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VARIATION IN ELECTROCUTION RATE AND DEMOGRAPHIC COMPOSITION OF SAKER FALCONS ELECTROCUTED AT POWER LINES IN MONGOLIA

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Abstract.—We examined variation in the number and demographic composition of electrocuted Saker Falcons (*Falco cherrug*) in Mongolia. We found 1721 electrocuted Saker Falcons during our surveys of multiple power lines in 2013–2015 and 2018. At a single power line surveyed over a 16-mo period in 2013–2014, the lowest electrocution rates occurred from December to March, with a rise in April coinciding with the return of migrant juveniles from their wintering areas. Electrocution rates rose sharply during juvenile post-fledging dispersal, and then declined in October as migrants departed. Monthly changes in electrocution rate and age profile reflected predicted variation in abundance and age structure of the local Saker Falcon population. We found that 88% of electrocuted Saker Falcons were juveniles, mostly killed during their first calendar year. The sex ratio of electrocuted juveniles fledged in the 2013 cohort (hatch-year birds) was significantly female-biased, in contrast to the equal sex ratio of the 2012 juvenile cohort (second calendar-year birds) killed in the same year (2013). Sex ratio of the 2013 juvenile cohort did not differ significantly from parity at other power lines across Mongolia, indicating that sex ratio of electrocuted juveniles can vary in time and space. The sex of electrocuted adults, predominantly males, and an age profile of breeding Saker Falcons that includes younger females suggests a possible male-biased sex ratio among adult Saker Falcons in Mongolia. Given that large numbers of endangered Saker Falcons are electrocuted annually in Mongolia, our study suggests electrocution may be an important driver of demographic trends that can potentially result in population declines.

Key Words: *Saker Falcon*; Falco cherrug; *endangered species*; *population demography*; *power line*; *raptor*.

VARIACIÓN EN LA TASA DE ELECTROCUCIÓN Y COMPOSICIÓN DEMOGRÁFICA DE INDIVIDUOS DE *FALCO CHERRUG* ELECTROCUTADOS EN LÍNEAS ELÉCTRICAS EN MONGOLIA

Resumen.—Examinamos la variación en el número y la composición demográfica de *Falco cherrug* electrocutados en Mongolia. Encontramos 1721 individuos electrocutados durante nuestros muestreos de múltiples líneas eléctricas en el periodo 2013–2015 y en 2018. En una única línea eléctrica muestreada a lo largo de un período de 16 meses en los años 2013 y 2014, las tasas de electrocución más bajas fueron registradas desde diciembre a marzo, con un aumento en abril, coincidente con el regreso de los migrantes

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juveniles desde sus áreas de invernada. Las tasas de electrocución aumentaron marcadamente durante la dispersión juvenil una vez abandonado el nido, y luego disminuyeron en octubre a medida que los ejemplares iniciaron la migración. Los cambios mensuales en la tasa de electrocución y en el perfil de edades reflejaron la variación predicha en la abundancia y estructura de edades de la población local de *F. cherrug*. Encontramos que el 88% de los individuos electrocutados eran juveniles, que murieron durante su primer año calendario. La proporción de sexos de juveniles electrocutados pertenecientes a la cohorte de 2013 (aves de primer año-calendario) estuvo significativamente sesgada hacia las hembras, en contraste con la paridad en la proporción de sexos de la cohorte de juveniles de 2012 (aves de segundo año-calendario) muertos en el mismo año (2013). La proporción de sexos en la cohorte de juveniles del 2013 no varió significativamente de la paridad en otras líneas eléctricas de Mongolia, indicando que la proporción de sexos de los juveniles electrocutados puede variar en el tiempo y el espacio. La electrocución predominantemente de machos adultos y un perfil de edades de los individuos reproductores de *F. cherrug* que incluye hembras jóvenes, sugiere un posible sesgo hacia los machos entre los adultos de *F. cherrug* en Mongolia. Considerando el alto número de individuos que se electrocutan anualmente en Mongolia, nuestro estudio sugiere que la electrocución puede ser un importante impulsor de las tendencias demográficas que potencialmente pueden dar lugar a la disminución de la población de esta especie amenazada.

[Traducción del equipo editorial]

Electrocution of birds on power distribution lines is a widespread phenomenon (e.g., Prinsen et al. 2011, Dwyer et al. 2013, Harness et al. 2013) that can result in high levels of mortality, causing concern for the conservation of certain species (e.g., López-López et al. 2011, Angelov et al. 2013, Kovacs et al. 2014, Hernández-Matías et al. 2015). Many studies of avian electrocution focus on the number of birds killed and on various ways of reducing these mortalities (see references in Avian Powerline Interaction Committee 2006, Prinsen et al. 2012), but few studies have evaluated population effects of electrocution (Lehman et al. 2007, but see Sergio et al. 2004, López-López et al. 2011, Hernandez-Matias et al. 2015). Understanding the impact of electrocution on population dynamics typically requires unbiased estimates of mortality and a determination of each cause, including electrocution, and knowledge of whether each is additive to other forms of mortality (Schaub et al. 2010). Data on demographic patterns of electrocution are scant, limiting our ability to understand the potential role of electrocution as a driver of demographic trends (Morrison et al. 2016).

Larger birds have a higher risk of electrocution because their size makes them more likely to simultaneously touch two energized wires or a single energized wire and a grounded component (Janss 2000). Among raptors, which exhibit varying degrees of reversed size dimorphism, electrocution of females is more frequent than electrocution of males in Spanish Imperial Eagles (*Aquila adalberti*; Ferrer and Hiraldo 1992), but not in Bonelli's Eagles (*A. fasciata*; Real et al. 2001). Female Great Horned Owls (*Bubo virginianus*) and Red-tailed Hawks (*Buteo jamaicensis*), each of which is larger than their respective males, are electrocuted at higher rates than males, but only in the latter species is the mortality greater than that expected based on their estimated proportion in the population (Platt 2005). Sex bias in electrocutions may reflect the ratio of the sexes in the population, which is not necessarily parity, or it may be a consequence of sex differences in electrocution risk. Immature birds are electrocuted more frequently than adults in at least three eagle species, Golden Eagle (*A. chrysaetos*; Harness and Wilson 2001), Bonelli's Eagle (Real et al. 2001) and Spanish Imperial Eagle (Ferrer and Hiraldo 1992). This may be a consequence of age-related differences in the propensity to aggregate at prey-rich settlement areas, particularly for large predators inhabiting open landscapes where power poles are attractive perching sites (e.g., Real et al. 2001, Lasch et al. 2010). Furthermore, behavioral differences in the ability of immature and adult birds to land on and take off from perches on power poles without contacting wires is believed to be an important factor in elevating electrocution risk for younger eagles (Nelson and Nelson 1976).

The Saker Falcon (*Falco cherrug*) is classified as Endangered on the IUCN Red List of Endangered Species (BirdLife International 2016). Electrocution is a conservation concern across much of the range of the species, with high levels of mortality in Kazakhstan and Russia (Lasch et al. 2010, Karyakin 2012), Mongolia and China (Dixon et al. 2013, 2017), and in Europe (Fidlóczky et al. 2014). These findings have heightened concern about the potential population-level effects of electrocution on Saker Falcons (Kovacs et al. 2014). Demographic parameters, especially age structure and adult sex ratio, are likely to be useful indicators of population trajectory, and understanding their variation and drivers can inform management of species of high conservation concern or commercial importance (Donald 2007). Here we report variation in the number, age, and sex of Saker Falcons electrocuted at power lines in Mongolia and discuss the potential effect of electrocution on Saker Falcon populations.

METHODS

Power Line Surveys. For this study we draw on data from three distinct studies of electrocution at power lines in Mongolia: (1) high-frequency monitoring of a single power line in 2013–2014, (2) single visit surveys to multiple power lines in 2013–2015, and (3) repeated visits to four power lines in eastern Mongolia in 2018.

High-frequency monitoring of a single line. From April 2013 to August 2014, we conducted monitoring of a 56-km, 3-phase, 15-kV electricity distribution line traversing open, undulating steppe landscape at an elevation of approximately 1250 masl between the district centers of Uulbayan and Munkhkhaan in Sukhbaatar Province, Mongolia (46°29.46′N, 112°20.82′E to 46°58.02′N, 112°3.18′E). The regional climate is characterized by cold winters (typically below freezing from October to April) and short summers (frost-free period from June to August). Most precipitation falls during July and August. The landscape and vegetation cover around the line was relatively homogenous along its whole length, and characterized by short, sparse grasses growing in sandy soil, enabling clear visibility of carcasses lying on the ground below power poles.

The line comprised 496 line poles (also termed tangent poles) and 36 anchor poles (also termed double dead-end poles) constructed of steel-reinforced concrete (Fig. 1; Dixon et al. 2013, 2017). Line poles had an upright pin insulator affixed to a vertical section of angled steel at the top of the concrete pole, with a single horizontal crossarm of angled steel with one (or two near villages at each end of the line; $n = 29$) upright pin-insulator bolted to each end to carry the outer phases. Anchor poles had jumper wires passing over the pole top at the middle phase and jumper wires passing under the crossarm on the outer phases. We marked all poles on the line sequentially with a painted number from 1 to 532. As part of a concurrent study of this line wherein we evaluated the effectiveness of a range of different mitigation materials, we conducted carcass surveys by motorbike. Because assessment of those materials has been published elsewhere (Dixon et al. 2019), we do not report that here. From 1 April to 20 August 2013 (142-d period) we conducted 71 line surveys at intervals ranging from 1 to 4 d. From 21 August 2013 to 15 August 2014 (360-d period), we conducted daily surveys. During each survey, we photographed all carcasses of birds found below power poles. We also collected carcasses of Saker Falcons, which were labelled, individually bagged, and frozen at –20°C on the day they were collected and subsequently thawed in the laboratory 12–431 d later so we could make biometric measurements.

To examine temporal variation in Saker Falcon electrocution rates, we used two separate sets of sample data: (1) we restricted our analysis to poles that had a constant, unmanipulated configuration for the full period of study (“unmanipulated poles,” $n = 163$; 1 April 2013–31 July 2014) and (2) we restricted our analysis to the remaining poles on the line over the period from 1 September 2013 to 31 July 2014 when they maintained a consistent configuration (“mitigated poles,” $n = 369$ poles). We calculated mean daily electrocution rate of Saker Falcons for each month.

Single visit surveys of multiple lines (2013–2015). We undertook single-visit surveys to 15-kV electricity distribution lines across Mongolia during the post-fledging dispersal period from 30 September through 3 October 2013 ($n = 29$ lines, 16,152 poles, approximately 1775 km), 12–17 August 2014 ($n = 30$ lines, 15,559 poles, approximately 1710 km) and 15–20 August 2015 ($n = 19$ lines, 10,081 poles, approximately 1110 km). Pole configurations at the surveyed lines were similar to those described above.

Repeat visits to four power lines (2018). We made repeated visits at 10-d intervals from 12 June to 14 November 2018 to power lines in Sukhbaatar Province, eastern Mongolia ($n = 4$ lines, 1604 poles, approximately 163 km). One of these lines was the Uulbayan-Munkhkhaan line monitored previously in 2013–2014. The other lines, of similar design configuration, connected the district center of Baruun Urt to a mine at Talbulag (10 kV), Baruun Urt to a radar mast at Ulgii (10 kV), and the district centers of Ongon and Naran (15 kV).

Age and Sex of Electrocuted Saker Falcons. We determined falcon age on the basis of plumage, skin color and molt. Juvenile plumage typically has less

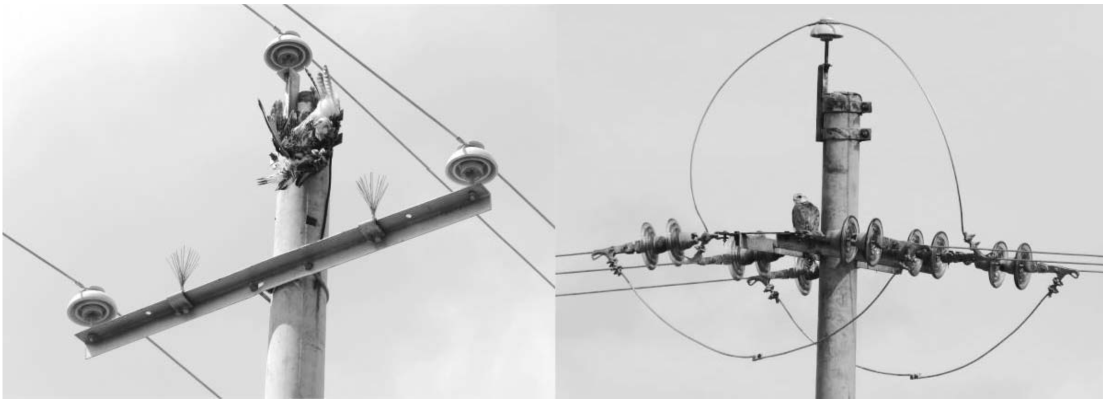

Figure 1. Typical configuration of line pole (left) and anchor pole (right) at 15-kV electricity distribution lines in Mongolia. Perch deflector brushes are deployed on the crossarm of line pole, with electrocuted Saker Falcon at the middle phase. The anchor pole illustrates the configuration in which jumper wires at the middle phase pass over the crossarm and those at the outer phases pass underneath; Saker Falcon perched at crossarm.

dorsal barring than adult plumage and juveniles tend to be more heavily marked ventrally, especially on the breast, resulting in juveniles having a more streaky appearance than adults. Juveniles in their hatch-year (1^{st} calendar-year; 1cy) have gray-blue skin on their bare parts (legs, cere, and orbital ring), which gradually becomes greenish-yellow to yellow-orange with age, typically turning yellow during the latter stages of post-juvenile molt in the year after hatch (2^{nd} calendar-year; 2cy). Molt from juvenile to adult plumage takes place in the 2cy and birds that have completed post-juvenile molt are indistinguishable from adults that are >2cy old (plumage, skin, and molt descriptions from Ferguson-Lees and Christie 2010). We use the term juvenile to describe 1cy and 2cy birds with juvenile plumage or in active post-juvenile molt.

We determined sex of Saker Falcon carcasses collected during the high-frequency monitoring in 2013–2014 by dissection of the gonads or by the flattened wing chord length from the bend of the wing to the tip of the longest primary. In this approach, we classified 1cy juveniles with a wing chord of ≥390 mm as female and <390 mm as male, and we classified 2cy juveniles and adults with a wing chord of ≥385 mm as female and <385 mm as male. Only birds with fully grown 9th primaries (i.e., longest primary) were assigned sex using this method.

Band Recoveries. We fitted color bands to Saker Falcon nestlings over three breeding seasons at artificial nests erected in 20 districts of central and eastern Mongolia (Dixon 2016). The color bands were inscribed with a unique alphanumeric code enabling individual identification. The recovery of electrocuted Saker Falcons that had been fitted with color bands as nestlings enabled us to identify the location of the natal site and record distance from the banding site to the recovery site. Furthermore, in 2016, we recorded the presence or absence of color bands on breeding Saker Falcons occupying artificial nests in an extensive study area across central and eastern Mongolia and determined their sex by observation of size and plumage color, with males being smaller and typically lighter-colored than females (Eastham et al. 2002).

RESULTS

Power Line Surveys. We recorded a total of 1721 electrocuted Saker Falcons. These included 490 found during high-frequency monitoring of a single line in 2013–2014, 657 found during single-visit surveys of multiple lines from 2013 through 2015, and 574 found during repeat visits to four power lines in 2018.

High-frequency monitoring of a single line (2013–2014). We collected 459 carcasses from the 490 electrocuted Saker Falcons found during our monitoring. Electrocution rate varied over the year, exhibiting a similar pattern in two datasets derived from unmanipulated and mitigated poles (Fig. 2), with the highest mortality during post-fledging dispersal in August and September 2013, followed by a sharp decline after October and further declining over winter until there was an increase in

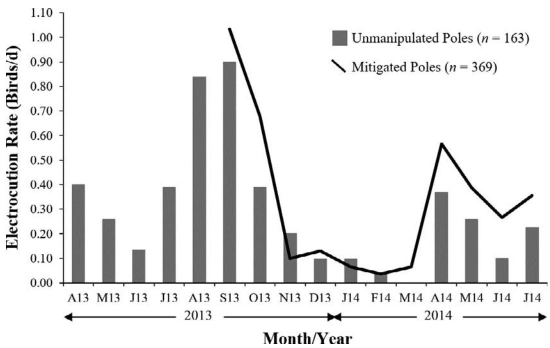

Figure 2. Mean daily electrocution rate of Saker Falcons in each month from two separate datasets obtained on the same power line. Unmanipulated poles maintained a constant configuration from April 2013 to July 2014, and the mitigated poles maintained a constant configuration during September 2013 to July 2014.

April 2014, after which mortality subsequently declined over the breeding season (Fig. 3).

Of 459 Saker Falcon carcasses of known age, 88% ($n = 404$) were electrocuted in their first year after fledging, i.e., before July in the year after hatching. During the breeding season (March–June) most of the electrocuted Saker Falcons were 2cy birds (84%, $n = 148$), whereas juveniles made up (90%, $n = 289$) of the electrocuted Saker Falcons in the post-breeding period of July through October. Only 10% (n = 45) of the electrocuted birds were classified as adults, a category that can include post-molt 2cy birds, which were indistinguishable from older birds.

We determined the sex of 447 carcasses: 267 (52%) by dissection of the gonads (Fig. 4) and the remainder by flattened wing chord length (Fig 4). Overall, female Saker Falcons made up the majority of electrocuted birds, but this female bias was only significant among juveniles (252♀:150♂ juveniles, Fisher's exact test, $P = 0.0004$). In 2013, electrocuted 2cy juveniles i.e., from the cohort hatched in 2012, did not exhibit any sex bias (41♀:38♂ 2cy juveniles, Fisher's exact test, $P = 1.00$), contrasting with female-biased sex ratio of 1cy juveniles from the 2013 cohort (160♀:93♂ 1cy juveniles, Fisher's exact test, P = 0.003). However, there was little temporal overlap in the electrocution of these cohorts with 2cy birds from 2012 electrocuted mainly from April–June (94%, n = 78), while all 1cy birds from 2013 were electrocuted from July–December (n = 263). The 2013 cohort continued to exhibit this female-biased sex ratio the following year (46♀:13♂ 2cy juveniles, Fisher's exact test, $P = 0.002$).

In contrast to the female bias we detected among electrocuted juveniles, we found more electrocuted adult males than adult females, but these numbers did not differ statistically (15♀:30♂ adults, Fisher's exact test, $P = 0.20$).

Single visit surveys of multiple lines (2013–2015). Over the 3 yr, we visited 42 of 65 dangerous 15-kV lines indicated on a 2013 map of the Mongolian energy system (Tserennyam 2013); 11 lines were surveyed in each of the three years, 10 were surveyed in 2 of the 3 years and 21 in one year only. We recorded carcasses of 160 electrocuted Saker Falcons in 2013, 291 in 2014, and 206 in 2015. In 2013, 1cy juveniles electrocuted in August and September exhibited an equal sex ratio at power lines across Mongolia (25♀:27♂; Fisher's exact test, $P = 1.00$), in contrast to the significantly female-biased composition of 1cy juveniles electrocuted in the same 2 mo at the Uulbayan-Munkhkhaan line (102♀:60♂; Fisher's exact test, $P = 0.03$).

In 2014 and 2015, 1cy juveniles electrocuted in August exhibited an equal sex ratio at power lines across Mongolia (2014 = 82♀:111♂, Fisher's exact test, $P = 0.18$; 2015 = 18♀:20♂, Fisher's exact test, $P = 1.00$), which again contrasted with the significantly female-biased composition of 1cy juveniles electrocuted in August 2013 at the Uulbayan-Munkhkhaan line (70♀:38♂; Fisher's exact test, $P = 0.04$).

Repeat visits to four power lines (2018). As in 2013, at the same Uulbayan-Munkhkhaan line, juveniles were the age class most frequently electrocuted in the post-breeding period from July to November 2018 (86%, 209 of 244 birds where age was determined). There was no significant deviation from an equal sex ratio among juveniles electrocuted in their 1cy from the cohort hatched in 2018 (111♀:98♂ 1cy juveniles, Fisher's exact test, P = 0.56) nor among juveniles electrocuted in their 2cy from the cohort hatched in 2017 (16♀:15♂ 2cy juveniles, Fisher's exact test, $P = 1.00$). Similarly, data from three other lines in eastern Mongolia did not reveal any significant deviation from parity in the sex of electrocuted juveniles (2018 cohort = 55♀:54♂ 1cy juveniles, Fisher's exact test, $P = 1.00$; 2017 cohort = 11♀:22♂ 2cy juveniles, Fisher's exact test, $P = 0.32$).

Band Recoveries. An increase in electrocution rate during the period of post-fledging dispersal from July through September was associated with an increase in the distance from the power line to the natal site (Fig. 5). In July, the median distance was 27

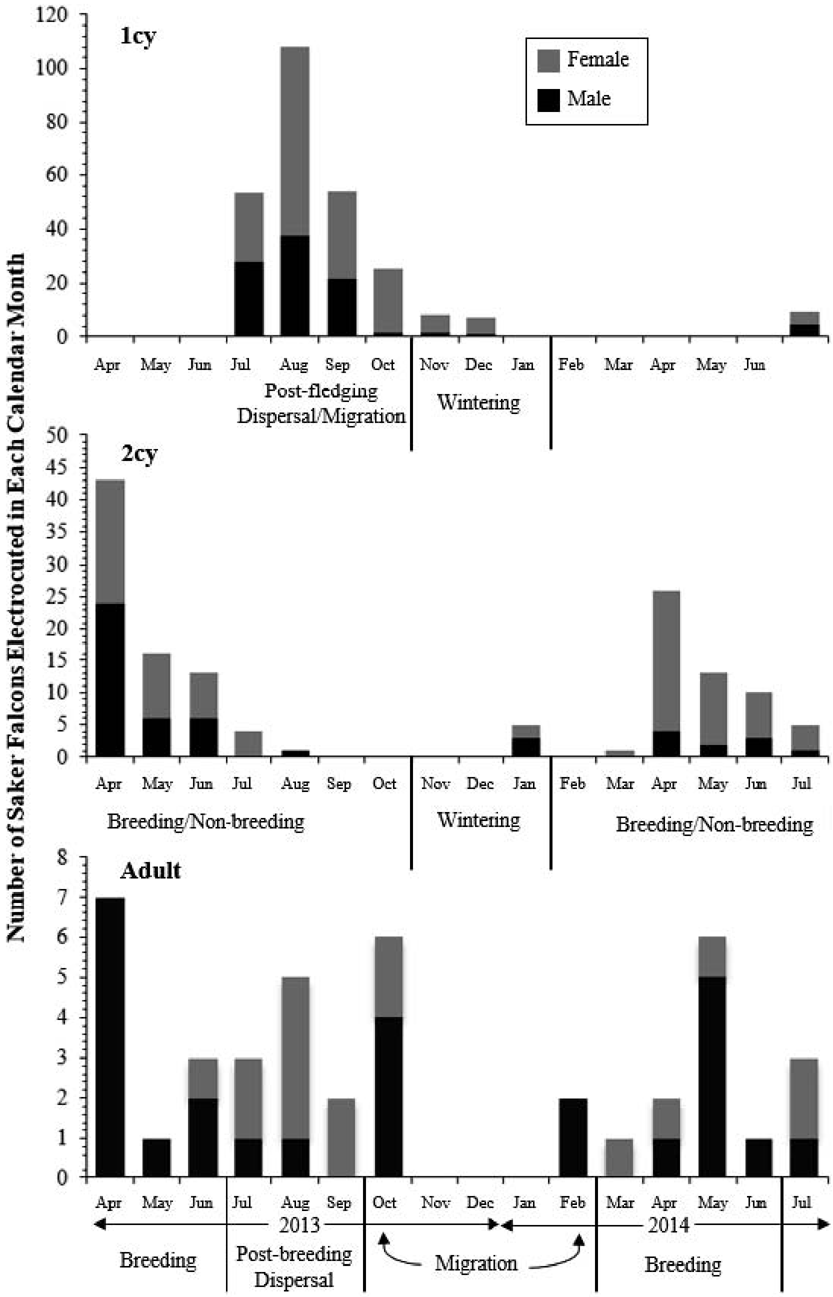

Figure 3. Number and sex of Saker Falcons electrocuted in each month over the period April 2013–July 2014 relative to age. Top: 1cy = 1st calendar-year juveniles, center: 2cy = 2nd calendar year juveniles, bottom: adults (note that birds classified as adults electrocuted August–October inclusive may include 2cy birds that had completed their post-juvenile molt). Main periods of annual cycle are given for each age class.

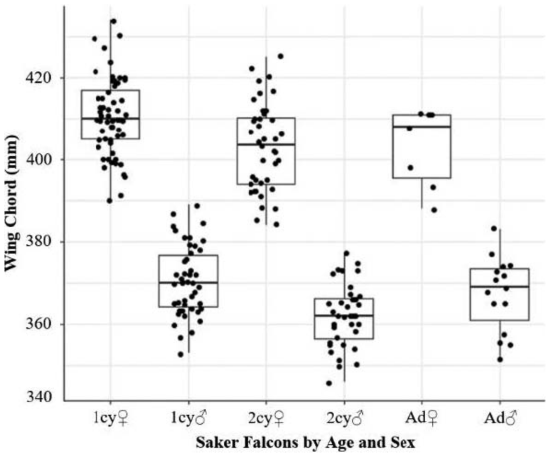

Figure 4. Wing chord (mm) for Saker Falcons of known sex and age. Sex determined by dissection and examination of gonads. 1cy = 1st calendar-year juveniles ($n = 103$), 2cy = 2nd calendar-year juveniles (prior to post-juvenile molt completion; $n = 80$) and Ad = 2nd calendar-year birds (after completion of post-juvenile molt) and older ($n = 23$).

km (range 3–193 km; $n = 23$ recoveries), whereas the corresponding distances for August and September were 73 km (range 6–346 km; $n = 31$) and 87 km (range 9–311 km; $n = 12$), respectively. Overall, the median distance from the natal site for juvenile Saker Falcons electrocuted during the post-fledging dispersal period (July–October) was 70 km ($n = 68$; mean ± SE = 80 ± 9 km). For 2cy birds electrocuted during the breeding season from March to June, the median distance from the natal site was 177 km ($n = 25$; mean ± SE = 173 ± 20 km).

We banded 5609 Saker Falcon nestlings (1678 in 2013, 2420 in 2014, and 1511 in 2015). We observed color bands on 59 Saker Falcons of known sex that were occupying artificial nest sites in the breeding season of 2016; two were 1-yr-old birds in juvenile plumage (both female), 32 were 2-yr-old birds (23 females, 9 males), and 25 were 3 yr old (11 females, 14 males). Breeding females were significantly younger than males, with 69% of females ≤ 2 yr old compared with 39% of males (Fisher's exact test, $P = 0.0312$).

DISCUSSION

Scale and Extent of Electrocution in Mongolia. We found 1721 electrocuted Saker Falcons during our surveys. The high number of electrocutions found at the Uulbayan-Munkhkhaan power line during this study was consistent with previous surveys of the same power line in 2007, 2009, 2011, and 2012 (Harness et al. 2008, Dixon 2010, Dixon et al. 2013, 2017), revealing the persistent nature of this high mortality rate. The problem of electrocution is not only long-standing, but also is widespread in Mongolia (Amartuvshin and Gombobaatar 2012, Dixon 2016) and throughout the range of Mongolian Saker Falcons (Dixon et al. 2013, 2015).

Temporal Variation in Electrocution Rate. Our data on temporal variation in the quantity and demographic composition of electrocuted Saker Falcons highlight the inherent difficulty of using single-visit and short-term survey data to assess avian electrocution rates, especially in comparative studies (Lehman et al. 2007). Temporal variation can concurrently reflect oscillations in habitat quality and seasonal patterns in climate, both of which drive Saker Falcon ecology. For example, in steppe landscapes of Mongolia, small-mammal breeding cycles produce an annual population maximum in late summer and early autumn, with a population nadir in late winter and early spring (Li and Liu 1999). In a previous study of the Uulbayan-Munkhkhaan power line, we found that electrocution rates were positively associated with the density of small-mammal prey species in the surrounding areas (Dixon et al. 2017).

In Mongolia, Saker Falcon nestlings begin to fledge in June, and then typically spend approximately 40 d during the post-fledging dependence period in the vicinity of their natal site before dispersing (Rahman et al. 2015). The increase in electrocution rate after the end of the breeding season in June was commensurate with a local population increase with the arrival of juveniles during the post-fledging dispersal period to exploit an abundant supply of small mammals (Dixon et al. 2017). The first juveniles we found electrocuted were found in July, and banding data indicated that these birds primarily came from local nest sites within 50 km, whereas throughout August and September, juveniles from more distant nest sites arrived in the district of the power line. The natal origin of electrocuted juveniles was consistent with the timing and pattern of post-fledging dispersal exhibited by Saker Falcons (Rahman et al. 2015) when they often occupy one or more temporary settlement areas (Prommer et al. 2012, Nemček et al. 2016). In Mongolia, temporary settlement areas are typically characterized by high densities of small-mammal prey, and can also attract large numbers of other predatory raptors such as Upland Buzzards

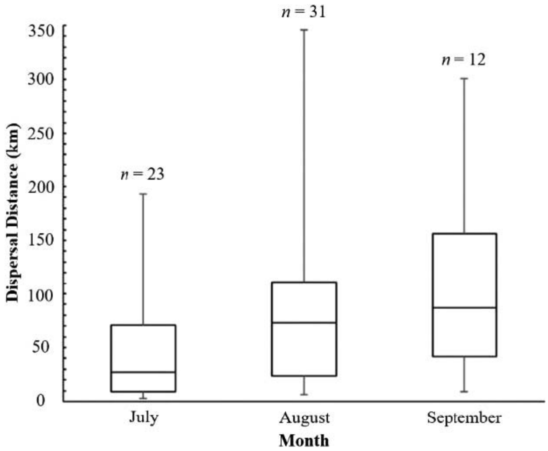

Figure 5. Dispersal distance for electrocuted juvenile Saker Falcons in July, August, and September (minimum, first quartile, median, third quartile, and maximum).

(*Buteo hemilasius*) and Steppe Eagles (*Aquila nipalensis*), which are also at risk of electrocution (Dixon et al. 2013).

Satellite telemetry indicates that Mongolian Saker Falcons typically initiate autumn migration to their wintering areas in October (Dixon et al. 2015); this departure period coincided with a reduction in electrocution rate during October. Some juveniles spend the winter in Mongolia, which was reflected in a small number of birds that were electrocuted during winter. The sharp increase in juvenile birds electrocuted in April probably reflected the arrival of migrants, mainly juveniles, returning from wintering areas. The number of electrocuted juvenile birds declined sharply in May, suggesting that the population increase in April was due mainly to itinerant birds that subsequently left the district. Smaller numbers of juvenile birds continued to be electrocuted through the remainder of the year until the juvenile birds became indistinguishable from the adults after molting.

Demographic Profile of Electrocuted Saker Falcons. The risk of electrocution may not be the same across age classes if, for example, juveniles spend more time perch-hunting from power poles than adults. Unfortunately, we have no information on the hunting behavior of juveniles and adults to assess this potential age-related electrocution risk for Saker Falcons. As the age profile of electrocuted birds fitted the pattern predicted by juvenile dispersal, we suggest that electrocution rates likely reflect the proportion of different age classes in the local population encountering the power line.

Female-biased electrocution of juveniles at the Uulbayan-Munkhkhaan line from the cohort hatched in 2013 is difficult to explain and unlikely to simply be a consequence of their larger size (Janss 2000), as no such bias was exhibited by the 2012 juvenile cohort electrocuted in the same year, nor by juveniles from the 2013 cohort electrocuted at other power lines of identical configuration. We suggest the most likely explanation is that the sex ratio of the 2013 cohort of juveniles in the vicinity of the line was female-biased, either as a consequence of female-biased nestling production or sex differences in post-fledging dispersal and settlement behavior. With regard to the former, no bias was previously detected in nestling sex ratios of Mongolian Saker Falcons (Rahman et al. 2014), and population sex ratios of nestlings in each year from 2012 to 2015 did not significantly deviate from parity at a central Mongolian study area (A. Dixon unpubl. data). As sex bias was not initially exhibited among 1cy juveniles electrocuted in July, sex-bias resulting from sex differences in regional movements seems the most likely explanation. Either juvenile males of the 2013 cohort were more likely to emigrate from the region or juvenile females were more likely to immigrate to the region. In areas of high prey availability, where large numbers of Saker Falcons congregate, intraspecific competition may favor larger females, causing males to move to alternative post-dispersal settlement areas. The persistence of this biased sex ratio among 2cy juveniles of the 2013 cohort may reflect regional philopatry to post-dispersal settlement areas by juveniles returning from wintering areas the following spring.

At the Uulbayan-Munkhkhaan line in 2013 and 2014, more adult males than females were electrocuted, but the difference was not significant, possibly due to small sample size. We suggest that electrocution rates reflect the proportion of males and females in the adult Saker Falcon population. Breeding turnover, as a proxy of survival, was higher for females than males in our study population in two consecutive years (2011–2012, 2012–2013; Hou et al. 2018), which is consistent with the possibility that the adult population is male-biased. We do not know the breeding status of most of the adults that were electrocuted, but if the sex ratio actually differs, such difference might result because the local adult nonbreeding population was male-biased or because some behavioral characteristic of adult males made electrocution more likely, e.g., adult males may range more widely than females, increasing the likelihood of them encountering dangerous power lines. This latter seems likely during part of the breeding season, when males are more likely to hunt while their mates incubate or attend young. However, this potential explanation is inconsistent with lower turnover for breeding males (Hou et al. 2018) and assumes that most electrocuted adults are breeding birds.

Potential Demographic Effect of Electrocution. Our electrocution data suggests that the adult Saker Falcon population might be male-biased, although that needs further study. In addition, our observation of banded birds showed breeding females are significantly younger than males, which is consistent with the hypothesis that females are the limiting sex in the adult population; in our study population occupying artificial nests, the availability of nest sites was not a limiting factor preventing breeding by younger males. The coincidence of power lines and prey availability can result in high rates of juvenile electrocution due to their propensity to congregate in temporary settlement areas following post-fledging dispersal. The demographics of the electrocuted birds likely reflects the demographic composition of the local Saker Falcon population, which can vary in time and space, resulting in situations where electrocution of juvenile females can significantly exceed that of juvenile males. This female bias in electrocution may be related to intraspecific competition in temporary settlement areas, where larger females displace males. The key question is whether the female-biased juvenile electrocution causes a male-biased adult sex ratio in the Mongolian Saker Falcon population.

The size and distribution of the Saker Falcon breeding population in Mongolia is limited by nest-site availability, as demonstrated by the experimental provision of artificial nests (Rahman et al. 2016). Consequently, the adult population comprises both breeding and nonbreeding birds of both sexes, with the nonbreeding component perhaps exhibiting the demographic male-bias. The nonbreeding component of the adult population has an important role in buffering potential effects of environmental stochasticity, with factors affecting survival of non-breeders influencing overall population dynamics and population persistence (Penteriani et al. 2005). Knowledge of demographic variation in electrocution rates is important for conservation managers to assess the potential effect of electrocution on the survival of threatened populations. Saker Falcons on the Mongolian and Tibetan plateaus are impacted by electrocution (Dixon et al. 2013), which potentially threatens their long-term persistence. Effective mitigation measures need to be implemented to reduce electrocution mortality and retain the demographic integrity of these globally important breeding populations.

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