ORIGINAL RESEARCH ARTICLE

The population characteristics of *Lithocarpus polystachyus* in natural secondary forests under different human disturbance intensity

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ABSTRACT

In November 2018, the sample plot survey method was used to analyze the population characteristics of *Lithocarpus polystachyus* in the natural secondary forest with different disturbance intensity in Jianning, Fujian Province, and compile its population static life table. The results showed that the number of individuals in the population was small, but it was clustered. With the increase of interference intensity, the first and second age seedlings and young trees decreased. The population types affected by human disturbance are all lacking level V trees, and the population type belongs to primary population (N_1); The undisturbed population lacks level I and II seedlings and young trees, but there are level V trees, and the population type belongs to medium decline population (S_2). In general, all populations of *L. polystachyus* are unstable and belong to the transitional type. In the static life table, the mortality of level I and II seedlings and young trees is high, the survival rate has a small peak in level III and IV, and then the survival rate decreases rapidly, and the average life expectation of level II is the highest. It shows that artificial conservation measures and appropriate space re-lease are needed to maintain the stability of the population.

Keywords: *Lithocarpus Polystachyus*; Population Characteristics; Static Life Table; Natural Secondary Forest; Interference Intensity

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1. Introduction

Lithocarpus polystachyus is an evergreen tree plant, it belongs to the family Fagaceae. It is rich in flavonoids and has good pharmacological effects[1-4]. It has obvious effects in lipid-lowering, antioxidant, anti-aging, anti-allergy and anti-tumor. It is known as "Cordyceps sinensis on trees"[5]. The content of dihydro-chalcone (DHC) in leaves reached 12.0%[6]; at the same time, it is also a natural sweetener. Its sweetness is 300 times that of sucrose[2,7]. It has no calorific value or low calorific value and no side effects. It is an edible sweetener for diabetic and cardiovascular patients. It can inhibit the absorption of sugar and repair insulin in the body. In addition, *L. polystachyus* contains natural brown pigment, which has been listed in the national health license[8]. It is a plant with the same origin of medicine and food. It has a wide range of uses and broad development prospects in the pharmaceutical industry, food processing, health products and beverages, and its economic value has been highly valued. *L. polystachyus* is naturally distributed in provinces and regions south of the Yangtze river, and the Wuyi mountains at the junction of Jiangxi and Fujian are the most widely distributed[7]. The original natural resources are rich, but with a large area of evergreen broad-leaved forest being cut down and utilized, its natural resources are less and less. The existing ones are mostly sporadic distribu-

tion in the wild, which cannot meet the needs of industrial processing. Great attention has been paid to the utilization and development of *L. polystachyus*, and research results have been achieved in many aspects, mainly involving the extraction of chemical components, the use of active substances and medical and health care functions[1-4, 8-12]. There are also a few reports on the distribution of natural resources and artificial cultivation[12-14], However, the population characteristics of natural resources have not been reported. This study investigated different types of *L. polystachyus* populations in Jianning, Fujian Province, and analyzed the population characteristics such as relative density, spatial distribution pattern, population structure and static life table, trying to provide a reference for effective protection of natural populations and reasonable artificial management.

1.2 Natural overview of the study area

The research site is located in Shangping village, Xiyuan Township, Jianning County, Fujian Province (26°32′–27°06′N, 116°30′–117°03′E). Jianning county is located in the northwest of Fujian Province, in the middle of Wuyishan Mountain range, and borders Nanfeng County, Guangchang county and Lichuan County of Jiangxi Province in the northwest. The landform is mostly low mountains and hills, with complex terrain, crisscross mountains and streams, and is the source of Min-Jiang River. The climate is warm and humid, belonging to the mid subtropical marine climate and continental monsoon mountain climate. The temperature is cold in winter and the temperature difference between day and night in summer is large. The average annual temperature is 16.8 ℃, extreme maximum temperature 39.9 ℃, extreme minimum temperature -12.8 ℃, the average annual precipitation is 1,822 mm, and the annual accumulated temperature is 4,900 ~ 5,069.7 ℃, the annual frost-free period is 280 days, and the average annual snowfall is 6.5 d, the first snow in late December and the last snow in mid-February. The forest vegetation belongs to the evergreen Castanopsis semi evergreen Quercus laurilignosa forest area in the mountains and hills of Fujian, Zhejiang and Jiangxi. The ex-

perimental forest belongs to 12 compartment, 25 large-compartment, 7, 12, 13, 23 and 26 sub-compartment, all of which are natural secondary evergreen broad-leaved forests.

2. Research method

In November 2018, five typical sections were selected from the natural secondary evergreen broad-leaved forest mixed with *L. polystachyus* in Shangping village, and a 1,200 m² sample plot was established respectively to record the factors such as altitude, aspect, slope, slope position and disturbed condition and other factors (**Table 1**). According to the classification method of relevant literature[15-17], the interference level is divided into four levels: (1) no human interference, no human interference from tending, felling or tourism for a long time, no picking of *L. polystachyus* branches and leaves, and the population is far away from residential areas; (2) slight disturbance, no traces of grazing and illegal cutting, and human disturbance is mainly the picking of branches and leaves of *L. polystachyus*, with a crown closure of 0.55–0.7; (3) moderate disturbance, close to the residential area, often grazing, collecting litter, and cutting a small amount of branch fuelwood, but there is no trace of illegal cutting of trees, crown closure 0.3–0.5; (4) severe disturbance, close to the residential area, there is a path to the forest stand, often grazing, collecting litter, and there are traces of illegal cutting of trees and firewood. The *L. polystachyus* is often cut and picked by the whole plant every year, and the crown closure ≤0.3. The large sample plot is divided into 12 small sample plots of 10 m × 10 m, investigate the tree height (H) and diameter at breast height (DBH) of all *L. polystachyus* in the small sample plot. According to the standard of Qu[18], the individual size structure of the population is divided into level I seedling stage (DBH < 2.5 cm, H < 33 cm), level II seedling stage (DBH < 2.5 cm, H ≥ 33 cm), and level III young tree stage (7.5 cm > DBH ≥2.5 cm), level IV medium tree stage (22.5 cm > DBH ≥ 7.5 cm), level V large tree stage (DBH > 22.5 cm). The population types are divided into primary population (N1, with only level I, II, III, IV or level I and II trees in the population), vig-

orous population (N2, with level I, II or level I ~ III or grade I ~ IV trees in the population), mature population (N3, with all grade trees in the population), initial decline population (S1, with no level III or level II, III or level III and IV trees in the population) There are six types of middle aged population (S2, the population lacks trees of level I, II or I ~ III), and old aged population (S3, the population lacks trees of level I ~ IV).

Table 1. Basic information of sample plot

Population	Altitude/m	Slope/°	Aspect	Slope position	Crown closure	Traffic conditions	Interference intensity	Remark
A	370	27	SW	Middle and lower slope	0.48	Country road side	Moderate disturbance	Grazing is often carried out, and there are often cut downs to pick many ears of branches and leaves, but there is no trace of illegal logging of large trees
B	573	38	SE	Ridge	0.86	Forest trail only	No human interference	For a long time, it has not been subject to human interference such as child-care, logging or tourism. No or less multi-eared foliage is picked, and the population is far away from the residential area
C	402	32	NW	Valley	0.55	There are roads for transporting timber	Slight disturbance	In 2013, the fire burned the ground. There are no traces of grazing and logging. There are many branches and leaves picked
D	525	37	SW	Middle slope	0.62	There are roads for transporting timber	Slight disturbance	There are many ears of branches and leaves, and there are no traces of grazing and logging
E	305	22	NE	Lower slope	0.30	Country road side	Severe disturbance	Grazing is frequent, with traces of stolen trees and wood cutting

In each sample plot, select five 5 m × 5 m shrub quadrat and five 1 m × 1 m herbaceous quadrat according to the "X" type. Investigate shrub species, individual number and height in shrub quadrat, and herb species and average height in herb quadrat.

According to the survey data, calculate the population density (M), relative density (RM, DBH ≥ 2.5 cm) and dispersion (S^2). The calculation formula is: M = number of individuals of *L. polystachyus* in a quadrat/area of sample plot, RM = number of individuals of *L. polystachyus*/number of individuals of all plants × 100, $S^2 = \sum \frac{(x-m)^2}{n} - 1$, where: x is the actual number of *L. polystachyus* in the quadrat; m is the average number of *L. polystachyus* in the quadrat; n is the number of quadrats. According to the S^2 value, the dispersion is divided into three types: uniform type, cluster type and ran-

dom type. Homogeneous type, $S^2 = 0$, population individual equidistant distribution; Cluster type, $S^2 > m$, the individual population is extremely uneven and locally densely distributed; Random type, $S^2 = m$. The population is randomly distributed[19].

The diameter classes of the five populations are summarized as *L. polystachyus* population in Shangping village, Jianning County, and the static life table of Shangping *L. polystachyus* population is compiled. The calculation formula is: $l_X = a_x/a_0 \times 1{,}000$, $d_x = l_x - l_{x+1}$, $q_x = d_x/l_x \times 100\%$, $L_x = (l_x + l_{x+1})/2$, $T_x = \Sigma l_x$, $e_x = T_x/l_x$, $K_x = \ln l_x - \ln l_{x+1}$, where a_x, x, l_x, d_x, q_x, L_x, T_x, e_x and K_x are survival rate, age class, standardized survival number, death number, mortality rate, average number of surviving individuals from the x to the $x + 1$ diameter class, number of living individuals exceeding the x-diameter class, life expectation and disappearance rate re-

spectively[20].

3. Results and analysis

3.1 population density

Population density is the most basic quantitative characteristic. The investigation and calculation results of density and dispersion of five populations are shown in **Table 2** There are differences in population density among the five populations. The order from large to small is E > C > A > D > B. The number of individuals of population E with the largest population density is 265.3% higher than that of population B with the smallest population density; The relative density from large to small is also E > C > A > D > B. No matter what type, the number of individuals of the *L. polystachyus* population is relatively small, indicating that the population is in an associated position in the natural secondary forest and belongs to a transitional tree species.

Table 2. Densities and dispersion of different population types

Population	Density (plant·hm⁻²)	M	RM	S²
A	1,200	11	0.31	35.0
B	1,080	13	0.18	47.9
C	2,955	35	0.14	160.9
D	2,325	28	0.26	71.0
E	3,945	47	0.41	39.7

It can be seen from **Table 2** that the population density of *L. polystachyus* in the sample plot with large interference and convenient transportation is relatively large, which is related to the characteristics of light loving and strong budding ability of *L. polystachyus*. In the disturbance state, the number of trees decreases, the stand gap expands, and the light in the forest increases, which is conducive to the survival and healthy growth of the light loving plant corydalis and the production of ramets from roots and tillers. In the sample plots with less disturbance, the number of individuals of *L. polystachyus* is small, indicating that the growth and development of *L. polystachyus* is inhibited in the evergreen broad-leaved forest with normal growth and development, indicating that *L. polystachyus* plays a pioneering role in the initial stage of group construction, but it will gradually withdraw after the

formation of evergreen broad-leaved forest. In the process of formation and succession of natural secondary broad-leaved forest, it is in an associated state. In the formation process of evergreen broad-leaved forest, it can provide a shaded growth environment for the growth and development of other shade tolerant tree species and create good living conditions. It is a transitional tree species. To explore, develop and utilize *L. polystachyus* and establish industrial raw material forest is a tentative and important management way.

3.2 population spatial distribution pattern

The distribution pattern of the population is the reflection of the relationship between the population and the growth environment and its role and position in the community[21]. It can be seen from **Table 2** that the average number of individuals in population A, B, C, D and E is 1,200, 1,080, 2,955, 2,325 and 3,945 plants · hm⁻² respectively, and the corresponding dispersion values are respectively 35.0, 47.9, 160.9, 71.0, 39.7, which is greater than the corresponding M value, indicating that the spatial distribution pattern is clustered distribution and the individual distribution of population is extremely uneven.

The cluster distribution of *L. polystachyus* in natural secondary broad-leaved forest is the result of the formation and adaptation in the long-term phylogeny of its growth environment. This is related to the biological characteristics and growth environment of *L. polystachyus*. It has large seeds, rich in starch and sweet. They are vulnerable to insect pests and bird food, especially rats. The germination of residual seeds is relatively concentrated and the displacement is small. The existing plants sprout more and close to the parent plants. The spatial distribution pattern of the clustered population is the embodiment of its adaptation to the ecological environment, and also forms a suitable branch configuration, which provides a good biological basis for dwarf and dense planting, which is of great significance to the intensive management and healthy development of the plantation.

3.3 Population structure and type

The population structure can not only reflect

the composition of different individuals, but also express the dynamics of population quantity[22]. The survey results of population age structure and population type are shown in **Table 3**. There are all level I ~ IV in populations A, C, D and E, but there is a lack of level V trees. The population type belongs to N_1 (primary population), which is caused by human disturbance. Local residents have a long-term habit of picking twigs and leaves of *L. polystachyus* to make sweet tea, and most of them are extensive whole plant felling, resulting in the lack of big trees. In these four populations, the composition is also different with the different interference intensity. The population E with high frequency and intensity disturbance has few seedlings and young trees of level I and II. The number of individuals of grade I and II is only 12 and 8, accounting for only 6.9%, 4.6% of the total number of individuals of *L. polystachyus*, the number of level III individuals is the largest, accounting for 64.4% of the total individuals followed by level IV, accounting for 35.6% of the total number of individuals. The number of population A, level I and II individuals in the moderately disturbed population accounted for 15.3% ,7.6% of the total number of individuals; The number of individuals with mild disturbance accounted for 31.2% 15.1% of the total population of level I and II. From population D to population A to population E, with the increase of interference intensity, the number of level I and II individuals is becoming less and less, indicating that human interference has led to a significant reduction in the seedlings and young trees. In order to conserve *L. polystachyus* population, closure measures should be taken in the early stage. The number of individuals in level I and II of population C is large, and the accounts for 52.9% and 29.3% of the total number, the level I seedlings increased by 5% compared with populations A, D and E, and the level II young trees increased by 440.9%, 36.8% and 891.7% compared with populations A, D and E respectively. After the interference of fire, the gap in the forest is large and the light in the forest increases, which is conducive to the germination and healthy growth of light-loving *L. polystachyus*, while the later closure makes the seedlings and young trees preserved. It

can also be seen from **Table 3** that the number of level III and IV individuals in the four populations affected by human disturbance is large, which is related to the fact it has been artificially cut down and has strong budding ability.

Table 3. The structure and type of age level in different population

Age level	Numbers of *L. polystachyus*				
	A	B	C	D	E
I	22	0	119	87	12
II	11	0	66	42	8
III	60	46	26	71	112
IV	51	75	14	79	62
V	0	8	0	0	0
Population type	N_1	S_1	N_1	N_1	N_1

The age level structure of population B is different from that of other populations. Population B does not have level I and II seedlings and young trees, but has level V trees. According to the introduction of reference[23], *L. polystachyus* grow and develop normally, and the DBH can reach more than 22.5 cm, even 60 cm. The population B belongs to S_2 (medium decline population), it belongs to the transitional type in the natural secondary broad-leaved forest with normal growth and development.

3.4 Analysis of Static life table

The change trend of population survival and disappearance was expressed by diameter class structure instead of time series. The static life table of *L. polystachyus* population in Shangping village, Jianning County formed by 5 populations is shown in **Table 4**. The largest number of individuals is level III, there are not many individuals of level I and II. This is related to the crown closure of the population. The number of level III and IV individuals is large, and the number of grade III and IV individuals accounts for 62.0% of the total number of individuals, which implies that the *L. polystachyus* depends on germination and regeneration or root tiller ramets, and relies on strong roots to quickly grow into a small tree with a certain volume, so as to avoid the disaster of extinction. However, the height growth of the tree has been at a low height level due to frequent picking or whole plant felling. Therefore, in the stand with small canopy

density, it is necessary to no logging for several years; In the stand with large canopy density, if conditions permit, the trees of other adjacent tree species can be thinned or pruned to increase the light transmittance in the forest, and even appropriate soil loosening measures can be taken to improve the growth environment of seedlings and young trees. In the natural secondary broad-leaved forest, the ecological and biological characteristics of the population determine its transitional and associated nature. In order to provide a large number of raw materials, we must also take the way of artificial cultivation.

The mortality of *L. polystachyus* is higher at the stage of seedling and young in the static life table based on 1,000 (**Table 4**), and the mortality from level I seedling to level II young tree is 44.8%, from level IV medium tree to level V big tree, the mortality rate was 97.0%. There are few surviving seedlings and young trees, especially under the forest with large canopy density and less human interference, there is a lack of seedlings and young trees and insufficient reserve resources. Only in the habitat with human disturbance or natural forest gap and moist and fertile forest soil, there are a small number of seedlings and young trees in the regeneration layer, and the population reproduction mainly depends on germination and regeneration.

Table 4. Static life table of *L. polystachyus* in Shangping village, Jianning County

Age level	a_x	l_x	lnl_x	d_x	q_x	L_x	T_x	K_x	e_x
I	230	1,000	6.91	448	0.448	776	4,176	0.60	4.18
II	127	552	6.31	-818	-1.48	961	3,179	-0.91	5.76
III	315	1,370	7.22	148	0.11	1,296	2,627	0.11	1.92
IV	281	1,222	7.11	1,187	0.97	629	1,257	3.55	1.03
V	8	35	3.56	35	1.00	18	35	-	1.00

However, due to its photophilic biological characteristics, the growth space of tree height is inhibited and the disappearance rate is increased. Therefore, the survival rate has been at a low level in level I ~ II, and there is a small peak in the survival rate in level III ~ IV. The number of individuals can be maintained at a certain level, which is related to germination and regeneration, and then the survival rate decreases rapidly. It shows that it was subjected to environmental stress during this period. The living environment, especially the light conditions, makes it difficult for the light loving plants to survive. The average life expectancy was the highest at grade II (e_x = 5.76), and then decreased gradually.

4. Conclusion and discussion

Population characteristics can reflect the status and role of the population in the biological community and the occurrence and development of the relationship between different populations[24]. In the natural secondary forest of Jianning, the number of individuals of *L. polystachyus* population in the community is small. From population D → population A → population E, with the increase of inter-

ference intensity, the number of level I and II individuals is less and less. The population types of A, C, D and E affected by different degrees belong to primary population (N_1), while the population of B without or less human interference belongs to medium decline population (S_2). In the natural secondary broad-leaved forest with normal growth and development, the population of *L. polystachyus* belongs to transition type. No matter what kind of population type, the spatial distribution pattern of *L. polystachyus* is aggregation distribution, and the individual distribution of population is very uneven. The characteristics of the population are the result of both biological characteristics and human disturbance. Liu *et al.*[25] believe that interference can temporarily increase the effectiveness of resources, so as to change the effectiveness pattern of resources. Human disturbance, especially felling and utilization, promotes the sprouting and formation of multi headed form, weakens the apical advantage and increases the individual number, but the high growth is inhibited and the photophile plants that lose the apical advantage. It means that they always play an associated role in the process of community formation and succession and are in a declining po-

sition. The position and function of *L. polystachyus* in the natural secondary forest are similar to the population characteristics of birch forest in Taiyue Mountain and the population of *Taxus wallichiana* in Enshi Prefecture, Hubei Province. Wei *et al.*[26] believed that the species group of birch forest in in Taiyue Mountain plays a pioneering role in the natural secondary forest community. However, the mortality rate of the population is high in the early stage and relatively stable in the later stage. Most of the seedlings and young trees are lack in the adult forest, so the population stability is difficult to maintain. In order to maintain the stability of the population of *Betula platyphylla*, artificial conservation measures are needed. Hu *et al.*[27] believed that the population of *Taxus wallichiana* in Enshi Prefecture, Hubei Province is large, but the structure is unreasonable, the number of regeneration layers is large, and the number of succession layers is small. The mortality in the process from seedlings and young trees to growing and standing trees is very high, so it is necessary to strengthen protection and appropriately release the growth space. Yu *et al.*[28] compiled the population static life table according to the population number of *Loropetalum subcordatum* in Maoming, Guizhou. They believe that belongs to a stable population, the life expectation of seedlings and young trees is the largest, and the death curve and disappearance curve first rise and then fall. Due to environmental screening, especially water stress, the mortality and disappearance degree of V age class are the highest. The survival curve is basically monotonically decreasing. In the static life table of *L. polystachyus* population in Jianning, the high-frequency human disturbance led to higher mortality and lower survival rate of seedlings and young trees, and the second level life expectation was the highest; In the stand with less disturbance, it is difficult for seedlings and young trees to survive due to the biological characteristics. The population characteristics of *L. polystachyus* in Jianning suggest that it is necessary to take appropriate artificial disturbance technical measures to develop and utilize to manage industrial raw material forest and maintain its single optimal community advantage.

Conflict of interest

The author declares no conflict of interest.

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