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The Box-counting Dimension of Spatial Patterns of Population Distribution of *Lilium regale*

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Abstract: The studied results of correlation dimension of spatial patterns of population distribution of *L. regale* by box-counting dimension show that: 1) in most sample plots the fractal properties of box-counting dimension are significant; 2) in most sample plots the box-counting dimension is small, indicating their spatial occupation degree is not high and they are not dominant in population; 3) plot 10 is the best habitat for *L. regale*; 4) there are different ecological gap latitudes in different plots, indicating they have more ecological space to occupy in population.

Introduction

Lilium regale (*L. regale*) is a perennial herbaceous plant that belongs to the lily family. It is native in Aba, Sichuan Province of China, along the area of Wenchuan, Lixian, Maoxian and Heishui. It is usually grown at an elevation from 800 meters to 2700 meters. You can find *L. regale* among the rocks of a cliff, grasses of a hillside, bushes or rubbles of a stream. It has great medical, edible and ornamental value. It is a precious genetic resource of wild flowers and important breeding material of lily industry [1-3].

The spatial pattern of plant population distribution, also known as the internal distribution, usually refers to the position and distribution of individual species in their living space. It is a basic quantitative character of a population, and the result of long-term coadaptation and selection between biological character of species and various specific habitat conditions [4-6]. The fractal analysis emphasizes on the importance of dimension, and different dimension reflects the real content of variation. Therefore, the fractal analysis becomes a powerful tool to describe the problem of dimension dependence [7]. Fractal geometry can reveal the rule of how population distribution changes with dimension. Different fractal dimension can describe various fractal properties of spatial patterns of population distribution respectively [8]. The fractal analysis of the spatial patterns of population distribution can reveal their change rules on different observation scales [9]. The box-counting dimension, also known as the Minkowski-Bouligand dimension, represents the occupation ability of population to ecological space, and is a relatively simple and commonly used fractal dimension [10]. The study on population box-counting dimension contributes to the understanding of occupation ability of population and the analysis of their habitat adaptation [11].

By far there are many researches about *L. regale*, however, there is no relevant report about the fractal properties of spatial patterns of wild population distribution [3,12-14]. This research chooses *L. regale* which is widely distributed in the barren valleys along the upper reaches of Minjiang River as study object. It uses the box-counting dimension to discuss the internal distribution pattern and to provide scientific evidence for protection, exploitation and utilization of wild resources.

Experimental methods

Research area

The barren valleys along the upper reaches of Minjiang River are located between Tibetan Plateau and Sichuan Basin with an elevation of 1200 to 2000 meters [15]. It lies along the corridor of Minjiang main stream and its branches: Heishui River and Zagunao River, which represents a landscape of xeric semi-desert. The major vegetation form is drought tolerant bushes. The common dominant species in shrub layer are *Sophora viciifolia, Bauhinia faberi,* etc., and the common dominant species in herb layer are *Carex lanceolat, Sedum wenchllanens, Artemisia igniaria, Artemisia sylvatica, Lilium regale,* etc. [16-18].

Field survey

In July 2012, in the barren valleys along the upper reaches of Minjiang River, areas in which *L. regale* is well protected were selected as research area, including Tonghuagou of Lixian, Longxigou of Wenchuan and Mianchaogou of Maoxian. Sample plots were set up including eleven 10m×10m plots (Table 1). One corner of the plot is set as zero point to build the coordinate system.

Table 1 some environment factors for the 11 plots

Plot No.	Latitude	Longitude	Elevation[m]	Slope	Slope-exposure
1	E103°25.736′	N31°33.161′	1667	71°	WN327°
2	E103°32.769′	N31°34.470′	1778	52°	EN62°
3	E103°45.276′	N31°36.220′	1588	51°	WS241°
4	E103°45.295′	N31°36.212′	1609	59°	W267°
5	E103°45.374′	N31°36.227′	1657	58°	WS223°
6	E103°45.364′	N31°36.127′	1715	54°	WS243°
7	E103°45.671′	N31°36.169′	1623	67°	WS244°
8	E103°45.676′	N31°36.159′	1647	57°	WS247°
9	E103°45.664′	N31°36.144′	1678	63°	WN68°
10	E103°45.682′	N31°36.181′	1625	56°	WN226°
11	E103°45.684′	N31°36.193′	1566	58°	WN293°

The measurement of box-counting dimension [6-7, 10]

In this formula, x is the divide scale. In the situation of covering *L. regale* population with grid, N(x) is the non-blank grids in the point bitmap of population distribution. Firstly, halve the length of sample plot 19 times, and obtain the number of non-blank grids according to the divide scale. Then in the log-log coordinate, make a linear fitting between the number of non-blank grids and corresponding grid length. The absolute value of the slope of linear fitting represents the estimated value of box-counting dimension.

Results and discussion

According to the above mentioned method, the box-counting dimension of 11 sample plots is measured, and the results are shown in Table 2.

The larger the box-counting dimension is, the higher the occupation degree of ecological space is, and the stronger the habitat adaptation is. It is suggested in this table that:

(1) F value of Plot 6 is smaller than 1.57, which makes the box-counting dimension not statistically significant. F value of the other 10 sample plots are larger than 1.57. Nine of them are significantly larger than 1.88, and the correlation index are mostly above 0.8, suggesting a significant fractal property.

(2) Except Plot 6, the box-counting dimension of ten sample plots are between 1.0896 and 1.9392. Among them 70% are smaller than 1.5 and close to 1, indicating a low occupation degree, which means *L. regale* does not take up a dominant position in its population. The box-counting

dimension of Plot 10, 8, 1 and 3 are relatively large and close to 2, probably because part of these habitat conditions is superior, which agrees with the actual field survey report. Moreover, the box-counting dimension of Plot 10 is the largest and very close to 2, indicating it is the best habitat for *L. regale*. When growing *L. regale* in preserve, it is reasonable to select or build a similar habitat as Plot 10 [19].

Table 2 the box-dimension of population distribution of *L. regale* population for the 11 plot

Plot	Box-dimension Model	Box-dimension	F-Statistic	Inflection point
1	Ln[N(x)]=1.5323·Ln(x)+10.4098	1.5323	318.3858	1.5700
2	Ln[N(x)]=1.2666·Ln(x)+9.7590	1.2666	154.8330	1.3738
3	Ln[N(x)]=1.3567·Ln(x)+8.5956	1.3567	142.8431	--
4	Ln[N(x)]=1.3771·Ln(x)+9.5421	1.3771	14.0967	1.3738
5	Ln[N(x)]=1.2990·Ln(x)+9.5832	1.2990	52.6645	2.1980
6	Ln[N(x)]=1.4181·Ln(x)+6.9780	1.4181	1.4816	0.9158
7	Ln[N(x)]=1.0896·Ln(x)+6.8422	1.0896	1.7524	0.9158
8	Ln[N(x)]=1.7472·Ln(x)+10.0439	1.7472	128.3265	2.7475
9	Ln[N(x)]=1.1876·Ln(x)+8.3669	1.1876	92.2159	--
10	Ln[N(x)]=1.9392·Ln(x)+11.3280	1.9392	28.4242	1.3738
11	Ln[N(x)]=1.3101·Ln(x)+7.0486	1.3101	8.3095	0.6869

*1.57 ＜$F_{0.05}$＜1.60, 1.88＜$F_{0.01}$＜1.93.

(3) Among the valid 10 box-counting dimensions, 8 of them are smaller than 1.5, and 2 of them are close to 2. In this study, the area of field survey is far bigger than minimum sampling area, and *L. regale* appeared in every plot. Still most the box-counting dimensions are relatively small, which is on account of its biological property and its low population density. On the one hand, *L. regale* is propagated by seeds, and the narrow range of wind dispersal makes the seeds aggregate around mother plant. Thus the distance between individual plants is small forming a poly block distribution. On the other hand, the natural geographical condition of the barren valleys along the upper reaches of Minjiang River is relatively severe, so *L. regale* does not take a dominant position in competition. As a result, the number of individuals is small and the population density is low. Because of these, the number of non-blank grids decreased, and to some extent, the property scale exceeds the fractal range of individual distribution pattern. And the absolute value of the slope of linear fitting diminishes and ends in the decrease of box-counting dimension [20-23].

(4) The box-counting dimension is ecological occupation dimension latitude, and the dimension gap from 2 is ecological gap dimension latitude. The former reflects the real situation of ecological space occupation of a population, and the latter reflects the potential ability of occupying ecological space [8]. Table 2 shows that the ten valid ecological gap dimensions are 0.4677、0.7334、0.6433、0.6229、0.701、0.9104、0.2528、0.8124、0.0608、0.6899，indicating the population of *L. regale* still has large ecological space to occupy [8, 23].

(5) In Plot 1, 2, 4, 5, 7, 8, 10 and 11, the box-counting dimension of spatial patterns of *L. regale* population distribution appear different scales of inflection point, which is between 0.6869 and 2.7475m. Although there is a lot of controversy among scholars about the ecological meaning of inflection point, generally speaking, the inflection point can partly indicate the aggregation scale of individuals in a population. At all the scales which are larger than the scale of inflection point, the population distribution is self-similar [8, 25].

Conclusions

(1) In different sample plots the fractal properties of box-counting dimension are significant.

(2) Overall, because of its biological properties and severe habitat, the population of *L. regale* is relatively small, and the box-counting dimension is small. The occupation degree in space is low, and it has no dominant position in its community.

(3) The box-counting dimension of Plot 10 is the biggest, which reaches to 1.9392, and is close to 2, indicating Plot 10 is the best suitable habitat for the growth of *L. regale*.

(4) There are different ecological gap latitudes in different plots, indicating they have more ecological space to occupy in population.

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