OPEN ACCESS

COMMENTARY

The Innovation Geoscience

Rapid development of wind energy infrastructure threatens bird migration

Xinmin Zhang,[1,*] Wenqiang Wan,[1] Hong Yang,[2] and Kunpeng Yi[3]

[1]School of Digital Economics, Jiangxi University of Finance and Economics, Nanchang 330013, China

[2]Department of Geography and Environmental Science, University of Reading, Reading RG6 6AB, UK

[3]State Key Laboratory of Urban and Regional Ecology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China

*Correspondence: zhangxm1217@aliyun.com

Received: September 29, 2024; Accepted: March 24, 2025; Published Online: May 6, 2025; https://doi.org/10.59717/j.xinn-geo.2025.100142

Citation: Zhang X., Wan W., Yang H., et al. (2025). Rapid development of wind energy infrastructure threatens bird migration. *The Innovation Geoscience* **3**:100142.

GLOBAL CLIMATE CHANGE AND ENERGY TRANSITION IN CHINA

Global climate change, which has been driven by anthropogenic activities, especially the burning of fossil fuels, has elevated the levels of heat-trapping greenhouse gases in the atmosphere and increased the Earth's surface temperature (Figure 1). Based on the *CO_2 Emissions in 2023* (https://www.iea.org/reports/co2-emissions-in-2023), global energy-related CO_2 emissions reached a record level of 37.4 billion tonnes, which was 1.1% greater than that in 2022. The substantial emissions of greenhouse gases have greatly altered global temperatures and precipitation patterns, leading to multiple issues, such as extreme weather events and environmental degradation, which further threaten global biodiversity. As the largest developing country, China accounted for 18% of the global population and was responsible for 34% of global CO_2 emissions in 2023 (https://www.iea.org/reports/co2-emissions-in-2023). To further enhance its nationally determined contributions, China set the dual goals of reaching its carbon peak by 2030 and achieving carbon neutrality by 2060.

By June 2023, China's installed renewable energy capacity exceeded 1.3 billion KW, marking a historic milestone as it surpassed coal-fire power capacity. Among the multiple types of renewable energy installations, wind energy installations accounted for 389 million KW, placing China first globally in renewable energy production from 2010 to 2023 (https://www.gov.cn/yaowen/liebiao/202308/content_6899173.htm), marking a new phase in China's energy transition. According to the *China Renewable Energy Development Report 2023*, wind energy became China's third-largest source of electricity (http://www.creei.cn/web/content.html?id=6460) and accounted for approximately 66% of the new wind capacity globally, with a total installed capacity equal to that of North America and Europe combined (https://www.iea.org/data-and-statistics/data-tools/renewable-energy-progress-tracker). Thus, wind energy development will be an important driving force for China's energy transition in the future.

Poyang Lake, the largest freshwater lake in China and only member of the "World Living Lakes Network", is the most important inland wintering site for migratory birds on the East Asian-Australasian Flyway (EAAF). The vast wetland resources of Poyang Lake provide abundant resources and habitats for overwintering migratory birds. Poyang Lake is narrow in the north and wide in the south, resembling the shape of a wine bottle. Its strong land-lake wind contributes to it being one of the regions with the most abundant wind energy resources in Central China. From November to March, approximately 700,000 migratory birds from higher-latitude breeding sites reach Poyang Lake. These birds include more than 98% of the global population of *Leucogeranus leucogeranus*, exceeding 80% of that of *Ciconia boyciana*, above 70% of that of *Grus vipio*, and over 60% of that of *Anser cygnoides*. Among these species, 4 are listed by the International Union for Conservation of Nature as critically endangered species, 7 as endangered species, and 22 as vulnerable species (https://phzy.jxnews.com.cn/system/2024/03/14/020430948.shtml).

Although the potential negative effects of onshore wind farms on migratory birds in coastal wetlands have attracted extensive attention along the EAAF in China,[1] the similar studies on inland wetlands concerning bird migration have received less attention. The narrow waterway connecting Poyang Lake to the Yangtze River in the north and the surrounding mountainous areas provides the necessary passage for migratory birds during their wintering period. Currently, with the acceleration of the energy transition, nine wind farms with a combined power generation capacity of 30–96 MW and a total of 252 wind turbines have been concentrated primarily in the "bottleneck" area of Poyang Lake (Figure 1). These wind turbines pose a severe threat to migratory birds flying from high-latitude breeding grounds, such as those in Northeastern China and the Siberian wilderness.

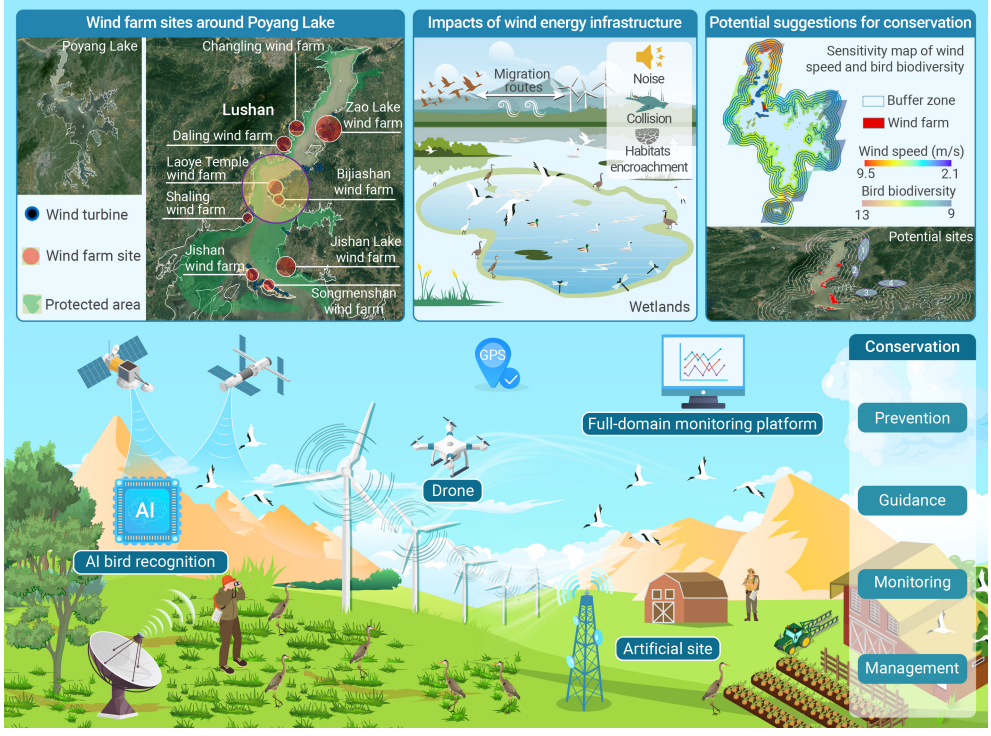

Figure 1. Wind energy infrastructure threatens bird migration around Poyang Lake.

IMPACTS OF WIND ENERGY INFRASTRUCTURE ON POYANG LAKE

Located on the eastern bank of Poyang Lake, the water area of Laoye Temple is known as the Bermuda of China. Lushan Mountain compresses and accelerates the cold air in this area. Influenced by the narrow and long channel of the northern part of Poyang Lake, the wind force can peak at level 16, and the annual average wind speed can reach 7 m/s when passing through the Laoye Temple water area (Figure 1). These elements support the construction of the Laoye Temple wind farm. When the wind farm is completed, a wake effect will be generated, leading to a reduction in the wind speed in downwind regions, and the rotation of the wind turbines

will accelerate the evaporation of surface water. Moreover, a 15-year study monitoring Northern China revealed that wind farms reduced the mean annual wind speed from 3.52 m/s before construction to 3.02 m/s after construction and increased the annual evapotranspiration from 34 mm to 95 mm.[2] As wind speeds weaken and with the presence of large wetland areas, the moist underlying surface will eventually cause surface temperatures to rise. When the atmospheric environment is changed by a wind farm, the energy and material exchanges between the land surface and the atmosphere are affected, which indirectly change the precipitation and cloud cover.

Globally important protected areas and wind energy facilities overlap in approximately 543 locations, which is greater than the number of overlaps between protected areas and photovoltaic power facilities.[3]Currently, Poyang Lake has established a relatively comprehensive system of nature reserves consisting of 11 protected areas. These protected areas are primarily distributed along the lakeshore and mainly protect rare and endangered migratory birds and wetland ecosystems. Wetlands provide crucial habitats for migratory birds and play a key role in the Poyang Lake ecosystem. However, due to the influences of topography and lake morphology, the wind energy closer to the lake is more abundant. Consequently, the lakeshore of the "bottleneck" area of Poyang Lake has become the site selected for wind farm construction (Figure 1). Nine large wind farms have been built, but some have already overlapped with certain protected areas, such as the Jishan Lake wind farm, which partially overlaps with the Duchang Jishan Lake Wetland. Once wind farms are constructed within protected areas, they alter the surface vegetation and soil composition, disrupt the habitats of benthic organisms, and potentially lead to the extinction of these organisms within these regions.[2] Furthermore, wind turbines can produce noise pollution, reducing the spatial activity range of flying species and even affecting the numbers of these species.

WIND ENERGY INFRASTRUCTURE THREATENS MIGRATORY BIRD SECURITY

Wind energy facilities have a greater impact on flying species than on other species, and wind turbines threaten certain bird and migratory bird populations (Figure 1). Species deaths caused by collisions with turbine blades or towers are direct impacts, whereas the construction and operation of wind energy facilities can lead to the displacement of habitats, resulting in indirect impacts. Currently, the wind turbines at Poyang Lake threaten the security of migratory birds. According to the latest research,[4] each standard-deviation increase in China's onshore wind turbines leads to a 9.75% decrease in bird abundance. Although this loss is much smaller than that caused by other anthropogenic activities, for the migratory birds at Poyang Lake, such as *Leucogeranus leucogeranus*, which are among the threatened species, the death of any threatened species poses a significant loss to the Earth's biodiversity. We further identified threatened birds affected by wind farms around Poyang Lake based on data from Bird International (https://datazone.birdlife.org/species/requestdis). A total of 17 bird species are threatened by wind turbines, including 2 critically endangered, 5 endangered, and 10 vulnerable species. Although the impacts of the wind turbines at Poyang Lake on the species richness of migratory birds are uncertain, research has shown that each standard-deviation increase in China's onshore wind turbines reduces bird species richness at the county level by 12.2%.[4] This result corroborates the potential threat of Poyang Lake's wind turbines to the security of migratory birds, as evidenced by collected data showing that in December 2021, a *Ciconia boyciana* monitored by the Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, died after colliding with a wind turbine at its wintering site in Poyang Lake. Therefore, if migratory birds wintering at Poyang Lake collide with rapidly rotating wind turbine blades and towers on the northern lake shore, the species abundance and richness may decrease accordingly, as each death of a migratory bird results in irreversible ecological, social, and economic losses.

Even if wind turbines do not cause direct collisions with the deaths of migratory birds, the construction and operation of wind farms may lead to avoidance behavior in birds, which may reduce collision mortality but increase the potential risk of birds changing their migration routes.[1] For example, a recent study revealed that an endangered black-faced spoonbill, changed its migration routes while crossing the Yellow Sea after encountering continuous offshore wind farms.[5] Notably, the bird did not collide with the wind turbines, but it ultimately died after failing to migrate southward. The "bottleneck" area of Poyang Lake is the construction site for wind turbines, where severe weather events such as dense fog, heavy rain, and strong headwinds frequently occur from November to January. This further increases the migration risk for wintering migratory birds passing through this area. During their migration, these birds may be forced to take detours or change their flight altitude, leading to unnecessary energy loss. This influences their selection of stopover and feeding locations along their flyways, as well as their molting patterns and disrupts the ecological connectivity between migratory regions. Consequently, this situation hinders their ability to complete migration in a typical manner by increasing the likelihood of encountering multiple threats and potentially death.

POTENTIAL SUGGESTIONS FOR MIGRATORY BIRD CONSERVATION

(1) Combined Prevention and Guidance Technology to Reduce Collision Risks and Explore Safe Migration Routes: The environmental evaluation of wind farms planning around Poyang Lake should be strengthened, and the construction of wind farms within key habitats of migratory birds should be prohibited or minimized based on advanced bird survey technologies. According to sensitivity analyses of wind speed and bird biodiversity, the potential conflicts between wind energy development and bird biodiversity can be minimized within the 8-10 km buffer zone. Wind speeds in these zones are high enough to support wind energy development, and the number of bird species remains relatively low. Consequently, specific regions within these buffer zones can be considered as potential sites for wind farm development (Figure 1). Moreover, it is essential to prepare appropriate human intervention measures in wind farm areas to address the impacts of adverse weather and terrain. Artificial fog dissipation technology can be used for fog clearance, and biomimetic flapping-wing aircraft and drones can be employed to guide migrating birds. Given that avoidance behaviors may also lead to bird mortality, it is important to reduce the high-density distribution of wind turbines. Furthermore, since migratory birds may migrate through the farmland areas surrounding Poyang Lake, it is necessary to designate these potential migration areas as stopover points and food supply stations. Additionally, setting up some artificial sites to guide the subsequent migration of the birds could ensure their safe arrival at wintering sites.

(2) Integrated Monitoring and Management Strategy to Establish a Full-Domain Monitoring Platform and Ensure Migratory Bird Security: Comprehensive monitoring is currently lacking around Poyang Lake wind farms and in migration areas. It is imperative that a full-domain monitoring platform be constructed for the wind farm region, leveraging the experience from wetland ecological protection and integrating existing monitoring and warning platforms, as well as intelligent management platforms. The implementation of a "monitoring + management" strategy would allow the integration of AI bird recognition and audio monitoring technologies and enable the setup of video monitoring systems in migration areas. Additionally, if the number of migratory birds in a wind farm area exceeds a certain threshold, temporarily shutting down the wind turbines is advisable. Finally, employing GPS-cellular and satellite trackers are recommended for tracking the flyway dynamics and stopover patterns of different bird populations. These approaches will aid in managing the migration activities of migratory birds and provide important scientific evidence for conservation.

REFERENCES

1. Zhao S., Xu H., Wang T., et al., (2024). Prioritizing landscapes for mitigating the impacts of onshore wind farms on multidimensional waterbird diversity in the Yellow Sea. Sea. *Curr. Zool.* **70**: 752–764. DOI: 10.1093/cz/zoae008.
2. Luo L., Zhuang Y., Duan Q., et al., (2021). Local climatic and environmental effects of an onshore wind farm in north China. *Agric. For. Meteorol.* **308–309**: 108607. DOI: 10.1016/j.agrformet.2021.108607.
3. Rehbein J., Watson J., Lane J., et al., (2020). Renewable energy development threatens many globally important biodiversity areas. *Glob. Change Biol.* **26**: 3040-3051. DOI: 10.1111/gcb.15067.
4. Meng L., Liu P., Zhou Y., et al., (2025). Blaming the wind? The impact of wind turbine on bird biodiversity. *J. Dev. Econ.* **172**: 103402. DOI: 10.1016/j.jdeveco.2024.103402.
5. Lai C., Choi C., Lee K., et al., (2025). Endangered Black-faced Spoonbills alter migration across the Yellow Sea due to offshore wind farms. *Ecology* **106**: e4485. DOI: 10.1002/ecy.4485.

FUNDING AND ACKNOWLEDGMENTS

This work was supported by the National Natural Science Foundation of China (32271674), and the Social Science Foundation of Jiangxi Province (24GL39). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

DECLARATION OF INTERESTS

The authors declare no competing interests.