

Biological characteristics of wild *Cycas fairylakea* population in Guangdong Province, China

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Abstract There are five wild populations of *Cycas fairylakea* in Guangdong Province, China, three of which are newly found. A study of the biological characteristics of *C. fairylakea* populations showed that this species had a narrow colonization area within 300 hm², and an island pattern of distribution. Because of the overexploitation, urbanization, environment pollution, plant diseases, and insect pests, the wild populations and individuals of *C. fairylakea* decreased markedly in the past decades. All five populations have an opposite pyramid age structure, few coning plants, few seed production, and low level of seed germination rate or sterility. In conclusion, *C. fairylakea* in Guangdong Province was threatened seriously and an urgent need to take effective efforts to protect the plants and habitats in its location sites was required.

Keywords *Cycas fairylakea*, wild population, endangered, conservation

1 Introduction

Cycads represent an ancient lineage that tends to be long-lived, outcrossing, and generally have restricted ranges, whose origin can be dated to the lower Permian or middle-late Carboniferous (Gao and Thomas, 1989; Norstog and Nicholls, 1997; Hu et al., 1999). *Cycas* are distributed in tropical and subtropical areas of Asia, Australia, Pacific islands, Eastern Africa, and Madagascar islands (Lindblad and Costa, 2002). In China, there are more than 20 species of *Cycas*, which grow in evergreen broadleaves forests, coniferous forests, or shrubs in the tropical and subtropical

areas, such as Sichuan, Guizhou, Hunan, Fujian, Guangxi, Guangdong, Yunnan, Hainan, and Taiwan Provinces. Because *Cycads* are treasured as ornamental plants, they are often over-exploited by human beings (Guan and Zhou, 1996; Wang et al., 1996). The distribution and number of individuals of most species in *Cycas* have decreased at an alarming speed, primarily due to destruction by human beings, poaching, insect pests, urbanization, and environment pollution (Keppel, 2002; Keppel et al., 2002). Although none of the cycad species in China is included in the 2000 IUCN Redlist (IUCN, 2001), all wild species of *Cycas* are classified under State Protection Category I in China (Yu, 1999).

C. fairylakea D.Y. Wang was only described in 1996 (Wang et al., 1996), and its natural populations were just discovered in 2000 (Wang et al., 2003). This species is phylogenetically close to *C. taiwaniana*, distinguished by ferruginous young fronds and a subulate apical segment of the megasporophyll. Irrespective of whether ovules have developed or not, ovulate strobilus of *C. fairylakea* become loose during the coning season (August–September), but *C. taiwaniana* has grey-brown young fronds and broad ovate to subulate apical segment of megasporophyll with serrulate margins. *C. fairylakea* is also similar to *C. szechuanensis*, differing in the apical segment of the megasporophyll similar to the lateral segments (Wang et al. 1996; Tang and Liao, 2001). As an endangered and endemic species in China, the natural populations of *C. fairylakea* are only found in three sites, i.e., Shengzhen (two populations of Tanglangshan and Meilin), Qujiang (two populations of Luokeng and Zhangshi) and Heshan, Guangdong Province, China.

In this study, biological characteristics of five natural *C. fairylakea* populations in Guangdong, China, were analyzed to address the implications for future conservation and breeding tasks for this species.

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2 Materials and methods

2.1 Distribution and population structure

Based on our investigation, population colonization area, pattern of distribution, habitat, the number of individuals, plant diseases, and insect pests were recorded and analyzed for each natural population of *C. fairylakea*.

Based on the field investigation, we found significant correlations between ages and heights of cycads ($r = 0.93$, $p < 0.01$, Jian et al. unpublished). Thus, we used the heights of cycads to measure their ages in this study. For age structure analysis, we set up three 20 m × 20 m plots in each large natural population and counted all individuals in each plot for the following age stages: A: stem height ≥ 1 m; B: 50 cm \leq stem height < 1 m; C: 25 cm \leq stem height < 50 cm; D: 5 cm \leq stem height < 25 cm; and E: stem height < 5 cm. In the two small populations with less than 20 individuals, we recorded all individuals. In addition, we recorded all coning individuals (male or female) in the entire population from 2000 to 2004. As the Meilin and Zhangshi populations were just found in March of 2003, there were only two years of data for these two populations.

To estimate the plant diseases and insect pests in each natural population, we recorded all individuals in each plot (same plots as that for age structure analysis) for the following grades (Serious: no leaf; Moderate: few leaves, not integrated; Slight or little: many leaves, some integrated; No: many leaves, integrated).

2.2 Coning and reproductive capacity

Based on the field investigation, coning individuals (male or female) and numbers of seed of each coning individual were recorded for each natural population. To estimate the germination rate, we collected seeds of *C. fairylakea* from each population, and sowed in a pot (20 cm high, 40 cm diameter)

holding 80% volume of sand soil in a greenhouse of South China Botanical Garden, and watered daily. The final seed germination rate (%) for each population was recorded.

3 Results

3.1 Growing characteristics and habitat

C. fairylakea often grew in clumps, and a single stem was rare. This species preferred to grow in humid environment with fertile soil, such as on the side of creek or brook along a mountain range. It grew well under moderate sunlight, but was very rarely found in open areas directly under sunlight or in a shady forest.

3.2 Distribution and population structure

Only five populations in three sites were found in Guangdong Province, China, within a narrow and fragmented area (< 3 km²) and less than 4,000 individuals in total. The location sites, habitats, and number of individuals of all five natural populations of *C. fairylakea* are presented in Table 1. In particular, more than 95% individuals of *C. fairylakea* were found in Tanglangshan and Meilin populations. More than 100 individuals were found in Luokeng and Zhangshi populations ten years ago, but only 7 to 11 individuals survived by 2003.

As presented by the data in Table 2, all five natural populations of *C. fairylakea* had an opposite pyramid age structure. There were many old individuals but few young individuals, especially for Luokeng, Zhangshi, and Heshan populations. Only a few young seedlings or individuals produced from seeds in the recent two years were found in Tanglangshan and Meilin population, and none in other three populations, indicating this species was very endangered.

Table 1 Location sites, habitats, and number of individuals of all five populations of *Cycas fairylakea* in Guangdong Province, China

Population	Location sites	Habitat	Altitude/m	Area/hm ²	No. of individuals
Tanglangshan	22°35.02'–22°35.95' N, 113°54.45'–113°55.05' E	In open evergreen broad-leaved forests	50–200	200	1830
Meilin	22°34.33'–22°34.91' N, 114°0.35'–114°0.67' E	In open evergreen broad-leaved forests	78–180	50	850
Luokeng	24°31.2'–24°31.2' N, 113°23.0'–113°23.0' E	In open coniferous tree forests	195	0.01	11
Zhangshi	24°34.88'–24°34.95' N, 113°27.4'–113°27.5' E	In evergreen broad-leaved forests	298–308	0.05	12
Heshan	22°50.2'–22°50.33' N, 112°52.25'–112°52.30' E	In hillside bamboo forests	298–303	0.05	4

Table 2 Age structures in the five natural populations of *Cycas fairylakea*

Stage	Tanglangshan	Meilin	Luokeng	Zhangshi	Heshan
Stem height ≥ 1 m	21	4	0	9	0
50 cm \leq Stem height < 1 m	42	17	1	1	2
25 cm \leq Stem height < 50 cm	23	12	8	1	2
5 cm \leq Stem height < 25 cm	7	7	1	1	0
Stem height < 5 cm	2	6	1	0	0

3.3 Coning individuals and reproductive capacity

As presented by the data in Table 3, few coning individuals were recorded in the five natural populations, especially for female ones from 2000 to 2004, and a descending trend was observed over the last 5 years. In particular, no male coning individual was found in the Luokeng, Zhangshi, and Heshan populations. In the Tanglangshan and Meilin populations, there were only 0.11%–0.85% coning individuals. This was a very important observation and implied that the reproductive capacity of *C. fairylakea* might be threatened.

As presented by the data in Table 4, all coning female individuals in the five populations of *C. fairylakea* could bear fruits. Each coning plant produced 55–150 seeds, and each weighed 10.6 ± 1.6 g. We found some 1–2 year old young seedlings produced from seeds in Tanglangshan and Meilin populations, but none in the other three populations. Similar results were obtained in the germination experiment in the greenhouse—only seeds collected from Meilin population could germinate (no seeds were collected from Tanglangshan and Luokeng for the seed germination experiment).

Anatomical results showed that only *C. fairylakea* seeds collected from Tanglangshan and Meilin populations had valid embryos in all five populations. Because of lack of valid embryos in the seeds, *C. fairylakea* in Luokeng, Zhangshi, and Heshan populations could not reproduce offspring by seeds (sexual reproduction), but could by tillers repetition from maternal plants (asexual reproduction). As only a few young seedlings were found in the Tanglangshan and Meilin populations in the field, we inferred that *C. fairylakea* in these two populations reproduced offspring

mainly by asexual reproduction (by tillers), though sexual reproduction was available.

3.4 Plant diseases and insect pests

As presented by the data in Table 5, plant diseases and insect pests were very serious in two Shenzhen populations, especially for the largest one of Tanglangshan. About 90 % of the individuals of cycads in the Tanglangshan population were harmed by horsfield (*Chilades pandava*), an invasive pest (Gao et al., 2004), and more than 50 % of the infected plants had no leaf at all. Although horsfield was not found on the cycads in the other three populations, some other kinds of plant diseases and insect pests occurred to some degree.

4 Discussion

Finding natural populations of *C. fairylakea* in Shenzhen, Qiujiang, and Heshan is very important for studies on conservation, phylogeny, and evolution of cycads in China. *C. fairylakea* is a dioecious plant species, and the female cone is lagged than the male one. It reproduces offspring mainly by seeds or sometimes by tillers repetition from maternal plants. Our field observations confirm that *C. fairylakea* is mainly insect-pollinated, but sometimes wind-pollinated. And animals may also play important roles in pollination. The seeds of *C. fairylakea* are mainly spread by its weight,

Table 3 Coning individuals in the five populations of *Cycas fairylakea* from 2000 to 2004

Population	2000	2001	2002	2003	2004
Tanglangshan	6 (M), 3 (F)	5 (M), 2 (F)	3 (M), 0 (F)	2 (M), 0 (F)	4 (M), 0 (F)
Meilin				5 (M), 2 (F)	6 (M), 1 (F)
Luokeng		U (M), 1 (F)	0 (M), 0 (F)	0 (M), 0 (F)	0 (M), 0 (F)
Zhangshi				0 (M), 5 (F)	0 (M), 0 (F)
Heshan			U (M), 2 (F)	0 (M), 2 (F)	0 (M), 1 (F)

M = male, F = female, U = unknown

Table 4 Seed germination rates in all five populations of *Cycas fairylakea*

Population	In field	In nursery		
		Number of seeds sowed	Number of seeds germinated	Germination rate /%
Tanglangshan	> 0	—	—	—
Meilin	> 0	3	1	33.3
Luokeng	0	—	—	—
Zhangshi	0	40	0	0
Heshan	0	15	0	0

Table 5 Plant diseases and insect pests in the five populations of *Cycas fairylakea*

Extent	Tanglangshan	Meilin	Luokeng	Zhangshi	Heshan
Serious	47	1	0	0	0
Moderate	29	13	5	0	2
Slight or little	12	9	5	4	2
No	7	24	1	8	0

or sometimes moved by animals (Guan and Zhou, 1996; Wang, 1996).

As seeds could not germinate, *C. fairylakea* in Luokeng, Zhangshi and Heshan population reproduced offsprings by tillers repetition from the maternal plant, which could be an adaptive strategy for survival. Although *C. fairylakea* could produce seeds (only endosperm), no offspring could be produced because of nonavailability of valid embryos in some populations and no male individual could produce pollen.

Our study of the biological characteristics of natural populations of *C. fairylakea* showed some typical characteristics of endangered species, such as limited and fragmented distribution, small population size (less than 4,000 individuals), inverted pyramid age structure, low number of coning plants (especially for male individuals in Luokeng, Zhangshi, and Heshan), few seeds production, and low level of germination rate or sterility, all of which resulted in low levels of reproductive capacity of this species. Based on the criteria of IUCN, *C. fairylakea* should be classified as a very endangered species (IUCN, 2001). On the other hand, with the development of economy and urbanization, environmental pollution, plant diseases, and insect pests have become more serious in the past decades, resulting in habitat degradation and significant losses of wild individuals of *C. fairylakea*. Furthermore, human beings also played an important role in the losses of wild individuals of *C. fairylakea*. For example, there were more than 100 individuals in Zhangshi population 10 years ago, but only 11 plants survived in 2003, most of which were dug for profit by local people because of its ornamental value as a garden plant. All of the causes mentioned above seriously threatened the survival of *C. fairylakea*. Therefore, the major factors threatening *C. fairylakea* populations are human activities (e.g., overexploitation for gardening, habitat destruction, urbanization, pollution, etc.), and the breeding system of this species. Meanwhile, the small population size, fragmented habitat, and low number of coning plants may also result in low levels of gene flow and genetic variation, as well as a decreased adaptability to environmental changes in the long term (Shapcott 1998; Zhang and Jiang, 1999).

In conclusion, *C. fairylakea* in China is seriously threatened and requires urgent actions to preserve the species and its habitat, e.g., setting up natural reserves and protection stations, enhancing the propagation and education of cycad protection, enhancing the research and popularization of technology for fast reproduction of the cycad, and strengthening the management force of the government to strictly forbid purchase of wild cycads. For rehabilitation, the seeds or donor propagulum should be collected from populations that have high genetic similarity to one another, and habitat remediation should also be carried out.

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