

Original Paper

The Construction of a Low-altitude Ecological Monitoring System: The Impact on the Biological Community and the Governance of the Ecological Environment

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Abstract

In the process of promoting the construction of smart cities, UAVs have been widely used, and low-altitude ecological monitoring has become an important tool for urban governance. The use of UAVs by government departments to conduct grid inspections can make up for the shortcomings of ground patrols, find pollution sources, evaluate vegetation health, and obtain good ecological benefits. However, there are many types of aircraft flying in the buffer zones around the wetlands and rivers, and the flight paths are intersected. Artificial light, noise, rotor downwash and other factors have caused serious interference to amphibians and birds, resulting in negative externalities. Based on the environmental externality theory, digital governance theory, collaborative governance theory and other theories, this paper takes the low altitude flight route density and low altitude ecological inspection coverage rate as the core quantitative indicators, and systematically analyzes the impact of the low altitude monitoring system on the biological community and urban ecological system. In this study, the reasons for the rapid expansion of low-altitude flight routes are analyzed from the market, technology and system levels. In response, this paper puts forward a reasonable governance framework: first, to establish a dynamic control mechanism, divide the functional airspace reasonably, and strengthen digital supervision; secondly, to adopt standardized operational protocols; thirdly, to implement the ecological sensitivity principle; fourthly, to coordinate the relationship between departments; fifthly, to introduce market-oriented tools and internalize ecological costs. The research results can make the operation of the low altitude monitoring system more efficient, and also play an important role in the development of low altitude economy and urban ecological protection.

Keywords

Low-Altitude Ecological Monitoring, Low-altitude ecological inspection coverage rate, Low-Altitude

1. Introduction

In the process of manual ecological inspection, it is inevitably restricted by the complex terrain and the availability of labor, which can not achieve the purpose of monitoring, and there are more and more surveillance gaps. In the process of reforming the management of low-altitude airspace, automated docking stations have been widely used, and the development of low-altitude ecological monitoring system has been significantly accelerated.

At present, the application of low altitude has a strong duality. Some unmanned aerial vehicles are used to trace pollution sources, detect forest fires, and conduct ecological inspections, which has improved operational efficiency, while others are used for leisure, entertainment and aerial photography, and the number of such flights is increasing. However, the development of regulatory framework is relatively lagging, and more and more flights are carried out without authorization in ecologically sensitive areas, and the behavior of flying without authorization endangers the habitat of wild animals and their reproductive behavior. Therefore, we should make an effective balance between low-altitude monitoring and ecological security, and put forward more practical challenges for urban environmental governance.

The research results of other countries in the world are relatively rich, which can show that the technology of unmanned aerial vehicle remote sensing can play a good role in monitoring wild animals and wetlands, and also carry out field research^[1], which can reflect the impact of flight height and time on the stress of birds, and put forward reasonable suggestions for the breeding season of wetlands^[2]. Although some scholars have conducted in-depth research in this field, most of them are related to natural reserves, and there are relatively few research results related to urban wetlands.

Domestic scholars are studying in two aspects: one is to build a sound monitoring system, and the other is to improve the governance system to solve the problems caused by the use of UAVs. In technical research, we should focus on the value of UAV monitoring, while governance research should focus on how to plug institutional loopholes and improve management efficiency. At present, there are not many studies in this regard, and this paper fills this gap.

This study combines a variety of methods, including literature review, quantitative analysis, inductive reasoning and so on. It strictly defines the basic concepts, takes the help of reasonable formulas to calculate the indicators, finds the factors that can lead to negative externalities, and puts forward a reasonable governance framework. The results of the analysis are visualized in a variety of ways, including spatial grid maps, bar charts and line charts.

2. Concept Definitions and Theoretical Framework

2.1 Core Concept and Quantitative Indicators

Low altitude ecological monitoring system: The system is built on a digital twin platform and urban big

data platform, which is a terminal system that can operate at a height of 300 meters, supported by intelligent docking stations, and can monitor ecological changes in the three-dimensional space, integrating satellite remote sensing and Internet of things monitoring stations, and can operate in two modes, commercial and regulatory^[3].

Low-altitude ecological inspection coverage rate (R): This is a quantitative indicator that measures the effectiveness of the inspection activities of the competent authorities, and whether the blind spots in supervision can be eliminated. It should be calculated with the help of GIS, overlay the ecological zoning layer with the flight track buffer layer, and get the result.

$$R = \frac{S_{cover}}{S_{total}} \times 100\%,$$

$$R_i = \frac{S_{cover-i}}{S_{total-i}} \times 100\%$$

$R_i S_{cover} S_{total}$ 1. The coverage rate of the three areas is analyzed, including the general control area, the buffer zone and the core habitat. 2. The buffer zone is an important component of the flight route. 3. Analyze the area under ecological control.

$D_{gov} D_{all}$ Low altitude flight route density: In the process of research, the difference between the overall flight route density and the official service flight route density should be clearly identified, and the mileage of private flights, commercial flights and official service flights should be integrated:

$$D_{gov} = \frac{L_{gov}}{S_i},$$

$$D_{all} = \frac{L_{gov} + L_{com} + L_{pri}}{S_i}$$

$L_{gov} L_{com} L_{pri} D_{all} \leq 5 \text{ km/km}^2 D_{all} \leq 10 \text{ km/km}^2 D_{all} \leq 20 \text{ km/km}^2$ Where is the annual total mileage of private flights, and the annual total mileage of commercial and official flights, respectively, and S_i is the ecological area of each zone. The safety threshold is set as: Bird reproduction core habitat, ecological buffer zone, general control zone.

In the process of low-altitude flight, environmental negative externalities will be generated: UAVs can produce noise, which will interfere with the breeding, foraging and other activities of wild animals and affect the use of their habitats^[4]. In this regard, UAV operators should internalize the ecological costs and not passively bear the responsibility of protecting the ecological environment of wetlands.

In the breeding season, the water birds are displaced due to the high density of UAVs, their habitat is deteriorating, and the nestlings can not survive^[5].

2.2 Basic Theories and Analytical Framework

Environmental externality theory: If government departments organize inspections, positive externalities can be achieved; if the market is not effectively regulated, the number of flight routes will increase significantly, which will lead to ecological losses and will not be internalized. At the same time, it is difficult for the market to self-regulate to eliminate risks, and it is necessary to introduce government supervision and establish market compensation mechanisms.

Digital governance: Build a low altitude big data platform to collect flight data, calculate key indicators, and grasp the density of flight routes to ensure safe flight^[3].

Cooperative governance theory: Because the management of airspace and the protection of the ecological environment require the administration of many departments, the governance of these two aspects must be promoted by multiple departments, data should be shared, management standards should be formulated, operational efficiency should be improved, and the goals of protecting biodiversity should be achieved^[6].

This paper constructs a binary framework in the analysis process: the coverage rate of low-altitude ecological patrol can reflect the benefits brought by the monitoring system, and the density of regional flight routes can represent the risk caused by biological interference. The core content is to make up for the shortcomings in the process of improving the coverage rate of official inspection, and to avoid the excessive density of flight routes in sensitive areas.

3. Positive Environmental Effects of the Low-Altitude Ecological Monitoring System

The official service UAV grid inspection needs to rely on the docking station, and to build a monitoring grid with perfect spatial structure, we need to make strategic arrangements for the docking station. The docking density and distribution of UAVs, as well as the corresponding route density, have a direct impact on the buffer zone coverage, and the increase of patrol coverage can bring more ecological benefits^[7]:

- ① The shortcomings of the ground-based environmental supervision system should be made up for, and environmental violations should be identified quickly, including burning and discharging wastewater without authorization.
- ② It is convenient to analyze the aerial images in chronological order, and to grasp the changes in the community vegetation in terms of time and space, which provides support for the evaluation of ecological projects.
- ③ Aerial patrols can reduce the use of ground vehicles and personnel, will not interfere with the habitat, will not cause damage to the hydrological, vegetation and soil, and will not interfere with sensitive wetlands.

It should be made clear that the dense official flight route is not necessarily advantageous. In the process of patrol, the frequency should be increased appropriately, and the patrol should be carried out in urban green space and waterway. In order to avoid ecological disturbance, it is necessary to control the flight

distance and frequency of official flights, and to set reasonable limits for the density of official flight routes.

4. Relationship between Biological Disturbance and Flight Route Density

4.1 Main Manifestations of Disturbance to Biological Communities

It is worth noting that the use of UAVs will produce noise, which will seriously affect the reproduction of birds. The noise of UAVs overlaps with the bird calls of many species, which will cause stress and escape behavior in birds, and the survival rate of nestlings will decline sharply^[4].

Second, the downwash caused by the rotation of the rotor will have a negative impact on the wetland and aquatic ecosystems. The UAV flies at a low altitude, causing the sediment to rise again, the water quality will be damaged, and the survival of amphibians and plankton will be threatened. At the same time, turbulence can destroy the growth of vegetation, especially reed, which has a negative impact on the function of wetland biological communities^[4].

Third, the use of lighting equipment in aircraft operations will have a negative impact on nocturnal animals, resulting in the interruption of their natural behavioral patterns and the disruption of their circadian rhythms. Artificial lighting will also have a negative impact on bats and waterfowl, which are nocturnal animals, and the three behaviors of these animals will be disturbed, leading to a reduction in biodiversity^[4].

4.2 Causes of the Unregulated Increase in Flight Route Density

- ① Imperfect airspace planning: At present, many cities only formulate broad no-fly zones without specifying the flight route density threshold of the habitat, and aerial operations are carried out in ecologically sensitive areas without operational differentiation^[8].
- ② Fragmented digital supervision infrastructure: There is no platform that can play a monitoring role in the whole jurisdiction, and it can not analyze the flight trajectory in real time, resulting in the failure to calculate the flight density according to the division, and the data of each department can not be shared, which is only limited to the data of its own jurisdiction, and can not achieve the purpose of prevention^[3].
- ③ Market mechanism failure: The current business model encourages enterprises to carry out aerial operations in wetlands with high ecological value, but the operators do not need to bear the corresponding responsibility, which has a negative impact on the ecological environment, and there is no motivation to protect sensitive habitats^[9].
- ④ There is no coordination framework between departments: the ecological department has the authority to manage spatial data, and the civil aviation department is responsible for approval and supervision of flights. The biggest problem is that the current flight authorization procedures do not take into account the route density, and the effectiveness of source supervision is not ideal^[6].

5. Pathways for Collaborative Governance to Coordinate Flight Route Density and Patrol Coverage Rate

Approach: To increase the flight mileage of official inspection missions in the General Ecological Control Zone and increase the coverage of patrols; to strictly limit the operation of commercial and private flights in the Buffer Zone and Core Habitat to ensure that the flight route density in the region does not exceed the ecological threshold^[10].

(1) In order to achieve the purpose of zoning management, the airspace is divided into three levels. Firstly, set up a no-fly zone, and all ecological buffer zones are set up as restricted zones, and the rest of the areas are set up as general ecological control zones^[8]. In no-fly zones, only a small number of official inspections can be carried out in an emergency situation; in restricted zones, official inspections can be carried out, but the total flight mileage of commercial flights must be strictly controlled; in general ecological control zones, the grid layout of official inspections should be as comprehensive as possible, and commercial flights should meet the requirements of supervision and administration.

(2) In the process of building a digital supervision platform, we should not only integrate the ecological space database, but also integrate the flight trajectory database, calculate the density of the flight route and the patrol rate, set a reasonable threshold, and issue a warning once the threshold is exceeded, so as to achieve the purpose of effective supervision, which is to warn before the incident and punish after the incident^[3]. The statistics of the data are standardized, and the reports can provide reliable basis for the authorization of flight routes.

(3) In the layout design of official flights, the flight routes should be adjusted according to the nature of the area. The patrol rate in the General Control Zone should be more than 75%; the flight route in the core habitat should be shortened, and the route density should be strictly controlled; the inspection frequency in the sensitive area should be reduced, and the flight altitude should be increased, so as to minimize the disturbance to the ecological environment and achieve the purpose of comprehensive monitoring^[2].

(4) In the process of administrative supervision, a sound management system should be formulated to formulate relevant standards for low-altitude flight operations in wetlands, and to set a reasonable maximum flight altitude, reasonable flight time and reasonable flight distance. In the process of flight operation, the activities carried out in ecologically sensitive areas should be evaluated, and administrative penalties should be imposed on those who violate the rules^[2].

(5) The establishment of a cross-departmental coordination mechanism requires the joint efforts of departments such as Ecology and Environment, Natural Resources, and Big Data Administration. In this way, the monthly inter-departmental coordination meeting can be held regularly to update the ecological habitat space layer, set up a unified platform, calculate the two ecological indicators, require the airspace management department to approve the flight route according to the indicator, and implement the law enforcement inspection jointly to eliminate the data silo^[6].

(6) In the process of implementing market-based measures, the external costs should be internalized,

and the quota system should be implemented in the operation of commercial flights, which should be based on the distance. If the company exceeds the quota, it needs to pay a certain amount of ecological compensation, and the funds should be used for wetland maintenance, so that all market participants can actively reduce the number of flights in sensitive areas^[6].

6 Conclusions

6.1 Main Conclusions

(1) This paper puts forward two key indicators, low altitude flight route density and low altitude ecological patrol coverage rate, and establishes a sound quantitative evaluation system. In the process of using GIS system and low altitude big data, the two indicators can make zone level assessment with the help of space, which can clearly distinguish between the positive governance results and ecological disturbance risks.

(2) The increase of official inspection flights can make up for the shortcomings of ground supervision, improve the ability to trace pollution sources, evaluate ecological restoration and monitor the health of vegetation. In this way, it can also reduce the degradation rate of the ground habitat, but we should be cautious in choosing the flight route in the ecologically sensitive area and should not increase it blindly^[7].

(3) The increase in the number of flights in a certain area will have a negative impact on aquatic and avian communities, including noise, artificial light and so on, which will lead to a decline in breeding success rate and even cause the abandonment of habitats. The main reasons are the lack of perfect airspace planning, the lack of digital monitoring infrastructure, the lack of market incentives, and the low degree of coordination between departments^[9].

(4) In the construction of the airspace control system, we should adopt a three-tier differentiated strategy: first, in the ecological areas, we should ensure that the patrol coverage rate is relatively high; secondly, in the biologically sensitive areas, we should strictly control the flight route density; thirdly, we should use digital platforms to monitor the two indicators dynamically, and coordinate with administrative supervision and market compensation to achieve multi-departmental coordination^[10].

6.2 Research Limitations

This paper analyzes the monitoring data, and in the next stage of research, the trajectory data set should be introduced into the model to optimize the regression model, and set the safety threshold for different bird species.

6.3 Future Prospects

With the continuous updating of technology, the platform can automatically calculate various data, which can also be updated in real time. With the continuous improvement of the platform, it can not only increase the patrol rate, but also reduce the impact of flying, which is conducive to the sustainable development of low-altitude ecological monitoring and the protection of biodiversity.

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