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Effectiveness of Spiral Diverters in Preventing Asian Houbara Power Line Collisions in Abbas Abad Wildlife Refuge, Iran

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ABSTRACT

Aims: Bird collisions with power lines threaten large birds, particularly bustards (Otididae), including the Asian Houbara (*Chlamydotis macqueenii*). This study evaluates the effectiveness of spiral diverters in reducing these collisions at Abbas Abad Wildlife Refuge, Iran, aiming to develop effective mitigation strategies for vulnerable large bird species in high-risk areas.
Materials & Methods: Field observations and stakeholder reports were systematically collected one year before and one year after installing spiral diverters along a 21-kilometer stretch of power lines. Kernel Density Estimation (KDE) identified a 7-kilometer segment as a hotspot for collisions, where 450 spiral diverters were installed.
Findings: After installing the spiral diverters, no collisions were recorded the following year.
Conclusion: The study demonstrates that spiral diverters effectively mitigate collisions for large birds, specifically the Asian Houbara. Future research should focus on long-term monitoring to assess the sustained impact of spiral diverters and explore their effectiveness for other large bird species at risk from power line collisions.

Keywords: Bird Collisions; *Chlamydotis macqueenii*; Spiral Diverters; Power Line.

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Introduction

Power line collisions significantly impact the populations of large birds [1], particularly species such as cranes and bustards [2]. These birds are vulnerable to such threats due to their tendency to fly at low altitudes during migration or while foraging [3]. Collisions with power lines can result in high mortality rates, endangering species facing conservation challenges [4]. The Asian Houbara (*Chlamydotis macqueenii*), also known as MacQueen's bustard, is vulnerable due to habitat loss, hunting pressure, and other human-induced threats [5].

Various methods have been developed to reduce bird collisions with power lines [6], particularly in areas where large species like bustards are at risk [7]. These methods include installing devices such as spirals, markers, and flappers, which increase the visibility of power lines and help birds detect and avoid them during flight [8]. Spiral diverters, in particular, have been widely studied and implemented as practical tools to reduce bird collisions with power lines, especially for large, vulnerable species. These devices increase line visibility, aiding birds in detecting and avoiding power lines, which is crucial for species that fly at low altitudes or during low-light conditions [8]. Studies have shown that spiral diverters are particularly effective for large birds like bustards, cranes, and raptors, which are at higher risk of collisions due to their flight behaviors and poor maneuverability near obstacles [6]. For example, Ferrer et al. [9]. found that spiral diverters significantly reduced bird mortality among several large species by creating a visual barrier that deters flight into power lines. Alonso et al. [10] also reported success using marked lines, including spirals, to mitigate collisions in high-risk areas frequented by large birds. Moreover, Jenkins et al. [8] highlighted that spiral diverters offer a long-lasting, durable solution in regions where extreme weather conditions might affect other collision prevention devices.

While numerous studies have focused on the impact of power line collisions on large birds globally, limited research has been directed specifically toward the Asian Houbara (*Chlamydotis macqueenii*) and its unique vulnerabilities in this context. Unlike other large birds, the Asian Houbara faces specific challenges due to its desert habitat, which is increasingly intersected by infrastructure like power lines as human development expands into remote areas. Additionally, the Asian Houbara's low-altitude flight patterns during migration and foraging place it at a heightened risk of collision. Although spiral diverters have shown success in other regions and with other species, few studies have assessed their efficacy specifically for the Asian Houbara in Iran's desert and semi-desert ecosystems. This study aims to address this gap by evaluating the effectiveness of spiral diverters in reducing collision rates among Asian Houbaras in the Abbas Abad Wildlife Refuge, providing critical insights for species-specific conservation strategies. Iran is a crucial region for conserving Asian Houbara, hosting significant populations in its desert and semi-desert habitats [11]. As these areas are increasingly intersected by infrastructure like power lines, the risk of collisions has become a critical issue for the survival of the Asian Houbara in Iran.

This study addresses two critical research gaps: the scarcity of studies on the Asian Houbara's vulnerability to power line collisions in Iran and the limited research on spiral diverters as a mitigation strategy for large birds in the region. We hypothesize that installing spiral diverters will significantly reduce Asian Houbara (*Chlamydotis macqueenii*) collision rates with power lines in the Abbas Abad Wildlife Refuge. By implementing these diverters along high-risk

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segments identified through Kernel Density Estimation (KDE), this study assesses the effectiveness of this intervention in reducing collision risks for this vulnerable species.

Materials & Methods

Study Area

The Abbas Abad Wildlife Refuge (AWR) occupies an area of 3054 km^2 and is located in the central Iranian plateau (33°11’45’’N to 33°38’15’’N; 54°20’30’’E to 55°08’25’’E). Officially protected since 2005, the area was upgraded to a wildlife refuge in 2008. The landscape is dominated by a central mountain range that spans 110 km in length and 23 km in width, surrounded by hills and plateaus. Elevation varies from 620 m at the southern boundary to 2400 m at its central peak, with an average elevation of 1045 m [11].

The power line selected for this project spans 21 km, starting at 33°35’5.34 “N 54°17’29.61 “E and ending at 33°35’44.54 “N 54°4’5.29 “E.

Due to the presence of barley fields in 8 km of 21 km adjacent to the power line, the area attracts Asian Houbara, which forage in these fields and are consequently at greater risk of collisions along the line. Observations showed that 7 of the 9 recorded collisions before intervention occurred within this high-traffic area, establishing it as a focal point for mitigation efforts.

Anti-Collision Spirals

Spiral diverters were selected over alternatives like flappers and marker balls due to their effectiveness for large birds and stability in harsh environmental conditions. They also aligned well with budgetary limitations, offering a cost-effective solution. The anti-collision spirals used in this project

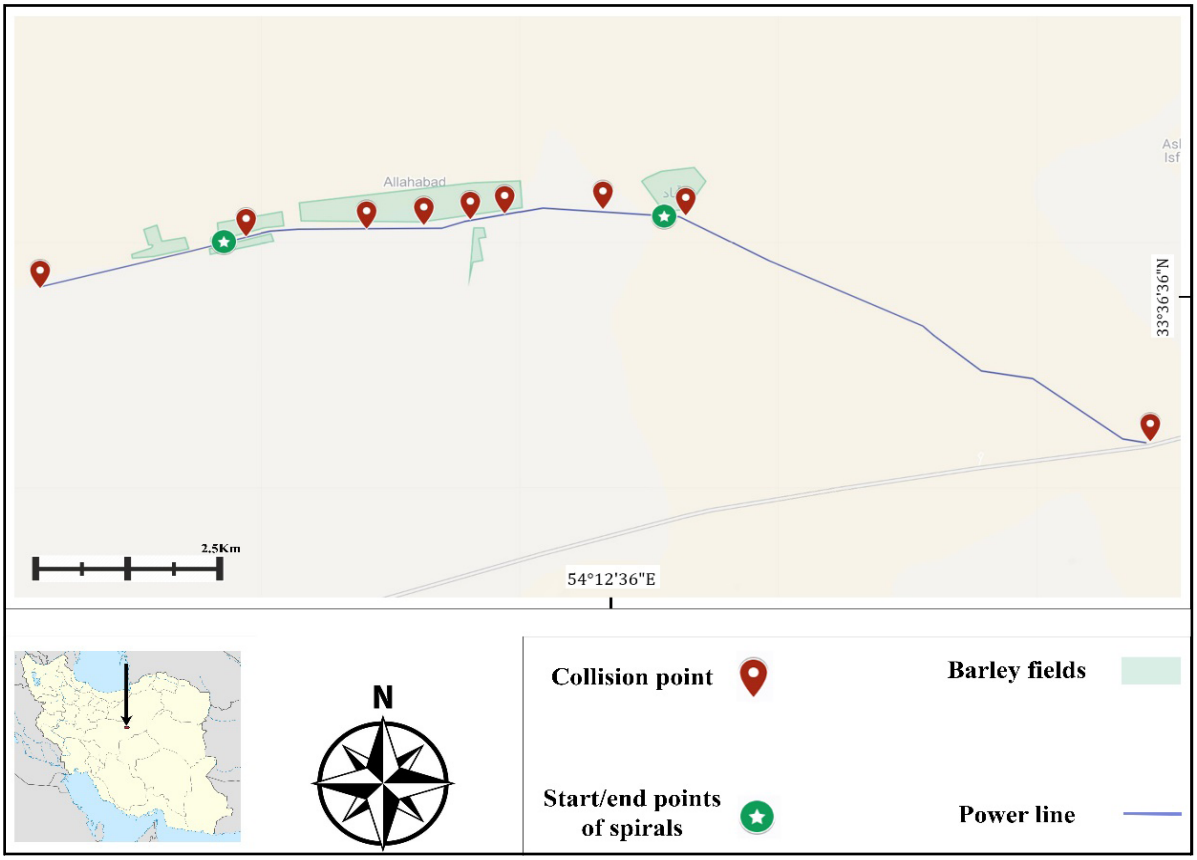

Figure 1) Map of the study area showing collision points, barley fields, power lines, and locations of spiral diverter installation in Abbas Abad Wildlife Refuge.

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were made from UV-resistant plastic and came in two pronounced colors: orange and yellow. These spirals, approximately 30 cm in diameter, were designed to increase the visibility of the power lines, making them more detectable for birds like the Asian Houbara, which often flies at low altitudes. The alternating colors enhanced contrast against the sky, improving the deterrence effect for birds in flight. The materials were chosen for their durability in withstanding the extreme environmental conditions typical of the Abbas Abad Wildlife Refuge, including high temperatures and intense UV exposure.

In total, 450 spirals were installed along 7 km of power lines. Six spirals were placed between each electric pole, with the poles spaced approximately 40 m apart. This arrangement ensured comprehensive coverage of the most critical sections of the power lines. Workers installed hydraulic lifts to attach the spirals securely to the lines, as illustrated in the accompanying images. The strategic placement of these spirals was intended to mitigate the risk of bird collisions by creating a more visible barrier that would prevent the birds from flying into the power lines.

Field Observations

Rangers participated in a one-day field workshop where they were trained in standardized protocols for identifying bird collisions, including recognizing physical signs such as feathers, injuries, or remains near power lines. They were provided with two dedicated contact numbers to report any observed collisions or signs of impact immediately. Rangers conducted bi-weekly inspections of the power lines one year before and one year after installing the anti-collision spirals, documenting any observed bird collisions and focusing on the Asian Houbara. Additionally, local community members and conservationists were informed of the project and encouraged to report any bird collisions they witnessed. Rangers verified any reports from stakeholders through on-site visits to confirm collision evidence. This collaborative approach ensured thorough

Figure 2) An Asian Houbara found dead after colliding with a power line in the Abbas Abad Wildlife Refuge (Photo: Mr. Mehdi Jalalpour).

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and consistent data collection throughout the two-year monitoring period.

High-Risk Area Identification and Expansion

A total of 9 collision points were reported in the year before the intervention. We conducted a Kernel Density Estimation (KDE) analysis with an adaptive bandwidth to prioritize the sections of the power lines with the highest collision risk. This approach allowed us to accurately capture variations in collision density along the power line, identifying a 4.5 km segment as the area with the highest concentration of collisions. To statistically confirm the significance of this clustering, a chi-square test was performed, comparing the observed collision frequency within the identified high-density segment to the expected frequency if collisions were evenly distributed across the 21 km line. The chi-square test indicated that the collision density within this segment was significantly higher ($p < 0.05$). However, the KDE analysis highlighted this critical segment; the project budget allowed for 7 km of spiral installation. Therefore, we extended the installation by adding similar lengths to both ends of the identified high-risk segment, ensuring broader protection across the power lines."

Findings

In the year before the installation of the anti-collision spirals, nine collisions involving Asian Houbaras were recorded along the power line. These collisions were primarily concentrated near the barley fields that attract the bustards, with three incidents reported by rangers during their bi-weekly inspections and six reported by local stakeholders, including farmers and community members. This pattern underscored the high-risk nature of this area for Asian Houbara collisions.

Following the installation of the spirals, no collisions involving Asian Houbaras were reported during the subsequent year. This reduction was verified through bi-weekly ranger inspections and corroborated by a lack of reports from local stakeholders. To confirm the significance of this decrease in collisions, we conducted a chi-square test comparing the collision frequency before and after the intervention. The test results showed a significant reduction in collisions ($\chi^2 = 9.0$, $p < 0.05$), indicating that installing the spiral diverters statistically impacted reducing collisions.

Additionally, as both rangers and local stakeholders noted, no significant population fluctuations of the Asian Houbara were reported during the study period. This stability in the population suggests that the observed decrease in collisions was not due to a reduction in the number of birds but was likely a result of the effectiveness of the installed diverters.

Discussion

The observed reduction in Asian Houbara

Figure 3) Installation of anti-collision spirals on power lines in the Abbas Abad Wildlife Refuge.

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collisions following the installation of spiral diverters aligns with findings from other studies on collision mitigation for large bird species. Similar interventions using diverters have been effective for cranes, raptors, and other vulnerable species, which, like bustards, are prone to power line collisions due to their low-altitude flight and limited maneuverability. Barrientos et al. [12] and Bernardino et al. [7] demonstrated that diverters, including spirals, significantly reduced bird mortality by improving power line visibility across various species. Specifically, Ferrer et al. [9]. found that spiral diverters reduced collisions among large bird species by creating visual barriers that birds could detect more readily, a finding echoed by Jenkins et al. [8]. in their study on collision prevention for large birds in South Africa. However, some studies suggest that not all species respond equally to diverters; for example, Bernardino et al. [7] reported that bustards with a narrow field of forward vision may be less responsive to specific mitigation devices. These results emphasize the need for species-specific approaches, and the success observed in this study highlights the potential of using brightly colored spiral diverters, particularly in high-risk foraging areas, to mitigate collision risks for bustards. The reduction in collisions observed that additional confounding factors beyond installing spiral diverters may have influenced post-intervention. Seasonal variations in food availability, weather conditions, and changes in bird migration patterns could all affect the presence and behavior of the Asian Houbara in the study area. For instance, fluctuations in rainfall could impact the density of barley fields and other vegetation, thereby altering foraging patterns and reducing collision risks if fewer birds are drawn to the area [6]. Weather conditions, including wind speed and visibility, also affect collision likelihood, as poor weather can impair birds' ability to avoid power lines [7]. Additionally, bustards, including the Asian Houbara, exhibit irruptive behavior in response to food and water availability, which may lead to seasonal population changes near the power lines [2]. Although we did not observe substantial population shifts during the study, these factors highlight the complexity of collision dynamics and underscore the importance of monitoring environmental conditions in future studies to isolate the effectiveness of spiral diverters.

The effectiveness of the spiral diverters in reducing collisions among Asian Houbaras may be attributed to several key factors, particularly color contrast and bird flight behavior. Unlike standard white spirals used in other regions, the colored spirals employed in this study (orange and yellow) may have provided a higher visual contrast against the sky, increasing bird visibility. Research has shown that high-contrast markers can more effectively prevent collisions, making them easier for birds to detect in various lighting conditions [12]. Additionally, bustards are known to have limited forward vision, a factor that has historically complicated collision prevention for this group [7]. By enhancing the visibility of the power lines in a high-risk foraging area, the colored spirals appear to have mitigated the likelihood of collisions, possibly because birds could perceive and avoid the obstacles with greater ease. The use of color may be a critical factor in future studies aimed at improving diverter effectiveness, particularly for species with restricted fields of vision.

Spiral diverters also offer a cost-effective approach to reducing bird collisions, particularly compared to mitigation options like marker balls or flappers. Spiral diverters are relatively inexpensive to manufacture and install, requiring minimal specialized equipment and lower maintenance costs

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over time, making them viable for large-scale power-lines applications in areas with limited conservation funding [7]. In addition to lower upfront costs, spiral diverters are durable, withstand harsh environmental conditions like those in the Abbas Abad Wildlife Refuge, and maintain visibility without frequent replacement. Given the reduced installation and upkeep costs and the significant reduction in collisions observed in this study, spiral diverters may offer a high cost-benefit ratio, particularly in high-risk zones for large birds such as bustards and cranes. Conservation efforts could benefit from further analysis comparing spiral diverters' long-term costs and benefits to other markers, which may help optimize resource allocation in collision mitigation strategies.

Despite the positive outcomes, the study had several limitations. The one-year post-installation monitoring period may not fully capture long-term trends or potential future collisions, necessitating a longer observation timeframe to confirm the sustained effectiveness of spiral diverters. The findings primarily apply to the 7-kilometer segment of the power line that intersects barley fields, where a high concentration of Asian Houbara collisions were initially observed. This geographical scope limits the generalizability of the results to other parts of the power line or different power lines in varying habitats. Moreover, the absence of a control area along the same power line means we cannot conclusively rule out that changes in bird behavior or environmental conditions did not contribute to the observed reduction in collisions. Additionally, our reliance on reports from local stakeholders for collision data introduces potential reporting bias. Although rangers verified each reported incident, the potential for unreported collisions remains. Future research should focus on long-term monitoring across broader areas and incorporate systematic data collection methods to reduce bias and enhance the reliability of findings.

Conclusion

Installing spiral bird diverters significantly reduced Asian Houbara collisions with power lines in the Abbas Abad Wildlife Refuge, with no collisions reported post-intervention. This study highlights the potential of high-contrast spiral diverters as an effective mitigation strategy for large birds in high-risk areas and underscores the importance of species-specific interventions. To confirm the persistence of these positive outcomes, long-term monitoring is recommended to evaluate whether the reduction in collisions holds across varying environmental conditions and bird activity cycles. We encourage policymakers and conservation practitioners to consider spiral diverters in other regions facing similar risks, and future research should test additional deterrent designs as well as study impacts on diverse bird species. Continued exploration of cost-effective and scalable solutions is essential for advancing bird conservation efforts globally.

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