A discussion on the dynamics of small population of living collection

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Introduction

Over the last 45 years, a collection of *Taxus chinensis* var. *mairei* planted in 1957-58 in Nanjing Botanical Garden with only 11 individuals, 5 male and 6 female, has generated and developed a new naturalised population of more than 500 individuals which is located mainly in the nearby natural woodlands. This paper discusses: 1. the process of the formation of natural population from a living collection of an endangered species in botanical garden, 2. the reason why it could exist outside its natural distribution areas, the endangerment mechanism – the "endangering habitat", 3. the necessary biological and physical conditions for the development of the new natural population, 4. *ex-situ* cultivation or *ex-situ* conservation, 5. the number of individuals needed for a minimum viable population and 6. the improvement of design and field practice in order to provide appropriate ecological conditions for *ex-situ* conservation.

It has been a traditional practice for a period of more than 400 years, since the 16th century, for plants to be introduced into botanical gardens for education, research and other uses. Hence there are always a great number of taxa, each with only a few individuals, because of limited land, human, and financial resources. In the late 1970s, as people realized that the current speed of species loss was more than one thousand times that of the normal speed in history, Botanical gardens possessing thousands of plant taxa were praised as important bases for *ex-situ* conservation and the "Arch" for saving plants. Unfortunately, the number of individuals in each collection is too small, and according to the theory of population ecology, it is impossible for the very small populations of the collections to exist sustainably; they are even considered as "living dead" plants (Janzen, 1986; Franklin, 1980; Menges, 1991; Primack, 2000). Indeed, plant collections are often lost in botanical gardens. But so far, the main causes of plant loss are mainly attributed to: 1) less adaptability of the plants introduced, 2) problems with insects and diseases, 3) lack of proper maintenance, and 4) disturbances by people. There is no reported evidence concerning the loss of living collections caused by reasons of population biology, minimum population. However, whether at the present time or for a long time in the future, most of the thousands of living collections in botanical gardens can only be maintained with limited numbers of individuals. The authors have worked in a botanical garden for several decades and found the occasional naturalised population of *Taxus chinensis* var. *mairei* (Li, 1999). In order to strengthen the role of conservation in botanical gardens, it is important to study the possibility of, and the conditions necessary for, the process of the formation of naturalised populations from a botanical garden's living collections.

The performance of the naturalised *Taxus chinensis* population

Based on the data from *Jiangsu Flora* (Jiangsu Institute of Botany, 1977), there is no record of the presence of *T. chinensis* var. *mairei* in the Nanjing area, including the Purple Mountain and areas in its vicinity, of Jiangsu Province. Nevertheless, in the natural woods of the Nanjing Botanical Garden, there appears to be a naturalised population of several hundred *T. chinensis* var. *mairei* individuals.

The living collection of *T. chinensis* var. *mairei* in the Nanjing Garden

Seedlings and seeds of *T. chinensis* var. *mairei* were introduced to the Nanjing Botanical Garden from Lushan Botanical Garden in 1954 and again in 1955. The collection is located in the Coniferous Section under cultivated conditions. The nearby collections include dawn redwood (*Metaseqouia glyptostroboides*) and taxodium (*Taxodium asendens*); they stand on level ground and they have formed a continuous forest. There are 11 individuals of *T. chinensis* var. *mairei*, five female and six male. The trees are growing well, bearing flowers, fruits and viable seeds. The average height of the trees is 6.0–8.0 m with an average breast-high diameter of 16.9–29.3 cm. The tallest tree, 345 cm high, was planted in 1957. According to the records, the age of the collection is about 40–46 years old and it probably started bearing seeds when the trees were 30 years old because the largest tree of the new naturalised population is about 15 years old.

The new naturalised population occurs mainly in the Garden's natural woodland and it is recognized that the original collection is the seed source of the naturalised population (Fig. 1).

Numbers and ages of individuals in the naturalised population

In 1999, the new naturalised population consists of a total of 461 individuals, with 23 trees, 4.99% of the total measuring more than 200 cm in height; 424 plants, 91.9% of the total, measuring 20–200 cm in height; and 14 plants, 3.04% of the total, measuring less than 20 cm in height. Based on the observation of the biological behaviour of their branching systems, the oldest tree is about 15 years old and the youngest tree is about one year old. The distribution pattern is random, with single plants and clumps of 2–3 or 4–7 plants. In general, it is a growing population.

Location and habitat of the new naturalised population

It is unexpected that the new plants generated by seeds from the original population occur mostly not on the land in the Coniferous Section of the Nanjing Garden, but in the nearby natural forests. The population is distributed in communities dominated by species such as *Quercus acutissima* on the mountainous slopes and by species such as *Pterocarya stenoptera* in the stream valleys. The area of the population is about 400 m from north to south and 100–150 m from east to west. Its elevation is 35–60 m. Its various habitats include sunny slopes and shaded slopes, as well as, valleys with streams that flow all year round. The habitats are moist, and the soils contain rocks and gravel which provide good drainage; there is a rich biodiversity with more than 40 species of accompanying plants.

The significance of the new naturalised population

A region of naturally occurring distribution is always recognized as an appropriate habitat for a species. But in this case, the new naturalised population of the endangered species *T. chinensis* var. *mairei* occurs in the Nanjing area, outside its natural distribution region. It is obvious that the new site has become a suitable habitat for it to survive. This phenomenon demonstrates the concept of 'endangering habitat', that “the conditions of a specific habitat which causes the population of a certain species located in that habitat to

become endangered"(He, 1996; He, 1998; He, 1999). Hence, it is not necessary to reintroduce the species back to its original distributed areas, since the original site is no longer a suitable habitat for the species.

Conditions for the formation of the naturalised population

It is worth mentioning that there are only a few young seedlings and no evidence of the succession of the population could be found on the cultivated site of the *Taxus* collection, though there were many matured seeds left on the ground. It seems obvious that a natural habitat is the necessary condition for the formation of a population. In addition, it is interesting to mention that a similar situation was also found in the species *Cephalotaxus sinensis*. This phenomenon is, to a certain degree, common to many species. More research should be conducted in order to explain this fact and the apparent reason for two aspects are as follows.

Dispersal and germination of seeds need specific conditions

Because of the distances between the cultivated population and the naturalised populations, it is possible that birds transferred the seeds. Reports (Harper, 1977; Rudolf, 1974) indicate that *Taxus* seeds are usually eaten by birds, and under natural conditions, germinated seeds are often those having passed through the digestion system of birds. From observations of the cultivated *Taxus* population, the authors also noted the frequent presence bird species such as *Streptopelia orientalis*, *S. chinensis, Garralax canorus, Turdus merula*, *Pycnonotus sinensis, Cyanopica cyana* and *Phasianus colchicus*.

Since birds should be involved in the formation of a new population, it is necessary to have an environment rich in plant species diversity for the birds. In fact, the naturalised population occurs those areas of natural woodland, which have more than 40 species of plants in mixed forests dominated by broad-leaved trees, but not in the forests dominated by coniferous trees. Obviously, water and heat conditions, as well as the richness of plant diversity, in the natural woodland are better than those on the site of the cultivated land in the botanical garden. It is probable that the *Taxus* seeds need biomass cover to overwinter and to protect them from the damage caused by field mice, etc. The consumption of seeds by mice is different from birds, because seeds can be completely destroyed by mice but not by birds. The complex relationships among various biological species and the relationship between biological species and environments determine the appearance of the naturalised population in the natural habitats mentioned above.

The growth of seedlings and the formation of a population need favorable and stable environments

The growth of seedlings depends on the presence of temperate, cool, moist and shaded areas. The development of a population needs a stable environment as well. In the botanical garden there are too many activities by people, including visitors, weeding practices, etc.

In general, it is impossible to have a naturalised population on agricultural or horticultural land.

Creating the ecological conditions favourable for the formation of naturalised populations

In the early stages of the history of botanical gardens, collections were used for research and application. Introduced plants were fully under artificial cultivated conditions. So that, for collections in botanical gardens it is more appropriate to say '*ex-situ* cultivation' than '*ex-situ* conservation', because all introduced plants can grow well in an appropriate cultivated environment. The ecological conditions of current plant collections in botanical gardens are substantially not for conservation. In order to promote the formation of

naturalised populations and to promote the role of botanical gardens in conservation, the improvement of the ecological conditions of *ex-situ* conservation collections should be conducted based on the principles of biological conservation.

The combination of artificial cultivated and natural habitats

Natural habitats are a necessity for the formation of a naturalised population. It is necessary to have natural habitats inside the sites of living collections for conservation in botanical gardens. Two categories of fields, cultivated and wild, should be arranged next to each other and the border line should be kept as long as possible in order to promote the transition of cultivated populations to naturalised populations, particularly because plants cannot move as easily as animals do. The dispersal and transfer of seeds and other propagules of plants need external forces and it is impossible for them to find a suitable environment far from the parent plants (Fig.2).

Appropriate artificial interruption

Based on the observations of the appearance of the naturalised population, it is found that the formation of a naturalised population is always associated with a forest gap. This indicates that the interruption of the habitat is favourable for the entering of a new species. This so-called 'interruption' should include protection for the new entering species. Otherwise, the newly introduced plant material may not survive.

In order to add and introduce natural habitats into and to improve the cultural practice for the *ex-situ* conservation system in botanical gardens, a new kind of layout and management system based on the principles of both *in-situ* conservation and *ex-situ* conservation must be established. The authors consider that it is an important concept worthy of further research.

Individual number of minimum population

It is apparent that for conservation we need a relatively large population. But in this case, a small population can only develop to a large one if the ecological conditions are appropriate. We may take a dynamic view about the appropriate initial population size, and not necessarily establish a large population for *ex-situ* conservation in living collections at the beginning. Certainly different species have different characters. At least, for the species that are suited to form new naturalised populations, such as *T. chinensis* var. *mairei*, or those similar to it, which are dioecious, wind-pollinated, self-compatibility, highly viable seeds, bird dispersal etc., we may have only need small population at the beginning.

Conclusion

The occurrence of a naturalised population of *Taxus* is a rare event, but it contains with it the certainty that there is the possibility for the formation of a natural population. Considering *Taxus* is an endangered species, it may have more significance in conservation. This kind of phenomenon could be only found in botanical gardens with a history of several decades. Hence, it significance should be closely investigated and researched.

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Fig.1 Taxus chinensis *var.* mairei: *distribution of the original planted Garden population (black areas) and the new naturalised population (grey areas)*

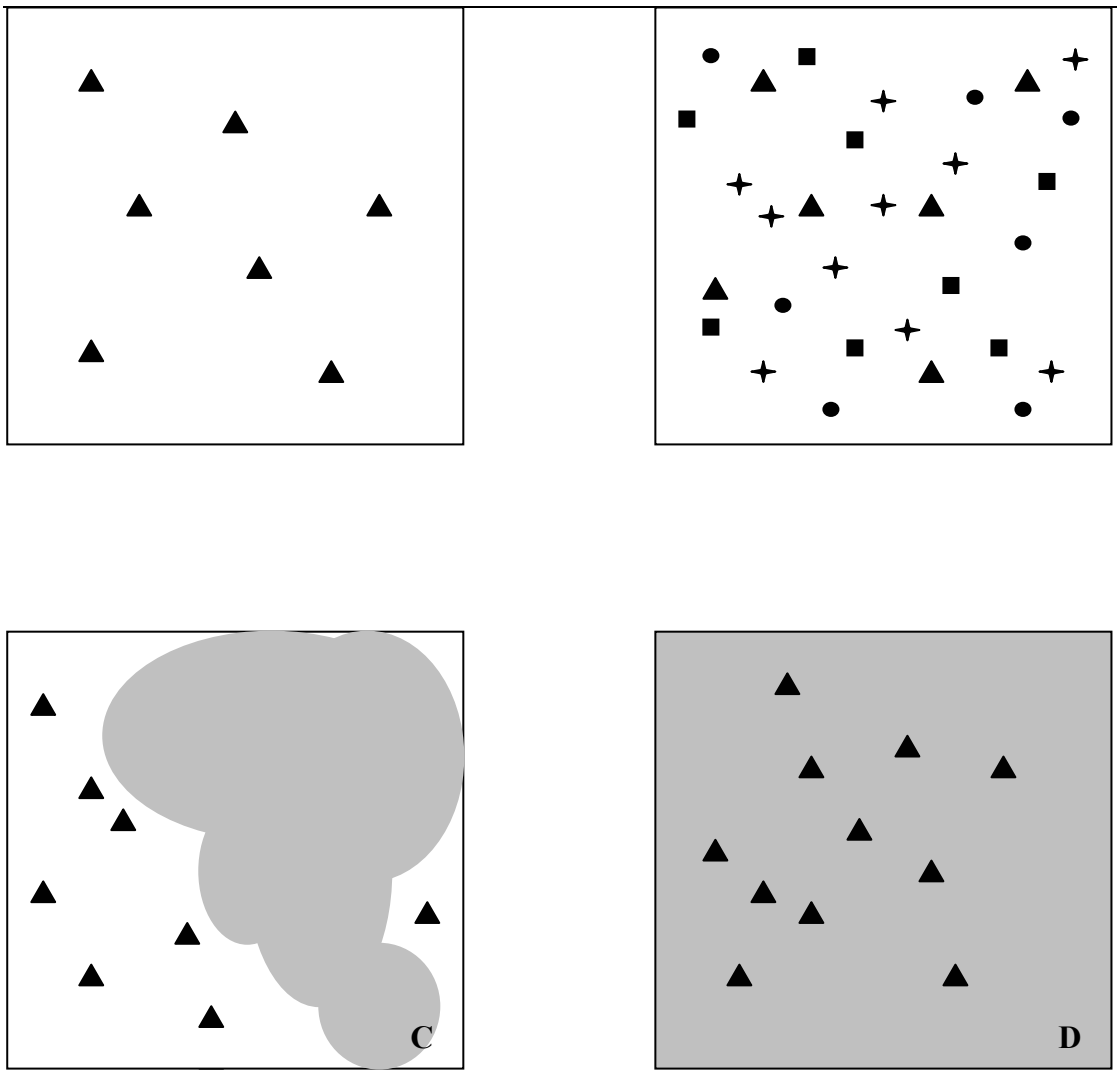

Fig. 2 The patterns of ex-situ *conservation*

Plants of other species *Plants of target species* *Plants of other species*

Plants of other species *Native vegetation* *Living collection*