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Study on Anti-birds Strategy of Overhead Transmission Line Based on Migration and Breeding Habits of Ciconia Boyciana in Heilongjiang Province

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Abstract: *In order to explore the migration and breeding characteristics of rare birds such as the oriental white stork (Ciconia boyciana) in Heilongjiang Province and the key factors affecting the birds-caused fault of power line, and to explore the solution of power line's bird-related faults based on the characteristics of the breeding grounds, we investigated the information of birds-caused fault of power line and oriental white stork nesting in the towers of Heilongjiang Province on the basis of summarizing the relevant research on migration and breeding habits of migratory birds in recent years, and we provide a strategy for preventing birds-caused faults in power lines based on the migration and breeding habits of the oriental white stork in Heilongjiang Province. The results of the study show that: Towers near migratory routes of migrating birds and in food-rich areas are more susceptible to bird-caused faults; in recent years, the change of migratory routes of migratory birds due to the influence of environment and climate has led to the expansion of the occurrence of bird faults, and the selection of bird control strategies for different regions involving in the migration is also very different. For the bird-caused faults of power lines in Heilongjiang, it is recommended to adopt differentiated bird prevention strategies, which are adjusted for different points of the tower, daily activity rhythms of adult and juvenile birds, and breeding and brooding patterns of birds. The results of this study can be used as a reference for the selection of bird protection strategies for power lines in the vicinity of migratory routes of migratory birds.*

Keywords: *oriental white stork (Ciconia boyciana); power lines; bird-caused faults; bird prevention strategies; migration habits*

1. Introduction

The geomorphology of Heilongjiang Province is characterized by "mountains occupying 50% of the province, water area occupying 1/10 of the province, 1 of the top 10 grasslands in the country and the largest arable land area in the country". The terrain is roughly high in the northwest, north and southeast, and low in the northeast and southwest, consisting of mountains, plateaus, plains and water; it has a cold-temperate and temperate continental monsoon climate. Heilongjiang Province is located in the hinterland of Northeast Asia, in the Heilongjiang River Basin composed of four major water systems: Heilongjiang, Songhua River, Ussuri River and Suifen River, with major rivers such as the Songhua River, Nenjiang River, Ussuri River, Mudanjiang River, Hulan River, Mayi River, Woken River, Tongken River, Anbang River, Naoli River, Hailang River, Huma River, Emu'er River, Nemu'er River, Tangwang River, Lalin River, Niaosihun River, Niaoyu'er River, Muleng River, etc.; and major lakes such as Xingkai Lake, Jingpo Lake, Lianhuan Lake and the Five Bead-like Lakes, which are 4 large lakes and dotted with bubbling marshes. The rolling Greater Khingan Mountains, Lesser Khingan Mountains, Zhang Guangcai Mountains and Laoyao Mountians in Heilongjiang Province constitute the province's natural landscape dominated by mountains and forests, with the province's forested area accounting for nearly half of the entire land area.

In his report to the 20th CPC National Congress, General Secretary pointed out that nature is the basic condition on which human beings depend for their survival and development. Respecting nature, adapting to it and protecting it are inherent requirements for building a modern socialist country in an all-round way. Over the past decade, the Party and the State have adhered to the concept that lucid waters and lush mountains are invaluable assets, and China's ecological environmental protection has undergone historic, transformative and global changes. The diversity of ecosystems in Heilongjiang Province has been significantly improved, with 390 species of wild birds distributing, including rare

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and endangered species such as red-crowned crane, white-headed crane, oriental white stork, Chinese merganser, great bustard, black-billed capercaillie and golden eagle. Among them, the oriental white stork, a national key wildlife species, arrives in March-April every year to nest and breed in Zhalong Wetland, Honghe Wetland and Kaixing Lake in the Songnen Plain and Sanjiang Plain of Heilongjiang Province.

In recent years, with the rapid development of China's economy, the power grid has traversed mountains, rivers, gobi, beaches and coats to transmit power to all walks of life and thousands of households. The tall and solid transmission towers have become the ideal nesting sites for more and more oriental white storks, but the oriental white storks nesting on the towers have also caused hidden dangers for their own safety and power supply [1-2]. The urgency of biodiversity protection, the complexity of the geographic environment and the criticality of safeguarding the power supply all require the power sector to be very careful in the birds-related fault prevention and control work of power line, so as to both ensure the safe and stable operation of the power grid and protect rare birds to flourish [3-4].

The research on bird-related faults of overhead power lines is relatively perfect, but most of them are conducted with the single goal of ensuring the safe and stable operation of the lines. In recent years, with the deepening of China's ecological civilization construction, the protection of birds and their living environment around transmission lines has gradually become an important factor for such research based on the large ecological construction [5-7]. Based on previous studies on bird-related faults in power lines, this paper investigated the nesting on transmission towers and line faults caused by oriental white stork in Qiqihar and Daqing regions of Heilongjiang Province, and put forward relevant suggestions with the purpose of ensuring the safe and stable operation of the power grid while protecting the reproduction and survival of rare birds by combining with the migration habits of oriental white stork and other factors.

2. Migratory Habits of the Oriental White Stork in Heilongjiang Province

The oriental white stork is a large wading bird with a body length of 110~128cm and a weight of about 4kg, with black flight feathers, large coverts and primary coverts all over the body and white feathers in other parts. Oriental white stork was listed as China's National First-class Protected Wildlife in 2021, is the species in Appendix I of Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), and the red-listed endangered species of the International Union for the Conservation of Nature (IUCN). According to the statistics of the Crane Joint Conservation Committee of the China Wildlife Conservation Association, there are more than 9,000 oriental white storks in the world [8-10].

Oriental white storks mainly feed on fish, but also eat other animal foods such as frog, small rodent, mollusk, arthropod, crustacean, annelid, insect and their larvae and chicks. It mainly lives in open and remote plains, grasslands and swamps, especially in various waters with sparse trees [11]. In China, Oriental white stork is a migratory bird. It mainly breeds in Qiqihar City, Sanjiang Plain, Xingkai Lake, and Xianghai and Momoge in Jilin Province from April to June every year; from July to August, they brood and raise babies in the breeding grounds; from the end of September to the beginning of October, they leave the breeding ground and fly south, mainly along the Songnen Plain through Momoge, Jilin Province, toward the sea, and along the Liaohe River basin through Shuangtaihezi and Beidaihe; from November to February, they overwinter in Poyang Lake in Jiangxi Province, Dongting Lake in Hunan Province, Shenhu Lake, Honghu Lake and Changhu Lake in Hubei Province, Shengjin Lake in Anhui Province and coastal wetlands in Jiangsu Province; they return to breeding grounds in March[12-14].

As the main breeding ground of oriental white stork, it is of great significance to study the living habits of young and adult birds in the late breeding period for the prevention and control of bird-related faults in power grids. Especially, the influence of the behavior characteristics of young birds in feeding, defecation and flight skills learning on the transmission line has its particularity in the field of bird-related fault prevention in the national power grid. In 2015, Xing Minyan *et al.* [15] from Northeast Forestry University conducted a study in Xingkai Lake, Heilongjiang Province, and found that the behavior of oriental white storks followed an obvious rhythm within a day: the rest time of adults and chicks was 20:00 -- 02:00; the single feeding time of adult birds is about 1-2h; 16:00-18:00 is the main time for oriental white stork adult birds to leave the nest for food; 18:00-20:00 is the main feeding time for chicks. In addition, oriental white stork chicks of about 50 days of age would mimic the behavior of adult birds in collecting branches and strengthening nests[16].

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3. Survey and Analysis of Bird-related Baults in Heilongjiang Province

In the western region of Heilongjiang Province, the border region between its southern region and Jilin Province, Qiqihar and Daqing region, the distribution of bird-related faults is concentrated, and the power lines in this area are mostly set up high overhead. Since the 18th CPC National Congress, the government has vigorously promoted the construction of ecological civilization, and the ecological environment in Heilongjiang Province has been improving year by year. With the increase of protection efforts, the wildlife resources in Heilongjiang Province have been continuously enriched. In particular, the number of large birds such as oriental white storks has increased significantly due to the improvement of their living environment and the promotion of protection levels. Since the power line tower is the main choice for its nesting, the power line fault caused by the oriental white stork has become the biggest hidden danger to the safe operation of the power grid in Heilongjiang Province in recent years. The oriental white stork and eggs found during patrols are shown in Figure 1.

Figure 1: Oriental white storks and eggs found during patrols

Statistics show that there were 125 trip-outs caused by bird activities in Heilongjiang from 2011 to 2021, including, classified by voltage level: 20 trip-outs of 500kV transmission line, 80 trip-outs of 220kV, and 25 trip-outs of 110kV; classified by the fault type: 108 trip-outs caused by bird droppings, 7 trip-outs of short-circuit caused by bird's body contact, and 10 trip-outs caused by bird nest. A total of 38 species of birds were observed, including 6 rare species. The results show that when the height of crossarm on the pole is less than 25m or more than 35m, the incidence of bird-caused fault is obviously reduced; when the height of upper crossarm is in the range of 25~35m, bird activity is obvious, and bird-caused faults are more likely to occur, where the main fault type is bird droppings. Avoiding faults caused by bird droppings should be the key direction of bird prevention strategy in Heilongjiang Province. The information and monthly statistics of bird-related faults are shown in Table 1 and Figure 2.

Table 1: Bird-related faults

Voltage Class/kV	Number of trip-out	Trip-outs caused by bird droppings	Trip-outs caused by bird's body contact	Trip-outs caused by nest and others	Average crossarm height
500	20	16	0	4	37
220	80	74	3	3	31
110	25	18	4	3	24

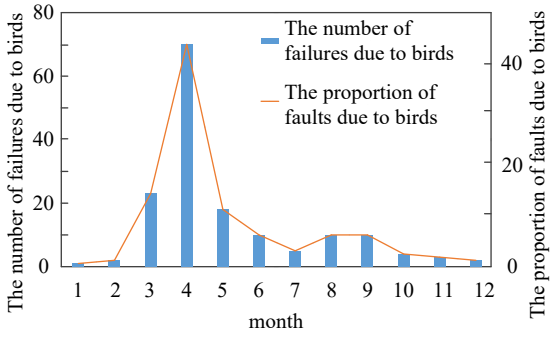

Figure 2: Monthly statistics of bird-caused fault

From March to May 2022, a field survey was carried out on the power lines in Qiqihar area of Heilongjiang Province, and 119 oriental white stork nests were found and recorded on the power line towers, all of which were located on 220kV and 110kV voltage lines. The specific numbers are shown

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in Table 2. Among them, there are 79 nests on 8 lines of 220kV voltage level, and 40 nests on 10 lines of 110kV voltage level; the nests were relatively concentrated on three lines, with 31, 23 and 21 nests respectively, which was more than 60% of the total number of recorded nests, and the perimeter of the line is dominated by open wetlands, which provide rich food for oriental white storks. From the information of pole tower with bird's nests, they are mostly linear towers, involving a variety of tower types, including π type, cat head type, and wine glass type. The recorded 119 bird's nests were on 96 towers, of which 21 towers had 2~3 nests and the remaining 77 towers had only 1 nest. The research results confirmed the conclusion proposed in previous studies that the density of bird nest distribution on the power line tower is positively correlated with the food supply for the surrounding oriental white storks, and negatively correlated with human disturbance factors.

Table 2: Tower with nest of oriental white stork in Qiqihar in spring of 2022

Item	Number of towers with 1 nest/base	Number of towers with 2 or more nest/base	Number of recorded towers with nest/base
220kV	61	8	69
110kV	14	13	27
Total	77	21	96

In the autumn of 2022, the study investigated the nesting situation of oriental white stork on tower in Daqing, which also located in Songnen Plain. After oriental white storks left their nests and moved south in October, 17 empty nests on towers were recorded in Daqing area. According to information, the local power grid company, after the analysis and research of the bird's nest point on the tower, as well as the video recording of the fault caused by oriental white stork's defecation (see screenshot in Figure 3), installed bird protection covers and bird dung baffles at key locations such as the tower insulators and below the bird's nest, upgraded line protection measures, and tried to ensure safe and stable power supply while retaining part of the bird's nests.

Figure 3: Flashover fault caused by Oriental white stork's droppings in the early morning in Daqing area

Based on the comprehensive consideration of the migration route of migratory birds and the distribution of the poles and towers of the power grid in Heilongjiang Province, and combined with the bird-caused fault analysis, the typical bird-related fault protection strategies in Heilongjiang Province were discussed, and the prevention strategies against power line fault caused by rare birds dominated by oriental white storks were differentially explored.

4. Typical Bird-Caused Faults and Bird Prevention Strategies

On April 29, 2021, a trip-out occurred, and the fault phase was identified as phase C (middle phase). Inspectors found obvious burn marks at the crossarm above the tower and the pressure balance ring at the lower end of the "V" type insulator string when they climbed the tower for inspection, and there were a lot of bird droppings around the burn marks. At the same time, signs of bird activity were observed near the tower. No bird nest was found above the crossarm, and the anti-bird sting was intact. During the fault period, the air humidity was 91%, which was relatively high. It should be the reason that droppings were left by the birds when birds migrating nearby flew over or approached the pole tower, and the falling feces then reduced the insulation strength of the crossarm and the pressure balancing ring under the "V" string, resulting in air gap breakdown and the formation of discharge channels. In summary, the fault was the transient single-phase ground short-circuit fault caused by bird activities, and it was a typical fault caused by bird's droppings.

At present, the work of domestic provincial power grid companies related to the bird-line contradiction are mainly aimed at maintaining the normal operation of the power grid, and they mostly

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take isolation and expulsion measures based on "blocking" against birds. However, due to the preference of birds such as oriental white stork and magpies for nest site selection, and even the habit of nesting and breeding in the same location for many years, investing a lot of manpower, material resources, and financial resources to drive out birds not only cannot keep birds away from the power grid facilities from the root, but also easily form a stalemate pattern of human-bird war, which is difficult to achieve long-term and significant results. Based on the existing data of the power grid in Heilongjiang Province and the field investigation results of power transmission lines in Qiqihar and other key areas, this study found that the damage of rare birds such as oriental white stork to the power grid was mainly concentrated in fault caused by droppings and body contact, and the former was closely related to the fault related to bird nest. That is, the occurrence site of fault caused by droppings was mostly located near the tower where birds were nesting. Although the photographic demonstration of the short circuit caused by bird's body contact could not be recorded due to the limitation of the research period and other factors, it can be inferred according to the characteristics of oriental white stork breeding and hatching young birds in Heilongjiang Province, and the confirmed research on the high correlation between the young birds such as black-necked cranes and the collision accident, that the occurrence of short circuit caused by bird's body contact is related to the fly exercises of the young birds in the bird nest on the tower, and it is also closely related to the nesting behavior of oriental white stork on the tower.

On the other hand, the power supply failure caused by bird defecation and body contact also caused a threat to the life of the oriental white stork as a rare bird. In view of the existing problems, the study implements the spirit of the 20th CPC National Congress. With the goal of promoting green development and harmonious coexistence between the power grid and nature, the study gives full consideration to the needs and contradictions of the power grid operation and the survival of rare birds, and takes the symbiosis between the birds and the lines as the starting point. It improves the isolation and expulsion methods, which are mainly based on the "blocking", into the comprehensive prevention and control measures combining the isolation, expulsion and guidance of the line management strategy with the humanistic intervention of the collaborative and symbiotic means. It combines "blocking" and "defusing", treating the surface with "blocking" and treating the root cause with "defusing". Meanwhile, it proposes to actively cooperate with bird protection organizations and the majority of residents, pays attention to protecting rare birds and maintaining ecological balance while ensuring the safety of the power grid, and explores the establishment of a harmonious symbiosis system between birds and lines with Heilongjiang regional characteristics.

4.1 Establishment of an integrated bird protection and bird prevention platform

The integrated bird protection and bird prevention platform aims to establish a long-term mechanism for active participation by the government, enterprises, public welfare organizations and the public, and to promote the attention of all sectors of society to the protection of the oriental white stork and other bird's migration. At the same time, Heilongjiang Power Grid Company cooperates with the Zhalong Nature Reserve and other nature reserves for bird protection cooperation and anti-bird synergy, to build a perfect information communication mechanism, where the staff of each nature reserve, inspection staff of each power supply company, bird protection experts and scholars, volunteers through WeChat, QQ and other platforms strive to establish a long-term and effective working group to form the smooth information channels and give timely feedback and sharing of information on the power line sections where birds are frequently active. At the same time, it strengthens the real-time monitoring of migration trajectory of oriental white stork and other migratory birds by combining with visualization monitoring system, provides relevant information each year to the nature reserve management unit, and the management unit provides the information including distribution of birds, habits, nesting records on transmission towers to the power supply company, so as to jointly lay a solid foundation for protecting birds.

4.2 Establishment of a permanent protection mechanism

This is to give full play to the advantages of joint creation and co-construction, promote the complementary expertise of line operation and maintenance personnel and bird patrol personnel, and jointly establish bird activity files along the transmission power line together with the local administration bureau of protection area, public welfare organizations of bird protection, and voluntary groups. During the period of frequent migratory bird activities from April to September every year, cross-collaborative inspections shall be organized and carried out to maintain power facilities and

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protect birds, and the comprehensive management level of line channels and the surrounding environment shall be improved. The power supply company shall summarize and analyze the historical data of bird distribution, life, migration and reproduction in various nature reserves in the province in a timely manner, and install eco-friendly bird protection devices according to local conditions. In addition, the intensity of line patrol and bird nest observation shall be enhanced in the annual breeding and nesting season, and a line-bird protection expert group shall be set up to make timely research and judgment of the bird nest risks registered in the process of line patrol, and formulate a disposal program based on the principle of one-policy-to-one-nest. In this way, the bird nest risk assessment system and management process will be formed to realize the dual working mechanism of professional line protection and scientific bird protection.

4.3 Differentiated bird protection strategies

Considering that only bird activities occurring in the key parts of the power line (such as the area where the insulator is located) will cause hidden dangers to the transmission safety and the safety of birds themselves, and that birds stopping or nesting in non-sensitive areas (such as the area where the pole and tower are far from the insulator hanging point, etc.) will not endanger the transmission safety, but have a positive effect on the survival and reproduction of birds, the bird prevention and bird repellent measures shall not be indiscriminately taken on the transmission tower, and the enhancement on the key parts of the transmission line can sufficiently provide guarantee for the safe operation of the line. Therefore, this research group proposes the following differentiation strategies.

1) Install isolation-type bird prevention device. For birds with rich diversity and quantity, birds that prefer to move on poles and towers, and areas where more bird-related faults have occurred in history, properly install anti-bird partitions, anti-bird covers, or replace them with large umbrella skirt insulators while routinely installing bird repels to prevent the risk of failure caused by bird droppings and other leakage or accumulation.

2) Timely replace bird-caused faulty insulators. Due to the diverse and frequent activities of birds, bird prevention, bird repellent and isolation devices in practice are usually difficult to completely block the interference of birds on power lines. Therefore, it is necessary to strengthen the insulator inspection and maintenance, timely clean the bird droppings-contaminated insulators, and timely report and replace the seriously polluted or bird-pecked insulators to reduce the risk of fault.

3) Remove and move the nest. Birds nesting in improper positions of poles and towers can significantly increase the risk of line fault, and birds nesting on the crossarm above the insulator should be dealt with as required. If the nest is clearly abandoned in previous years (that is, there are no birds breeding there during the breeding season), or is still in the nesting stage (April-June) but includes no laid eggs, it should be removed in time. This is because it is easier to prevent the parent birds from breeding in the area at this time, and the impact on bird reproduction is small. After removing the nest, install or maintain bird prevention and bird isolation equipment in time to prevent birds from nesting in the same position again. If the birds have laid eggs in the nest, relevant personnel shall try to avoid moving or removing the nest, and formulate and implement the “one-policy-to-one-nest” disposal program according to the aforementioned establishment of the bird protection expert group, so as to avoid improper handling of the parent birds to abandon the nest and affect the continuation of the population. Disposal methods may include the installation of temporary isolation devices (such as anti-bird screens, anti-bird covers, etc.) to block the influence of parent bird activities on the power line. If the eggs have hatched and the breeding has entered the brooding period, the parent birds are not easy to abandon the nest at this time, and the nest can be moved away from the insulator as a whole, so as to eliminate the potential security risks of the power grid without affecting the breeding of birds.

4) Strengthen inspections and establish records. It’s to actively carry out supervisory inspections, and the frequency of inspections shall be well distributed along the annual time line. In seasons when the risk of bird-related fault is high, the inspection cycle is shortened accordingly, while focusing on high-risk areas to identify potential risks in a timely manner. In addition, the data ledger of bird-related work of transmission lines in the inspection work shall be established synchronously to form a database, which makes it easy to grasp the information and integrate data analysis, so as to help form a practical and effective monitoring and early warning mechanism for bird-related faults.

4.4 Develop specific protection strategies for young birds

According to the behavior characteristics of birds incubating and raising chicks in breeding

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grounds, the research on adult birds raising chicks and young birds exercising fly is further strengthened, and the bird-prevention and bird-protection strategies for power line towers are formulated according to the research conclusions. For example, based on the conclusions of Xing Minyan *et al*. from Northeast Forestry University on the living habits of young and adult birds in the late breeding period, protection strategies such as the following can be formulated according to the birds' living habits in different stages and periods: 1) Install sound, light and electric anti-bird strike warning facilities on the line, turn on the devices during the feeding period from 16:00 to 18:00 and the high-frequency flight practice period of young birds every day during the breeding period, and turn off the devices during the birds' rest period from 20:00 to 02:00, so as to carry out harmless intervention on the flight route of birds in different periods to reduce the occurrence of bird strikes without affecting the rest of birds; 2) For the registered nests, observe and record the growth and development of the young birds in the nests, and strengthen the anti-bird baffle under the nests to prevent bird droppings and nest material falling during the period of about 50 days of age of the young birds, and increase line patrols to prevent the young birds from imitating the behavior of adult birds to collect branches and strengthen the nest, which will cause the short circuit fault caused by nest material.

5. Conclusions

1) Due to environmental change factors, the rare bird species in Heilongjiang Province increases year by year, the migration path of migratory birds becomes more complex, the coverage area of transmission lines increases year by year, and the risk of faults caused by birds thus increases in the region.

2) With more and more rare birds living on the transmission tower, comprehensive control measures should be adopted by combining the line management strategy of isolation, expulsion and guidance with the human intervention means of cooperation and symbiosis to establish a harmonious symbiosis working system between bird and lines.

3) Heilongjiang Province is the breeding ground of rare species such as oriental white stork, which is a national first-class protected animal. The bird-caused fault prevention strategy of transmission lines should be closely combined with the behavior and activity characteristics of birds, and the protection system should be differentially built based on the relevant research conclusions.

4) It is suggested that the subsequent transmission line construction path should avoid the areas where bird-related faults occur frequently over the years, and if it cannot be avoided, the tower design parameters should be adjusted to reduce the frequency of bird-related faults.

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