev-Ochir, Dimitar Ragirov and Paul Stafford for their assistance.

REFERENCES


