Postprint: Population Dynamics of Schefflera octophylla in Tongguling, Hainan

Authors: Wu Lyuxin, Yang Xiaobo, Li Donghai, Lü Anqi

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Abstract

Schefflera octophylla is a dominant species in the coastal forests within the Wenchang Tongguling National Nature Reserve in Hainan, and also a common companion species in tropical forests in other regions of Hainan. To gain an in-depth understanding of the survival status, regeneration mechanisms, and dynamic characteristics of future development of Schefflera octophylla populations in the coastal forests of this region, this study investigated the Schefflera octophylla population in a 2.56 hm^2 plot of tropical coastal forest in Hainan, used diameter class structure as a proxy for age structure to compile a static life table for the Schefflera octophylla population, and quantitatively analyzed the population structure and quantitative dynamics by integrating methods such as population dynamic quantification indices, survival functions, and time series prediction models. The results showed: (1) A total of 2,814 Schefflera octophylla individuals were recorded in the study area, which were divided into 12 age classes based on diameter class size; the age-class structure exhibited an inverted J-shape, indicating a population tending toward stability. (2) The survival curve of Schefflera octophylla in this region tended toward Deevey-II type, with mortality rates being relatively similar across diameter classes. (3) The quantification indices of the Schefflera octophylla population showed: Vpi=030.685>0, Vpi' =0.236>0, indicating that the population is currently in a growth stage and relatively stable. (4) According to predictions from the time series model: the number of individuals in each age class of the Schefflera octophylla population showed an overall increasing trend over the next 3, 6, and 9 years. The survey and analysis indicated that the habitat in this region is conducive to the growth of Schefflera octophylla populations and that the population has developed a sound survival strategy, with abundant young individuals and rich reserve resources that can adequately compensate for losses due to natural mortality across age classes, thereby playing a certain role in promoting natural forest regeneration.

Full Text

Preamble

Population Structure and Dynamics of *Schefflera octophylla* in Tongguling, Hainan Province

Wu Lüxin[1], Yang Xiaobo[2]*, Li Donghai[2], Lü Anqi[1]
(1. School of Life and Pharmaceutical Sciences, Hainan University, Haikou 570228, China;
2. School of Ecology and Environment, Hainan University, Haikou 570228, China)

Abstract

Schefflera octophylla is the dominant species in coastal forests within the Tongguling National Nature Reserve in Wenchang, Hainan, and also a common companion species in tropical forests elsewhere in Hainan. To understand the survival status, regeneration mechanisms, and future developmental dynamics of this species in the region' s coastal forests, we investigated a 2.56 hm^2 sample plot in Hainan' s tropical coastal forest. Using diameter class structure as a proxy for age structure, we compiled a static life table for the *S. octophylla* population and employed quantitative population dynamic indices, survival functions, and time series prediction models to analyze population structure and quantitative dynamics. The results showed: (1) A total of 2,814 *S. octophylla* individuals were recorded in the study area, divided into 12 age classes based on diameter class. The age class structure exhibited an inverted J-shape, indicating a stable population tending toward equilibrium. (2) The survival curve approximated Deevey-II type, with mortality rates being similar across diameter classes. (3) Quantitative indices revealed Vpi = 030.685 > 0 and Vpi' = 0.236 > 0, demonstrating that the population is currently in a growth stage and relatively stable. (4) Time series modeling predicted that individual numbers across all age classes would show an overall increasing trend in the next 3, 6, and 9 years. Our analysis indicates that the habitat conditions in this area are favorable for *S. octophylla* growth, and the population has developed effective survival strategies. With abundant young individuals and rich reserve resources, the population can adequately compensate for losses due to natural mortality across age classes, thereby promoting natural forest regeneration.

Keywords: population structure, static life table, survival analysis, time series prediction

Plant population ecology constitutes a fundamental component of ecological science, and plant population structure significantly influences community structure and development trends. A central issue in population ecology is population dynamics, which primarily examines the changing patterns of population size and distribution (Jiang et al., 2018). Population age structure, survival curves, and life tables are core components for studying quantitative dynamics in plant populations (Li et al., 2015; Jiang et al., 2018). Analyzing these aspects not only clarifies current population status but also predicts impacts on community changes and assesses environmental adaptability and stability. Therefore, in-depth study of population quantitative dynamics is crucial for understanding ecological characteristics, regeneration mechanisms, and revealing population development and succession patterns.

Schefflera octophylla, also known as goosefoot tree, belongs to the family Araliaceae and genus *Schefflera*. This evergreen tree or shrub possesses both ornamental and medicinal value, and is widely distributed across Taiwan, Fujian, Tibet, Guangxi, Yunnan, Zhejiang, Guangdong, and Hainan in China, as well as in Vietnam, Japan, and India. *S. octophylla* is a common plant in evergreen broad-leaved forests of tropical and subtropical regions, sometimes occurring as a dominant species (Liang et al., 2009), growing at elevations of 100–2100 m. In Hainan, it is widely distributed from coastal forests to the dwarf forests at the summit of Wuzhi Mountain in the central region (Yang, 1991, 1994, 1995). In the tropical coastal forests (evergreen monsoon elfin forests) of the Tongguling National Nature Reserve in Wenchang, Hainan, *S. octophylla* ranks as the primary dominant species with the highest importance value (Zhong et al., 1991; Che et al., 2006; Zhou, 2013).

Population is the basic unit of community composition, and population structure not only directly affects community structure but also objectively reflects community development and evolution trends (Wang et al., 2011). Dominant species play an irreplaceable role in maintaining forest community structure stability. Studying the population structure dynamics of community dominants provides theoretical support for revealing population regeneration and community succession mechanisms. Currently, numerous researchers investigate community structure characteristics through dominant species studies. For example, Long et al. (2013) analyzed population structure dynamics and interspecific associations of dominant species in tropical evergreen broad-leaved forests to reveal major plant composition and ecological patterns. Liu et al. (2014) examined population structure dynamics of dominants in different community types within the Daqinggou Nature Reserve, providing theoretical basis for sand gully plant ecosystem research. Dai et al. (2017) analyzed community species diversity and population structure characteristics of different dominants in subtropical evergreen broad-leaved forests to explore community stability and succession processes. Wu et al. (2018) studied population structure and quantitative dynamics of *Acer catalpifolium* to provide theoretical foundations for degraded karst forest restoration. Chen et al. (2019) investigated population dynamics of the dominant species *Schima superba* in the Dinghushan subtropical evergreen broad-leaved forest, combining diameter class and habitat analysis to examine mortality distribution characteristics and community construction mechanisms. Wang et al. (2019) integrated population structure characteristics and interspecific associations of the dominant species *Eurya alata* in evergreen-deciduous broad-leaved mixed forests to clarify its survival status and future development trends.

Thus, studying dominant species population structure dynamics is beneficial for understanding forest community regeneration and succession processes, community construction and restoration mechanisms, and ecosystem change patterns. Although research cases on dominant species population structure dynamics have become increasingly abundant, ecological studies on tropical coastal forest dominants have primarily focused on plant community resource distribution, species diversity, and interspecific associations (Wang et al., 2018; Zhang et al., 2019), with few reports on *S. octophylla* population dynamics. The developmental dynamics and trend patterns of *S. octophylla* populations in coastal natural forest communities require further elucidation. Therefore, this study focuses on the *S. octophylla* population, employing diameter class methods, static life tables, survival functions, dynamic quantitative indices, and time series models based on sample plot surveys to quantitatively analyze survival status, structural characteristics, and future development trends across age classes. This approach facilitates understanding of the population' s successional stage and its role in tropical coastal forest communities, providing fundamental data for vegetation research and resource conservation in this forest type.

1. Study Area Overview

The Tongguling National Nature Reserve is located in Wenchang City, northeastern Hainan Province (110°58 30 -111°03 00 E, 19°36 54 -19°41 21 N), bordering the South China Sea to the east and mainland to the west, covering approximately 44 km^2 (30.67 km^2 marine area and 13.33 km^2 terrestrial area). Tongguling is the highest peak in northeastern Hainan, with an elevation of about 338.2 m. The region' s geology is dominated by granite. The climate is tropical maritime monsoon, with an average annual temperature of 23.9°C, average annual precipitation of 1,721.6 mm, and annual sunshine duration of 2,137 hours. The area experiences no frost throughout the year and remains evergreen year-round. Soils are latosols; those facing the sea are relatively moist, while leeward soils have lower water content and greater exposed rock area. The nature reserve is rich in forest resources, with coastal forests, local plantations, foothill shrublands, coastal psammophytic vegetation, semi-mangroves, and mangroves distributed sequentially from hills to coast. The climax vegetation type is tropical coastal forest (Yang, 1991; Long et al., 2013).

In 2011, a permanent large sample plot of 160 m × 160 m was established in the Tongguling Reserve, divided into 64 square subplots of 20 m × 20 m. In 2018, we resurveyed the plot and conducted field surveys combining data from Class I forest resources in the Tongguling Reserve tropical coastal forest, covering a total area of 2.56 hm^2. Field investigations recorded tree species, height, number of individuals, crown width, diameter at breast height (DBH), coordinates, elevation, landform, slope, aspect, and other environmental factors for each plant. Based on the resurvey, we selected the community dominant species *S. octophylla* for population dynamics research and compiled statistics on its population size and growth conditions.

2.2.1 Diameter Class Division

To conserve forest resources, this study employed the diameter class method instead of core sampling to classify surveyed individuals by DBH from smallest to largest. Individuals with DBH $\leq$ 3 cm were assigned to Age Class I, with each subsequent diameter class interval being 3 cm, totaling 12 age classes: Class I (1 < DBH $\leq$ 6 cm), Class II (6 < DBH $\leq$ 9 cm), Class III (9 < DBH $\leq$ 12 cm), Class IV (12 < DBH $\leq$ 15 cm), Class V (15 < DBH $\leq$ 18 cm), Class VI (18 < DBH $\leq$ 21 cm), Class VII (21 < DBH $\leq$ 24 cm), Class VIII (24 < DBH $\leq$ 27 cm), Class IX (27 < DBH $\leq$ 30 cm), Class X (30 < DBH $\leq$ 33 cm), Class XI (33 < DBH $\leq$ 36 cm), and Class XII (DBH > 36 cm). Based on this classification standard, we counted individuals in each age class, conducted statistical analysis of *S. octophylla* population quantity and structural dynamics, and generated an age structure diagram to analyze population dynamic changes in the Tongguling Reserve coastal forest.

2.2.2 Quantitative Analysis Methods for Population Dynamics

To overcome limitations of age class division and enable more objective and accurate analysis, this study followed the methodology of Chen (1998), combining function curves and quantitative indices to analyze plant population structure. The specific formulas are as follows:

$$V_n = \frac{S_n - S_{n+1}}{\max(S_n, S_{n+1})} \times 100\%$$

$$V_{pi} = \frac{1}{k} \sum_{n=1}^{k-1} \frac{S_n - S_{n+1}}{\max(S_n, S_{n+1})}$$

$$V'_{pi} = \frac{1}{k} \sum_{n=1}^{k-1} \frac{S_n - S_{n+1}}{\max(S_n, S_{n+1})} \times \frac{\min(S_n, S_{n+1})}{\sum_{n=1}^{k} S_n}$$

where n represents age class, S represents the number of individuals in age class n, k represents the total number of age classes, V represents the dynamic index of population size changes, V represents the population quantitative dynamic index, and V ' represents the modified dynamic index.

2.2.3 Compilation of Static Life Table and Survival Curve

A static life table is an effective tool for assessing population status, age structure characteristics, and determining regeneration and development trends. This study compiled a static life table based on fundamental data such as the number of individuals in each diameter class. Parameters include: X (diameter class representing age class), N (number of surviving individuals in each class), L = $(N + N\ _1)/2$, lgL ($\log_{10}$ of L), $D = N$ - $N\ _1$, $Q = D/N$, $T = \Sigma L$, E =

T/N, and $K = \ln L - \ln L_1$. GraphPad Prism 5 software was used to plot the survival curve, which was then evaluated against Deevey' s (1947) three basic patterns (Type I: convex curve; Type II: diagonal line; Type III: concave curve). The exponential equation $N = N_0$e^(-bx) and power function $N = N_0$x^(-b) were used to verify the survival curve type (Silvertown, 1982).

2.2.4 Population Survival Analysis

Following Feng (1983), we examined the survival rate function *S(t)*, mortality density function *f(t)*, cumulative mortality function *F(t)*, and hazard rate function λ*(t)*:

$$S(t) = \prod_{i=1}^{t} P_i$$

$$f(t) = \frac{S_{t-1} - S_t}{h(t)}$$

$$F(t) = 1 - S(t)$$

$$\lambda(t) = \frac{2f(t)}{S_{t-1} + S_t}$$

where P represents survival rate and *h(t)* represents age class width.

2.2.5 Time Series Prediction of Population Size

Following Shen et al. (2008) and Xue et al. (2004), we predicted *S. octophylla* population numbers for the next 3, 6, and 9 age class intervals. The specific formula is:

$$M_t^{(n)} = \frac{1}{n} \sum_{k=t-n+1}^{t} X_k$$

where n represents the predicted future time period, t represents age class, M represents the predicted population size in age class t after n years, and X represents the current population size in age class k.

3.1 Age Structure of *S. octophylla* Population

Based on DBH classification of the *S. octophylla* population in Tongguling Nature Reserve, we generated an age structure diagram (Figure 1 [Figure 1: see original paper]). The sample plot contained 2,814 *S. octophylla* individuals, with Age Class I having the highest count at 1,427 individuals (41.4% of total). Class

II comprised 560 individuals (16.2%), and Class III comprised 267 individuals (9.5%). Higher age classes showed progressively fewer individuals: Classes IV–VIII accounted for 7.7%, 5.7%, 3.7%, 2.6%, 1.6%, and 0.9% respectively, while Classes IX–XII totaled only 1.7%. The population exhibited significantly more young individuals than old, consistent with plant growth patterns. Specifically, Classes I and II combined totaled 1,987 individuals (70.6% of the population), Classes III–IX comprised 782 individuals (27.8%), and Classes X–XII comprised only 45 individuals (1.6%). Individual numbers decreased continuously from Class II onward, with Classes VIII–XII being particularly scarce at only 2.6% of the total.

3.2 Quantitative Dynamic Characteristics of *S. octophylla* Population

Analysis of dynamic changes between adjacent age classes in the Tongguling *S. octophylla* population revealed the following individual number change dynamic indices (V): 60.76%, 52.32%, 26.22%, 35.53%, 28.35%, 40.66%, 40.74%, 56.25%, 7.14%, 23.08%, and -54.55%. The overall population structure dynamic index $V = 030.685 > 0$ (without environmental disturbance), and the population age structure dynamic index $V' = 0.236 > 0$ (with random disturbance), indicating that the population is growing and relatively stable.

Table 1 Dynamic index of age structure of *S. octophylla* population

3.3 Static Life Table and Survival Curve Analysis

As shown in Table 2 and Figure 1, the number of surviving *S. octophylla* individuals generally decreased monotonically with increasing age class. The population showed a monotonic decreasing trend from Age Class II onward. From Classes VII to XI, the number of surviving individuals declined overall and remained low, but increased again in Class XII. Additionally, both survival numbers and mortality rates showed small peak values in Classes I and II.

The survival curve reflects the life table, representing population quantity changes and visually expressing individual survival processes across age classes. Pearl (1923) first proposed population survival curves, which Deevey (1947) later categorized into three types: Type I (convex), Type II (diagonal), and Type III (concave). According to Deevey' s classification, the *S. octophylla* survival curve (Figure 2 [Figure 2: see original paper]) approximated a diagonal line, conforming to Deevey-II type, with similar mortality rates across diameter classes and a stable age class structure. Table 2 shows that young trees in Class II had the highest survival rate, which gradually decreased thereafter, with a slight upward trend from Class XI onward. Young age class survival rates were significantly higher than those of old age classes, consistent with the static life table analysis.

Table 2 Static life table of the population of *S. octophylla*

3.4 Population Survival Analysis

Based on four survival function values for the Tongguling *S. octophylla* population (Table 3), we generated curve diagrams (Figure 3 [Figure 3: see original paper]). The survival function curve and cumulative mortality curve showed axial symmetry, with the former decreasing monotonically while the latter showed the opposite trend, though both exhibited similar magnitude of change. The survival function curve revealed a substantial decline in Classes I–V, with the *S(i)* index decreasing from 2.240 to 0.143, followed by a slow decline in Classes VI–XII. Cumulative mortality increased substantially in Classes I–V, with the *F(i)* index rising from -1.240 to 0.857, then increasing slowly in Classes VI–XII. The survival and cumulative mortality curves displayed a corresponding, complementary negative correlation, indicating relatively stable population structure.

Table 3 Estimated values of four survival function of *S. octophylla* population

The mortality density and hazard rate curves showed similar trends. The mortality density curve initially declined then plateaued, remaining generally stable with a peak in Class I (Figure 4 [Figure 4: see original paper]) at *f(i)* = 0.4537. All age class *f(i)* values were below 0.5, indicating higher mortality density in young age classes than in older ones. The hazard rate curve showed wave-like fluctuations, with notable declines in Classes VIII–IX and X–XI, and slow variation from Classes I–IX. Peak hazard rates occurred in Classes I and VIII (0.564 and 0.539 respectively), while low estimates appeared in Classes IX and XI (0.092 and -2.560 respectively), further supporting the static life table analysis results.

Figure 4 [Figure 4: see original paper] Death density and risk rate curve of *S. octophylla* population in Tongguling Nature Reserve

3.5 Time Series Prediction Analysis

Based on individual numbers in each age class, we used the single moving average method to predict future individual numbers for each age class in 3, 6, and 9 years. Table 4 shows that total individual numbers will increase across all future time periods. After 3 age classes, all age classes except VII and XII showed increased individual numbers (which decreased by 22.2% and 81.8% respectively). Class II individuals increased from 560 to 875 (56.3% increase), while Class III increased from 267 to 751 (181.3% increase). After 6 age classes, post-Class VI age classes showed increases of 322%, 389%, 300%, 300%, 514.3%, 323.1%, 260%, and 9.1% respectively. After 9 age classes, post-Class IX age classes increased by 1078.1%, 2100%, 1061.5%, 790%, and 181.8% respectively.

Table 4 Time sequence prediction in the quantitative dynamics of *S. octophylla* population

4. Discussion and Conclusion

Population age structure is fundamental for reflecting population dynamic information (Wang et al., 1998), and using DBH to represent age structure can simplify population ecology research (Jin et al., 2017). Analyzing population age class structure is an important approach for revealing population survival status and regeneration strategies. In forest communities, dynamic changes in dominant tree species directly reflect community succession status and determine community construction and characteristics (Ni, 2001). This study focused on the dominant species *S. octophylla* in the coastal forest of Tongguling, Hainan, using the diameter class method for age classification and compiling a static life table. Results showed a total of 2,814 individuals, with saplings comprising the highest proportion (70.6% of total), followed by medium trees (27.8%), while large trees accounted for only 1.6%. The diameter class distribution showed an overall inverted J-shape, indicating abundant seedling resources and ideal regeneration status. Similar patterns were found in studies of dominant species in tropical evergreen monsoon forests (Fan et al., 2014; Dai et al., 2017). When a population has more juvenile than senescent individuals, environmental conditions are favorable and the population is developing (Liu et al., 2014; Li et al., 2017; Zheng et al., 2018). The scarcity of large-diameter individuals is attributed not only to natural or human disturbances but also to physiological decline and higher nutrient requirements. However, whether the high proportion of seedlings results from high soil seed germination rates or abundant seed production requires further investigation.

Building on the conventional diameter class method, this study integrated survival curves, dynamic quantitative indices, survival functions, and time series models for deeper analysis of population dynamics. We found that *S. octophylla* had similar mortality rates across diameter classes with a survival curve approximating a diagonal line, conforming to Deevey-II type and indicating stable growth. The population size class structure dynamic index (without environmental disturbance) was $V = 030.685 > 0$, and the age structure dynamic index (with random disturbance) was $V' = 0.236 > 0$, demonstrating that the habitat is favorable for *S. octophylla* growth and that the population is growing and stabilizing. However, the dynamic index for Class XI was negative, indicating that this age class had fewer individuals than adjacent classes and showed a declining structural dynamic relationship. The positive V value of 30.685 reflects the population' s growth potential under non-random disturbance, its sensitivity to environmental interference, and its strong adaptability to the local environment, forming effective survival strategies—similar to results from quantitative analyses of forest community dominants (Zhang, 2016; Chang, 2018).

Population age structure reflects not only the relationship between population and environment but also its role and status in the community. Coomes and Allen (2007) suggested that if tree mortality is primarily competition-driven, small-diameter trees should have higher mortality than large-diameter ones.

Zhang et al. (2011) found that poor light conditions and intense competition with co-occurring plants reduced *Pteroceltis tatarinowii* seedlings in Anhui' s Langya Mountain. Zhou et al. (2019) reported that *Pinus taiwanensis* population stability in Classes 4–9 resulted from reduced competition after plants reached a certain height. Li (2019) proposed that restricted growth from juvenile to middle age may be caused by physiological mechanisms. Our study yielded similar results: survival curve analysis revealed intraspecific and interspecific competition in early stages, causing survival numbers to decline gradually from Class II onward. As populations age, physiological functional decline increases environmental requirements, and combined with human disturbance, results in relatively few large-diameter *S. octophylla* individuals—consistent with Mueller (2005) and Nepstad et al. (2007), who attributed high large-tree mortality to reproductive costs and natural senescence. The increased survival numbers in Class XII can be explained by enhanced environmental adaptation of adult trees surviving intraspecific competition and natural selection. Although young *S. octophylla* individuals were numerous, their growth and competitive abilities were weak in early stages, and environmental adaptability was poor, resulting in peak survival numbers and mortality rates in Classes I and II. Furthermore, the survival and cumulative mortality curves showed near-axial symmetry, while mortality density and hazard rate curves remained relatively stable with gentle variation, showing a dynamic pattern of: early decline–mid-term growth–late-term stabilization.

Overall, our results from diameter class structure, quantitative dynamics, and survival functions were consistent: high early-stage mortality due to weak seedling resistance and intense competition, mid-stage development of competitive and adaptive capabilities, and late-stage retention of relatively stable numbers of older individuals to optimize environmental resource acquisition. Studies on population structure analysis (Han, 2014; Chang, 2018; Zhao, 2018) found that time series models predict increasing individual numbers in growing populations. Our study yielded identical results: *S. octophylla* individual numbers across all age classes will increase in the next 3, 6, and 9 years, with greater increases corresponding to higher age classes. This reflects abundant low-age individuals in the Tongguling population that can promptly compensate for natural mortality losses across age classes, and indicates that future middle-age *S. octophylla* in this forest will maintain good regeneration levels. Nevertheless, to ensure continued stable population development, effective protection of the reserve' s habitat must be maintained and strengthened.

In conclusion, current habitat conditions in the reserve are favorable for *S. octophylla* growth, with strong self-regeneration capacity, high survival quality, and stable development, ensuring its future dominance in the regional forest community. As the primary dominant species in Tongguling' s coastal forest, *S. octophylla* plays a crucial role in community construction and restoration. Studying dominant species population structure not only reflects survival status, future dynamics, and succession trends but also reveals plant-habitat fitness, providing fundamental research data for other population ecology studies in the reserve and contributing to understanding succession patterns and biodiversity maintenance in China’ s tropical secondary forests.

References

CHE XF, YUE P, YANG XB, et al., 2007. Structural characteristics of tropical evergreen monsoon elfin forest in Tongguling national nature reserve[J]. J Fujian For Sci Technol, (3): 87-91+144.

DHARMALINGAM M, MASON J, CAMPBELL, et al., 2017. The effect of altitude, patch size and disturbance on species richness and density of lianas in montane forest patches[J]. Acta Oecol, 83.

GUO XY, ZHANG HY, WANG YQ, et al., 2015. Mapping and Assessing Typhoon-induced Forest Disturbance in Changbai Mountain National Nature Reserve Using Time Series Landsat Imagery[J]. J MT SCI-ENGL, 12(2):404-416.

HUANG XT, YIN H, HUANG QJ, et al., 2018. Characteristics of population structure and community species diversity of an extremely small population of protected phyllitis scolopendrium[J]. Acta Ecolo Sin, 38(7): 2481-2492.

JI Y, CAO MY, BAI CF, et al., 2019. Population structure and dynamics of Alsophila Spinulosa in mount Emei[J]. Acta Bot Boreal-Occident Sin, 39(3): 543-551.

JIANG YH, XIANG WH, HE YH, et al., 2017. Population quantitative characteristics and dynamics of Horsfieldia hainanensis, a rare and extremely small population plant[J]. J Cent S Univ For Technol, 37(8): 66-71+80.

JIANG ZM, HE ZS, SU H, et al., 2018. Population structure and dynamic characteristics of endangered Syringa pinnatifolia Hemsl[J]. Acta Ecolo Sin, 38(7): 2471-2480.

JOANNE C, WHITE, MICHAEL AW, et al., 2017. A nationwide annual characterization of 25 years of forest disturbance and recovery for Canada using Landsat time series[J]. Remote Sens Environ,194.

LI D, ZHANG XR, YANG XB, et al., 2016. Exploration of the protective effect on endangered plant populations inside the nature reserve—a case study of vatica mangachapoi in Changjiang, Hainan[J]. Forest Resour Manage, (1): 118-125.

LI GH, ZHANG SK, YE YX, et al., 2018. Species diversity and dominate population dynamics of three Schefflera heptaphylla communities in Dongguan[J]. For Environ Sci, 34(3): 65-72.

LI WY, LI X, GAN XH. 2018. Population structure and dynamics of endangered plant tetracentron sinense[J], Subtrop Plant Sci, 47(3): 222-228.

LI XK, SU ZM, XIANG WS, et al., 2002. Study on the structure and spatial pattern of the endangered plant population of abies yuanbaoshanensis[J]. Acta

Ecolo Sin, (12): 2246-2253.

LI XL, SUN ZY, LI JY, et al., 2018. Population structure and dynamic change of endangered plant Camellia azalea[J]. J Plant Resour and Environ, 27(2): 17-23.

LIU Y, WANG YR, HOU GW, et al., 2018. Analysis of natural population dynamics of davidia involucrata in bayuelin nature reserve[J], J Sichuan For Sci Technol, 39(1): 87-90.

LONG C, YANG XB, LONG WX, et al., 2015. Population structure and spatial patterns of five syzygium species in tropical evergreen monsoon elfin forest, Tongguling[J]. Sci Silv Sin, 51(2): 18-27.

N. GAHUNGU, B. CHOW, S. TEWARI, , et al., 2019. Quantified coronary plaque characteristics between caucasians and morise score-matched south asian populations[J]. J HEART LUNG CIRCULATION, 28.

PATEL N, VERCHININA L, WICHOREK M, et al., 2019. Identification of population characteristics through implementation of the comprehensive diabetic retinopathy program.[J]. EXP CLIN ENDOCRINOL DIABETES, 5.

PENG C, LIU GL, FAN SH, et al., 2018. Population dynamics of natural regeneration of rattan in secondary lowland rain forest in Hainan Island, southern China[J]. J Beijing For Univ, 40(10): 86-94.

SHEN SK, MA HY, WANG YH, et al., 2008. The structure and dynamics of natural population of the endangered plant Euryodendron excelsum H.T.Chang[J]. Acta Ecolo Sin, (5): 2404-2412.

TAO C, YANG XB, WAN CH, et al., 2015. Decomposition characteristics of leaf litter of forests at two different succession stages in tongugling nature reserve, Hainan[J]. J Trop Biol, 6(1): 69-77.

WANG LL, WANG L, ZHANG LF, et al., 2015. Structure and dynamic characteristics of Gymnocarpos przewalskii in different habitats[J]. Chin J Plant Ecol, 39(10): 980-989.

WANG P, GOU ZH, NONG SQ, et al., 2018. Interspecific association of Schefflera octophylla secondary forest communities in the central part of Hainan[J]. J Trop Biol, 9(4): 409-417.

XIE CP, WU CH, FU G, et al., 2019. Population structure characteristics and dynamics of cycas hainanensis in wuzhi mountains, Hainan province[J]. J Cent S Univ For Technol, 39(1): 77-85.

XU BK, XU XG, LI Y, et al., 2019. Interspecific association analysis of castanopsis eyrei community in evergreen broad-leaved forests in Huangshan, Anhui Province,[J]. J Nanjing For Univ(Nat Sci Ed), 43(4): 77-84.

XU H, LIU YH. 2019. The population structure, dynamics features and protection strategy of acer catalpifolium extremely small population[J]. J Nanjing For

Univ(Nat Sci Ed), 43(2): 47-54.

YANG LR, ZHANG ZL, YUN Y, et al., 2018. The population structure and dynamics of dracaena cambodiana, an endangered tree on Hainan Island[J]. Acta Ecolo Sin, 38(8): 2802-2815.

YANG Q, ZHOU J, TAO C, et al., 2014. Comparative study on interspecific association in tropical evergreen monsoon elfin forest at two successional stages in Tongguling of Hainan Island[J]. Chin Agricul Sci Bull, 30(22): 8-15.

YANG XB, LONG WX, ZHOU W, et al., 2013. Investigation of the medicinal plants in the tongguling nature reserve of Hainan[J]. Guangdong Agric Sci, 40(10): 17-20.

YAO L, AI XR, Yi YM, et al., 2017. Structure and dynamics of dominant populations in the mixed forest of subtropical evergreen and deciduous broad-leaved tree species in the southwest of Hubei Province[J]. Sci Silv Sin, 53(2): 10-18.

YU Q, XIE ZQ, XIONG GM, et al. 2008. Community characteristics and population structure of dominant species of abies fargesii forests in shennongjia national natrue reserve[J]. Acta Ecolo Sin, 28(5): 1931-1941.

ZHANG KH, LIANG YN, YANG JW, et al., 2009. Structure and spatial patterns of dominant populations in the conifer and broadleaf mixed forest in middle-lower reaches of Xijiang River[J]. For Environ Sci, 25(4): 1-6.

ZHANG XR, LL D, YANG XB, et al., 2017. Structure and dynamic characteristics of wild longan population in Dongfang City, Hainan[J]. Guihaia, 37(4): 417-425.

ZHOU WS, FENG DD, LL DH, et al., 2014. Population dynamics of endangered medicinal plants in changjiang county[J], Hainan J Trop Biol. 5(4): 392-399.

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