Study on Coverage and Distribution Characteristics of Great Gerbil Burrow Groups in Desert Forests Based on UAV Low-Altitude Remote Sensing: A Case Study of the Southern Margin of the Gurbantünggüt Desert, Xinjiang (Postprint)

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Abstract

Grassland rodent damage is an important factor affecting grassland ecological balance, and monitoring of grassland rodent damage constitutes a crucial component of rodent control efforts. UAV low-altitude remote sensing represents a novel method for rodent damage monitoring, characterized by high spatial resolution, high timeliness, low cost, and low attrition, and has completed demonstration work in rodent damage monitoring and control approaches in Xinjiang. In October 2015 and May 2016, two UAV low-altitude aerial surveys were conducted in typical Rhombomys opimus damage areas of desert forests on the southern edge of the Gurbantünggüt Desert in Xinjiang, acquiring ultra-high-resolution imagery of the experimental areas with resolutions of 0.02 m and 0.024 m, respectively; visual interpretation of the entire images from both experimental areas was performed to obtain the distribution of rodent burrows; based on the burrow distribution maps, buffer analysis was conducted and trend lines were added to obtain the spatial distribution trends of the burrows, which were then overlaid with hillshade maps of the study area to analyze the relationship between burrow distribution and topography. Through GIS grid and GIS overlay analysis, the coverage rate of burrow colonies was obtained. The following conclusions were drawn: UAV low-altitude remote sensing can provide highly accurate interpretation results for Rhombomys opimus damage surveys; the coverage rates of burrow colonies in the desert forest Rhombomys opimus damage areas of the local study region on the southern edge of the Gurbantünggüt Desert were 19.4% and 18.8%, respectively, indicating high-density infestation areas; the Rhombomys opimus burrows in the study area exhibited obvious clustering characteristics and banded distribution patterns; the clustering characteristics indicate that burrows exist in the form of colonies; the banded distribution characteristics of burrows in the study area are closely related to topography; based on these spatial distribution characteristics, rodent control strategies can be scientifically planned; this study demonstrates that UAV low-altitude remote sensing has broad application prospects in rodent damage monitoring and control.

Full Text

Abstract

Grassland rodent pests represent a critical community component affecting the ecological balance of grassland ecosystems. Monitoring these pests is an essential component of integrated pest management. Unmanned aerial vehicle (UAV) low-altitude remote sensing emerges as a novel rodent monitoring approach characterized by high spatial resolution, high efficiency, low cost, and minimal potential for data loss. A demonstration project was conducted in Xinjiang to evaluate its potential for rodent monitoring and control. This study focused on the desert forest habitat of *Rhombomys opimus* near the southern margin of the Gurbantunggut Desert, conducting UAV low-altitude aerial surveys in October 2015 and May 2016. Ultra-high resolution imagery of the experimental area was acquired at 0.02 m and 0.024 m resolutions, respectively. The entire image area was subjected to visual interpretation to determine burrow distribution, followed by buffer zone analysis and trend line addition to characterize spatial distribution patterns. Overlay analysis with hillshade maps was performed to investigate relationships between burrow distribution and topography. Burrow group coverage rates were calculated, yielding the following conclusions: UAV low-altitude remote sensing can provide highly accurate interpretation results for *R. opimus* surveys; the burrow group coverage rates in the desert forest *R. opimus* damage zones at the southern margin of the Gurbantunggut Desert were 19.4% and 18.8%, respectively, indicating high-density infestation areas; burrows exhibited pronounced aggregation characteristics and zonal distribution patterns; the aggregation characteristics demonstrate that burrows exist as colony systems; the zonal distribution features are intimately related to topography; and these spatial distribution characteristics can inform scientific planning of rodent control strategies. This research demonstrates that UAV low-altitude remote sensing holds broad application prospects for rodent monitoring and control.

Keywords: UAV; low-altitude remote sensing; *Rhombomys opimus*; GIS grid; spatial distribution trends; hole group coverage

Introduction

Ecological environmental protection is increasingly important for green development in Xinjiang, the core region of the Silk Road Economic Belt. Rodent damage, as a primary destructive factor affecting Xinjiang' s grasslands and desert forests, seriously threatens the ecological security of desert grasslands and desert forests, as well as livestock production. The great gerbil (*Rhombomys opimus*) is a major pest in desert forests, feeding on the tender roots and bases of desert forest plants such as *Haloxylon ammodendron* and *Tamarix ramosissima* [?]. The decline and death of desert forest vegetation exacerbates desertification. Xinjiang' s rodent-infested areas are mostly located in remote desert forests with difficult access, numerous burrows, and challenging survey and control conditions. Traditional ground-based survey methods are time-consuming, labor-intensive, costly, and have long survey cycles, making it difficult to rapidly and comprehensively reflect the extent of rodent damage. Additionally, data on relationships between rodents and environmental factors such as vegetation are lacking in this region, preventing timely and effective implementation of targeted control measures. This has led to frequent rodent outbreaks, expanding damage areas, deteriorating regional ecological security, and serious impacts on pastoral economic development. Consequently, developing novel survey and monitoring methods for rodent control is imperative.

Previous studies have explored remote sensing technologies for rodent monitoring. Xuan et al. [?] used delta-wing aircraft for aerial photography of rodent-damaged wasteland. Li et al. [?] utilized remote sensing satellites to estimate rodent-damaged areas in the Altun Mountains. Wen et al. [?] applied UAV low-altitude remote sensing for rodent damage aerial photography and attempted computer-automated interpretation. Zhao et al. [?] conducted rodent control trials using aircraft-dispersed rodenticides. Addink et al. [?] used high-resolution remote sensing for rodent surveillance in Kazakhstan. Huang et al. [?] analyzed soil-adjusted vegetation indices before and after *R. opimus* control in natural *Haloxylon* forests. These studies provide scientific foundations for satellite remote sensing-based rodent management and dynamic monitoring.

However, in our study area, *R. opimus* burrow entrances typically measure approximately 10 cm in diameter and are often obscured by surface vegetation cover, making accurate burrow information extraction impossible from satellite imagery. This highlights the limitations of low spatial resolution. Satellite remote sensing also suffers from fixed revisit cycles and cloud cover issues, significantly constraining the timeliness and flexibility of rodent surveys. While custom high-resolution imagery is expensive, UAV low-altitude remote sensing offers a new research approach for Xinjiang rodent surveys.

Numerous scientific research projects have successfully employed UAVs as remote sensing platforms. Li et al. [?] used UAVs equipped with Tetracam ADC cameras to monitor winter wheat coverage changes in Beijing. Gao et al. [?] used octocopter electric UAVs with Sony DSC-QX100 cameras for aerial photography of mangroves in Luogang Bay. Zhang et al. [?] utilized UAVs for forest resource inventory in Lin' an City. Feng et al. [?] used pusher fixed-wing UAVs for studies in Yingluo Bay, demonstrating advantages of UAV low-altitude remote sensing in mangrove information extraction and classification. These projects highlight the significant advantages of UAV low-altitude remote sensing for low-altitude aerial photography, effectively compensating for cloud obstruction limitations of satellite optical remote sensing and manned aerial photography, and becoming an important new remote sensing method. UAV remote sensing can flexibly acquire multi-temporal ground observation data, making it well-suited for Xinjiang rodent survey research.

Traditional manual surveys involve large-area carpet surveys using methods such as hole blocking, capture-per-unit-area, and hole coefficient methods [?, ?, ?, ?]. These methods require substantial ground support work and are difficult to integrate with UAV low-altitude remote sensing. In contrast, burrow group coverage can be directly calculated from imagery and easily combined with UAV low-altitude remote sensing data. Burrow group coverage [?] refers to the percentage of area occupied by *R. opimus* burrow groups (including abandoned groups) relative to the total survey area. This indicator reflects recent or longer-term damage levels to desert pastures and enables assessment of rodent damage severity for developing more reliable and effective control measures.

This study employed a UAV low-altitude remote sensing platform to conduct two aerial surveys of typical *R. opimus* damage areas in desert forests at the southern margin of the Gurbantunggut Desert. Using UAV imagery, we calculated burrow group coverage rates, classified rodent damage levels, analyzed burrow distribution trends, evaluated the effectiveness of UAV low-altitude remote sensing for monitoring *R. opimus* spatial distribution and density, and assessed regional rodent damage conditions to provide a scientific basis for controlling desert forest *R. opimus* damage.

1. Study Area Overview

The study area was selected in typical *R. opimus* damage zones within desert forests at the southern margin of the Gurbantunggut Desert in Xinjiang Uygur Autonomous Region. The area faces severe ecological threats from rodent damage, with vegetation coverage of 40%-50% on fixed dunes and 15%-25% on semi-fixed dunes. The primary pest species is the great gerbil (*Rhombomys opimus*). Vegetation consists mainly of *Haloxylon ammodendron*, *Tamarix chinensis*, *Ephedra* spp., and *Kalidium foliatum*. Two experimental plots were selected: the first plot measures 2.4 km × 1.5 km, centered at 44.413°N, 87.857°E; the second plot measures 1 km × 1 km, centered at 44.583°N, 88.160°E.

2. UAV Low-Altitude Remote Sensing

The aerial platform consisted of a fixed-wing UAV (DOPSV360) with strong wind resistance capable of carrying multiple remote sensors. Two professional-grade DSLR cameras were used: the Sony ilce-7m and another Sony model, both meeting resolution requirements for burrow photography and UAV payload constraints. Detailed UAV and camera parameters are provided in Table 2.

[Figure 1: see original paper] Real shot of rat holes in the study area

Aerial equipment parameters

2.1 Aerial Data Acquisition

Following flight mission determination, an experimental area flight plan was designed to establish the photographic scale and ground resolution required for burrow extraction. The first experimental area was photographed around 12:00, and the second around 14:00. Both surveys were conducted at noon during periods of good lighting to ensure stable flight attitude and minimal shadows, facilitating high-quality image acquisition. Forward overlap was controlled at 60%-65%, and side overlap at 30%-35%. The UAV low-altitude remote sensing data consisted of individual photographs. Software was used to mosaic single images from both experimental areas and perform projection correction to obtain complete aerial photographs. The spatial resolution was 0.02 m for the ilce-7m and 0.024 m for the other camera.

2.2 Data Processing

After obtaining complete aerial imagery, visual interpretation was performed manually. Based on orthophotos and field investigations, *R. opimus* burrow entrances were found distributed primarily on sand dunes, clay, and gravel lands. Burrows appeared as similar and distinct black patches with bright, raised sand mounds in the aerial imagery. Each gerbil colony has multiple entrances. Using these characteristics, interpretation keys were established for visual interpretation of burrows in the experimental areas. Following visual interpretation, buffer zones were created around burrow distribution maps and trend lines were added to analyze spatial distribution patterns and inter-burrow relationships. Hillshade was extracted from the low-altitude remote sensing imagery and overlaid with burrows to analyze topographic relationships. Grid analysis was applied to calculate burrow group coverage rates.

A 5 m × 5 m grid size was determined based on experimental area extent, technical requirements, and burrow distribution characteristics. Using ArcGIS overlay analysis, burrow distribution maps and grid maps were superimposed, assigning each burrow a location grid identifier. Spatial statistical analysis was then used to count grids containing burrows.

4. Rodent Damage Classification

Following visual interpretation of the entire study area imagery to obtain total burrow counts and distribution, burrow group coverage rates were calculated to assess damage severity. The coverage rate formula is:

$$C = \frac{S_1}{S_2} \times 100\%$$

where C is the burrow group coverage rate in the damaged area, S_1 is the area occupied by burrows, and S_2 is the total study area.

Since large-area burrow measurement is difficult and traditional methods are error-prone due to human factors, the grid method was employed using uniform grids as basic units to approximate burrow area:

$$C = \frac{N_1}{N_2} \times 100\%$$

where N_1 is the number of grids containing burrows and N_2 is the total number of grids in the study area.

According to the *Xinjiang Local Standard for Desert Forest Great Gerbil Monitoring and Investigation Methods* (DB65), desert forest *R. opimus* damage levels are classified by burrow group coverage rate: low density (0 < C 5%), moderate density (5 < C 10%), high density (10 < C 15%), very high density (15 < C 20%), and extreme density (C > 20%).

2. Results and Analysis

Visual interpretation and statistical analysis revealed burrows in the first experimental area and burrows in the second experimental area. Buffer analysis of the interpreted burrow distribution maps was conducted by establishing buffer zones around burrows to explore inter-burrow relationships.

[Figure 8: see original paper] Rat holes buffer

The results demonstrate that burrows form contiguous patches after buffer creation, indicating that *R. opimus* live in colonies and form complete burrow systems. To investigate overall distribution characteristics, trend lines were added to the burrow distribution maps.

[Figure 9: see original paper] Rat holes distribution trend

The results show that burrows exhibit distinct zonal distribution patterns in space. To explore driving factors behind this pattern, hillshade was extracted from UAV imagery and overlaid with burrows for spatial analysis [Figure 10: see original paper].

[Figure 10: see original paper] The shadow of the mountain and mousehole superposition

The results indicate that burrows show zonal distribution along topographic features, demonstrating a close relationship between burrow distribution and terrain. This suggests that *R. opimus* in the study area have a habit of constructing burrows on slopes. Grid-based analysis was performed to calculate burrow group coverage rates. After grid creation and overlay analysis, the first experimental area contained grids, with grids containing burrows, yielding a coverage rate of 19.4%. The second experimental area contained grids, with grids containing burrows, yielding a coverage rate of 18.8% [Figure 11: see original paper].

[Figure 11: see original paper] Experimental zone grid

According to the damage level classification standard, both study areas fall within the high-density damage category, requiring active and effective control measures.

Rat hierarchies

3. Discussion

3.1 Application of UAV in Rodent Survey

Xinjiang' s severe rodent damage areas are mostly located in remote, inaccessible regions. Traditional ground survey methods such as hole blocking and trap placement require enormous ground work, making them extremely difficult to integrate with remote sensing imagery. In modern practice, reliance on traditional manual surveys alone cannot meet the needs for rapid information updates. Burrow group coverage, however, can reflect recent or longer-term damage to desert pastures without extensive ground work, making it readily compatible with UAV low-altitude remote sensing.

Some scholars have attempted satellite remote sensing for grassland rodent surveys. Xu et al. [?] used MODIS imagery to extract vegetation indices in Dongting Lake area to assess damage from *Microtus fortis* outbreaks. However, the relatively low spatial resolution of remote sensing imagery cannot directly enumerate burrows and must rely on proxy parameters like vegetation indices, making it suitable only for areas with dramatic rodent population fluctuations and simple vegetation structures. Huang et al. [?] used high-resolution remote sensing to compare soil-adjusted vegetation indices before and after *R. opimus* control in natural *Haloxylon* forests, but cloud cover and fixed satellite revisit cycles greatly affected flexibility and temporal consistency.

This study utilized UAV low-altitude remote sensing to obtain ultra-high resolution imagery (0.02-0.024 m) of typical *R. opimus* damage areas in desert forests at the southern margin of the Gurbantunggut Desert. Flight routes were designed to avoid obstacles such as tall buildings and chimneys. Since ground vegetation shadows affect visual interpretation accuracy, aerial operations were conducted at noon during periods of good lighting to ensure stable flight attitude and minimal shadows. After visual interpretation, grid-based overlay analysis yielded burrow group coverage rates of 19.4% and 18.8%, classifying both areas as high-density damage zones requiring active control measures. The consistency between the two study areas validates the accuracy of using UAV imagery to calculate burrow group coverage and demonstrates the universality of UAV low-altitude remote sensing for rodent analysis across different regions and areas. Compared with traditional ground surveys, UAV-based visual interpretation significantly improves survey speed and accuracy while reducing subjective bias. UAV aerial photography can also be supplemented with ground verification methods like hole blocking for unclear areas, providing a new approach for forest rodent survey and control.

3.2 Relationship Between Burrow Distribution Characteristics and Topography

Buffer analysis of extracted burrow vector data reveals distinct spatial characteristics. Burrows show obvious aggregation, mostly forming patches or strips as colony systems. For *R. opimus* control and survey, focusing on burrow colony systems as units can effectively improve control efficiency. Trend line analysis reveals clear zonal distribution patterns. Overlay with topographic features shows that burrows are predominantly distributed on slopes, with far fewer burrows on flat terrain. This indicates that the zonal distribution characteristics are closely related to local terrain structure and that *R. opimus* in this region have a habit of constructing burrows on sand slopes.

During control operations, understanding these spatial distribution characteristics enables targeted chemical application, reducing costs and biological toxin accumulation associated with large-area spraying. When deploying control tools like bow-shaped traps, spatial distribution trends can guide placement to improve control efficiency.

4. Conclusions

This study explored the application of UAV low-altitude remote sensing for grassland rodent damage in Xinjiang and processed the resulting imagery. The main conclusions are:

1. UAV low-altitude remote sensing can provide highly accurate interpretation results for *R. opimus* surveys, with burrow group coverage rates of 18.8%-19.4% in typical damage areas at the southern margin of the Gurbantunggut Desert, indicating high-density infestations requiring immediate scientific control.
2. Burrows exhibit aggregation characteristics and distinct zonal spatial distribution patterns closely related to terrain, demonstrating the species' habit of constructing burrows on slopes.
3. Compared with traditional ground surveys, UAV low-altitude remote sensing offers numerous advantages. The imagery enables visual interpretation of burrow locations and counts, calculation of burrow group coverage rates, and significantly improved survey efficiency.
4. UAV low-altitude remote sensing shows excellent application prospects for rodent survey and control. This study successfully demonstrates that UAV remote sensing can fulfill rodent survey requirements and provides new insights for forest rodent survey and control.

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Note: Figure translations are in progress. See original paper for figures.