越南鸟栈国家公园赤颈鹤(*Grus antigone sharpii*)种群增长模型及景观特征分析

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摘 要:【目的】越南鸟栈国家公园是赤颈鹤东方亚种(*Grus antigone sharpii*)在越南区域的主要分布地，也是中国赤颈鹤种群重引入前的野化地。但该区域的赤颈鹤种群自1986年被发现后整体呈下降趋势，很不乐观。【方法】为了探究鸟栈公园赤颈鹤种群下降原因，本研究从种群内在增长和外在景观环境两方面着手，利用逻辑斯蒂方程、马尔萨斯方程、周限增长率分别拟合了世代重叠种群有限环境中、世代重叠种群无限环境中、世代不重叠种群无限环境中赤颈鹤种群增长模型，并进而利用ENVI5.3、ArcGIS10.5软件和1988-2022年Landsat遥感影像从土地利用类型和景观特征水平分析了其对赤颈鹤种群增长的环境阻力。【结果】结果表明：(1)赤颈种群大小在1988-2022年间呈种群衰退状态，直至数量为零。(2)用三种方法拟合了赤颈鹤种群增长模型。世代重叠前提下，在有限环境中，逻辑斯蒂方程显示出赤颈鹤种群拟合曲线总体较平缓，与观察种群曲线不重叠，在2000年，两曲线发生交叉。世代重叠前提下，在无限环境中，马尔萨斯方程显示出赤颈鹤种群拟合曲线与观察种群曲线在1988-2000年具有一定的同步性，但其波动不如观察种群明显；在2000年后，拟合种群曲线稳定，拟合种群大小显著高于观察种群大小。世代不重叠前提下，在无限环境中， 赤颈鹤种群周限增长率平均值为0.89，拟合种群曲线中，1992年和1996年观察种群数量明显偏离拟合种群数量，其余年份间观察种群数量均围绕着拟合种群曲线波动，总体呈现出一定的同步性。(3)鸟栈公园植物群落包括白千层、莲花、铺地黍草-野生稻、荸荠属草、混合植物、水道(特指人工水渠)和水域(属于季节性地表积水)；其中，铺地黍草-野生稻和白千层是优势植物群落，白千层植物群落面积与赤颈鹤种群的数量呈显著负相关；而荸荠属草植物群落面积波动较大，与赤颈鹤种群的数量呈显著正相关。 (4)斑块类型水平和景观水平均影响着赤颈鹤种群。其中，斑块类型水平上，赤颈鹤种群数量与荸荠属草面积、莲花的周长面积分维数以及混合植物的最大斑块指数呈显著或极显著正相关；与白千层面积及铺地黍草-野生稻的散布与并列指数呈显著或极显著负相关。景观水平上，赤颈鹤种群数量只与周长面积分维数呈显著正相关。【结论】进一步分析表明，1988-2000年间，赤颈鹤观察种群在鸟栈公园受到环境资源有限性的阻力，并且环境阻力存在时滞效应；环境中的荸荠属草植物群落显著下降和白千层植物群落面积显著增加对赤颈鹤种群下降有影响。基于此，建议越南鸟栈国家公园根据需要对荸荠属草植物群落和白千层植物群落进行适当管理。

关键词: 种群增长模型；土地利用类型；景观特征；赤颈鹤东方亚种；越南鸟栈国家公园

Population growth model and landscape characteristics analysis of the Sarus crane (*Grus antigone sharpii*) in Tram Chim National Park, Vietnam

Abstract: 【Objective】Vietnam Tram Chim National Park is the main distribution site of *Grus antigone sharpii* in Vietnam, and also the rewilding site of Chinese Sarus Crane population before reintroduction. However, the population of Sarus Cranes in this area has been declining since it was discovered in 1986, which is not encouraging. 【Method】In order to explore the reasons for population decline of Sarus Cranes in Tram Chim national Park, this study started from the two aspects of population internal factors and external landscape environmental factors, used logistic equation, Malthus equation and circumferent growth rate to fit the growth models of overlapping population in finite environment, non-overlapping population in infinite environment and

overlapping population in infinite environment respectively. ENVI5.3, ArcGIS10.5 and Landsat remote sensing images from 1988 to 2022 were used to analyze the environmental resistance to the population growth of Sarus Crane from the level of land use type and landscape characteristics. 【Result】 The results showed that: (1) the population size of Sarus Crane population declined during 1988-2022 until it reached zero. (2) Three methods were used to fit the population growth model of Sarus Crane. Under the premise of overlapping generations, in a finite environment, the logistic equation showed that the population fitting curve of Sarus Crane was relatively flat on the whole, and did not overlap with the observed population curve. In 2000, the two curves crossed. Under the premise of overlapping generations, the Malthusian equation showed that the population fitting curve and the observed population curve had a certain synchronization during 1988-2000, but the fluctuation was not as obvious as that of the observed population. After 2000, the fitted population curve was stable and the fitted population size was significantly higher than the observed population size. Under the condition of non-overlapping generations, the average circumferential growth rate of the population was 0.89 in an infinite environment. In the fitted population curve, the observed population in 1992 and 1996 deviated significantly from the fitted population, and the observed population fluctuated around the fitted population curve in other years, showing a certain degree of synchro. (3) The plant communities in the park include *melaleuca* biome, *Nelumbo* biome, *Panicum repens* - *Oryza* biome, *Eleocharis* biome, mixed plant biome, water canal (especially artificial canals), and water area (seasonal surface water); The dominant plant communities were *Panicum repens* - *Oryza* biome and *melaleuca* biome, and the biome area of *melaleuca* biome was negatively correlated with the population of Sarus Crane. The area of *Eleocharis* biome fluctuated greatly, which was positively correlated with the population of Sarus Crane. (4) Both patch type level and landscape level affected the population of Sarus Crane. At the level of patch type, the population of Sarus Crane was positively correlated with the area of *Eleocharis* biome, the perimeter integral dimension of *Nelumbo*, and the maximum patch index of mixed plants. There was a significant or extremely significant negative correlation with *melaleuca* biome area and the distribution index of *Panicum repens* - *Oryza*. At the landscape level, the population of Sarus Crane was positively correlated with the integral dimension of its perimeter. 【Conclusion】 Further analysis shows that the observed population of Sarus Cranes was subjected to the limitation of environmental resources in the park from 1988 to 2000, and there is a delay effect in the environmental resistance. The decrease of the population was influenced by the significant decrease of the *Eleocharis* biome and the significant increase of the *melaleuca* biome. Based on this, it is suggested that the biome of *Eleocharis* biome and *melaleuca* biome should be properly managed according to the needs.

Key words: poulation growth model; land use type; landscape characteristic; sarus crane; Tram Chim National Park.