Effects of the Russian-Kazakh frontier zone: Increased mortality of red-listed diurnal birds of prey on overhead power lines in the Orenburg Region frontier steppe

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Abstract. The report focuses on rare diurnal birds of prey killed by electrocution on 6–10 kV hazardous overhead power lines in the Orenburg Region steppe, located in the extreme southeastern European part of the Russian Federation, on the border with Kazakhstan. Field surveys of power lines over a ten-year period indicated that 94% of rare diurnal birds of prey (steppe eagle, imperial eagle, long-legged buzzard, lesser kestrel, red-footed falcon) killed in the study area died from electrocution within a 50-km wide Russian-Kazakh frontier zone. Within that frontier area, 75% of birds died in a 25-km wide band. Statistically significant differences were found in the average values for dead birds in the distance ranges of 0–25 km, 25–50 km and >50 km from the Russian-Kazakh border. The total number of killed birds also differed significantly among the marginal distance groups of 0–25 km and >50 km. It is assumed that the increased concentration of birds of prey in the frontier zone is associated with better feeding conditions and reduced anthropogenic load, compared to other more developed and transformed areas in agricultural and technogenic terms. Complete insulation of power lines within at least the 25-km frontier zone would significantly reduce mortality of red-listed diurnal raptors on overhead power lines in the region.

1. Introduction

The electrocution death of birds, including diurnal raptors, on power lines, is a globally recognized problem that has generated significant attention in recent years [1, 2, 3, 4]. During long-term survey work to identify the most bird-hazardous overhead power lines in the Orenburg Region, a clear pattern was found. Distribution of dead red-listed diurnal birds of prey across the area was not random, but had a rather clear link to the Russian-Kazakh border.

It is mainly the following rare species of diurnal birds of prey that die due to electrocution on overhead power lines in the Orenburg area: long-legged buzzard *Buteo rufinus* (categorized Rare in the Red Data Book of the Russian Federation) [5], imperial eagle *Aquila heliaca* (categorized Vulnerable in the IUCN Red List of Threatened Species) [6], steppe eagle *Aquila nipalensis* (categorized Endangered in the IUCN Red List of Threatened Species) [7], red-footed falcon *Falco vespertinus* (categorized Near Threatened in the IUCN Red List of Threatened Species) [8] and lesser kestrel *Falco naumanni* (categorized Endangered in the Red Data Book of the Russian Federation) [5].

This report describes the phenomenon of increased mortality of birds of prey in the frontier zone and its possible causes. In addition, the data gathered allow the proposal of measures to effectively reduce rare diurnal raptor mortality in the Orenburg Region.
2. Materials and Methods

2.1. Study Area
The Orenburg Region (124,000 km²) is located on the southeastern edge of European Russia, at the junction of Europe and Asia. The region stretches 750 km from west to east, and the extreme southern and northern edges are 435 km apart. In the north, the Orenburg Region borders with Russian Tatarstan, Bashkortostan, and Chelyabinsk Region, in the west with Samara and Saratov Regions, and in the east and south with the Republic of Kazakhstan. The region’s boundaries are quite jagged and almost never form straight lines. The international border with Kazakhstan is 1,876 km in length here [9].

The Orenburg Region’s climate is characterized by pronounced continentality and aridity in general. Average July temperatures are between +19 and +22°C, while average January temperatures range from −14 to −17°C. Average annual precipitation ranges from less than 200 mm per year in the south and southeast to more than 450 mm per year in the north and northwest [10].

The Orenburg Region is situated mainly within steppe ecosystems, and only the northern and northwestern parts of the region contain forest-steppe. Depending on moisture content, the steppe zone can be divided into northern steppe (herb-bunchgrass plant communities on ordinary chernozem soils), typical steppe (fescue-feathergrass communities on southern chernozem soils), and southern steppe (sagebrush-grass communities on dark chestnut soils) types [10].

2.2. Materials
The data for this study were largely collected between 2010 and 2020 in 16 administrative districts, within the Orenburg Region’s steppe zone.

The first phase of work was quite intensive (2010–2012) and was associated with implementation of the UNDP/GEF project “Improving the Coverage and Management Efficiency of Protected Areas in the Steppe Biome of Russia.” During this phase, 10 administrative districts directly bordering Kazakhstan in the region’s southwest, south, southeast, east, and northeast were surveyed in detail, and the majority of electrocuted red-listed diurnal birds-of-prey were documented [11, 12, 13, 14]. All 6–10 kV overhead power lines are owned by the region’s main state network operator OAO MRSK Volga–Orenburgenergo. The operator’s power grid evenly covers the entire Orenburg Region.

During the second phase (2013–2020), data on bird mortality on overhead power lines were accumulated less systematically and in conjunction with other research work, but it is important that they were collected mostly in 6 central, non-border steppe and 4 northwestern forest-steppe administrative districts in Orenburg Region that had not been previously visited. During this phase, only one red-listed casualty was recorded: in 2020, a red-footed falcon was found under a power line owned by an oil and gas operator, once again near the Russian-Kazakh border in the region’s south.

At the time of the 2010–2012 survey work, all overhead power lines were hazardous for birds, and the situation changed little in subsequent years. Today, some oil and gas operators have started equipping their power lines with bird-protective devices in the northwestern forest-steppe and in some central agricultural and oil and gas districts in the region, but these lines represent only a very small percentage of the total volume of bird-hazardous linear objects in the region.

A GIS map representing the locations of fatally electrocuted red-listed diurnal birds of prey was compiled on the basis of all survey data. Thus, the study area in a narrower sense included 16 steppe administrative districts, surveyed with the same intensity up to a depth of 150–200 km from the Kazakh border (figure 1).
2.3. Methods
Surveying to detect bird-hazardous (6–10 kV) power lines took place seasonally, in summer and fall. In 2011 and 2012, the operator OAO MRSK Volga–Orenburgenergo provided district power line schematic maps. For each power line, 2–6 km segments were selectively surveyed, geolocation coordinates were recorded using GPS navigators, and then points were plotted on the map in the GIS environment. This method was used (mostly foot surveys) to examine 350 km of lines in 16 key administrative districts containing steppe in the region (figure 1) and at least an additional 20 km in 4 forest-steppe ecosystem districts in the region’s northwest for an overall assessment of the situation.

Each dead bird was identified by species, and in cases where it was difficult to make a determination, eagle carcasses were labeled “Genus Aquila” (imperial eagle, steppe eagle). Since the quantity of dead birds did not follow a normal distribution, nonparametric methods were used in the statistical analysis: Friedman test for comparing multiple dependent groups and Wilcoxon test for two related samples. The analysis was performed using STATISTICA 10 software.

3. Results
During the entire survey period that took place 2010–2020, the remains of 65 individuals of 5 red-listed species of diurnal birds of prey were found. Only 4 of the total number of carcasses (6%) were located at a distance greater than 50 km from the Russian-Kazakh border, while 12 (19%) occurred at a distance of 25–50 km, and 49 (75%) at a distance of 0–25 km from the border (table 1). Interestingly, those few birds from the first group (>50 km) were also found near the 50-km line, namely, 50–60 km from the border. Despite the ongoing intensive survey of power lines deep into the Orenburg Region, no bird carcasses were found more than 60 km from the border.

The total number of dead birds in the 0–25 km, 25–50 km and >50 km groups differed significantly from their average band values (Friedman test: $\chi^2=8.67, df=2, p=0.01, N=6$) (figure 2). The number of red-listed diurnal raptors killed by electrocution on overhead power lines increased as the distance to the border with Kazakhstan decreased (figure 3). The total number of birds killed also differed significantly between the marginal distance groups of 0–25 km and >50 km (Wilcoxon test: $Z=2.20, p=0.03, N=6$).
4. Discussion
The frontier zone attracts birds of prey for the following reasons.

1. Decrease in forest cover on average from about 18% (of total land area) in the north-west to 2% in the border south-east and south districts of the region [15]. Observations indicate that bird mortality on overhead power lines in wooded areas both in steppe and in forest-steppe areas is generally atypical for the Orenburg Region. All birds died from electrocution in open steppe landscapes or on open sections of lines crossing forest-steppe landscapes.

2. Reduction of anthropogenic load and minimal disturbances in the frontier zone.
Against the backdrop of a decline in the Orenburg Region’s population that began in 1990–2005 and continues to this day [15], both sides of the border have a very low rural population density. According to the 2002 and 2010 population censuses in the Orenburg Region and in 1999 and 2009 in the Republic of Kazakhstan, rural population density begins to increase 20 kilometers from the border [16]. In addition, a special access regime was introduced in the Orenburg Region’s border area in the late 1990s, limiting access to the frontier zone (border patrols, entry and vehicle access permits, blocking travel on roads crossing into Kazakhstan, and the establishment of special border checkpoints).

As a result of the population decline in border districts since 1990–2005, these areas face partial or complete degradation of rural settlements, abandonment of cultivated lands (also influenced by increasing drought conditions), and increased distribution of fallow lands and rangeland in recovering steppe areas. According to some estimates, the Orenburg Region possesses 300,000–400,000 hectares of these abandoned and fallow lands, half of which are situated in the region’s border areas [17].

3. Better forage resources on rangeland and fallow lands along the border. Plentiful rodents and locusts, especially on rangeland, clearly attracted diurnal birds of prey to these areas. All discoveries of dead steppe eagles and imperial eagles were confined to pastures with disturbed vegetation cover. Eagles, buzzards and small falcons use power poles as convenient perches for tracking prey. Thus, for birds in the frontier zone, the most dangerous power lines are those segments that cross areas with a high concentration of livestock (near summer livestock camps and routes used regularly to move livestock with damaged grass cover).

Thus, the Orenburg Region has contrasting landscapes, where northwestern and central districts are agricultural lands mixed with oil and gas infrastructure, and border areas where biological diversity is recovering. In addition to this report, other publications illustrate these differences. For example, multi-year population surveys show that average abundance of Siberian roe deer (Capreolus pygargus) and European hare (Lepus europaeus) and the variance of steppe marmot (Marmota bobak) population were significantly higher in the lightly transformed southern border area than in the heavily transformed technogenic west and northwest Orenburg Region [18].

Analysis of the distribution of electrocuted diurnal raptors mainly along the Russian-Kazakh border is consistent with other researchers’ data. For example, in October 2014, at least 3 of 4 imperial eagles (the exact location of the fourth bird was unknown) killed by electrocution in the Orenburg Region were found 28–35 km from the border with Kazakhstan, in the south of the region [19].

In conclusion, measures may be proposed to reduce electrocution mortality of red-listed diurnal birds of prey in the region. One option is prioritizing isolation of sections of 6–10 kV power lines in places where livestock are concentrated within the 25-kilometer frontier zone, followed by phased retrofitting (equipping with bird-protective devices) of all lines in the 50–60 km-wide frontier zone.

This work is intended to draw attention to bird mortality in transborder areas; the problem may be relevant for all southern steppe border regions in the Russian Federation.

5. Conclusion
Long-term data indicates that 94% of red-listed diurnal birds of prey (steppe eagle, imperial eagle, long-legged buzzard, lesser kestrel, and red-footed falcon) in the study area die from electrocution on overhead power lines in the Orenburg Region within a relatively narrow 50-km border zone with the Republic of Kazakhstan. It is suggested that more attractive feeding conditions have arisen on rangeland and fallow lands along the border where anthropogenic load is reduced and manifests in the form of low human population density and minimal human disturbance. Complete insulation of 6–10 kV overhead power lines within this 50-kilometer zone would significantly reduce mortality of diurnal raptors in the region.

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