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Review

Mitigating the Negative Impact of Wind Power on Soaring Birds through Government Restrictions

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Abstract: Wind power is widely used and creates value worldwide. However, it also poses a threat to the survival of soaring birds. This study focuses on the role of government restrictions in mitigating the adverse effects of wind power on soaring birds. We used an overall research method to identify research questions, selected typical wind farms from different provinces and topographic landscapes in China for descriptive analysis, and supported by data from environmental impact reports, government gazettes, and walk-through surveys, analyzed and concluded that government restrictions can be used as a means of weakening the impacts of wind power generation on soaring birds. And our findings suggest that site control for wind farms that have not yet been established, restrictions on the timing of power generation for wind farms in operation, and ecological restoration of wind farms that have caused environmental damage are effective implementation options for government restrictions. Additionally, the policy strengths of the above government restrictions are guided, recommended, and mandatory, respectively. Government restrictions can serve as an effective means of mitigating the negative impact of wind power on soaring birds, generating economic value while maximizing the protection of soaring birds' subsistence. Based on our findings, we call on governments to pay attention to the negative impacts of wind farms on soaring birds and put forward three concrete and feasible recommendations, expecting countries to enact governmental constraints to find a balance between economic, social, and ecological benefits.

Keywords: government restrictions; wind power; soaring birds

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1. Introduction

Renewable energy, particularly wind energy, is gaining significant attention worldwide [1]. As a clean and eco-friendly energy source, wind energy is increasingly integrated into the power mix to achieve greenhouse gas emission reduction goals [2]. The benefits of wind energy are extensive and extend beyond clean power generation. Evidence suggests that wind energy can help governments accelerate green economic growth [3], create sustainable jobs, reduce water consumption resulting from power generation, and promote local capital flows.

Wind energy is widely used in most countries and regions [4]. According to the International Energy Agency (IEA), the global cumulative installed wind power capacity reached 825 GW by 2021, 135% higher than the cumulative installed wind power capacity of 349 GW in 2014 [5]. In 2022, among all regions, Asia had the largest electricity capacity at 48.4%, followed by Europe at 21.01% and North America at 14.51%, and the total electricity capacity in other regions was 16.13% (Figure 1). From a national perspective, the top five market contributors to global cumulative installed wind power capacity are China, the United States, Germany, Spain, and India [6]. Among them, China has a cumulative installed capacity of about 329 GW, which is approximately 1.5 times more than the sum of the installed capacity of the second (the United States, 133 GW) and third (Germany, 64 GW) ranked countries [5]. This has led to an estimated reduction of about 420 million tons in

China's CO_2 emissions [5]. Notably, China's wind power industry has been booming over the last two decades due to national policies and rapidly growing market demand [7].

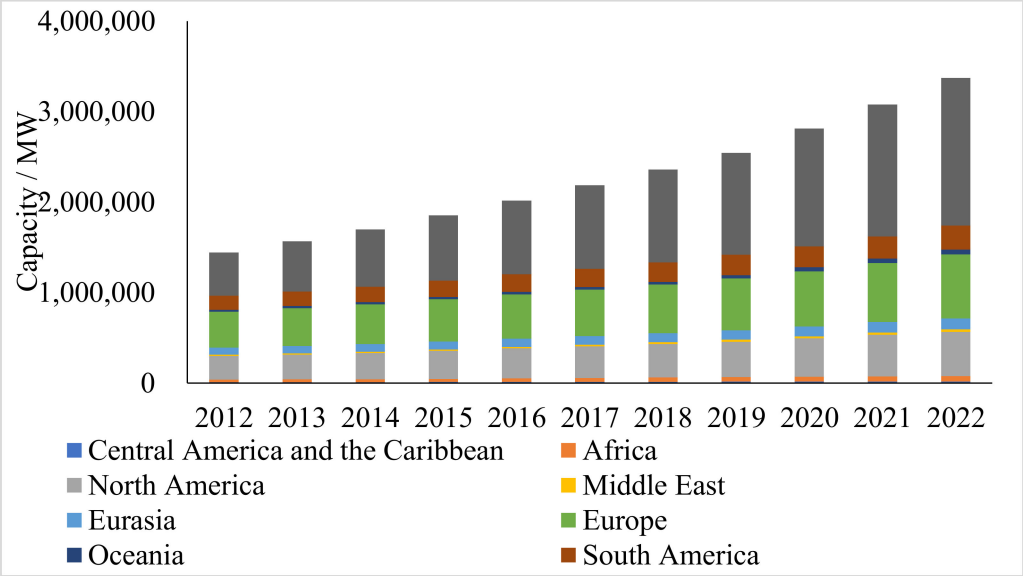

Figure 1. Electricity capacity of wind power worldwide from 2012 to 2022. Data from International Energy Agency, https://www.irena.org/Data/View-data-by-topic/Capacity-and-Generation/Regional-Trends (accessed on 28 March 2023).

However, wind energy also affects the environment. Although the environmental impact of wind power is relatively small compared to other conventional power generation, there is public concern that wind turbines may negatively impact wildlife [8]. In particular, soaring birds, including most raptors, storks, and other large birds, are among the most severely affected groups [9]. Wind energy generation could significantly negatively impact their migration and populations [10]. Studies have indicated that wind turbines may increase the risk of collisions with birds, reduce breeding success, and affect birds due to noise and visual disturbance [11]. Although wind farms do not affect all bird species, some are more sensitive to mortality due to wind turbines [12]. For example, species that frequently fly in the dark are more likely to collide with wind turbines than species that fly only during the day [13]. Simultaneously, some raptors with slow breeding rates, which die after hitting the turbine blades, may be adversely affected. In fact, wind farms kill millions of birds each year worldwide, and the high mortality rate of rare raptors is of particular concern [14]. The impact of wind energy on soaring birds is more widespread than previously acknowledged [15].

Countries and regions should recognize the further impacts of wind energy production and develop effective regulations to reduce such impacts. Proper planning, limiting, and restoration are critical to reducing the impact of wind power on wildlife, especially soaring birds, in countries and regions such as China that are on the rise in terms of wind power development. Therefore, this study aims to investigate possible ways to mitigate the negative impacts of wind power on soaring birds and to use government restrictions as an important tool to achieve this goal in China. While previous studies have mainly focused on resource allocation [16], technology status [17], and industrial development of wind power generation [18], few studies have analyzed the problems related to wind power generation and environmental improvement. Although some scholars have noted that the impact of individual turbines on soaring birds varies depending on their geographic location [19], there is no clear answer as to how to plan and select these geographic locations to minimize the negative impact of wind power on soaring birds. In our study, we believe that government planning and restriction tools can be used to counteract the effects of wind power on soaring birds and reduce harm to them under reasonable usage patterns.

In Section 2, we present the research background and overall research methodology, including the research question, case selection, data collection, analysis, and summary. In Section 3, we present three models for government restrictions to weaken the negative impacts of wind power on birds. In Section 4, we focus on the role of government restrictions and provide a comparative analysis of the three models. Further, we analyze the similarities and differences between China and other countries regarding the weakening of adverse effects of wind power on soaring birds. Then, the limitations of this study are expanded upon as well as future research directions. In Section 5, we conclude with a discussion of the importance of government restrictions and three feasible recommendations for turning "virtual" government power into "real" protection for soaring birds. In summary, we demonstrate that government restrictions are an effective means of weakening the negative impacts of wind farms on soaring birds, and we hope that the case described in this study will provide lessons and examples for other countries.

2. Background and Methods

2.1. Background

Wind farms are often located in exposed areas with high average wind speeds, typically upland areas, and may negatively affect the breeding, migration, and survival of birds. Wind power generation has direct and indirect effects on birds, with direct effects including mortality due to collisions between birds and wind turbines and indirect effects in the form of habitat loss for birds due to wind farm construction and operation [20].

Numerous studies have proposed solutions to reduce the negative impacts of wind power projects on birds, most of which apply to onshore wind projects. Among these, the site selection is considered the most effective means of reducing harm to birds [14]. This involves constructing wind plants to avoid areas of high bird use or known breeding, foraging, and loitering sites and other locations where birds are concentrated. However, very few wind projects are deliberately sited with the impact on birds in mind [21]. Additionally, the temporary shutdown of wind turbines is an effective measure that has been shown to effectively reduce the collision mortality of vulnerable species [22]. For example, an experiment that selectively shut down the ten most dangerous turbines for Griffon vultures found that shutting down turbines during the vultures' fall migration reduced mortality by 50% [23]. Such measures require supervisory control and data collection for wind farm areas, but in most wind power areas in China, electric companies rarely implement monitoring programs due to higher costs. Furthermore, using a general environmental impact rating system to encourage compensatory restoration by developers [24] is an effective restoration measure for areas of severe habitat destruction for birds. Developers in the US and EU have undertaken compensatory restoration to address the destruction of wildlife habitats [25]. However, such ex post compensation has stringent requirements for compensation schemes, such as determining the area to be compensated and what damages can be addressed by compensation. Additionally, such measures are challenging for developers to manage cost-effectively [26] and require more government involvement to encourage ecological compensation.

Government participation is crucial to developing new energy projects worldwide, particularly in developing countries [27]. Many countries promote wind power through various policies, such as direct subsidies, lower taxes, and quotas [21], and such government incentives have been remarkably effective in wind energy development. Therefore, we believe that government restrictions can also play an essential role in mitigating the conflict between soaring birds and wind power. This is because the government has coercive power, and the industry seeks rent from the government to promote its benefits. In other words, to avoid more significant negative impacts of wind energy on soaring birds, we must increase government restrictions on the industry, especially in developing countries such as China, where government power is concentrated, energy consumption is high, and wind power projects are in their infancy.

2.2. Methods

An overall research method was used in this study and the specific research steps are depicted in Figure 2. The overall research aim is to study socioeconomic phenomena in depth and solve practical problems with a limited number of observations [28] through in-depth, multifaceted exploration of complex real-life circumstances [29]. The popularity of this qualitative approach is increasing yearly, with applications in a variety of fields such as land use [30,31] and animal welfare [32]. The method is flexible, capable of handling large amounts of verbal or graphical data [33], focuses on observing phenomena, and can understand things from the perspective of the observed subject [34].

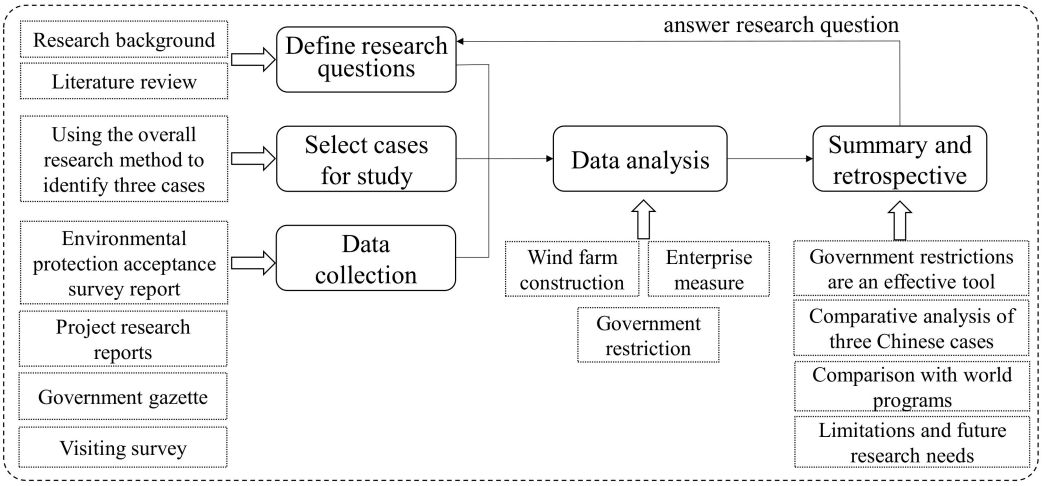

Figure 2. Research steps.

The primary purpose of this study is to explore models that effectively mitigate the negative impacts of wind farms on soaring birds. However, the implementation process and effects of the models have not been systematically studied due to the lack of attention to the issue and limitations of technology. Therefore, we analyzed three typical cases of wind farms in China using an overall research approach. The method provides a detailed analysis of the location and natural conditions of wind farms in different terrains and proposes a global perspective on the options available to mitigate the negative impacts of wind farms on soaring birds, making the conclusions more representative. Additionally, the method provides a detailed understanding of the role of government restrictions in mitigating the negative impacts of wind farms on soaring birds, improving the rigor and accuracy of our study. Finally, we summarize three effective models that can be replicated in similar countries or regions. Thus, with the application of an overall research methodology, this study is more representative of the current situation of wind farms in China and provides new ideas and solutions to mitigate their adverse effects on soaring birds.

This study is divided into several steps, as shown in Figure 2. Step 1 defines the research questions, which include (1) What tools does China use to mitigate the impact of wind power on soaring birds? (2) What is the role of the Chinese government? (3) Are these tools effective?

Step 2 comprises case selection. China boasts 9.6 million square kilometers of diverse topography, which contains abundant wind resources [35]. To select the most representative cases from a large number of wind farms and analyze the role of government restrictions in mitigating the adverse effects of wind power on soaring birds, we identified wind farms located in three different topographies in China, classified as Gobi-type, plain-type, and mountain-type wind farms. These cases are situated in the western, northern, and central parts of China, respectively. Notably, these cases differ in terms of the conservation measures taken under government restrictions. Gobi-type wind farms focus on careful site selection, plain-type wind farms avoid soaring bird migration times, and mountain-type wind farms implement ecological restoration measures. The three cases provide

distinct approaches for mitigating the impact of wind farms on soaring birds and, thus, can offer valuable insights into the conservation of soaring birds in wind farms worldwide. Therefore, we consider these three cases highly typical and relevant for this study.

Step 3 comprises data collection. The data of this study primarily derive from three categories: feasibility study reports and environmental protection acceptance survey reports of wind power enterprise projects [36,37], government gazettes [38–40], and the authors' visits and surveys. The feasibility and environmental protection reports provide specific details on wind farm construction projects and their environmental impact, respectively. Government gazettes outline the government's guiding and supervisory role in wind farm construction and the conservation of soaring birds. Finally, the authors' visits and surveys offer an experiential understanding of the negative impact of wind power on birds, including the overall decline in the number and quality of life of birds. This experience inspired this study.

In step 4, a comprehensive data analysis was conducted to describe the basic situation of wind power construction, the processes and content of government restrictions, and the measures taken by the companies implementing the subjects in these three cases. Based on the aforementioned cases, our study then explores the role of government restrictions in mitigating the negative impacts of wind farms on soaring birds. Finally, an analysis and extension of the effects of these three cases are presented.

Step 5, the summary and review section of this study, begins by highlighting the effectiveness of government restrictions in mitigating the negative impacts of wind farms on soaring birds. It provides a comparative analysis of three Chinese models—planning, restriction, and restoration—to evaluate their effectiveness. Additionally, this section examines similar programs implemented in other countries and regions worldwide and identifies objective constraints present in developing countries to implement conservation measures.

Moreover, this study also analyzes its limitations and recognizes the potential for further improvement and optimization of the Chinese models. Ultimately, we aim to raise awareness about the negative impacts of wind farms on soaring birds, emphasizing the role of government in mitigating these impacts and providing solutions for other countries or regions. The study ultimately seeks to balance the economic and ecological benefits of protecting soaring birds in wind farm areas.

3. Results

3.1. Gobi-Type Wind Farms, Restricting the Siting of Wind Farms to Protect Bird Habitat

The Gobi Desert is a remote and inaccessible desert with a dry climate and fewer creatures than plains and mountains [41], making it a suitable terrain for constructing wind farms that require large areas of land while minimizing ecological damage. In fact, the first wind farm in China was a Gobi-type wind farm. Despite being a harsh environment with frequent sandstorms [42] that make it difficult for birds to survive, the Gobi Desert also provides a unique habitat for soaring raptors such as vultures, white-shouldered eagles, and golden eagles that require protection.

Therefore, to avoid disturbing or affecting the normal activities of soaring birds, the sites of wind farms should be shifted from ecological reserves to the Gobi Desert area (Figure 3), away from areas of gathering and frequent activities of soaring birds. Furthermore, the Chinese government, in conjunction with environmental protection associations and regional environmental monitoring stations, monitor the animals in site selection areas in advance, thus limiting site selection for wind farm construction and achieving the protection of soaring birds and other flora and fauna.

The Naomao Lake wind farm, located in the Hami region of Xinjiang Province (Figure 4), covered a total area of 76,568.53 m^2 in its first phase, including a total of 33 wind turbines. The total investment in the project was CNY 412.18 million, with a 0.23% investment in environmental protection, accounting for CNY 950 thousand. Following the directive of the government's Environmental Protection Bureau, the construction of the wind farm intentionally avoided ecological protection zones. The construction area was

a Gobi wasteland with no bird habitats, such as marshes and lakes, and was not located near endemic or cherished protected animals' habitats, migration corridors, or frequent activity areas. As a result, the Naomao Lake wind farm fundamentally prevented any negative impact on soaring birds after it was put into operation. The government conducted an environmental protection inspection of the wind power plant project after its construction to ensure that its ecological impact was within tolerable limits. Generally, the Gobi Desert region has a lower density of soaring birds, making the construction and operation of wind power machinery less harmful to animals. Constructing wind farms in remote areas can help mitigate adverse ecological impacts.

(**a**) (**b**)

Figure 3. Site selection control through government restrictions. (**a**) shows wind farms in ecological reserve areas, from the website of Shanxi People's Government. http://www.shanxi.gov.cn/ywdt/tpxw/202307/t20230710_8903002.shtml (accessed on 28 March 2023). (**b**) shows wind farms in the Gobi Desert, from the website of Hami Municipal People's Government. http://www.hami.gov.cn/info/4454/332090.htm (accessed on 28 March 2023).

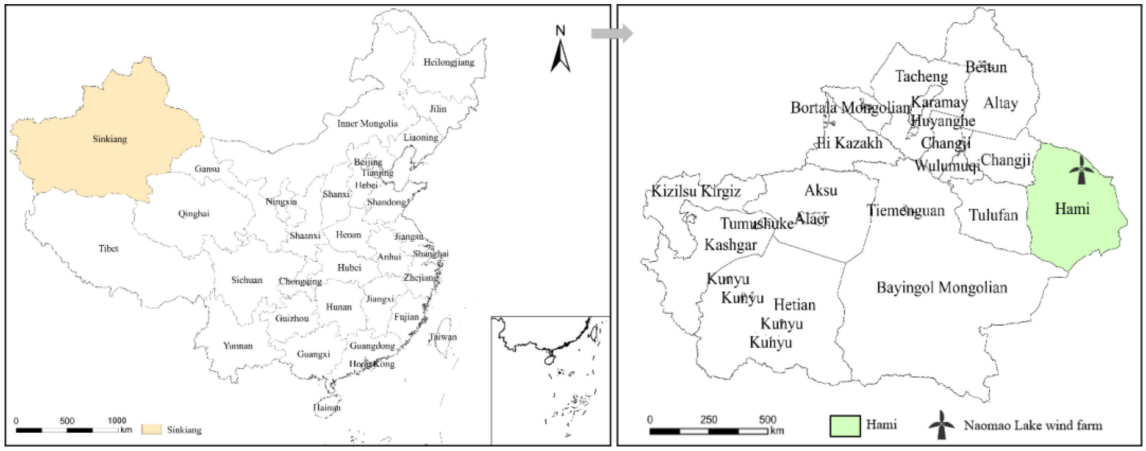

Figure 4. Geographic location of Naomao Lake wind farm.

The Chinese government avoids building wind farms in ecologically protected areas through siting restrictions, opting more for areas with a smaller biomass, such as the Gobi Desert. However, this does not mean that wind power development in the Gobi Desert is uncontrolled, and ecological monitoring of the Gobi Desert will continue to be carried out while the economic value of the Gobi Desert is exploited. This is a balanced game of economy and ecology.

3.2. Plain-Based Wind Farms, Restricting Generation Times to Avoid Bird Migration

Plain-type terrain is open and flat, with abundant and stable wind resources, making it a cost-effective option for wind farm construction compared to remote Gobi-type wind farms. Compared to mountainous areas, the ecological environment of plain-type terrain is more stable, which is beneficial for mitigating the biological impact of wind farm construction. However, for soaring birds, the impact of wind farms is highly variable [43], influenced by factors such as the geographical location of the wind farm, flight height of the birds, and weather changes [44]. Specifically, the alteration of magnetic fields by wind turbines affects the orientation of soaring birds to their destinations [45]. Wind energy machinery increases the frequency of soaring bird collisions [46] and changes in airflow resulting from the operation of wind turbines impact flight [47]. Areas or times of high soaring bird activity increase the risk of collision, and the chance of mortality due to wind farm impacts varies with time and space [48]. To protect soaring birds, the Chinese Environmental Protection Bureau supervised the shift of wind turbines from rotating to stalled (Figure 5) during periods of high bird activity, thereby minimizing the adverse effects of wind power on soaring bird flight.

(**a**) (**b**)

Figure 5. Stopping wind turbine operations through government restrictions. (**a**) shows wind farms in operation and rotation, from the website of the People's Government of Inner Mongolia. https://www.nmg.gov.cn/ztzl/xyesdjgxsd/ffsn/202209/t20220906_2127546.html (accessed on 28 March 2023). (**b**) shows a stalled wind turbine; the picture was taken by the author.

The Qingsong wind farm, located in Linghai City, Liaoning Province (Figure 6), covers a total area of 69,067 m^2, with a total of 30 wind turbines. The actual investment in the project was CNY 505.88 million, with an investment of CNY 2.368 million in environmental protection funds, accounting for 0.46%. The wind farm is situated north of the Jinzhou Linghekou Municipal Nature Reserve, which is located on the edge of the bird migration corridor and requires efforts to mitigate the impact of the wind farm on birds in the nature reserve. The Qingsong wind farm implements several measures to protect wildlife, including educating construction and operation staff not to hunt and to protect young birds and bird eggs. Furthermore, the project design ensures the wind turbines are located far from animal habitats and night construction is prohibited. Additionally, lights have been added to the turbines at the edge of the wind turbine group and flash and vary in color to prevent birds from colliding with and chasing the wind blades. The wind turbine operation at Qingsong wind farm includes a time-limited shutdown mechanism to observe the bird migration throughout the day during peak migration times, proposing shutdown plans for grid dispatch according to the Grid Dispatch Operation Regulations. The wind farm also includes lighting devices to protect bird migration, turning them on during foggy weather and peak bird migration periods (late March and April in the spring and September and October in the fall). Simultaneously, special personnel are assigned to patrol the wind farm

during bad weather, such as windy and foggy days, and send any impacted and injured birds to the bird observation station in time for emergency rescue by the bird observation station personnel.

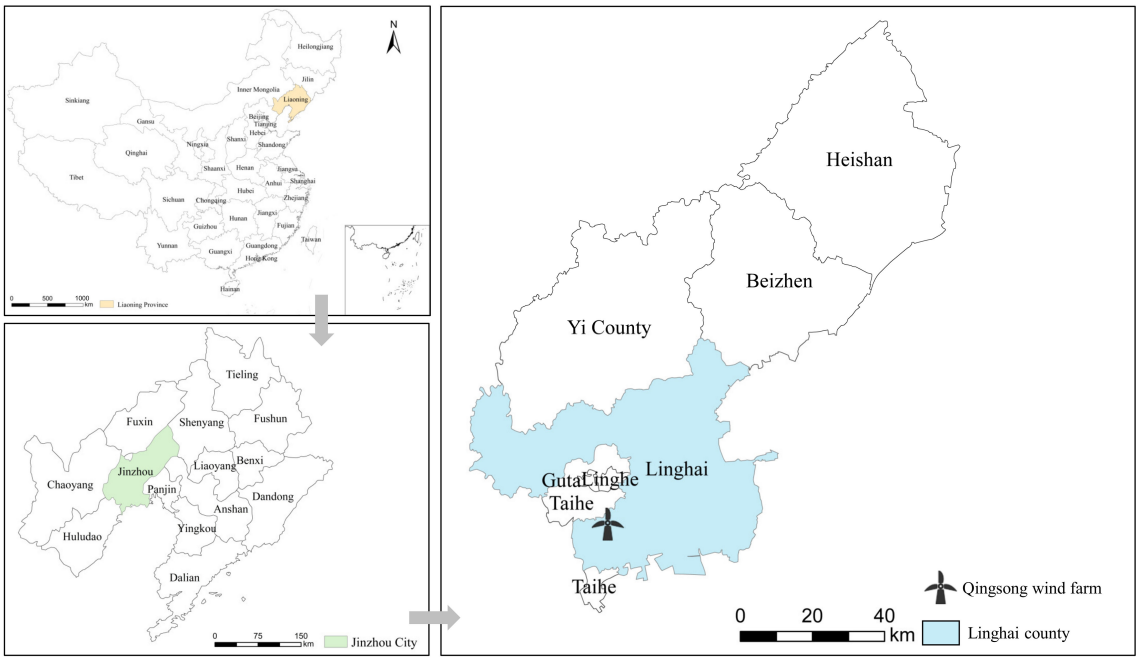

Figure 6. Geographic location of Qingsong wind farm.

The Chinese government aims to implement necessary protection measures for soaring birds in the process of promoting wind power construction. The measures mentioned above effectively mitigate the impact of personnel, construction, wind turbine facilities, equipment operation, and adverse weather conditions on soaring birds, providing good solutions for bird survival, migration, and rescue in wind farms. In particular, the restricted power generation time effectively reduces the conflict between wind power generation and bird migration, opening up "life passages" for soaring birds.

3.3. Mountain-Type Wind Farms, Restricting Ecological Damage and Restoring the Living Environment of Birds

Mountain-type wind farms tend to cause more harm to the environment than Gobi-type and plain-type wind farms. Mountains are an important part of the Earth's ecosystem, containing fragile ecosystems and being one of the most vulnerable areas to environmental change. This is because mountains are three-dimensional, with more complex biological structures, more diverse ecological functions [49], and broader ecospheric impacts. Additionally, the construction of mountain-type wind farms requires the opening of new roads or the widening of existing roads, making construction more difficult and causing a greater environmental impact. Urged by the Chinese government, companies are carrying out ecological restoration measures to transform wind farms from ecological degradation to ecological restoration (Figure 7), with the parallel of mountain-type wind farms with ecological protection and restoration measures being imminent.

(**a**) (**b**)

Figure 7. Ecological restoration through government restrictions. (**a**) shows ecological damage to wind farms, from the website of Hunan Provincial People's Government. http://www.hunan.gov.cn/hnszf/hnyw/jdt2/202203/t20220314_22704831.html (accessed on 28 March 2023). (**b**) shows ecological restoration of wind farms, from the website of the People's Government of Yunnan Province. https://www.yn.gov.cn/ywdt/zsdt/202204/t20220421_241021.html (accessed on 28 March 2023).

The Hougu'ao wind farm is in Rucheng County, Chenzhou City, Hunan Province (Figure 8). The project covers a total area of 647,870 m^2, with a permanent land area of 17,150 m^2, and has 20 wind turbines installed. The actual investment of the project is CNY 429.87 million, with CNY 3.7655 million invested in environmental protection, accounting for 0.88% of the total investment. A total of 84 bird species inhabit the area, of which 8 are protected by the State Grade II. During the project's construction, the complex and mountainous terrain posed ecological and environmental problems, such as surface exposure, vegetation destruction, landslides, and soil erosion, which destroyed the habitat and living environment of birds. To address this, the Chinese government, per the Environmental Protection Law of the People's Republic of China [50], insisted on the principle of "whoever develops, protects and whoever pollutes, treats", requiring construction companies to perform ecological restoration measures. The first measure was waste remediation, rectifying waste soil and rocks during the construction of wind farms to reduce pressure on the slopes and forbid random piling to prevent landslides. Second, vegetation restoration involves grass planting, mixing nutrients and grass seeds, and then using air compressors jet planting to restore mountain vegetation and reduce the bare surface area. Third, ditch management concentrated on drainage ditches to effectively reduce erosion caused by rainwater washing on the surface of the ground [51,52]. The above three measures effectively improved the ecological damage of wind farm construction. Additionally, the Hougu'ao wind farm hired experts to observe birds, ensuring the scientific and protective nature of the observation process. The observation method was based on the Technical Guidelines for Biodiversity Observation—Birds issued by the Chinese Ministry of Environmental Protection to avoid possible secondary damage to the birds due to the observation. Under the guidance, requirements, and supervision of the government, the Hougu'ao wind farm followed policies and regulations to carry out restoration measures, including those of land, vegetation, water, and soil, to restore the living environment of soaring birds.

The Chinese government has taken timely measures to remedy the ecological damage caused by the construction of wind farms. The effective containment of landslides and the protection of land and vegetation weakens the adverse effects of ecological changes on soaring birds and their habitats, providing suitable practices for ecological restoration of wind farms in similar areas.

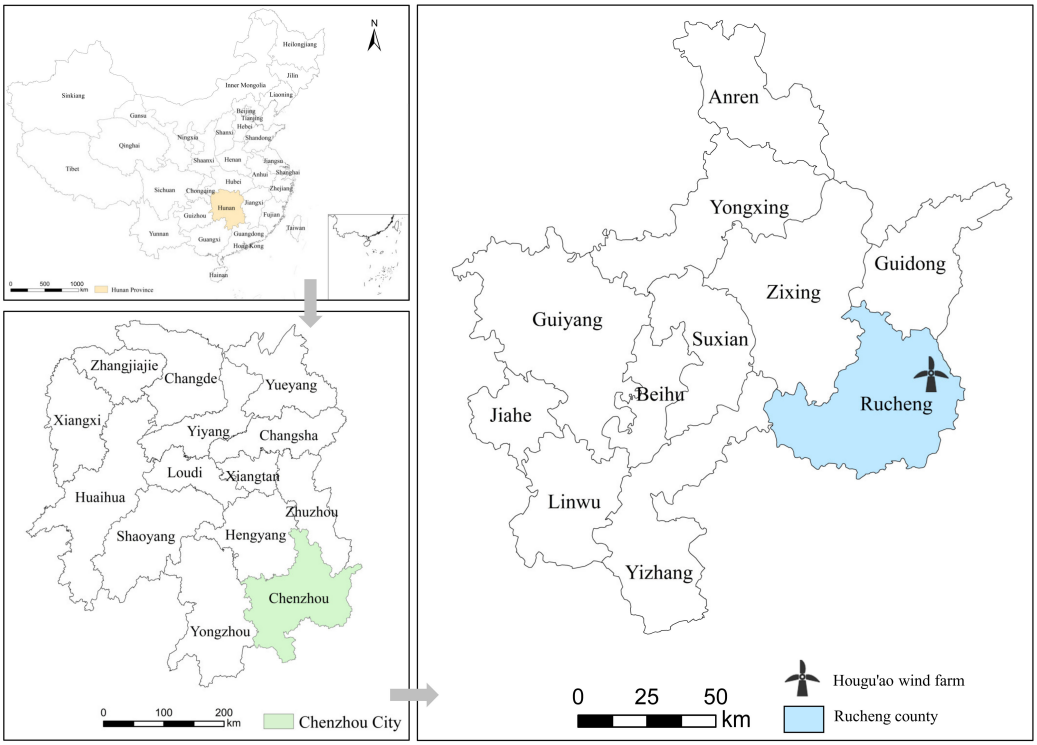

Figure 8. Geographic location of Hougu'ao wind farm.

4. Discussion

4.1. Government Restrictions Are an Important Tool for Mitigating the Adverse Effects of Wind Power on Soaring Birds

With the rise in global warming and the increasing popularity of clean energy, developing countries are shifting toward cleaner power generation [53]. China, for instance, planned to add 37.63 million kilowatts of wind power in 2022, with renewable energy expected to make up 31.6% of the country's electricity consumption. However, due to the high demand for wind power in China, government restrictions have become a crucial defense mechanism to mitigate the adverse impacts of wind power on soaring birds.

First, the policies formulated by the government have effectively weakened the negative impact of wind power generation on soaring birds. Large-scale wind power development requires governmental support, and the Chinese government is leading in the design and construction of wind power. In this regard, the Chinese government has implemented policies to address the potential ecological and bird impacts of wind power construction. For example, the Interim Measures for the Management of Land Use and Environmental Protection [54], issued in 2005, require the implementation of an environmental assessment system to significantly minimize ecological damage. Furthermore, the Chinese government also introduced the "three simultaneous" system, which mandates that environmental protection, soil, and water conservation, woodland vegetation restoration and treatment projects, and the main project are designed, constructed, and put into use simultaneously. All these policies and regulations protect the ecological environment. In the case of wind farms, the government is mainly focused on regulating the construction zones of wind power, limiting periods of wind power generation, and enforcing ecological restoration measures. These measures protect soaring birds before wind farm construction, during operation, and after ecological damages have occurred.

Second, governments weaken the negative impacts of wind power on soaring birds by influencing corporate behavior. The government plays an important role in raising companies' environmental awareness, developing eco-friendly measures, and guiding behaviors pro-environmentally [55]. For companies pursuing economic benefits, the protection of soaring birds in wind farms incurs additional costs, and without government regulation,

companies disregard ecological damage in order to make profits [56]. Specifically, governments must restrict corporate behavior during the profit-seeking process to mitigate the ecological impact of wind farm business on soaring birds [57,58]. As a vulnerable group in the ecosystem, birds are less able to withstand the significant environmental changes caused by wind farm construction [59]. Allowing wind power to develop in the market could significantly impact the quality and quantity of bird populations, and rare bird species may even face extinction [60]. Therefore, government restrictions are essential to ensure the safety of soaring birds in wind farms.

4.2. Comparative Analysis of the Effects of Three Chinese Models of Mitigating Wind Power on Soaring Birds

This study analyzes three cases that represent different types of wind farms and provides three models for mitigating the impact of wind farms on soaring birds under governmental restrictions. These models can serve as useful guides for other countries or regions (Table 1), emphasizing the need for governmental restrictions on wind farms.

Table 1. Three Chinese models for mitigating the impact of wind farms on soaring birds through government restrictions.

Name	**Naomao Lake Wind Farm**	**Qingsong Wind Farm**	**Hougu'ao Wind Farm**
Geographic location	Western China	Eastern China	Central China
Type	Gobi	Plain	Mountain
Topographic features	Gobi Desert	Plain grassland	Mountain forest
Permanent land area	76,568 m^2	69,067 m^2	17,150 m^2
Number of wind turbines	33	30	20
Proportion of environmental protection investment in total investment	0.23%	0.46%	0.88%
Timing of government restrictions	Before construction	In operation	After destruction
Government-restricted programs	Restricted construction location	Limit power generation time	Requires ecological restoration
Strength of government restrictions	Guide	Recommend	Mandatory
Effects of government restrictions	Reduce the occupation of bird habitats	Does not hinder and assists bird migration	Good restoration of birds' living environment
Policies and regulations	(a) Environmental Protection Law of the People's Republic of China (b) Wildlife Protection Law of the People's Republic of China (c) Technical Guidelines for Biodiversity Observation—Birds		

The three Chinese models recommend measures to minimize the impact of wind farms on soaring birds at different time points, including before construction, during use, and after construction with ecological restoration. Practical solutions are classified into three categories. First, for wind farms that have not yet been established, the government restricts site selection [61] and focuses on building wind farms in remote, biologically scarce areas such as the Gobi Desert instead of wind-rich ecological reserves to protect bird populations. Second, for wind farms in use, the government requires companies to implement systematic measures to help soaring birds migrate, including time-limited power generation, scientific avoidance, and appropriate lighting to ensure their survival. Finally, for wind farms that have caused ecological damage, the government should require, supervise, and urge enterprises to implement ecological restoration measures to restore a suitable environment for the survival and development of birds.

Each of the three government restrictions has its own advantages. In comparison, restricting construction location is most effective, but it is often difficult to realize because the planning and construction of wind farms do not only involve soaring birds. Therefore, the government can limit periods of power generation to avoid operation during times of frequent bird activity. Further, ecological restoration is required when the ecology of wind farms is damaged. These governmental restrictions are moderate and hierarchical, as internalized in the three models mentioned above. Guiding policies, recommended measures, and mandatory regulations are all effective in mitigating the adverse impacts of wind farms on soaring birds in different contexts.

4.3. Similarities and Differences between This Study Case and Similar Projects around the World

Wind power has a long history, and wind energy is widely used in various countries and regions worldwide. For instance, the United States in North America [62], New Zealand in Australia [63], Denmark [64] in Europe, and Cameroon [65] and Nigeria in Africa [66] all have abundant wind resources and encourage the use of wind power as a clean energy source.

In China, government restrictions have been effective in mitigating the adverse effects of wind power on soaring birds. Similarly, international protection of birds near wind farms involves significant government participation. For example, in Spain, where wind farms are rampant and partly located in migratory bird areas, systematic coordination of all levels of administration is utilized to prevent the multiple impacts of wind farms on birds [67]. In Germany, an analysis found that wind farms have a more significant impact on vultures than on other birds, resulting in the development of a wildlife conservation plan to ensure population stability [68]. In Scotland, bird sensitivity maps have been created to protect vulnerable birds and to avoid conflicts between wind farm construction sites and bird habitats [69]. California is exploring alternative and safer wind turbine designs to reduce the impact on wildlife, including birds [70]. Most of these countries are major wind power generators and have developed various mitigation measures based on the impact of wind power on birds, including government restrictions, innovative power generation measures by companies, and guidelines by animal protection organizations.

Although the methods used to protect birds on wind farms differ worldwide, the ultimate goal is to safeguard the natural survival and reproduction of birds. However, compared with developed countries, developing countries face some objective constraints that hinder them from implementing effective measures to protect birds. These constraints include (1) insufficient awareness of bird protection, (2) lower levels of wind power generation technology, which may cause greater impacts on birds through mechanical equipment, and (3) unreasonable planning, construction, and operation of wind farms [71,72]. This makes it more difficult for developing countries to protect soaring birds.

In China, government restrictions have played a significant role in mitigating the adverse impact of wind farms on birds, producing far greater benefits than relying solely on the conscientious acts of companies for ecological protection. This experience provides valuable lessons for other countries, particularly those with a large number of wind power facilities that aspire to sustain the development of clean energy sources such as wind. Using the power of the government to develop policies and regulations that consider the socioeconomic and ecological benefits and protect organisms in wind farm areas is essential for achieving sustainable ecological and socioeconomic development.

4.4. Limitations of This Study and the Need for Future Research

This study proposes three options for mitigating the impact of wind power on soaring birds but does not consider the associated costs of implementing these options, namely (1) construction costs [73,74]: choosing the Gobi region for wind farms is characterized by long distances and inadequate infrastructure, resulting in high construction costs, such as those associated with roads for transporting wind turbines, information and communication equipment for observing wind farm operations, and daily operation and maintenance

management costs; (2) transmission costs [75,76]: restricting the hours of power generation stops wind turbines and substations, and this repeated shutdown and startup of large machinery results in additional energy use, leading to increased transmission costs; and (3) labor costs [77]: ecological restoration is a systematic project that requires long-term restoration and monitoring, which has led to a sharp rise in labor costs. Government subsidies may be a good solution for the three sources of costs mentioned above. Government subsidization of these additional costs incurred in the conservation of soaring birds can motivate more interested parties to take conservation measures. Future research should investigate the additional costs incurred to weaken the impact of wind farms on soaring birds, looking for a balance between economics and ecology.

This study focused primarily on the impact of wind farms on soaring birds and has given less attention to the effects on other flora and fauna. (1) Other organisms, including mammals, insects, and many other types exist in the mountain-, plain-, and Gobi-type regions [78,79]. The construction of wind farms has a detrimental effect on their living environment, including habitat reduction [80], environmental changes due to large facilities causing animal discomfort [81], inconvenient migration of terrestrial animals, and various pollution or problems that arise. (2) Plants are also affected [82]. Wind farm construction also occupies a large portion of land [83,84], devastatingly impacting the living environment of plants. In addition to the permanent occupation of land, the temporary occupation of land, if not ecologically restored after use, leads to a decrease in plant species and green cover. Simultaneously, wind farm construction may also lead to land desertification, further deterioration of ecological conditions, and deprivation of plant living spaces. Future research should consider the impact of wind farms on plants and animals other than soaring birds. The ecology of a complete cyclic system should focus on all subjects within the ecological space.

There are limitations to the power of government restrictions as the government's authority is not without borders [85]. When formulating policies, the government cannot only consider the survival of soaring birds but must also consider the feasibility of the policy, the balance between economic and ecological interests, and public support [86]. This leads to constraints in government policy making that cannot be fully attuned to the interests of the survival of a particular class of species. Thus, mitigating the negative effects of wind power on soaring birds requires the participation of stakeholders [87], including the public, businesses, and animal protection organizations. For the conservation of soaring birds, future endeavors should promote the formation of a comprehensive conservation network with multiple stakeholders, including the government, enterprises, conservation organizations, and the public, to narrow the inadequacy of conservation due to the limitations of the government.

5. Conclusions and Recommendations

With the increasing prevalence of wind power generation, the protection of flora and fauna in wind farm areas is an inevitable trend for future wind power development and a requirement for ecological sustainability. For soaring birds, the adverse effects of wind farm construction are even more significant. Therefore, it is necessary to leverage governmental power to mitigate the negative impacts on birds while promoting the development of wind power. This study discusses three Chinese options for mitigating the impact of wind power on soaring birds through government restrictions, hoping that other countries or regions of the world may take note of the substantial impact of wind power on soaring birds through the example of China. Simultaneously, the role of the government should be brought into play, and policy instruments should be used to take reasonable countermeasures.

This study proposes the following recommendations based on three different states of wind farm construction with a view toward weakening the negative impacts of wind power generation on soaring birds: (1) for wind farms that have not yet been established, this study recommends that the government restrict construction location, that is, select remote areas such as the Gobi Desert, where there are fewer signs of activity, to build

wind farms in order to reduce the risk of mass animal deaths. Site control is the most cost-effective and efficient way to address the adverse effects of wind farm construction on the survival of soaring birds. Simultaneously, the government should encourage enterprises to develop remote areas with poor ecology, achieving both economic and social benefits while effectively reducing ecological conservation costs. (2) For operating wind farms, this study recommends that the government consider the multiple possible impacts on soaring birds in advance and scientifically develop restriction programs to promote measures to protect birds. Specific methods include stopping the use of wind turbines during peak migration periods to reduce the impact on migration, installing lighting devices to prevent collisions and aid bird migration, and conducting manned patrols during bad weather to rescue injured birds in time. (3) For wind farms that have been ecologically damaged, this study recommends that the government adopt measures or policies to guide and supervise the planning and implementation of ecological restoration measures. These measures can restore the damaged ecological environment to the greatest extent possible, mitigate the impact of wind farms on soaring birds, especially in mountainous areas with high bird densities, and prevent the deaths of birds due to frequent impacts with wind turbine fan blades or due to ecological degradation. Additionally, ecological restoration measures carried out at wind farms can also contribute to the conservation of flora and fauna, creating a favorable ecological cycle that is conducive to the survival of soaring birds.

What is clear is that the absolute power of China's central government makes it easier to implement "restriction" programs on a national scale to protect soaring birds that live near wind farms. As mentioned in the above recommendations, the government can guide wind farm sites away from ecologically fragile areas, advise to halt wind power generation during periods of high bird activity, and mandate ecological restoration after damage to wind farm ecosystems. For other countries where wind power is developing rapidly, the role of government restrictions should be emphasized. National governments should avoid approving wind farm construction in ecological reserves and areas of high animal activity. During the operation and use of wind farms, they should limit the hours of power generation, train staff, and set up rescue sites. When the ecological environment of wind farms is damaged, governments should require the responsible parties to perform ecological restoration. The government is not only the main decision-making body for wind power projects but also the pioneering body for soaring bird protection. The state should make appropriate use of government power, formulate policies and regulations to mitigate the adverse impact of wind power on birds, and ensure that wind power development and the ecological environment are fully integrated.

However, this study did not consider three aspects that are possible directions for future research. First, it did not account for the additional costs incurred by companies taking measures to protect birds under government restrictions, determining the feasibility of corporate projects. Second, the ecological protection of wind farms in this study is limited to soaring birds, and the impact of wind farm construction and development on other flora and fauna is not considered. Finally, the limitations of government restrictions must also be considered, and the government needs to balance the interests of multiple parties. These three issues can be further explored, and if cost constraints, ecological damage, and government limitations can be effectively addressed, soaring bird conservation will become more scientifically and effectively implemented.

Despite the shortcomings in this study, there are valuable lessons to be learned. Coping with the adverse effects of wind farms on birds is a crucial issue that must be addressed in countries where wind farms are expected to be built. As a clean energy source, wind power should not only reduce carbon emissions but also coexist harmoniously with animals. Countries should develop wind resources without affecting the biosphere and pursue comprehensive and coordinated economic, social, and ecological development. Finally, protecting soaring birds also protects humans, and progress in wind power generation must not come at the cost of increased bird mortality.

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