EVALUATION OF THE CONSERVATION STATUS AND RISKS FOR SOME ENDANGERED PLANT SPECIES IN BA BE NATIONAL PARK, BAC KAN PROVINCE, VIETNAM

By
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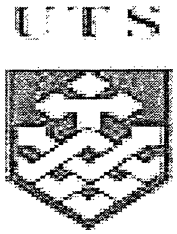

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Certificate of Authorship/Originality

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as acknowledged within the text.
I also certify that the written preparation of the thesis, and all experimental work associated with it, has been carried out solely by me, unless otherwise indicated. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. Finally, I certify that all information sources and literature used are acknowledged in the text.

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Van Hung Hoang
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ABSTRACT

Ba Be National Park, in the northern mountainous region of Vietnam, is an important conservation area with numerous rare, endangered and endemic plant and animal species. The plant resources of the park are exploited by local ethnic minority (hill tribe) people to provide food, medicines and wood products; their high birth rate, general ignorance of plant propagation and husbandry and their dependence on the forest resources to maintain a subsistence level of life has placed many plant species in the Park at increasing risk of local extinction. Moreover, many essential plants are becoming so difficult to find that the local peoples' lifestyle is threatened. This thesis evalualuates the socio-economic features of the threat to plant species in the Park, the broad ecological determinants of the distribution of plants in the area and the genetic diversity of a selected number of plant species. The results demonstrate that national and international schemes for the classification of the conservation status of plant species is of limited relevance in the local context and a mixture of national, international and local criteria enabled the compilation of a plant species conservation ranking for the Park. A suite of environmental factors was chosen to investigate their collective influence on plant species distribution; the main determinants of floristic composition appear to be topography and disturbance, with soil factors being important for endangered species, though other factors not measured here may influence species composition at small scales. The genetic diversity of four priority plant species was determined using the Randomly Amplified Polymorphic DNA (RAPD) technique and the Random Amplified Microsatellite Polymorphisms (RAMP) technique was used to further investigate genetic diversity in two of the four species; the latter proved somewhat more useful in distinguishing between populations than the former. A preliminary evaluation of the location of high-genetic-diversity populations and individuals should allow an informed selection of source plants for future propagation. Some recommendations on future management of the National Park are made.

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TECHNICAL ABBREVIATIONS USED IN THE THESIS

AFLP	amplified fragment length polymorphisms
ALP	amlicon length polymorphisms
ANOVA	analysis of variance
BME	beta mercapto ethanol
CTAB	cetyltrimethylammonium bromide
DO	dominant tree
DT	disturbance
D.W	dry weight
DNA	deoxyribonucleic acid
DT1	disturbance 1
DT2	disturbance 2
EDTA	ethylene diaminetetra acetic acid
EN	endangered species
MS	moist site
PCR	polymerase chain reaction
PH	physical (factor)
PRA	participatory rural appraisal
PVP	polyvinyl-pyrrolidone
RAMP	random amplified microsatellite polymorphisms
RAMPo	random amplified microsatellite polymorphisms
RAMP-PCR	ramdom amplified microsatellite polymorphisms – polymerase chain reaction
RAPD	random amplified polymorphic DNA
RAPD-PCR	random amplified polymorphic DNA – polymerase chain reaction
RFLP	restriction frament length polymorphisms
RNA	ribonucleic acid
RRA	rural rapid appraisal
RU	relatively undisturbed
SO	Soil (factor)
SSR	simple sequence repeats
Taq	thermus aquaticus
TBE	tris borate EDTA
TE	tris – EDTA
V/V	volume per volume
VE	Vegetation (factor)
W/V	weight per volume

INSTITUTIONAL ABBREVIATIONS USED IN THE THESIS

ASEAN	Association of South East Asian Nations
BBNP	Ba Be National Park
(S)CBD	(Secretariat for the) Convention on Biological Diversity
CITES	Convention on International Trade in Endangered Species
FAO	Food and Agriculture Organisation (United Nations)
FIPI	Forest Inventory and Planning Institute (Vietnam)
GOV	Government of Vietnam
HELVETAS (helvetas)	helvetas Vietnam: Swiss Association for International Cooperation
IUCN	International Union for the Conservation of Nature
MARD	Ministry of Agriculture and Rural Development (Vietnam)
MSTE	Ministry of Science, Technology and the Environment (Vietnam)
PARC	Protected Areas for Research and Conservation (Vietnam)
SCEMMA	State Committee for Ethnic Minorities and Mountainous Areas (Vietnam)
SEE	Society for Environmental Exploration
SRV	Socialist Republic of Vietnam
UNEP	United Nations Environment Program
UNESCO	United Nations Educational, Scientific and Cultural Organisation
WB	World Bank
WRI	World Resources Institute
WWF	World Wildlife Fund

Chapter I

Introduction

1.1 Overview

Forest plants play a crucial role in terrestrial ecosystems, offering major ecological benefits in terms of climate control, carbon fixation, wildlife maintenance, water conservation and prevention of desertification (Vaxevanidou *et al.,* 2006). Forests and forest products also greatly contribute to human existence. Currently, more than 1.6 billion people depend on forests and forest products for their livelihood, while more than 3 billion people, mostly in developing countries, derive a significant part of their subsistence needs and income from gathered plant and animal products (Iqbal, 1993; Walter, 2001; Djoghlaf, 2007). Gathering of high value products such as vegetables and medicinal plants continues in developed countries for cultural and economic reasons (Myers, 1983; Jones *et al.,* 2002).

There is a worldwide trend of increasing demand for many popular, effective medicinal plant species in Asia, Europe and North America, growing between 8 and 15% per year (Grunwald and Buttel, 1996). For example, in Germany, with a strong tradition of medicinal plant use, 31% of over-the-counter products in pharmacies in 2001 were phytophamaceutical preparations; a similar figure applies in the United States (Schippmann *et al.,* 2002). Iqbal (1993) estimates that 4,000 to 6,000 botanicals are of commercial importance; another source refers to 5,000 to 6,000 botanicals entering the world market (SCBD, 2001). The level of wild plant use in most developing countries is much higher than in developed countries and it is increasing (Schippmann *et al.,* 2002).

Beside over-exploitation, mass extinction is also due to large-scale habitat destruction caused by human activities (Quy and Hoe, 1994; Frankham *et al.*,

1995; Liu *et al.,* 2007), while changing environmental factors are also indirect or direct factors affecting extinction.

Estimates for the global number of vascular plant species commonly range from 250,000 to 270,000 (IUCN, 1997; Govaert, 2001; Bramwell, 2002). Some 12,043 plant species are currently listed in the Red List of IUCN (2004), many being faced with high risk of extinction: 34,000 species including more than 8,447 tree species or 8% of the world's total flora, are threatened with extinction, and the situation has grown worse over recent years (Walter and Gillett, 1998; IUCN, 2007); 976 tree species are in a critical situation. An effective and efficient methodology to arrest these declines is essential to ensure the future persistence of the species and, by implication, ecosystem processes.

As a fundamental element of any ecosystem approach, it has to be recognized that humans, with their cultural diversity, are an integral component of ecosystems. In conceptual terms, the essence of sustainable development is expressed by the relationship between people and the ecosystems around them (Schippmann *et al.,* 2002). This implies that ultimately one is entirely dependent on the other. Human and ecosystem well-being need to be assessed together. A society is thought to be sustainable when both the human condition and the condition of the ecosystem are satisfactory or 'improving'. The system improves only when both the condition of the ecosystem and human condition improve (Prescott-Allen and Prescott-Allen, 1996).

Evaluation of conservation status is increasingly seen to be the most important conservation strategy for most endangered species and their habitats, given their current and potential contributions to local economies and their great value to ecology over the long term, the most important ingredient in this being information (Peters, 1994). Each species has unique ecological, socio-economic and cultural associations that must be understood (Schippmann *et al.,* 2002). In reality, the evaluations are always confronted with a lack of adequate information about the plants used, their distribution, the genetic diversity of wild populations and relevant environmental factors (Iqbal, 1993). Research on the evaluation of

the conservation status of endangered species and their habitats has fallen far behind the demand for this globally important resource.

Evaluation of the conservation status of forest plant resources, especially endangered species, is one priority for research work in order to understand the conservation situation, to re-evaluate the level of risk of species facing extinction and to find solutions to enhance future conservation activities.

Because people are the plant users, local knowledge in nature conservation is a useful resource and methods to enable local people to share, enhance and analyse their knowledge of life and conditions, to plan and to act are needed for a realistic evaluation of and approach to plant conservation (Chambers, 1992). Indigenous people in all parts of the world have developed highly complex and very specific knowledge of their local vegetation, and, until quite recently, many of them depended on plants from local flora for their livelihood and subsistence (Quac *et al.,* 1999; Phuong, 2000; On *et al.*, 2001). In many countries, such as Norway, Sweden and Finland, the knowledge of local people in evaluating the conservation status has been successfully applied to promote nature conservation (On *et al.,* 2001; Chambers, 1992; Batabyal and Beladi, 2004; Hidayati, 2006). Priorities for the conservation of endangered forest plant species can be assigned by local people and be fundamental for the next steps of evaluation of conservation status and taking action to conserve.

Some forest ecosystems in the world have been fragmented by logging and other human disturbance, resulting in highly dissected landscape patterns and species extinctions (Liu *et al.,* 2007).

The distribution of plant species is widely accepted as a response to a variety of interacting biotic and abiotic factors (Le Broque and Buckney, 1995). Environmental variation often produces modifications in the pattern of vegetation (Aronson and Shmida, 1992; Bertiller *et al.,* 1993). The examination of species' distributions in relation to environmental factors (both biotic and abiotic) can be achieved through the approach of gradient analysis (Austin, 1996;

Ruedas *et al.,* 2006), and the correlation between floristic and environmental patterns (Le Broque and Buckney, 1995; King and Buckney, 2001; Thorne, 2005). In addition, studies in other regions have found species to respond to complexes of environmental variables (multiple environmental gradients) rather than single environmental gradients (Margules *et al.*, 1987; Fensham and Kirkpatrick, 1992; Le Broque and Buckney, 1995; Bertiller *et al.,* 1995). Therefore, the study of relationships between vegetation and environmental patterns for endangered forest plant species is necessary for their adequate conservation.

Evaluation of the conservation status of plants can be achieved in a number of complementary ways (Li *et al.,* 2001). In recent years, the protection of genetic diversity within species has become one of the major targets of conservation efforts. Intraspecific genetic diversity is thought to be an important factor for persistence of populations against changing environments, and is recognized as a fundamental component of biodiversity (Newton *et al.,* 1999; Honjo *et al.,* 2004). Understanding patterns of genetic variation within threatened plant species is of fundamental importance to the development of conservation strategies, both for defining appropriate units for *in situ* conservation and for developing effective sample collection strategies for *ex situ* conservation (Holsinger and Gottlieb, 1991; Hogbin and Peakall, 1999; Zhang *et al.,* 2006). A number of polymerase chain reaction (PCR)-based DNA techniques have been used successfully to understand genetic structure and differentiation among various plant species across their natural populations (De Fillipis *et al.,* 1996; Culley and Wolfe, 2001; Heider *et al.,* 2007). A large number of studies have been undertaken to assess the extent of genetic variation in threatened species and their genetic diversity (Hamrick and Godt, 1989; Karp *et al.,* 1996; Young *et al.,* 1996; Zhang *et al.,* 2006), particularly with the realization of the need for genetic diversity in the future evolution of any species (New, 2000). The population genetics of many endangered plant species identified by local people remains unknown. Thus, an understanding of the extent and distribution of genetic variation within these populations are essential for devising future conservation strategies.

In recent years attempts have been made to differentiate between ecological and genetic conservation, respectively. While much interest has been focused on developing models for ecosystem and habitat conservation (Forey *et al.,* 1994), for defining various aspects of genetic conservation (Marshall and Brown, 1975; Yonezawa, 1985; Li *et al.,* 2002) and to gain scientific knowledge to contribute to research (Johnston and Soulsby, 2004), less progress has been made in checking the efficiency of conservation status evaluation and the risks for endangered species.

Nguyen Hoang Nghia (2007) defined conservation as the proper management and use of biological resources to obtain sustainable benefits for present and future generations, including maintaining ecological processes and other support systems of the living biosphere (water and soil resources), conserving genetic diversity among species and populations, and using natural resources sustainably. Presently, evaluation of conservation status and progress is basically dependent on secondary data or existing documents (Khanh *et al.,* 2002; On *et al.,* 2003), particularly in developing countries.

For those reasons, IUCN, WWF, many countries and other international organizations established cooperative action programs on biodiversity conservation. IUCN and other agencies agreed that evaluation of the conservation status of endangered plant species is an important element for biodiversity conservation to prevent genetic diversity and habitat loss and to help the local people who do not passively depend on the natural resources (Farrell, 2005; Farrier *et al.,* 2007; Joseph and Possingham, 2008). Many documents and guidebooks in conservation evaluation have been produced. The conservation of endangered forest plant species was mentioned at the conference on Biodiversity Conservation held in Hanoi in 2007, organized by the Ministry of Natural Resources and Environment of Vietnam (MNRE), supported by IUCN and WWF, with many international organizations and leading scientists participating (MRE, 2007).

This thesis relates specifically to forest plant conservation in Vietnam and in particular to the northern mountainous region (NMR) of the country. The following pages provide an overview of the situation in Vietnam.

Vietnam is located in south-east Asia with moist tropical conditions and diversified cultures. It has been endowed with an abundance and diversity of ecosystems, species and genetic resources which are generally regarded as highly diverse. According to Aubreville *et al.,* (1942) and Maurand (1943), the country has more than 7000 plant species in 1850 genera and 290 families. Of these, 64 genera and 2084 of the local plant species are endemic to Vietnam, which ensures that Vietnam has been ranked among the top twenty (16^{th}) mega-biodiversity countries in the world (Paine *et al.,* 1997). Recently, many scientists of Vietnam have found more species; Pham Hoang Ho (1993) found that there are 10,500 species in Pteridophyta, Gymnospermae and Angiospermae. The National Biodiversity Action Plan, approved by the government in 1995, estimates that there are about 12,000 plant species occuring in Vietnam (only 7000 of which have been formally named) (Chan *et al.,* 1999). These resources greatly contribute to the economic development and biodiversity of Vietnam and beyond.

In terms of economic value, all agricultural, forestry or marine products, which come from biodiversity resources are estimated to bring about 2 billion USD to Vietnam's revenue every year. In many places, especially in the mountainous regions, food and foodstuff sources, medicinal plants and essential sources of income rely largely on biodiversity exploitation. However, the national rapid population growth, the decreasing forest areas, over-exploitation or the over-introduction of new varieties in agricultural production, have lead to the reduction or loss of ecosystems, resulting in many species being in danger of local extinction; it has been estimated that the speed of biodiversity degradation is more rapid in Vietnam than in other countries of the region (Quy, 1997).

In Vietnam's Red Book (1996), 350 flora species were listed as endangered species; this increased to 380 species in 2004 (Thanh, 2006). The total of

threatened species is high for a single country, reflecting the seriousness of the threats to wild habitats in Vietnam caused by over-exploitation and shifting cultivation, as well as the encroachment of sedentary cultivation, environment change, habitat loss, and transition to the market economy (Quy, 1985; Quy, 1987; Huynh *et al.,* 1996; Sang and La, 1991; World Bank, 1995; Quy, 1997). Behind these direct or proximate causes of biodiversity loss are often underlying root causes fueled by social or economic factors at the protected area, provincial, national, and international scales. Intermediate and distant determinants of biodiversity loss, such as timber exports, international demand for endangered species, or planned migrations are rarely evaluated for their impact on a country's biodiversity (Mackinnon *et al.,* 1989; World Bank, 1995; WWF and IUCN, 1995; Kemp and Dilger, 1996; Quy, 1997).

Thus, currently, some species of forest plants and trees are at risk of becoming locally extinct. This urgent problem is mainly caused by using the resources inappropriately. Local indigenous residents' lives are mainly based on forest resources. Therefore, preservation and sustainable use of the resources are very necessary, both for biodiversity conservation and for preservation of the local peoples' lifestyles.

In the northern mountainous region (NMR) of Vietnam, there are many communities of ethnic minorities such as Tay, H'mong and Dao, as well as the ethinic majority Vietnamese (Kinh), living together. Their livelihood is built around a system of itinerant agriculture and the use of forest resources (Hung *et al.,* 2002; Dung *et al.,* 2003). They use a variety of plant and animal exploitation forms including clearing and burning the forest off for agriculture, hunting animals for food, harvesting plants for food, construction, medicines, trade and cultural and religious purposes (Raintree *et al.,* 1999; Chau *et al.,* 2003). Through many years, these forms of cultivation and use of resources have had a serious influence on the forest, in particular causing some plants and trees to become in danger of local extinction (Centre for Natural Resources and Environmental Studies 1997; Quy, 2007). Population growth among the ethnic

minorities ranges between 3.5% and 5% in some villages, so demand for forest resources is increasing.

Breakdown of the traditional land tenure systems and forest fragmentation make it difficult for the ethnic minority people to move from where they are settled now, as they would do in the past when resources became depleted. In addition, these people are living at a subsistence level; because agriculture often cannot meet all their needs, they have little alternative than to exploit forest products and in this activity, many practices are unsustainable. Many programs, which were implemented in combination with the establishment of cooperatives, were ineffective because of lack of analysis of the needs of the various ethnic groups and other social and economic factors (Zingerli *et al.,* 2002). In other words what the indigenous people do and what their future needs and practices are envisaged to be cannot be completely ignored.

1.2 Objectives and Scope of the Study

The principal objectives of the present study focus on the interactions between the local indigenous people, their environment and the need to conserve and sustainably use the forest resources of BBNP, Vietnam. There are several tasks that will assist in this broad objective. They are:

1. Investigating the plants and trees present in Ba Be National Park

Based on standard plots of 0.1 hectare, it is proposed to describe the species composition of the forest types and identify any strong associations between rare/endangered species and the more common species. Investigation of the most obvious environmental factors responsible for local species composition will be conducted, including measurement of soil characteristics (particle size, pH, organic content, nutrient levels) and other environmental variables (slope, canopy density/light intensity, disturbance etc). It is proposed to use multivariate analysis and correlation to identify the patterns in community composition and environmental relationships.

2. Identifying the cultural and social factors related to collection, processing, use and conservation of these kinds of plants and trees in the research area.

Investigation of indigenous peoples' use of resources will be undertaken to create an inventory of the communities' precious and scarce trees and other plants by direct interviews and questionnaires. Using this and other information it is proposed to set local priorities for conservation and research.

3. Ranking of species in danger of extinction and identifying priorities for special protection measures and/or future propagation.

Ranking will be based on the frequency with which a species is mentioned by local people in the contexts of usage and scarcity, as well as on international and national evaluations of conservation status. The data obtained in 1. and 2. will indicate the abundance of the endangered species in the area and their rate of exploitation.

4. Attempt to determine the most appropriate individual plants or plant populations from which to propagate for the maintenance of genetic diversity in the populations.

Two methods to measure genetic diversity will be used; randomly amplified polymorphic DNA- polymerase chain reaction (RAPD-PCR) and random amplified microsatellite polymorphisms-polymerase chain reaction (RAMP-PCR). Data will also explain amounts of heterozygosity in populations. A number of genetic diversity indices can be generated from the data. Initially, a limited number of species will be used, including at least one species classed as endangered/rare/threatened by IUCN and at least one perceived by the local people to be so.

1.3 The Principal Questions being Asked are:

(1) What are the known rare/endangered/threatened species in BBNP and where are they?

These questions mostly can be answered by consulting IUCN publications, the records of BBNP, some of the local people and experienced experts working in the Park.

(2) What are the plant species most used by the ethnic minority people?

(3) What species do they perceive to be endangered or threatened?

(4) What species do they believe to be most in need of cultivation and or propagation in the forest or villages?

These questions will be answered through the use of questionnaires.

(5) How do conservation priorities identified by surveys of the local people compare with national and international priorites?

(6) Do particular rare, endangered or threatened species have special environmental needs?

(7) Are there particular areas in the forest to which they could be transplanted for protection or grown for exploitation?

These questions will be answered by examining environmental relationships between species, including multivariate analysis and correlations to determine whether those species have strong associations with plant species that are more abundant and about which more is known.

(8) Are there particular plants or populations from which propagation material should be selected to maximise the genetic diversity, and sustainability, of propagated plants?

This question will be answered through an examination of the DNA characteristics of some of the most critical species from more than one population each. Work on other species will be conducted in Vietnam in future years.

1.4 Significance of the Study

1.4.1 Scientific significance

The study will:

1. Identify and evaluate the types of forest plants in Ba Be, and those in danger of becoming locally extinct and the factors threatening them;
2. Generate a database to aid future research and preservation of forest trees and plants in general;
3. Contribute to the understanding of the ecology of the forest types in Ba Be National Park.
4. Establish a method for identifying the 'best' populations or individuals from which to propagate for conservation.

1.4.2 Practical Significance

The study will:

1. Contribute to conservation of the forest plants in BBNP by identifying priorities for protection;
2. Identify species of plants that should be selected to be propagated in botanical gardens, seedling gardens and communities;
3. Create a database of the plants that are in danger of being extinct and, at least for a few, determine genetic diversity;
4. Assist in the development of a comprehensive plan for the sustainable use of the plants in BBNP including the endangered species.

1.4.3 Integration of information

There are basically two field/laboratory based studies and one study based on socioeconomic survey results. The integration of the three should enable recognition and documentation of the amount of biodiversity at risk in BBNP. There will be a more comprehensive description of species abundance and diversity in the park, and identification of some species that are locally rare and endangered. A few of these rare species will have more detailed genetic analysis and will contribute to an appreciation and better understanding of genetic diversity problems in their early stages. Finally the use of resources and wishes of the indigenous inhabitants of the area will be documented.

The wishes of the indigenous people may or may not be compatible with species conservation and diversity, especially of rare and endangered plants. This study could emerge as the first step in trying to change the customs and practices of native inhabitants so that they can change and adapt to new management systems. Conservation practices will be included in recommendations of this study, so that a fully integrated management plan for BBNP can be developed.

Chapter II

Literature Review

2.1 Forest Plant Conservation

2.1.1 Forest plant resources and endangered forest plant species in the world

(a) Introduction and Historical Background

Since time immemorial, people have gathered forest resources for their needs. These products were used for construction of shelter and housing, clothing or utensils, and plant or animal products for food, medicinal, cosmetic or cultural uses (Schippmann *et al.,* 2002). Thus, these forest resources have been closely associated with human social development.

In the context of this study, the term *forestry* will be used to include all of the above activities. In particular, it includes the gathering of non-timber forest products.

The ancient Neaderthal in Iraq used some wild plants for medicinal purposes from 60,000 years ago; some are still used in modern medicine such as *Anaphalis nubigena*, and *Senecio vulgaris* (On, 2003; Mastrantoni *et al.,* 2005). Mexican aboriginal people thousands of years ago used a species of *Euphorbia* that today is known for containing hallucinogens and antibacterial substances (Tim *et al.,* 1994). Reference materials and documents have recorded the use of forest plants. Ancient Egyptians used many plant species like *Aloe ferfoliata, Myrmecodia tuberose* and *Triumfetta lappula* 3,600 years ago (Maurand, 1943; On, 2003). The ancient Chinese listed many species for medicine and food in the Book of the Flora of Emperor Shen Nong 5,000 years ago (Flora Hainanica, 1974; Flora Yunnanica, 1977; On, 2003). In Vietnam, many books recorded

medicinal species in the book of Nam Duoc Than Hieu in the twelfth century and Hong Nghia Giac Tu Y Thu in the fourteenth century (Khanh, 2002).

Using wild plants for subsistence has involved a process of trial and error and learning from experiences over generations. From practical demands of development, humans domesticated and conserved wild plants for easy use and their sustainable development. In ancient Persia (now Iran), forest protection and nature conservation laws were in effect as early as 1,700 B.C. Two thousand years ago the Chinese practiced what they called "four sides"; forest plants were planted on hill sides, village sides, road sides, and water sides. More than 1,000 years ago, Javanese maharajahs brought in teak and began to cultivate it. In the African tropics, agro-forestry (growing of food crops in association with forest trees) has been practiced for hundreds of years. In the Yucatan Peninsula of southern Mexico, the Mayas cultivated fruit and nut trees along with such staples as corn, beans and squash. Bark, fibers and resin were obtained from plants grown in fields, kitchen gardens, and orchards. Early in their civilization, the Mayas practiced slash and burn agriculture and dug drainage channels and canals to move water to and from cultivated areas, and filled in swampland to plant crops. The agricultural skills of the Mayas enabled their society to grow and flourish. Causes of their decline in about A.D. 820 are not fully known, but some believe that the Mayas made unsustainable demands on their environment.

Relatively little is known about tropical forestry before the mid 1800's when European colonial empires brought modern forest management practices to Indonesia, India, Africa, and the Caribbean. Centres for forestry and forestry research were established, and more careful records were kept. Tran Van On (2003) reported that there are 12 centers of biodiversity in the world: China-Japan, Indochina-Indonesia, Australia, India, Central Asia, Far East, Mediterrranean, Africa, Europe-Siberia, North Mexico, South America, and North America. Many wild plant species were reclaimed and cultivated in these centers. For instance: *Papaver somniferum, Panax quinquefolium, Caryophyllus aromaticus, Myristica fragrans, Cinnamomum zeylanicum, Mentha spicata, Salvia officinalis* or *Cinchona officinalis* (Ly, 1993; On, 2003).

In Vietnam, many wild species have been domesticated and cultivated in local gardens. Thousand years ago Vietnamese people domesticated upland rice for their subsistence and presently this species has become one of the major crops of humankind (Dap, 1999). Many native species were used for various purposes such as vegetables, fruit, medicinal or cultural purposes. Ethnic minority people in the north of Vietnam (e.g. Bac Kan, Thai Nguyen and Son La provinces) have used forest plants for thousands of years (MacKinnon, 1990; Van *et al.,* 1993). In ancient societies, humans participated in a form of conservation through their experience of using natural resources (Quy, 1999; On, 2003).

Biological conservation began to arise as a concern by the 1960s and one response to the problem of habitat destruction was to create nature reserve networks throughout the world, though some reserves had been created much earlier.

In the United States in the 1970s, ecologists tried to manage reserves by treating them as islands in oceans of anthropogenically transformed habitat (May, 1975; Diamond and May, 1976). The theory of island biogeography came under increasing critical experimental scrutiny (Simberloff, 1976). Nevertheless, its principles were adopted for reserve network design by some international conservation agencies without any assessment of whether its empirical basis was sound.

The use of island biogeography theory in reserve network design was criticized by Margules *et al.,* (1982), who pointed out that the model had not been empirically established and that there were important differences between biological reserves and islands. In particular, areas between reserves were not as inhospitable to species in the reserves as oceans were to insular species. Several researchers, mainly in Australia, pioneered a different approach to biological conservation, which partly reflected the fact that modern methods of extensive habitat conversion had begun only relatively recently in Australia compared to Asia, Europe, and North America (Margules, 1989). It reflected the practical

background of Australian conservation in the management biological resources (rather than just academic research).

Conservation biology emerged as a distinct professional enterprise with its own practices, culture and social institutions in the 1980s (Redford and Richter, 1999; Biggs and Matsaert, 1999). In the late 1990s a consensus framework was formulated for the design and adaptive management of conservation area networks. The framework included an analysis of issues concerning four theoretical problems that emerged:

(i) developing prioritization for conservation action;
(ii) the selection of surrogates for biodiversity in conservation planning;
(iii) the assessement of vulnerability of conservation areas; and
(iv) the synchronization of incommensurable criteria including socio-economic constraints on conservation planning.

(b) Status of evaluation of endangered plant species in the world

(1) Causes of biodiversity loss and the risk of extinction

The primary factors contributing to extinction are directly or indirectly related to human impacts (Frankham *et al.,* 2000). Habitat loss and degradation, invasive species, global warming, pollution, pesticides, human population growth, agriculture, logging and fire suppression, mining and drilling, poaching, and urbanization are the main causes of biodiversity loss and of species becoming endangered (Nghia, 2002; Gurevitch and Padilla, 2004).

In Vietnam and other developing countries, biodiversity is also threatened by rapid population growth and perceived compelling requirements of people; this threat is particularly pronounced in the tropics. Biodiversity is affected by a large number of processes and factors, such as deforestation which can be driven by human activities, agricultural encroachment, fuel wood harvesting, medicinal collection, illegal logging, housing and others (Mackinnon *et al.*, 1989). Behind these direct causes of biodiversity loss are often underlying root causes fuelled

by social or economic factors at the protected area, provincial, national and international scales (Rosser and Mainka, 2002, McKee *et al.,* 2003). Intermediate and distant determinants of biodiversity loss, such as timber exporting, international demand for endangered species, or migrations are often not considered as factors contributing to the problem (Yen and Sung, 1995; World Bank, 1995).

Originally, the forest land areas in Viet Nam occupied three-quarters of the total land area (Ministry of Forestry, 1991; General statistic Office, 2005), but over the past few decades the forest of Viet Nam has suffered serious depletion (Ly, 1993; Nghia, 2000). Apart from habitat loss, many species are endangered or have been lost as a result of massive over use. Precious medicinal plants and rare timber collection, and over exploitation and collecting for the wildlife trade have had a significant impact. Many species are confined to small geographical ranges and occur at low individual densities, which render them highly vulnerable as the forests are cut into smaller patches and eventually completely cleared (Quy, 1985; Spitzer *et al.*, 1993; World Bank, 1995). Until now, most studies on the protected areas of Vietnam, including the most important works, provided little speculation about underlying root causes of biodiversity loss (Mackinnon *et al.,* 1989; Quy, 2007).

(2) Viewpoint and approach in endangered species conservation

The management of endangered plants is species specific and conservation strategies need to consider anthropogenic effects on natural, ecological and evolutionary processes. To optimize conservation efforts it would be ideal to have information regarding life history variation, dispersal in heterogenous environments and the local extinction and colonisation rates (Lande, 1992). Swenson *et al.,* (1995) stated that proper assessments of diversity should be based on more than one method and should take into account the level of variation likely to be encountered in the populations under study. By measuring influencing factors, vegetation-environmental patterns and genetic diversity in species, short and long term viability can be estimated, since together the

methods evaluate the capacity of the plants to deal with environmental changes in the short term and the genetic variations that are available for future adaptations. Sound conservation policies should be based on an understanding of the biology of the species and the factors that cause their decline.

Since its adoption in 1992, the Convention on Biological Diversity (CBD) has strived to implement its three major goals: the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of the benefits from the use of genetic resources (Schippmann *et al.*, 2002). Although endangered plant species have not been explicitly on the agenda of the various CBD meetings, all three goals of the convention are fully applicable to endangered plant species resources. CBD also adopted the ecosystem approach as the primary framework for action under the convention. It is a strategy for the integrated management of habitats that promotes conservation and sustainable use in an equitable way. The ecosystem approach is based on the application of appropriate scientific methodologies focused on levels of biological organization which encompass the essential processes, functions and interactions among organisms and their environment.

In April 2002, the Convention on Biological Diversity adopted the Global Strategy for Plant Conservation, including 14 global targets for 2010. The ultimate and long term objective of the strategy is to halt the current and continuing loss of plant diversity. Policy relevant to the conservation challenges that arise from the increasing global demand for wild harvest and cultivation of endangered plant species has been scattered among many different areas: forestry, health, agriculture, indigenous knowledge, access and benefit sharing, and sustainable livelihoods. The Global Strategy for Plant Conservation provides a policy environment that is suited to addressing these challenges for endangered plant species.

Targets for the year 2010 include:

(1) *Understanding and Documenting Plant Diversity*, including a widely accessible working list of known plant species, as a step towards a complete

world flora, an assessment of the conservation status of all known species, and an understanding of basic conservation needs for threatened plant species, with conservation protocols developed for 50% of such species.

(2) *Conserving Plant Diversity*: 10% of each of the world's ecological regions and 50% of the world's threatened species effectively conserved *in situ*, 90% of threatened plant species in accessible *ex situ* collections and 20% of them included in recovery programs; 30% of production lands managed consistent with the conservation of plant diversity; 70% of the genetic diversity of crops and other major socio-economically valuable plant species conserved, and threats to plant diversity from invasive alien species tackled.

(3) *Using Plant Diversity Sustainably*: no species of wild flora subject to unsustainable exploitation because of international trade; 30% of plant based products derived from sources that are sustainably managed, and the decline of plant resources that support sustainable livelihoods, local food security and health care reversed.

(4) *Promoting Education and Awareness about Plant Diversity*: every child aware of the importance of plant diversity and the need for its conservation.

(5) *Building Capacity for the Conservation of Plant Diversity*: the number of trained people working with adequate facilities in plant conservation and related activities doubled, and networks for plant conservation activities established or strengthened at international, regional, and national levels.

(3) Some activities for endangered species conservation

Many activities for endangered species conservation have been commenced. National legislation and international agreements for the conservation of particular species, for the protection of sites or habitats, and for the regulation of activities that can pose threats to biodiversity have been established (IUCN, 2004). Internationally, The Convention on International Trade in Endangered Species of Wild Fauna and Flora in 1975 regulated international trade of the species listed. The Convention on Biological Diversity in 1992 encouraged parties to take a wide range of actions for biodiversity conservation and sustainable use. The European Union Habitats Directive 1992 (Ministry of

Science, Technology and Environment, 1992) stated that the natural habitats listed must be maintained at a favourable status, particularly through the creation of a network of protected sites. The World Heritage Convention 1972 (Ministry of Science, Technology and Environment, 1992) provides for identification, protection and preservation of cultural and natural heritage (including habitat of threatened species) around the world considered to be of outstanding value to humanity; countries submit places for designation under the world heritage list.

On a national scale, the US was one of the first countries to pioneer research into endangered species conservation; the United States Endangered Species Act. (1973) states that the species listed are protected from exploitation and disturbance, and their habitats are subject to legal protection. However, the Brazil Forestry Law (1965) places more attention on the sites and habitats of endangered species; this law establishes that each rural property in the Amazon basin must preserve at least 80% of its forest cover. In the Asia-Pacific area, Thailand's National Park Act. (1960) established a legal basis for creation of conservation areas or protected areas, including national parks (144 sites), wildlife sanctuaries (53 sites) and forest parks (42 sites), while Australia concentrated on strict control measures aimed at preventing the introduction of pests and diseases (mainly established to protect the agriculture sector, but also human health and the native flora and fauna) by the Australian Quarantine Act (1908). The Endangered Species Act and activities established a legal mandate to promote the collection, analysis, and exchange of biological information. It requires that for each endangered and threatened species occurring in the world, a recovery plan be developed which delineates, justifies, and schedules the research and management actions necessary to support the recovery of a species (Schemske *et al.,* 1994; IUCN, 2004).

In-situ conservation is one effective way for endangered plant species conservation. *In-situ* conservation is widely applied to the conservation of biodiversity, especially of endangered plant species. Conservation that maintains recovering populations in surroundings where they have developed their distinctive properties helps ensure the ongoing processes of evolution and

adaptation within their environments (Tewksbury *et al.,* 1999; Heywood and Dullo, 2005). Wildlife and livestock conservation is mostly based on *in-situ* conservation. This involves the protection of wildlife habitats. Also, sufficiently large reserves are maintained to enable the target species to exist in large numbers. The population size must be sufficient to enable the necessary genetic diversity to survive within the population, so that it has a good chance of continuing to adapt and evolve over time (Rhodes *et al.,* 1994; Cardoso *et al.,* 1998; Knaepkens *et al.,* 2004). This reserve size can be calculated for target species by examining the population density in naturally occurring situations (Javis *et al.,* 2000).

As of 1993 nearly 7,000 parks and protected areas covering in excess of 650 million acres had been established worldwide (WRI, 1992). When combined with smaller areas such as national parks and nature reserves, a large portion of the planet's land surface is receiving some degree of protection. All eight Natural Realms and 14 Biomes, as categorized by Udvardy (1975), are present in reserves. In the United States, for instance, the national park system, the national forest service's wilderness areas, various state parks, and private reserves protect forest ecosystems, which in turn protect portions of the genetic resources of the contained species (Holland and Jain, 1981; Schemske *et al.,* 1994). Similar areas have been preserved in many other countries. Most are in the temperate zone, but a growing number of natural areas are being set aside in the tropics.

Many activities affecting *in situ* conservation of forest genetic resources have been initiated by international agencies from the 1980s (FAO, IUCN, UNESCO) and these agencies have also carried out studies aimed at outlining a methodology for *in situ* conservation and drawing up tentative guidelines for action. Project plans exist for gene conservation in three countries: Cameroon, Malaysia (FAO, 1985) and Peru (FAO, 1987). The plans summarize the current status, problems and opportunities for *in situ* conservation of 20 important forest species in each country.

Ex-situ conservation is the process of protecting an endangered species of plant or animal by removing part of the population from a threatened habitat and placing it in a new location, which may be a wild area or within the care of humans (Yonezawa, 1985; Hawkes, 1987; Hamilton, 1994).

Ex-situ conservation activities have been directed to endangered species conservation. Efforts at forest *ex situ* conservation range from small stands for seed collection, to stands for establishing breeding populations, to international provenance testing programs (Brown and Biggs, 1991; Maunder, 1994; Ma *et al.,* 1996; Li *et al.,* 2001; Farnsworth *et al.,* 2006). Currently, seed stands have been established for some 130 species, breeding stands have been established for some 40 species (excluding species of *Eucalyptus* and *Acacia*) (Chen and De Filippis, 2001; Hai *et al.,* 2007). *Ex-situ* conservation efforts are concentrated on economically valuable, fast growing plantation species. There is little deliberate *ex situ* conservation of non commercial species. In the United States, about 6,000 ha of established seed orchards and clone banks provide extensive *ex situ* conservation of some of the most valuable domestic species (U.S Forest Service, 1982) (Schemske *et al.,* 1994). The *ex situ* conservation programs in tropical countries are for the most part smaller and more recent than those in temperate countries. An FAO and UNEP project for conservation of genetic resources of selected forest tree species and provenance, begun in 1975, established about 40 *ex situ* conservation and selection stands (about 10 ha each in six tropical Asian and African countries) using 11 provenances of four species: *Eucalyptus camaldulensis, E. tereticornis, Pinus oocarpa* and *P. caribaea.* Many tropical countries are now establishing provenance trials for fast-growing plantation species and a large proportion of those plantings will probably evolve into seedling and seed orchards or provenance conservation stands. In this way, the extent of *ex situ* conservation will be expanded.

2.2 Molecular Biology and Nature Conservation

2.2.1 Genetic diversity

Genetic diversity represents the heritable (able to be passed on to offspring) variation that exists between individuals within populations, between populations within species and between species. This is the raw material upon which natural selection acts (Burgman and Lindenmayer, 1998). Such diversity is stored in the DNA of an organism, and - where other influences are absent - is maintained through the major evolutionary processes of mutation, selection, random genetic drift, migration and mating (New, 2000)

Studies have found that a loss of genetic diversity decreases the ability of wild populations to survive climatic extremes, pollutants, pests, and diseases (Frankham, 1995). Genetic diversity is therefore considered crucial for the long-term survival of a species since it enables populations to adapt to new environmental conditions while contributing to the reproductive effectiveness of individuals and the viability of their offspring (Burgman and Lindenmayer, 1998). According to Hopper and Coates (1990), the maintenance of genetic diversity and heterozygosity in natural populations may provide the best general strategy for ensuring the persistence of most organisms.

a) Factors reducing genetic diversity.

The amount of genetic diversity present in any species may be reduced by chance. Natural catastrophes (such as floods and droughts) may wipe out entire populations, or may reduce the size of populations, removing from the gene pool the part of the variation stored in those individuals that are killed. Diversity in any remaining populations may then be further reduced through genetic, demographic or environmental stochasticity (Knaepkens *et al.,* 2004; Savolainen and Pyhajarvi, 2007).

Of more concern today, however, are the impacts of humans. Activities such as habitat destruction, introduction of exotic species, pollution and overexploitation

– the primary factors contributing to extinction (Frankham, 1995) – tend to reduce species to small and fragmented populations, as has been the case with endangered forest plant species in Ba Be National Park (Dinh, 2003). These smaller populations are much more susceptible to stochastic (chance) effects that include inbreeding, loss of genetic variation, inbreeding depression, and the accumulation of deleterious alleles (Lande, 1994; Frankham, 1995; Lynch *et al.*, 1995; Bucci *et al.,* 1997).

In plant populations, fragmentation may limit gene flow by preventing the exchange of pollen between distant individuals (Groom, 2001) and by limiting the dispersal of seeds. This may occur simply as a result of the distance between fragments (especially in the case of wind-pollinated plants and wind-dispersed seeds), or may be due to altered behaviour patterns in pollinating and dispersal agents (Inceoglu et al., 2000; Perveen and Qaiser, 2003; Wu et al., 2005). Phung, (1999), for example, found that fragmentation altered the behaviour of pollinating animal species feeding on *Melientha suavious* and *Erythropalum scandens* flowers. These animals showed more intra-plant movements, and less inter-plant movements, when plant populations were small – a factor that could well lead to increased inbreeding in the smaller populations.

b) Inbreeding and extinction risks.

Inbreeding is a term referring to the mating of closely related plants or animals (Dudash and Fenster, 2000). In plants that are self-compatible, the process may also occur as a result of self-pollination. Inbreeding tends to produce homozygosity at gene loci – where individuals may once have been heterozygous for certain genes (having alternative alleles inherited from both parents), their offspring have a greater chance of being homozygous (having identical alleles) for those same genes. This reduces the level of genetic variation in the offspring and can lead to the expression of deleterious alleles (Falconer and Mackay, 1996).

Inbreeding, in turn, may lead to inbreeding depression in which the viability of

offspring is reduced. This may be manifested in reduced germination rates, reduced survival rates of germinated seedlings, reduced longevity and reduced fecundity in the offspring (Dudash and Fenster, 2000). Since inbreeding depresses components of reproductive fitness, it may also increase a species' risk of extinction (Frankham, 1995). This is a particular problem in small populations where inbreeding is more likely to cause the fixation of mildly deleterious mutations (Lande, 1994).

Though Caro and Laurenson (1994) have claimed that there is no evidence that populations in the wild suffer from inbreeding depression, a number of studies have revealed inbreeding depression in natural populations of plants (Dudash, 1990; Fenster, 1991; Johnston, 1992). Some authors are also of the opinion that catastrophes and demographic or environmental stochasticity are more important causes of extinction than inbreeding (Fenster, 1991; Johnston, 1992; Agren and Schemske, 1993; Hauser and Loeschcke, 1994). Frankham (1995), however, believes that extinctions may be incorrectly attributed to 'non-genetic' factors alone when it is the interaction between genetic and 'non-genetic' factors that is important.

c) Why measure genetic diversity?

Measuring and mapping genetic variation within a species is an essential requirement to ensure that conserved populations provide a representative sample of the existing genetic variation (Hopper and Coates, 1990). It would be incorrect to simply assume that geographically close individuals or populations will have genetic similarity, or to assume that the greatest variation lies within the largest populations. Various studies have found correlations between genetic distance and geographical distance to differ with species, with some showing more variation within populations and others showing more variation between populations (Hopper and Coates, 1990). Other studies have found that large populations show no more genetic diversity than smaller populations of the same species (Llorens *et al*, 1999; Fleishman *et al*, 2001).

To ensure that the maximum possible genetic diversity is maintained, the variation extant in endangered species should ideally be analysed on an individual basis. Unfortunately, as noted by New (2000), saving species is expensive. The funds available for conserving a given species are often limited and genetic considerations may therefore be placed low on the priority lists of recovery plans. In light of this situation, it would be useful to have a method of analysing genetic diversity that is informative, inexpensive and demanding of little in the way of equipment and expertise.

2.2.2 Methods of Measuring Genetic Diversity

Genetic differences between plant species can be measured by a number of methods. In general, these may be broken into three major categories: morphological, biochemical and molecular methods. Morphological methods have been the traditional approach (Karp *et al.*, 1996) and may include the measurement of gross characteristics such as height, width, leaf length, petiole length, etc., or microscopic characteristics such as size and number of leaf hairs or stomates. Where consistent morphometric differences are seen between populations, a genetic basis to the patterns may be inferred (Hopper and Coates, 1990). Morphological (or phenotypic) attributes, however, are influenced by the environment as well as the species' genotype (Raven *et al.*, 1992). This makes it difficult to determine how much of any observed morphological variation may be attributed to underlying genetic variation.

Where a species is morphologically uniform, hidden variation in the genome may be revealed by other methods such as a study of chromosome number and structure, variation in secondary compounds such as flavonoids and terpenoids, or variation in specific enzymes (Hopper and Coates, 1990; Karp *et al.*, 1996). Though these methods are useful, they provide only a small sample of an organism's genetic make-up. A lack of variation in secondary compounds or enzymes does not necessarily mean that genetic variation is absent in the species (Hopper and Coates, 1990).

A more direct way of measuring genetic diversity is the use of molecular analyses. Such techniques have the potential to reveal an immense number of characters, though they may also vary in the way they resolve genetic differences, in the type of data they generate, and in the taxonomic levels at which they are best applied (Karp *et al.*, 1996). The method chosen for a given study also depends on the amount of tissue available to work with, the degree of expertise required, and the availability of funds. In some cases, researchers have chosen to apply two or more methods to the same problem (e.g. Wong and Sun, 1999; Cabrita *et al.*, 2001).

The molecular methods currently available for use may be roughly divided into two categories – those based on enzyme digestion and blotting, and those based on the polymerase chain reaction (PCR).

2.2.3 General conservation status of endangered forest plant species in Vietnam

(a) Biodiversity conservation and endangered forest tree species status in Vietnam

Vietnam is sixteenth in the world ranking of the mega-biodiversity countries because of the rich abundance of plant species (Paine, 1997; Ho, 1999; Chan *et al.*, 1999; Khanh, 2002). The diversity of the Vietnam flora may result from many causes. The country is situated in a monsoon tropic climatic area, is very sunny, rainy and humid. These features are complicated by factors such as relief, the maximum altitude being 3,143 m above the sea (Fansipan Peak). The Vietnam flora also has specific traits representative of near tropical and temperate climatic areas.

In respect of geographical structure, Vietnam lies in the Indoxiniam bloc of the Earth, which has been stable for hundreds of millions of years (Chan *et al.*, 1999; Canh *et al.*, 2001), and not covered by glaciers. The Vietnam flora has many species recognised as endemic. Simultaneously, Vietnam is on the border of three exchange 'currents' of vegetation. One current is from the South, called the

Malaysian-Indonesian factor with Dipterocarpaceae as diagnostic, with Borneo as the genetic center. The second current, from the West and South-West, is named the Indian-Burmese factor consisting of species characteristic of droughty-arid climate areas. Thirdly, a current from the North-West, includes chiefly species of temperate latitudes of South China.

In Vietnam, since early years to the twentieth century, many studies on the classification of Vietnam flora have been produced by French authors; Lecomte (1907-1951) recorded and made a statistic table of 7,004 species of higher vascular plants in Indochina (Vietnam, Laos and Cambodia); of course this number is still far from the present species in all three nations. However, the Indochina general flora book remains a precious document source among the study works on Vietnam flora in particular and Indochina in general. With quotations from the Indochina general flora in 1965, Pocs made lists of the northern Vietnam flora with 5,190 species (including species between 12^0 and 17^0 North latitude and 155 species imported. Another French author (Aubreville) studied in Vietnam, Laos, and Cambodia from 1942 to 1969 (Trung, 1970; Thin, 1995). In Vietnam, initial documents on the north of Vietnam recorded 5,609 species of 1,660 genera and 240 families arranged in accordance with the English system from 1954 to 1964 (Loc, 1970). Pham Hoang Ho (1993) reported in the book of Vietnam Flora 10,500 species of vascular plants. However, the number of studies on identification of Vietnam plants is considerably larger; many authors mainly listed species by collection statistics as secondary data, whereas the number of studies on particular areas by local people identifying species and their priority for conservation are still small.

The Vietnam Red Book of Threatened Species is the most comprehensive resource detailing the national conservation status of plants and animals. The first edition for fauna species was published in 1992 but for flora species was initially published in 1996. Its criteria were generally based on the categories of IUCN but separated into different levels of extinction risks. Moreover, the Red Book assessment process itself has developed substantially over the past decade, extending the value of the Red Book for the assignation of threat status. The Red

Book, in conjunction with the comprehensive data compiled to support it and in spite of several important limitations, has become an increasingly useful tool for conservation planning, management, monitoring and decision making. From 1992, the natural resources status in general and biodiversity in particular in Vietnam have changed dramatically and the Red Book needed to be informatively revised (Thanh, 2006). From that point of view, the Red Book of Vietnam was updated in 2004; in this version it was revealed that after about ten years the total of fauna and flora species endangered at different levels had increased to 853 species (including 407 fauna species and 450 flora species). More importantly, endangered levels in each natural population have changed from time to time. There were six fauna species recorded as Critically Endangered in the 1992 Red Book but they were extinct in their natural range in the Red Book in 2004. Presently, 194 fauna species are listed as endangered species (46 critically) compared with 71 species in 1992. Among the flora, the Red Book in 1996 recorded some species as Vulnerable that were upgraded as Critically Endangered or Endangered in 2004. There were only 24 flora species recorded as endangered species in the 1996 Red Book; that was increased to 192 species in 2004 (including 45 species recorded as Critically Endangered). Most of them belonged to Magnoliophyta and Pinophyta.

(b) Regulations and strategies on biological diversity in Vietnam

The Vietnamese Government was aware early of the important role of biodiversity and endangered forest plant species conservation. Numerous regulations were established such as the Forest Protection Decree in 1972, the Natural Conservation Strategy in 1985, the national planning of environment and sustainable development period 1991-2000. The decree no. 48/2002/ND-CP established rare and endangered species conservation efforts.

The Convention on Biological Diversity (CBD) (held in Hanoi, Vietnam in 2007) attached great importance on the need to protect biology from unsustainable trade. The CBD and CITES share the goal of achieving, by 2010 a substantial reduction in the current loss of biodiversity. The conventions address

some important areas of cooperation on energy, sustainable use, economic and incentive measures, international trade and illegal use.

Demand for a wide variety of wild species is increasing with growth in human needs, numbers and commercial trade. With the increased realization that some wild species are being over-exploited, a number of agencies have reported that many wild species face the risk of extinction worldwide (Lambeck, 1997; IUCN and WWF, 2006). The opportunities for governments to develop legislation to control and monitor the trade of endangered species and consider conservation and sustainable use of forest resources as a priority in establishing protected areas have been greatly enhanced. After the International Conference on Environment and Development in Rio de Janeiro (1992), the Vietnamese Government approved the biodiversity convention in 1994 and established The national Biodiversity Action Plan in 1995 (GOV., 1995). Meanwhile, endangered forest tree species were recognized as the principal focus for an urgent active plan for biodiversity conservation in Vietnam.

In 1997, the Ministry of Science and Environment promulgated a regulation for management and conservation of floral genetic resources including:

(i) investigation, survey and collection of genetic resources,
(ii) long-term conservation and safety of genetic resources collected,
(iii) genetic evaluation by biological criteria,
(iv) documentation of genetic resources and
(v) exchange of information and genetic resources.

(c) Biological diversity conservation activities in Vietnam

In situ conservation has been implemented in Vietnam from the 1960s. Cuc Phuong was Vietnam's first established national park in 1962, and since Cuc Phuong, ten more national parks have been created (Ratajszczak *et al.,* 1990). In addition to national parks, there are 27 cultural, historical and environmental reserves, 55 natural reserves and 18 landscape reserves established, with a total area of 2.97 million ha, occupying about 9% of the total national area (Sung,

1995; World Bank, 1995) Many of these reserves were created by the state in two administrative orders in 1977 and 1986 (Sung, 1995).

The main functions of national parks initially were to protect intact ecological systems. Conservation of rare and endangered species currently lacks priority in terms of detailed tasks, such as inventoring and monitoring (On, 2003).

The implementation of the national Biodiversity Action Plan has included many projects in plant species conservation but mainly for medicinal and commercial plants.

In comparision with *in situ* conservation, *ex situ* conservation has commenced more recently. A project for medicinal and oil plant *ex-situ* conservation was implemented in 1988 and continues with participation of 14 institutions in the country (Ban *et al.,* 2001). There is an established framework of medicinal plant conservation in 11 scientific institutions, with 250 species conserved, evaluated and exchanged; these have supplied material for research and production. The project proposed 500 medicinal plants should be prioritied for conservation in the period 2006-2010 (Khanh *et al.,* 2005).

Twelve rare and endangered medicinal plants faced with high risk of extinction at different levels have been researched and cultivated; these include *Acanthopanax trifoliatus, Asarum caudigerum, Berberis julianae, Fibraurea tinctoria, Panax bipinnatifidus, Panax stipuleanatus, Polygonatum kingianum, Rauvolfia verticillata* and *Tretrapanax papyriferus*. All these species were recognized for *ex situ* conservation (Chau and Tap, 1996; Tap, 1996). In 2005, the Ministry of Agriculture and Rural Development (MARD) promulgated a catalogue of rare and endangered crops needing conservation (MARD, 2005).

In terms of genetic diversity studies, the work conducted in Vietnam so far has been limited (Nong *et al.,* 1995; Hoang, 2002).

2.3 The Study Area

2.3.1 General description

a) Location

Ba Be National Park is located in Ba Be district, Bac Kan province, northern mountainous area of Vietnam, co-ordinates 22°24'N by 105°37'E (Figure 2.1). The Park, in the area of the Nam Mau commune, is encompassed by the Cao Thuong commune in the North, Khang Ninh and Cao Tri communes to the East, Quang Khe to the South and in the West it is bounded by the Nam Cuong and Xuan Lac communes of Cho Don district, Bac Kan Province, and the Da Vi commune of Na Hang district, Tuyen Quang Province. Most of the area was declared a national park in French colonial times (Kemp *et al.,* 1994; Quac *et al.,* 1999) and forms an important link with other adjoining reserves such as Na Hang Natural Reserve of Tuyen Quang province.

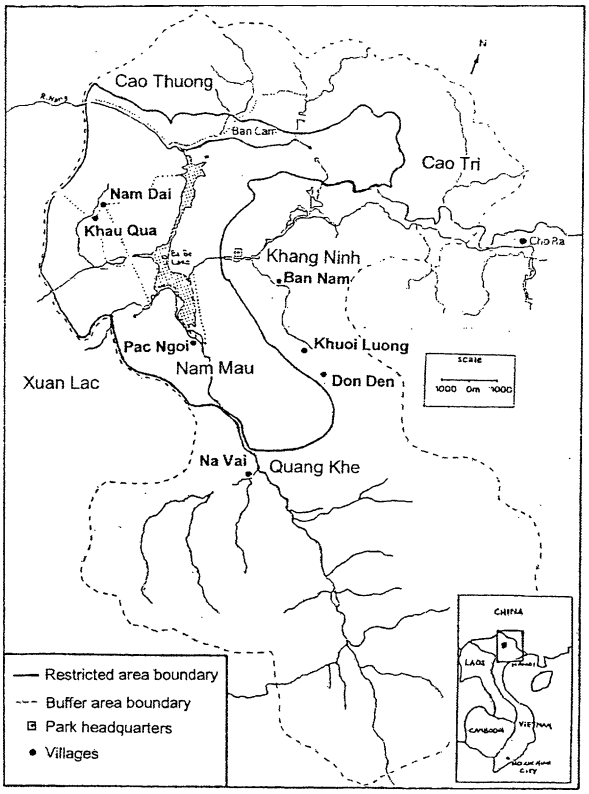


Figure 2.1: Map showing the geographic position of Ba Be National Park, Ba Be District, Bac Kan Province, Vietnam.

The Park is 254km north from Hanoi, and 18km South-West of the town of Cho Ra. The National Park (BBNP) includes a natural area, fresh water lake and a system of rivers and streams (Kamp *et al.,* 1994; Hill *et al.,* 1997; Scott, 1989). The park is centered on Ba Be Lake which is the largest natural Lake in Viet Nam, and was recognized as one of 20 special freshwater lakes worldwide in need of protection at the Conference on World Freshwater Lakes held in America in 1995 (Dinh, 2003). Many valuable plants and animals that have been recorded in the Red Book of Vietnam and the Red List of important species (IUCN) occur there (Hill *et al.,* 1997; Chan *et al.,* 2003). A Nature Reserve since 1977, Ba Be National Park (BBNP) became Vietnam's eighth National Park in 1992, comprising 7,610 ha of limestone mountains, rivers and lakes. The majority of the protected area is steep and forested. On the steep slopes, soil tends to be shallow, and non-existent on the steepest slopes. The only flat land (less than 10% of the Park) lines the rivers and flood plains around the Lake, providing farmland for the ethnic minority people who settled inside the park in the 1970s. Weekly markets with local products – many gathered from the forests - are important features of village lifestyle.

Geology and soil have a great influence on the fauna and flora of the National Park. There are two main forest types: tropical moist evergreen forests and tropical evergreen limestone forests. Hill *et al.,* (1997) identified a total of 603 species of vascular plants in 137 families, not counting fungi, algae, mosses and ferns which largely have yet to be investigated. Presently, the known flora comprises 162 families, 672 genera with about 1,281 species (BBNP, 2005). Subtropical species dominate, such as palms (foxtail palm, *Cayota sp.),* ginger (Zingiberaceae family), and various species of lianas, trees and bamboo (Trai *et al.,* 2004). The rare "string" bamboo (*Ampelocalamus* sp/*Sinocalamus mucclure* sp.) is only found in BBNP. Some plant species there are identified as Globally Critical Endangered Species by IUCN. They include Emerson slipper orchids *(Raphiopedilum emersonii)* (BBNP, 2005; Do, 2001; Chan *et al.,* 2003), among others.

Of the total area of the National Park 3,226ha make up a strictly protected zone, and 4,083ha the tourist subzone (Cao Van Sung, 1995); the lake surface accounts for 500ha of the park's area (MARD, 2001).

The Park falls within the biogeographical subunit 6a (South China) of the biogeographical classification of the Indo-Malayan realm developed by MacKinnon and Mackinnon (1986).

b) History and status

Ba Be was recognized as a cultural-historical and environmental reserve, to protect its landscape and historical relics, in 1977. In 1992, it was established as a National Park (Cao Van Sung, 1995). A management plan for the National Park was produced in 1991 (Government of SRV, 1994).

Vietnam's Tropical Forest Action Plan (MacKinnon, 1990) proposed that the National Park be extended from its current 7,611ha to around 44,000ha. The Biodiversity Action Plan for Vietnam (Government of SRV, 1994) has proposed that the management of the Ba Be National Park and the Na Hang Nature Reserve, 30km away in Tuyen Quang province, be integrated. This plan has to be implemented by many projects such as the PARC (Creating Protected Areas for Resource Conservation using Landscape Ecology) project.

Ba Be National Park staff have been preparing scientific dossiers to be submitted to UNESCO seeking world natural heritage status for the Park. According to the National Heritage Council (BBNP, 2005), Ba Be National Park is one of the 19 tangible and intangible heritage units that Vietnam will ask UNESCO to recognise as world heritage. In late 2004, the Park was recognized as an ASEAN heritage park.

2.3.2 Detailed description of study area

a) Topography

Ba Be lake is 170m above sea level, and is surrounded by limestone peaks which slope steeply, reaching 893m asl (Scott, 1989). Further from the lake, there are higher peaks up to 1,520m asl (SCEMMA, 1992) The lake contains numerous small islands, with a combined surface area of 1.4ha (Dinh, 2003). The only flat land occurs beside the River Nang and in some places beside the lake (less than 10% of Park area) and has been converted to agricultural land uses (Kemp *et al.,* 1994), mainly rice paddies. The topography and geological features of Ba Be National Park are shown in Figure 2.1

b) Climate

BBNP is located in the sub-climatic zone of North-Eastern Vietnam, which has a mild tropical climate, dominated by the summer monsoon. Winters are cool and relatively dry, summers hot and wet. The majority of annual rainfall occurs between the months of June and September (Kemp *et al.,* 1994), when the rainfall increases to 7-12 times the monthly average (SCEMMA, 1992). The mean annual temperature is 22° C, the average temperature of the hottest period is 39°C (in July), the lowest temperature is 0.6 °C (in January). The annual mean humidity is 83%. Total annual rainfall is 1,378 mm/year. The cold season lasts from October to March and includes 14-17% of total rainfall. The hot season from April to September has about 85% of total annual rainfall. Climate is tropical monsoonal.

Mean climatic data collected at the Cho Ra meteorological station (2.2km from Ba Be Lake), over the period 1961-2007 are shown in Table 2.1.

Table 2.1: Average annual meteorological statistics for Cho Ra town from 1961-2007 (source: Department of Statistic of Ba Be district, 2008)

Average air temperature	22°C
Max. air temperature	29°C
Min. air temperature	0.6°C
Average annual rainfall	1378mm
Average humidity	83%

d) Geology and soils

The underlying geology of the National Park area is limestone, which has been influenced by denudation and karstic processes. An extensive network of caves has been able to form, most of which are presumably still forming (Sung, 1995). In the high peak areas, karst basins (depressions surrounded by peaks and ridges) have also formed. Few of these have formed lakes as water easily seeps through the fissured limestone rock. Although limestone is dominant in the region a large proportion of outcrops are dolomite rich, producing weak easily-fractured structures. There is also some evidence of frost-heat shattering on the very highest peaks around the lake (over 700m) (Kemp *et al.,* 1994).

The soil derived from the limestone rock is alkaline and clay-rich (Kemp *et al.,* 1994). The structure of rocks and soils as a substrate for plants will have dictated the type of flora present at BBNP. Due to the topography of the area, the substrate is generally very rocky with pockets of soil between outcrops. Consequently, on steep slopes, soil is shallow and trees have not been able to grow to any great height. In some very steep areas and on the tops of peaks, there is little or no soil on the surface. In flatter areas soil has been able to accumulate and supports a quite different fauna and flora (Kemp *et al.,* 1994; Hung *et al.,* 2003).

e) Hydrology and catchment protection

Ba Be lake is 7.5km long, and 200-800m wide (mean width 500m) (Cao Van Sung, 1995). At its deepest point, it is 29m deep (Kemp *et al.,* 1994). The lake is

fed by the Cho Leng River, which enters the lake at its southern end. Two other small rivers (Nam Ban Tao and Bo Lu River) flow into the lake from the West.

Water drains from the lake into the Nang River to the north-west. During the rainy season, water flow into the lake can cause lake levels to rise as much as 2.8m (Kemp *et al.,* 1994), but water never flows from the Nang River into the lake, even at times of heavy rain (SCEMMA, 1992).

The lake plays an important role in the regulation of flooding on the Nang River as when the Nang is flooded the flow from the lake into the Nang ceases and lake levels rise (Hill *et al.,* 1997). The lake can retain up to 8.4 million m^3 in this way (SCEMMA, 1992).

f) Vegetation

A wide variety of plant community types have been recognised within BBNP and have been well documented (Kemp *et al.,* 1994; Hill *et al.,* 1997). Nguyen Nghia Thin (1995) and Le Tran Chan *et al.,* (1999) identified the vegetation structure of BBNP as native to the North of Vietnam, characterised by 4 basic factors:

- Characteristic indigenous families: Laurecceae, Fagaceae, Fabacceae etc.
- Characterictic biogeography:
  + Indo-Malaya characteristics with *Dipterocarpus costatus* Gaertn.f.
  + Wannan – Quizhou (South of China) with *Rhododendron ferrugineum* L., *Juglans regia* L.
  + Burma-India with *Tetrameles nudiflora* R.Br, *Gossampinus rumphii* Schott. & Endl.
- Characteristic rare, endangered or endemic species in BBNP:

  Burretiodendron tonkinensis, Garcinia fagraeoides and *Markhamia stipulata* in limestone forest, and a group consisting of *Tetrameles nudiflora, Gossampinus rumphii* and *Dracontomelon duperreanum* with large diameter and average height from 20-40m, growing in the valleys.

- Characteristic endemic: String bamboo *(Sinocalamus mucclure)* on the limestone and red algae in the lake.

Le Trong Trai *et al.,* (2004) reported that the terrestrial vegetation of BBNP is dominated by evergreen tropical forest on limestone. Dominant tree species include *Teonongia tonkinensis* (Moraceae), which is an important element of the low canopy, especially on the disturbed rocky slopes and where intensive felling has occurred. *Burretiodendron hsienmu* (Timaliaceae) is a common upper canopy tree. The lowland forest formations are characterised by a relatively simple canopy structure, lower canopy height, and the scarcity of climbing species. The tree species represented in higher altitude forests differ physiologically from those of lowland tropical rain forest, and plant families which are uncommon or completely absent at lower altitude form an important component of the canopy, including Lauraceae, Fagaceae and Podocarpaceae.

According to the report of BBNP (2005) the Park is home to 1,280 plant species of almost 140 families with many of them being listed in the Red Book of Vietnam and Red List of IUCN as endangered species. Worthy of note is that 23 flora species found in the Park were present in the 2004 Red List of IUCN. Tables 2.2-3 summarize the information on the flora of the Park.

There are eight vascular Classes in Vietnam, with five in BBNP (Dien, 2005). The number of such taxa is not distributed evenly; most are Magnoliophyta (90%), and then Polypodiophyta (7.7%) and the smallest group is Equisetophyta (0.078%). The distribution of families in BBNP is different. Some families have restricted distribution but their frequency of occurrence is high (such as Polypodiaceae, Lauraceae, Moraceae, Acanthaceae, Asteraceae, Melastomataceae and Rutaceae). Some species have wide distribution in the Park, including *Burretiodendron tonkinensis, Streblus tonkinensis, Clausena lansium, Cinnamomum camphora, Erythropalum scandens, Amomum villosum, Dracontomelum duperreanum, Meliantha suavious, Garcinia fragraeoides* and *Chuckrasia tabularis.*

Table 2.2: General vegetation information in Ba Be National Park (source: BBNP, 2005).

Taxon	Families	Genera	Species
Lycopodiophyta	2	3	13
Equisetophyta	1	1	1
Polypodiophyta	19	39	99
Pinophyta	7	13	15
Magnoliophyta	153	616	1153
- Dicotyledon	*133*	*466*	*809*
- Monocotyledon	*20*	*150*	*344*
Total	162	672	1281

Table 2.3: The families with the highest number of species in Ba Be National Park (source: BBNP, 2005)

Order	Familes	Vietnamese name	Total species	Percentage
1	Orchidaceae	Lan	184	14.4
2	Euphorbiaceae	Thau dau	79	6.2
3	Poaceae	Co	56	4.2
4	Asteraceae	Cuc	56	4.3
5	Cyperaceae	Coi	36	2.8
6	Fabaceae	Dau	34	2.6
7	Rubiaceae	Ca phe	31	2.4
8	Moraceae	Dau tam	29	2.1
9	Lauraceae	Long nao	23	1.8
10	Annonaceae	Na	23	1.8

g) Previous related Study of the National Park

Previous studies of the biodiversity of Ba Be National Park have included the first survey by Vietnamese scientists in 1990 (FIPI, 1990), which formed the basis for the National Park management plan. A later study by the Society for Environmental Exploration (Kemp *et al.,* 1994) involved surveys of vegetation, birds, mammals and butterflies. Many endangered plant and animal species were recorded in the study by interview with local people, and some species listed may no longer exist in the Park.

Hill *et al.,* (1997) studied biodiversity and recorded a total 603 species of vascular plants in 137 families in Ba Be National Park, including 10 species listed in the Red Book of Vietnam. Raintree *et al.,* (1999) identified the main threats to biodiversity from households in the buffer zone as follows: illegal timber and firewood collection for domestic use, illegal harvesting of other non timber forest products, hunting, continued occupation of agricultural land within the national park, grazing of cattle within the park and pollution of the lake water.

Many international projects have been conducted in BBNP from 1991 (Dinh, 2003). The PARC project (The Creating Protected Areas for Resource Conservation Using Landscape Ecology) was one of the largest projects (Dien, 2003). The Netherlands government has supported a project for sustainable utilisation of non-timber forest products, with technical support from IUCN (Dinh, 2003).

Tran Cong Khanh *et al.,* (2003) made an inventory of the useful plants in Khang Ninh and Nam Mau communes (Ba Be National Park). The authors focussed on three main target plant species groups including medicinal plants, wild vegetables, fruit trees and timbers. However, the study only concentrated on listing the useful plants and identified some important endangered trees by the PRA (participatory rural appraisal) method in limited areas of the Park. The research did not study other factors of urgency in the area such as wood plants or broader conservation. Some authors also have carried out a survey on vegetation composition, ecological factors, and contribution of useful plants used by members of the Tay ethnic group. Tran Van On *et al.,* (2003) identified a total of 523 plants classified by the communities as "useful plants". Of these, 427 plants were identified, of which 241 species were identified by their scientific names, 141 plants were identified to their genera and 45 plants were identified to their families; 105 types of plant (19.73 %) were unknown by scientific name. Of the identified plants, 347 were medicinal (81.26%), 65 were used as vegetables (15.22%), and 63 were fruit trees (14.75%). Based on two criteria "level of use" and "availability of resource" a total of 37 species were identified by local

communities as species of high conservation priority. According to local requirements, 26 species need to be cultivated in the two communes.

Phan Ke Loc *et al.,* (2003) researched conifers and slipper orchids in this area, finding that these plants have high diversity and scientific and practical significance. They also suffer from over-exploitation, meaning there are a lot of threatened species in these groups. The seven hitherto known species of conifer are *Amentotaxus argotaenia, Dacrydium elatum, Nageia fleuryi, Pinus kwangtungensis, Podocarpus neriifolius, Pseudotsuga brevifolia* and *Faxus chinensis*, found on limestone mountains. For the conifer study, *Calocedrus macrolepis* should be considered as Endangered, *Amentotaxus argotaenia, Fokienia hodginsii* and *Taxus chinensis* as Vulnerable. The other species are at lower risk. The authors identified eight species of slipper orchids (Paphiopedilum) as follows: *Paphiopedilum concolor, P. hangianum, P. henryanum, P. hirsutissimum, P. malipoense (all three varieties), P. micranthum, P. purpuratum and P. tranlienianum.* All of these plants grow only on limestone substrates. It is expected that *P.dianthum* and *P.emersonii* should be found there as well. The authors judged that most of the slipper orchids from the study areas are threatened, due mainly to over-exploitation for export. Based on their study, slipper orchids that should be conserved are as follows:

- Critically Endangered: *Paphiopedilum malipoense,*
- Endangered: *P. emersonii, P. hangianum, P. purpuratum* and *P. tranlienianum,*
- Vulnerable: *P. henryanum, P. micranthum* and *P. dianthum,*
- Lower risk: Only *P. concolor* and *P. hirsutissimum*

Some information on the bamboo (Bambusoideae) species of Ba Be National Park has been provided by Le Mong Chan and Bui Van Nguyen (2003). In this survey, 16 species of bamboo were found, seven of which were new records for the Park; the morphological features of these also were analysed. Notably, six bamboo species were found for the first time in Vietnam: *Chimonobambusa grandifolia, Schizostachyum funghomii, Schizostachyum chinense, Phyllostachys,*

Indosasa sp. and *Indosasa sp.* The ferns (Polypodiophyta) were investigated in the strictly protected area and the authors found 59 species belonging to 31 genera and 14 families; among the ferns of the Park two species are endangered, four are endemic to Vietnam, and two species are endemic to the North of Vietnam (Huyen and Toan, 2003).

2.4 Endangered Species Identification

2.4.1 The endangered species conservation approach

From 1994, under the auspices of the Species Survival Commission of the IUCN, the World Conservation Union set out to increase global awareness of conservation threats to wild plant species, and to promote conservation action as a goal and objectives (Warren *et al.,* 1997; Harcourt and Parks, 2003 Garnett el al., 2003). The overall aim is to support and promote efforts leading to rare and endangered species conservation and rational, sustainable use. The approach is to provide information, tools, and coordination that builds on the efforts of local, national, regional and global partners to conserve and use wild plants sustainably, focusing particularly on actions that reduce threats to endangered species and habitat.

The program has, among others, the following objectives:

(1) To identify priority rare and endangered species taxa and habitats threatened by non-sustainable harvest, high levels of trade, environmental degradation, and other factors contributing to loss of species and genetic diversity;

(2) To work with local, regional, national, and global partners to design and implement conservation action plans for priority endangered species and habitats;

(3) To support and encourage the sharing of information and collaboration among all stakeholders in finding common solutions to the sustainable use and conservation of endangered species;

(4) To provide opportunities for consumers, industry, and other beneficiaries to understand and participate more directly in conservation and sustainable use of wild plant species and their habitats.

2.4.2 Identification of endangered and extinct species

The IUCN (2001) has defined criteria to classify species into different threat levels. There are five sets of criteria or decision rules for determining the categories Critically Endangered (CR), Endangered (EN) and Vulnerable (VU). The following overview provides a brief outline of the full set of criteria, with example threshold values relating to the CR category.

A) Population reduction, as either of the following:

(1) At least 90% over the last ten years or three generations, whichever is the longer, where the causes of the reduction are clearly reversible, understood and have ceased.

(2) At least 80% over the last ten years or three generations, whichever is the longer, where the reduction or its causes might not have ceased, be understood or be reversible.

(3) At least 80%, projected or suspected, within the next ten years or three generations, whichever is the longer (up to a maximum of 100 years).

(4) As A2 but where the time period includes both the past and the future.

B) Small distribution area measured as either or both:

(1) Limited extent of occurrence (e.g. <100km^2);

(2) Limited area of occupancy (e.g. <10km^2); and at least two of the following: severe fragmentation; continuing decline; extreme fluctuations.

C) Small population (e.g. <250 mature individuals) and either:

(1) Continuing decline (e.g. at least 25% within three years or one generation, whichever is the longer, up to a maximum of 100 years); or

(2) Continuing decline and at least one of the following:

(a) population structure in the form of one of the following: no subpopulation contains more than 50 mature individuals; or at least 90% of the mature individuals are in one subpopulation;

(b) extreme fluctuations in the number of mature individuals.

D) Extremely small population (e.g. <50 mature individuals).

For category VU, there is a D2 option used when the population has a very restricted area of occupancy (typically <20km^2) or number of locations (typically <five) such that it is prone to the effects of human activities or stochastic events within a very short time period.

E) Quantitative analysis showing a probability of extinction

For example, at least 50% reduction within ten years or three generations.

These criteria are shown schematically in Figure 2.2.

A frequently suggested improvement is to change the IUCN criteria thresholds when they are used at local levels (Gardenfors, 2001). Two further limitations that the Red List faces are like those of organismal biology generally, namely the unstable application of species concepts and lack of knowledge of so many species (Mace, 2004). The Red List process will also need to make a greater effort to compile point locality data enabling the identification of priority sites for conservation, as well as to repeat comprehensive assessments to enable evaluation of Red List Indices (Rodrigues *et al.,* 2006).

Human societies have for generations interacted with their environments and over time developed basic knowledge structures (Johnson, 2000; Dovie *et al.,* 2008). Local people who have been living in the areas have experience with natural resources status and effectively, long term experimentation with biodiversity (Dovie *et al.,* 2008). However, this knowledge, which is often indigenous in nature or in origin, is generally poorly documented (Johnson, 2000; Dovie *et al.,* 2008; Atari *et al.,* 2009); key bioprospecting activities have often benefited from local knowledge. However, in contrast, indigenous

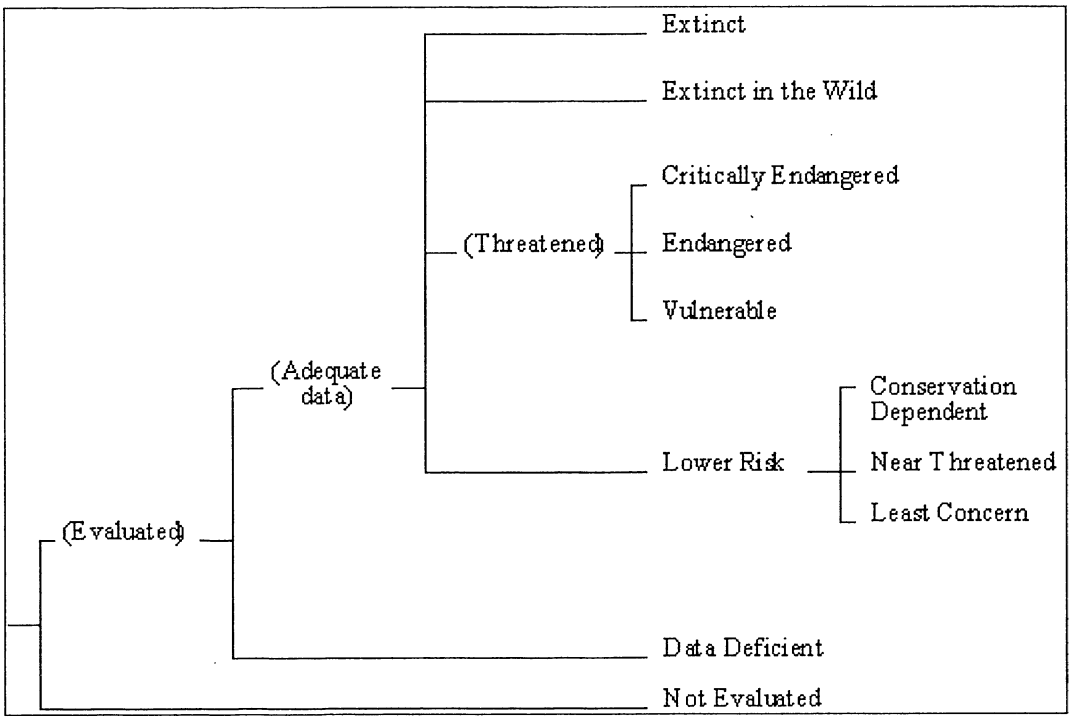


Figure 2.2: Structure of the 2001 IUCN Categories. Species in the categories critically endangered (CR), endangered (EN) and vulnerable (VU) are denoted as threatened. Species classified as least concern (LC) or not evaluated (NE) will not usually be published in a Red List. At national or other subglobal levels, an additional category can be included.

knowledge has not been properly examined in terms of its utility to support priority for biodiversity conservation. This is partly because of a poor understanding of the importance of the knowledge of the local people (Dovie *et al.,* 2008). Another factor may be the difficulty of many investigators to appreciate local cultures, interact effectively with local people and the significance of local forest utilization practices. There are also language barriers.

2.5 Summary

Research on the conservation and sustainable use of wild plant species and their habitats has fallen far behind the demand for the important resources, particularly in developing countries. Each species has unique ecological, socio-economic, and cultural associations that must be understood to achieve effective conservation (Schippmann *et al.,* 2002), and the relationships between these are poorly known. In particular, the assessment of the genetic component of

biodiversity has been little studied in developing countries. Evidence from the literature indicates that local peoples' priorities for plant conservation may be different to the priorities developed by international and national agencies whose focus is at a much larger scale than that of local people who rely on wild plant resources for their day-to-day existence.

Chapter III

Prioritisation of Species for Conservation

3.1 Introduction

Evaluation and reasonable use of plant resources for durable development and for nature conservation is one important task in Vietnam and worldwide. For that reason, several specific traits of the flora such as systematic structures, life-form spectra and geographic distribution must be thoroughly grasped at first (Chan *et al.,* 1999). Other things must be also known, namely habitat, use-value and phenologic phenomena.

Previous research identified that BBNP has 603 floral species in 300 genera and 137 families (Hill *et al.,* 1997; Quac *et al.,* 1999). These include 50 species of medicinal plants, 82 of woody species, 23 species for decoration, 6 species for oil and 6 valuable and rare species. Many biological resources have been critically reduced, many plant species over-exploited, so that many of them have become rare and endangered species. Khanh and On (2002) created an inventory of useful species in Tay villages in two communes in BBNP; the study found that there are 532 useful species for medicinal, vegetable and fruit purposes of which 427 species were classified with scientific names. However, most of the above studies concentrated on listing the species or were limited in the scope of the research.

The evaluation of conservation status has depended on the identification of priority for conservation especially species with high risk of extinction. The International Union for the Conservation of Nature (IUCN) criteria for classifying threatened species in Red Lists were constructed to be applied primarily on a global scale. Nonetheless, many nature conservation efforts are conducted at national levels and there is consequently a demand for Red Lists at subglobal scales (Gardenfors, 2001; Rodrigues *et al.,* 2006). In 1992 and 2000, a working group presented draft guidelines of how to apply the IUCN criteria at

the Vietnam level (Thanh *et al.,* 2006). Meanwhile, the 1994, 2001 and 2003 IUCN criteria were the subject of re-evaluation, resulting in the somewhat altered 2001 and 2003 IUCN criteria. Experiences of applying the suggested guidelines for national Red Data Books, particularly in Vietnam, revealed that the system is applicable to a wide range of taxa and geographical scales, even though there are issues that remain to be resolved (Gardenfors, 2001; Harcourt and Parks, 2003).

The Vietnam Red Book of Threatened Species is the most comprehensive resource detailing the national conservation status of plants and animals. The first edition for fauna species was published in 1992 and for flora species in 1996. Its criteria were generally based on the categories of IUCN but separated into different levels of extinction risks. Moreover, the Red Book assessment process has developed substantially over the past decade, extending the value of the Red Book for the assignation of threat status. The Red Book, in conjunction with the comprehensive data compiled to support it, and in spite of several limitations, has become a useful tool for conservation planning, management, monitoring and decision making. Since 1992, the natural resource status in general, and biodiversity in particular in Vietnam have changed dramatically and the Red Book needs to be progressively updated (Thanh, 2006); the most recent update was in 2004 and revealed that after about ten years the number of fauna and flora species endangered at different levels had increased. More importantly, endangered levels in each natural population have changed from time to time. Among the flora, the Red Book in 1996 recorded some species as Vulnerable but now upgraded as Critically Endangered or Endangered in 2004. There were only 24 flora species recorded as Endangered in the 1996 Red Book; that increased to 192 species in 2004 (including 45 species recorded as Critically Endangered) - most of them belonged to Magnoliophyta and Pinophyta.

The IUCN extinction risk classification is based on quantitative measures such as population size, range and decline in these (Keith *et al.,* 2000; Mattila *et al.,* 2008) and the Red Book of Vietnam mainly depends on IUCN categories but focuses more on specific areas, even getting data as statistical documents (Vui *et al.,* 2001; Do, 2005). IUCN Red List categories and criteria were designed for

international assessments. However, many people are interested in applying them to subsets of global data, especially at regional, national or local levels (IUCN, 2001). Gardenfors *et al.,* (2001) suggested that when applied at national, regional or local levels it must be recognized that global categories may not be the same as national, regional and local categories for a particular taxon (for instance, taxa classified as Least Concern globally might be Critically Endangered within a particular region where numbers are very small or declining, perhaps only because they are at the margins of their global range). Conversely, taxa classified as Vulnerable on the basis of their global declines in numbers or range might be Least Concern within a particular region where their populations are high or stable.

The quantitative Red List and Red Book categories based on decision rules that were adopted by both IUCN 2003 (IUCN, 2005; Loc *et al.,* 2006) and Vietnam (2004) criteria represented a significant advance for risk classification of species. However, some anomalies inherent in the structure of rules or their application can result in uninformative or poorly based classification for some taxa (Keith *et al.,* 2000).

The classification of species with respect to their conservation status using the local peoples' experiences and criteria is an important process in many countries, providing a guide for setting conservation priorities (Thanh, 2006). Recent advances have resulted in several approaches to dealing with participatory rural appraisal (PRA) or rural rapid appraisal (RRA) to classify species in this context (Farrington and Martin, 1988; Dunn, 1993; Simon, 2003; Robinson, 2006).

This study assesses conservation status of the plants, particularly endangered species present in BBNP, including species composition and identification of community types. It considers plant use (especially by the communities living in the research areas: medicine, vegetable, fruit, wood products and market purposes) and identifies priority species for conservation on the basis of the two measures for which most data are available: rareness levels and exploitation/use levels. The aim is to determine the ranking of species in danger of extinction and

identifying priorities for special protection measures, active propagation and the need for growing within the local human communities.

After discussion with local people for definition of the criteria for ranking is complete, all species considered at risk could be ranked according to at least one of 2 major categories (rareness level and use level). Rareness level would relate to 3 criteria: (1) area-limited; (2) resources-limited; (3) dispersal-limited (Lambeck, 1997). Area-limited endangered species are those or for which the patches of appropriate habitat are simply too small to support the species. For example: *Burretiodendron tonkinensis* only grows in limestone forest or *Sinocalamus mucclure* (string bamboo) only occurrs in the lower parts of limestone forest with high humidity around the lake and river. Similarly, the number of resource-limited, species that a region can support is determined by the carrying capacity at the time of lowest resource availability; the species is very rare and difficult to find for collection. For instance, local people may spend one day or more to find it and sometimes can not find it. Dispersal-limited species are those for which there are suitable habitat patches to support small populations, but the patches are beyond the distance over which individuals can transmit seeds or are separated by geographical conditions that are too hostile to permit spread; these criteria refer both to seed dispersal mechanisms and regeneration ability. Thus Ba Be Lake or Nang river may prevent spread of species from different areas. Use level would also be determined by three criteria: (1) proportion of local people using each listed species, that based on the list of species with high mark surveyed by RRA (Rural Rapid Appraisal) by questionnaire; (2) frequency and type of use that might indicate overexploitation and how much they use for their consumption; and (3) utility value (medicine, vegetable or market) and their price in the market (On *et al.*, 2001).

Thus, there are several methods and criteria for determining conservation needs: the Red List method, the Red Book method and the perceptions of the local people. This study attempts to identify the last of these within BBNP.

RRA (Rural Rapid Appraisal) methodology, which was introduced in 1978 and streamlined after worldwide applications of its techniques and tools has been applied extensively in many developing countries (Scrimshaw and Gleason, 1992). RRA is commonly described as a systematic but semi-structured activity out in the field by a multidisciplinary team and is designed to obtain new information and to formulate new hypotheses about rural life. The central characteristic of RRA is that its research teams are multidisciplinary (McCracken *et al.,* 1988). The distinction between RRA and other methodologies depends on this multidisciplinary approach and the combination of tools that it employs. A core concept of RRA is that research should be carried out not by individuals, but by a team comprised of members drawn from a variety of appropriate disciplines. Such teams are intended to be comprised of some members with relevant technical backgrounds and others with social science skills, including evaluation of conservation skills. In this way, it is thought that the varying perspectives of RRA research team members will provide a balanced picture. The technique of RRA includes:

- Interview and question design techniques for individual, household and key informant interviews
- Methods of cross-checking information from different sources
- Sampling techniques that can be adapted to a particular objective
- Methods of obtaining quantitative data in a short time frame
- Group interview techniques, including focus-group interviewing
- Methods of direct observation at site level, and
- Use of secondary data sources.

McCracken *et al.,* (1988) reported that RRA is a useful approach for conducting action-oriented research in developing countries. The application of RRA has been applied widely in a range of rural developments, for instance in health, nutrition, emergencies and disasters, non-formal education, agro-forestry, natural resource assessment and sociology approaches. Thus the term rapid appraisal does not refer to a single technique but to a range of investigation procedures. Their chief characteristics are that they take only a short time to complete, tend to

be relatively cheap to carry out and make use of informal data collection procedures. The techniques rely primarily on expert observation coupled with semi-structured interviewing of farmers, local leaders and officials. This method was used successfully in rural development activities in remote areas in the north of Vietnam (Phu *et al.,* 2001), RRA was used as an effective method for research on agriculture and rural development, in the early 1990s (Tuan, 1999).

Participatory Rural Appraisal (PRA) enables local people to share, enhance and analyse their knowledge of life and conditions, to plan and to act. PRA flows from and owes much to activist participatory research, agro-ecosystem analysis, applied anthropology, field research on farming systems, and rapid rural appraisal (RRA). In RRA information is elicited and extracted by outsiders; in PRA it is more shared and owned by local people. The behaviour and attitudes of outsider facilitators are crucial, including relaxing not rushing, showing respect, handing over the stick, and being self-critically aware. Modes of investigation, sharing and analysis are open-ended, and often visual, by groups, and through comparisons. Among many applications, PRA has been used in natural resources management (soil and water conservation, forestry, wildlife and village planning etc.) and agriculture (Chambers, 1992). The techniques have been used in studies on social and community forestry, degraded forest assessment, protection, nurseries and planting; identification of tree uses, uses and marketing of minor forest products, among other areas (Conway, 1985; Chambers, 1992). In Vietnam, the PRA method has been used as a useful tool for evaluating rural development, especially in evaluation of conservation status and identification of priority for conservation (Tuan, 1999).

3.1.1 Background to the problem

Before BBNP was established in 1992, natural forest resources were managed by the government as a natural preserved area but the local communities were not directly included in the resource protection planning (Kemp *et al.,* 1994). Consequently, forest was destroyed and cleared for food production, housing and commercial purpsoses, resulting in large areas of bare land. Wild animals were

hunted and lost their habitat (Hung, 2002). Until recently, sloping land cultivation has been common and conflict between food production on sloping land for consumption and forest protection has not yet been resolved. Hence, conservation is highly dependent on assistance from outside to improve local perceptions on conservation and to use resources for community development and biodiversity conservation.

Cultural and social factors of the local people remain a great challenge to nature conservation. Literacy of people in BBNP in general and in three surveyed communes is still low due to the separation of the commune from the outside by physical distance. This prevents local communities from accessing socio-economic information. This area supports four different ethnic groups (Dao, H'Mong, Kinh and Tay) with different languages; at present many (particularly older, experienced) people still cannot speak Vietnamese (Kinh language). However, traditional factors and experiences in using and conserving natural resources are very necessary for evaluation of perceived conservation status and identification of the priority species for conservation.

3.1.2 Study site

BBNP may be divided into three zones: strictly protected zone, ecological rehabilitation zone, and administration and service zone (PARC, 2001; BBNP, 2001; Truong *et al.,* 2004). In this project, the core zone and buffer zone have been selected for study.

One of the special characteristics of BBNP is the presence of human populations living within it. Therefore, aside from the main roles, BBNP also has one more responsibility, which is to guide local people to use resources sustainably and at the same time contribute to natural resource conservation. The participation of local communities is very critical for conservation because it can protect resources such as the forest and Ba Be Lake that otherwise rangers alone cannot (Dien, 2005). The Park also has advantages compared to other national parks. They are the diversity of natural resources and beautiful scenery to attract tourists. One special natural feature is Ba Be lake which is bounded by steep rock

cliffs. Ba Be lake plus the river, stream and cave systems such as Dau Dang falls, Puong cave and Angel Pond are attractive tourist places but these put more pressure on conservation. Many endemic plants, wild animals and rare fish species are present in the Park as valuable natural resources (Ratajszczak *et al.,* 1990; Hill *et al.,* 1997; Sang *et al.,* 2003; BBNP, 2005) . According to the newest report of BBNP (2005), there are about 1281 types of plants including 23 species recorded in the Red Lists of IUCN (1994), 46 species listed in Red Book of Vietnam (1996), 65 wild animal species, 140 types of birds, 30 types of reptiles, 15 types of frogs and 49 types of fish and many of them are listed in the Red Book of Vietnam and Red Lists of IUCN for high protection. As a result, evaluation of the conservation status and the risks for some endangered forest plant species in both the core and buffer zone is an urgent requirement.

People in three communes were interviewed. The following descriptive data are derived from the records of BBNP.

Nam Mau commune is located in the strictly protected area. Total area is 6444 ha of which is 105 ha is agriculture land (1.6%), 4681 ha forest land (75.7%), 357 ha water surface area (5.5%), and 17.2% of other land area, with 467 households, 2726 persons of which 2695 persons (98.9%) work in agricultural fields. The commune is divided into two regions (five lowland villages and five upland villages) which are quite different in natural and socio-economic conditions. Five lowland villages (Pac Ngoi, Bo Lu, Coc Toc, Ta ken, and Ban Cam) include major Tay populations with 233 households and 1248 persons. The literacy of the region is still quite low, the population increase rate is 1.35%; there are 357 school pupils (28.6%) and total food output of the region is 552 tonnes with average food 480.2kg /person/year. Food is produced mainly in lowland fields (447 tonnes or 81% of the total). Besides cultivation on lowlands, other income generation activities such as animal husbandry, fishing, tourism and transportation play an important role in cash income for family expenditure. Quite differently, the five upland villages (Khau Qua, Nam Dai, Dam May, Na Ban, Na Nghe) are inhabited by H'Mong and Dao people. There are 234 households and 1478 persons with population increase rate of 2.92% and a low

rate of school attendance compared to the population (310 pupils). Agriculture is a main income activity and produces 580 tonnes of food yearly of which sloping cultivation produces 384.5 tonnes (66.3%). Other income generation activities mainly depend on natural resources. In the Nam Mau commune, three villages were chosen for interview: Pac Ngoi, Na Ban and Nam Dai.

Pac Ngoi is located in the south of Nam Mau commune, with a total area of 845 ha of which there are 674 ha of forest land, 94.5 ha of agricultural land, 1.3 ha of residential land, 0.8 ha of special land and 74.0 ha of unused land. The total population of the village is 354 Tay people of which 337 work in agriculture with 7 main resource use activities: forest product collection, upland cultivation, lowland cultivation, gardening, animal husbandry, and transportation and tourism. Lowland cultivation plays the most important role in supplying for consumption (114.8 tons; 87% food product) while animal husbandry and fishing for cash income make up the rest. Some 664 ha of natural forest land have been allocated for community management but 10.0 ha of planted forest and 64.7 ha of new regenerated forest still are not allocated.

Na Ban is one of the upland villages with 590 H'Mong people, located in the West of the commune. Percentage of labor at working age of the village is quite low compared to other villages (38.13%). The total natural area is 754.5 ha of which rice land is 11 ha , sloping cultivation land is 257.68 ha, forest land is 401.15 ha, residential land is 3.7 ha and 3.6 ha of special land. The main income is from agriculture activities and from the forest.

Nam Dai village is situated in the upland area with 12 households and 73 persons, all H'Mong people. The main income is from crop production and animal husbandry with very high average food per capital (1150 kg/year). However, the transportation system to the village is very poor and soil fertility is gradually decreasing. This is an upland valley with available water sources around the year but it is located in the strictly

protected zone of BBNP which is 233.61 ha of natural land area which harbours wild animals.

Khang Ninh commune is located in the buffer zone of BBNP. Total population is 3374 people of which 64% is Tay, and 613 households, 53.6% work as laborers. By compiling data from 12 villages of the commune, the current population is 3374 persons.

Khang Ninh is a low place in BBNP and has six lowland villages on two sides of the main road to the Park. Further from this area is the high mountains where mainly H'Mong and Dao people are located in another six upland villages. The average elevation of mountains is 600-900 m. Due to topography and kast process in the limestone area, upland soils of the commune mainly are feralit acrisols developed on limestone. Lowland soils are alluvial and sedimentary soils. The total natural area of the commune is 4340 ha in which forest land occupies a high proportion (85.6%). Agricultural land is about 327.4 ha (about 7.54% of total area) and other land is quite a high proportion (297.8 ha). In agricultural land, the upland cultivation area is 327.85 ha (50.8% of total agricultural land). Lowland cultivation is distributed mainly around Ba Be lake.

Quang Khe commune is located in the South of BBNP. The total land area is 4126.88 ha of which 346.24 ha is agricultural land, 3746.98 ha forest land, 22 ha residential land and 11.66 ha of other land. Total population is 3,152 people in 603 households. Moreover, upland villages have conflicts such as proposals for their relocation. Ba Be District and Ba Be National Park have tried to solve the relocation issue by establishing new relocation areas, projects and detailed plans for relocation.

Na Vai village was interviewed in this commune, the total population of this village is 274 people and 47 households, all Dao people who conduct traditional shifting agriculture.

The local people use many forest products such as timber and bamboo for construction of housing, animal stalls and boats, fuel wood, palms for roofing

material, rattans and other weaving materials. Non-forest products include fruits, mushrooms, bamboo shoots, and grazing for animals. Although hunting within the park boundaries is prohibited, there was evidence that this practice is still widespread. Most forest products are used by local people for their consumption, and some products, especially bamboo shoots, timber and vegetables are collected for sale in the markets. All of the houses are built of wood and bamboo collected from the forest.

From structured questionnaires and informal conversations, as well as our own observations, it is apparent that people from inside and outside the Park have been fined for illegal cutting and harvesting. For example, when the local people collect vegetable or fruit they cut the entire tree but only get the young leaves or the fruit for their use. Clearly, this practice is unsustainable for those particular species.

3.2 Materials and Methods

This research exploits secondary data from the Library of BBNP, Department of Statistics of Ba Be District – Bac Kan Province, PARC (Protected Areas for Resource Conservation) project database, as well as from the Vietnam Red Book and IUCN Red List.

In 2005 and 2006, a household survey was conducted in two main areas of BBNP: Nam Mau commune in the strictly protected area and Khang Ninh,and Quang Khe communes in the buffer zone of the Park (Figure 3.1). A stratified sampling technique was employed. In each area, three to four villages were interviewed per commune according to available households in each village; in the strictly protected area, the main income and living of local residents depended on natural resources such as from fishing activities or forest products while in the buffer zone area, the incomes are from different sources such as from natural resources or off-forest products or work. The same procedure was applied to select villages in each commune. Another criterion used for selecting the sample was that surveyed households should be from ethnic minority groups

(hill tribe people) classified by national park authorities as Dao, H'Mong or Tay people. Different ethnic minorities have different behaviours and traditional cultivation methods (Phuong, 2000). Tay people cultivate in lowlands with paddy rice and the Dao and H'Mong cultivate in upland areas with traditional cultivation of slash and burn (Trai *et al.,* 2004).

A list of participants is in Appendix 1. The questionaire used is in Appendix 2; the field questionaire was presented in Kinh language. Figure 3.1 shows the locations of the villages sampled.

Based on this procedure, 200 households from 10 villages of 3 communes were interviewed. The survey was carried out in October, 2005 and November, 2006, and that was double-checked once more in 2007 to develop and complement information. Data for the two years (2005 and 2006) were collected using prepared questionnaires by the PRA and RRA methods of Chambers (1992); Grandstaff and Masserschmidt, (1995) and McCracken *et al.,* (1988). Lecturers and staff from the Faculty of Natural Resources and Environment Management, Faculty of Forestry, Thainguyen University of Agriculture and Forestry and staff from Department of Techniques, Ba Be National Park assisted the research team to conduct the survey. The backgrounds of the interviewers were from different specialties such as forest plant ecology, local knowledge, plant identification, and statistics. The author and supervisors participated as research team members of the project and attended both surveys. The presence of the Australian supervisor was used as a means of demonstrating that the survey was not simply of local interest.

The three communes selected have different characteristics and are located in different ecological regions of BBNP. Nam Mau commune, located in the main strictly protected area of the park, is characterised by natural forest around the villages. The main farming activities are related to the upland cultivation with H'Mong and Dao people, traditional shifting agriculture is likely while the Tay people cultivate in the lowland with paddy rice growing, maize, livestock, vegetables and fishing. On the other hand, Khang Ninh and Quang Khe

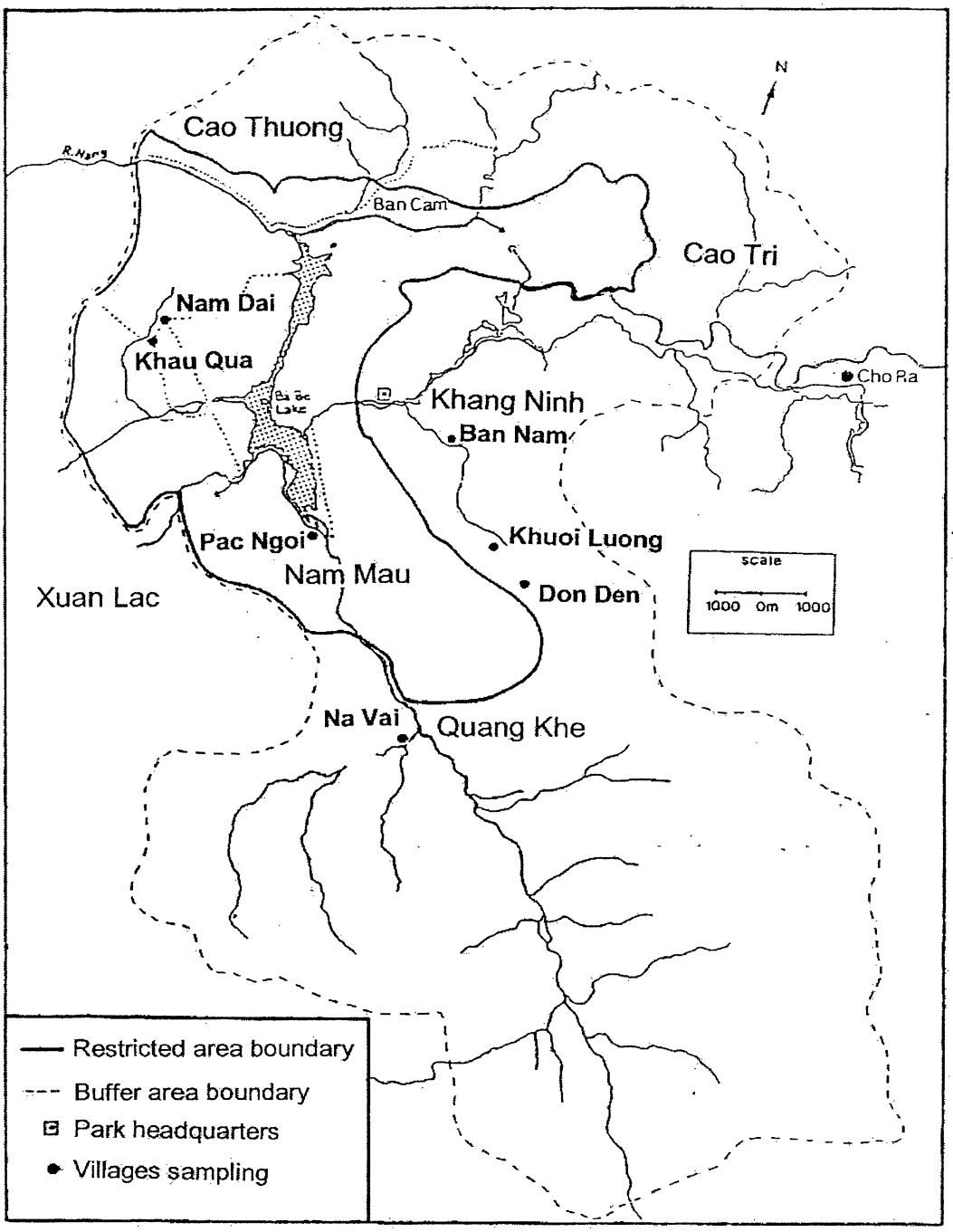


Figure 3.1: Map of Villages sampled in Ba Be National Park for interview.

communes are located in the buffer zone of the Park and the public infrastructure is more convenient than in other areas. The main farming activities related to paddy rice cultivation in Ban Nan village and the other villages have cultivated rice in terrace and rice in upland areas. All groups exploit forest plants to varied extents.

Although most people in Ba Be are of Tay ethnicity and Tay is the *lingua franca* of the other ethnic groups (Hill *et al.,* 1997; Huong, 2001; Hung, 2002), all school education is provided in Vietnamese (Kinh), which is the language most people will be familiar with for reading. However, local Tay names for most species rather than Vietnamese names may be more familiar to local people. In fact, in BBNP many older people cannot speak Vietnamese fluently but they have good knowledge and experience in species identification, usage, and assigning priority for conservation. For this reason, some staff or interviewers who can speak Tay were chosen to participate in the team work. The interview groups had at least one translator in the Tay language. Five forest protectors were also provided from BBNP office to help with the interviews.

In this study, 200 households, village leaders and BBNP officers were randomly selected for interview using the RRA (Rural Rapid Appraisal) method by questionnaires to inventory species which the local people in BBNP used for their consumption such as for medicinal plants, vegetables, fruit, fuel and housing and selling. To determine priority for conservation, two surveys were conducted one in the strictly protected zone and one in the buffer zone. Techniques of ranking were adapted to the PRA method (Participatory Rural Appraisal) that depended on 2 standards: level of use and rarity level. The most common method is sorting written responses into piles, carried out either by individuals in private or by groups. Plants specimens were collected for identification, 3 samples were collected for each species, pressed and dried; all samples were kept in the laboratories of BBNP and/or Thai Nguyen University of Agriculture and Forestry. Plant names were recognized by specialists in plant identification by their Latin name and local name (Tay language). Semi-structured and informal interviews were used to gather information from local government officials and local authority people.

For this study, data sorting and ranking was conducted using EXCEL. According to the results from the questionnaire in phase 1 (inventory of the useful plants in section 3.3.1), to determine priority for conservation the plants were ranked according to frequency of mention in questionnaires in terms of usefulness and

perceived scarcity/need for conservation or propagation. In order to reject biased opinions, the list of species was sorted alphabetically. Ranks were recorded by number from one to five, with one the lowest level to five the highest level of ranking. The result was analysed using EXCEL to determine the highest ranking level for conservation and propagation.

The PRIMER program was used to analyse the correlation between the classification for conservation priorities of the farmers' interview, Red Book of Vietnam and Red Lists of IUCN. Number "1" was used to represent Threatened or Non-Threatened, "2" is Vulnerable, "3" threatened, "4" is Endangered and "5" is Critically Endangered.

3.3 Results

3.3.1 Socio-Economic study of the Ethnic Minorities of Ba Be National Park

This study was to investigate the lifestyle of ethnic minorities living inside and around the Park. The impact on the natural resources and the conflict between conservation and the local people's needs were compared.

(a) The communities around Ba Be lake and their population

Table 3.1 sumarizes the population data for the villages sampled.

(b) The impact on the natural resources and the conflict between conservation

Table 3.2 summarises land use statistics for the sampled villages

Table 3.1: Population status and ethnic composition in three communes and in six surveyed villages in BBNP in the years of 2006 and 2007. (Source: *Ba Be National Park Library*)

Commune	Population density People/km^2	Birth ratio (%)	Population		Ethnic composition			
			No. of household	No. of people	Dao	H'Mong	Tay	Others
Khang Ninh	77.74	1.72	613	3,451	1012	153	2159	50
Don Den village			30	153	-	153	-	-
Ban Nan village			78	474	-	-	474	-
Nam Mau	43.73	2.5	467	2,802	117	1,478	1,248	20
Na Ban village				590	-	590	-	-
Nam Dai village			12	73	-	73	-	-
Pac Ngoi village			67	354	-	-	354	-
Quang Khe	76.37	1.58	603	2,993	-	-	-	-
Na Vai village			47	274	274	-	-	-

Table 3.2: Land use status of seven communes in Ba Be National Park, Bac Kan Province, Vietnam. Source: from Department of Statistics of Ba Be District in 2007

Order	Communes	No. of people	Total land area	Agriculture land			Forest land		
				Ha	%	Av/ps	Ha	%	Av/ps
1	Nam Mau	2,802	6,444.4	170.38	2.64	0.06	4952	76.84	1.77
2	Cao Thuong	3,189	3792	183.5	4.84	0.06	1006.1	26.53	0.32
3	Cao Tri	2,234	2325	220.19	9.47	0.1	1142.73	49.15	0.51
4	Khang Ninh	3,451	4340	309.4	7.13	0.09	3714.8	85.59	1.08
5	Quang Khe	2,993	5507	384.14	6.98	0.13	3831.7	69.58	1.28
6	Dong Phuc	2,573	5824	327.2	5.62	0.13	3656.5	62.78	1.42
7	Hoang Tri	1,221	3546	92	2.59	0.08	2353.5	66.37	1.93
	Total	18,463	31,778.4	1,686.81	5.31	0.09	20,657.33	65.00	1.12

3.3.2 Inventorying the plants and endangered tree species present in BBNP

(a) Species composition

According to the survey, 1005 species were determined by local people as in common usage, including 271 medicinal plants , 67 fruit trees, 51 vegetable species , 100 wood and fuel species, and 26 species for domestic markets.

In all, 463 species commonly used by local people were identified by scientific name (Table 1 and Appendix 3); there are 232 medicinal plants, 88 vegetables, 72 fruit trees and 150 species harvested for wood; 46 species are marketed.

Table 3.3 shows the detail of the above.

Table 3.3: The number of species in flora families used in BBNP, the families are in 'botanical order'.

Order	Families	No. Genera	No. species	Utility				
				Medicine	Vegetable	Fruit	Wood	Market
Fungi								
1	Auriculariaceae	1	3		3			3
2	Ganodermataceae	1	1	1	1			1
3	Pleurotaceae	2	3		3			3
4	Tricholomataceae	1	2		2			2
Polypodiophyta								
1	Aspidiaceae	1	2		2			
2	Polypodiaceae	2	2	2				
Pinophyta - Gymnospermae								
1	Gnetaceae	1	1	1				
2	Pinaceae	1	1				1	
Magnoliphyta – Angiospermae (Magnoliopsida)								
1	Acanthaceae	2	2	2				
2	Aceraceae	1	1				1	
3	Alangiaceae	1	1	1			1	
4	Amaranthaceae	2	3	3				
5	Anacardiaceae	6	9	1	3	5	5	3
6	Annonaceae	2	2	1		1		
7	Apocynaceae	4	6	2			4	
8	Araliaceae	4	9	7	2			

9	Asclepiadaceae	3	4	4				
10	Asteraceae	13	22	13	8		4	
11	Basellaceae	1	2	1	2			
12	Berberidaceae	1	1	1				
13	Betulaceae	1	1	1			1	
14	Bignoniaceae	2	6	1			6	
15	Bombaceae	1	2	1			2	
16	Brassicaceae	2	4		4			
17	Burseraceae	2	4	4	4	4	4	4
18	Cactaceae	1	1	1				
19	Caesalpiniaceae	5	9	3	1		7	
20	Campanulaceae	1	1	1	1			
21	Crassulaceae	1	1	1			1	
22	Caricaceae	1	1	1	1	1		1
23	Chenopodiaceae	1	1		1			
24	Clusiaceae	1	6			4	2	
25	Combretaceae	1	1	1			1	
26	Convolvulaceae	2	2	1	1			
27	Datiscaceae	1	1	1			1	
28	Dilleniaceae	1	1				1	
29	Diptercarpaceae	4	7				7	2
30	Ebenaceae	2	4	1		1	2	
31	Elaeagnaceae	1	3			3		
32	Erythropalaceae	1	2	1	2			1
33	Euphorbiaceae	9	18	13		3	8	
34	Fabaceae	7	10	10	1			
35	Fagaceae	3	9				9	
36	Flacourtiaceae	1	2			2		
37	Hernandiaceae	1	1	1				
38	Hippocastanaceae	1	1				1	
39	Hypericaceae	1	2	1			1	
40	Illiciaceae	1	2	2				2
41	Juglandaceae	2	3	1			3	
42	Lamiaceae	2	5	5	1			
43	Lauraceae	4	10	5			9	
44	Leeaceae	1	1	1				
45	Loranthaceae	1	14	14				
46	Magnoliaceae	3	5				5	
47	Malvaceae	1	1	1				
48	Melastomaceae	1	2	2		2		
49	Meliaceae	5	10	1		1	10	1

50	Menispermaceae	1	2	2				
51	Mimosaceae	2	2	1	1			
52	Moraceae	7	35	11		8	24	
53	Myrsinaceae	1	1	1				
54	Myrtaceae	4	6	3		4		
55	Opiliaceae	1	1		1			
56	Oxalidaceae	1	2		2	2		
57	Pentaphragmataceae	1	1	1	1			
58	Proteaceae	1	1	1				
59	Portulacaceae	1	1	1	1			
60	Rhamnaceae	3	3			3		
61	Rosaceae	3	7			7		3
62	Rubiaceae	7	8	5	2	1	2	
63	Rutaceae	8	19	10		13		
64	Sapindaceae	4	4			3	4	
65	Sapotaceae	1	1				1	
66	Sargentodoxaceae	1	2	2				
67	Schisandraceae	1	3	2		3		
68	Scrophulariaceae	2	2	1	1			
69	Solanaceae	4	6	5	3			
70	Sonneratiaceae	1	1				1	
71	Sterculiaceae	2	3				3	
72	Styraceae	1	1				1	
73	Theaceae	2	8	8				2
74	Thymelaceae	1	1	1				1
75	Titiaceae	3	3			1	3	
76	Ulmaceae	3	7				7	
77	Urticaceae	4	4	4				
78	Verbenaceae	1	2	1	2			
79	Vitaceae	3	4	4				1
Angiospermae (Liliopsida)								
1	Alismataceae	1	1	1				
2	Araceae	6	12	11	1			
3	Arecaceae	4	6	4			4	
4	Aspiaceae	1	1		1			
5	Convallariaceae	2	2	2				
6	Costaceae	1	1	1				
7	Cucurbitaceae	3	6	3	3			
8	Dioscoreaceae	1	3	1	2			
9	Dracaenaceae	1	1	1				

10	Maranthaceae	1	1					1
11	Musaceae	2	8	1	7			
12	Orchidaceae	5	8	2				6
13	Pandanaceae	1	3	3				
14	Piperaceae	1	1		1			
15	Poaceae	11	16	5	9		3	1
16	Polygonaceae	1	3		3			
17	Saururaceae	1	1	1	1			
18	Similaceae	2	4	4				3
19	Stemonaceae	1	2	2				
20	Zingiberaceae	4	11	10	3			5
Total	**107**	**251**	**463**	**232**	**88**	**72**	**150**	**46**

(b) The species usually used in the research area

Table 3.4 shows the list of species used by 50% or more of the participants.

According to the questionnaire survey, twenty-seven species were used by over 50% of households interviewed. Thirteen of these were used for medicine, twelve for fruit, eight as vegetables and six for wood and fuel (Table 3.4). Many of them were recorded in the Vietnam Red Book.

Table 3.4: The list of species used by more than 50% of local people in the research areas

Order	Scientific name	Family	Local name	Utility
1	*Psidium guajava*	Myrtaceae	Oi	F
2	*Erythropalum scandens*	Erythropalaceae	Phjac jien	V
3	*Smilax grabra*	Smilacaceae	Cau vai leng	M
4	*Tetramyxis allospondias*	Anacardiaceae	dau gia	F
5	*Allospondias lakonensis*	Anacaediaceae	Dau gia xoan	F
6	*Chukrasia tabularis*	Meliaceae	Lat	W
7	*(Bamboo)*	Poaceae	May	V
8	*Clausena lansium*	Rutaceae	Mac mat	F,M
9	*Ficus auriculata*	Moraceae	Mac ngoa	F,M
10	*Stemona tuberosa*	Stemonaceae	Mandang ma	M
11	*Dimerocarpus brenieri*	Moraceae	May teo	W
12	*Tamarindus indica*	Caesalpiniaceae	Me	F,V
13	*Auricularia auricula*		Moc nhi	V
14	*Heliciopsis lobata*	ProteaceaeAuriculariaceae	Mung phi	M
15	*Lenticus edodes*	Auriculariaceae	Nam huong	V
16	*Melientha suavis*	Opiliaceae	Phjac bon	V,M
17	*Burretiodendron tonkinensis*	Tiliaceae	Hien	W,M
18	*Dimocarpus longan*	Sapindaceae	Nhan	F,M
19	*Clausena wampi*	Rutaceae	Quat hong bi	F,M
20	*Callipteris esculenta*	Athyriaceae	Phjac cut	V
21	*Sterculia foetida*	Sterculiaceae	Mac noan	F,W
22	*Amomum subulatum*	Zingiberaceae	Sa nhan	M
23	*Dracontomelon duperreanum*	Anacardiaceae	Mac chu	F,W
24	*Canarium tramdenum*	Burseraceae	Cuom dam	F,M
25	*Canarium album*	Burseraceae	Mac cuom	F,M
26	*(Bamboo)*	Poaceae	May phjai	V
27	*Melia azedarach*	Meliaceae	Xoan	W,M

Note: *M = Medicine, F = Fruit, V = Vegetable, W = Wood and fuel*

(c) Identifying the priority species for protection

The technique of listing and marking of PRA was used, based on two standards: utility in the community and perceived rarity level in the forest areas. Fifteen species were recognised as the highest priority ranking for conservation,

comprising two species of fruit trees, ten species for wood and fuel, four species for vegetables, and three species for medicinal plants (Table 3.5). Many species were listed in the Red Book of Viet Nam such as *Meliantha suavis, Burretiodendron tonkinensis* or *Caryophyllus aromaticus*

Table 3.5: The list of priority species for protection ranked and marked by local people

Scientific name	Local name	Family name	Utility	Ranking in order
Chukrasia tabularis	Lat	Meliaceae	W	1
Dysoxylum sp.	Teng huong	Meliacea	W	2
Canarium album	Mac cuom	Burseraceae	V/F	3
Markhamia stipulata	Dinh thoi	Bignoniaceae	W	4
Burretiodendron tonkinensis	May hien	Tiliaceae	W/M	5
Parashorea chinensis	May tro chi	Diptercarpaceae	W	6
Spathodeopsis rossignolii	Dinh	Bignoniaceae	W	7
Dracontomelon duperreanum	May chu	Anacardiaceae	V/F/W	8
Heliciopsis lobata	Mung phi	Proteaceae	M	9
Meliantha suavious	Phjac bon	Opiliaceae	V/M	10
Hopea odorata	Sao	Diptercarpaceae	W	11
Garcinia fagraeoides	May li	Clusiaceae	W	12
Mahonia nepalensis	Di mi	Berberidaceae	M	13
Erythropalum scandens	Phjac jien	Erythropalaceae	V	14
Erythrophleum fordii	Lim	Caesalpiniaceae	W	15

Note: *W = Wood and fuel, V = Vegetable, M = Medicine, F = Fruit*

Of 1005 species in the research areas, nineteen species were listed in the Red Book of Viet Nam and Red Lists of IUCN and used by local people for their consumption. All these species are facing high risk of extinction at different status from rare to critically endangered and need conservation effort. However, according to the assessment of local people, only six species in this list were recommended for conservation: *Meliantha suavis, Chukrasia tabularis, Garcinia fragraeoides, Mahonia nepalensis, Markhamia stipulata* and *Burretiodendron tonkinensis,* and four species were recommended for propagation *Chukrasia tatularis, Burretiodendron tonkinensis, Markhamia stipulata,* and *Meliantha suavis* (Table 3.6).

Table 3.6: The list of species record in Red Book of Vietnam and Red Lists of IUCN used in the research areas

Order	Scientific name	Family	Community
1	*Aquilaria malaccensis*	Thymelaeaceae	-
2	*Balanophora laxiflora*	Blanophoaraceae	-
3	*Burretiodendron tonkinensis*	Tiliaceae	Propagated
4	*Caesalpinia sappan*	Leguminosae	-
5	*Chukrasia tatularis*	Meliaceae	Propagated
6	*Cibotium*	Dicksoniaceae	-
7	*Codonopsis javanica*	Campanulaceae	-
8	*Dipterocarpus retusus*	Dipterocarpaceae	-
9	*Disporopsis longifolla*	Convallariaceae	-
10	*Drynaria fortunei*	polypodiaceae	-
11	*Fallopia multiflora*	Polygonaceae	-
12	*Garcinia fragraeoides*	Clusiaceae	-
13	*Limnophila rugosa*	Lamiaceae	-
14	*Mahonia nepalensis*	Berberidaceae	-
15	*Markhamia stipulata*	Bignoniaceae	Propagated
16	*Melientha suavis*	Opiliaceae	Propagated
17	*Morinda officinalis*	Rubiaceae	-
18	*Parashorea chinensis*	Dipterocarpaceae	-
19	*Stephania dielsiana*	Menispermaceae	-

(d) Identifying the priority species for propagation

Based on the recommendation of the local people, 21 species were identified for cultivation including 2 species of orchids, 10 species for wood and fuel, 4 species for medicinal plants, 6 species for fruit and 4 species for vegetables (Table 3.7).

Table 3.7: The list of priority species for propagation in BBNP recommended by local people

Ord.	Scientific name	Family	Local name	Use
1	*Burretiodendron tonkinensis*	Tiliaceae	Nghien	W/M
2	*Chukrasia tabularis*	Meliaceae	Lat	W
3	*Markhamia stipulata*	Bignoniaceae	Dinh	W
4	*Canarium album*	Burseraceae	Tram trang	V/F/W
5	*Fagraea fragans*	Longaniaceae	Trai	W
6	*Parashorea chinensis*	Dipterocarpaceae	Tro chi	W
7	*Dracontomelon duperreanum*	Anacardiaceae	Sau	F/V
8	*Caryophyllus aromaticus*	Myrtaceae	Dinh huong	W
9	*Heliciopsis lobata*	Proteaceae	Mung phi	M
10	*Erythropalum scandens*	Erythropalaceae	Bo khai trang	V
11	*Melientha suavis*	Opiliaceae	Ngot rung	V/M
12	*Spathodeopsis rossignolii*	Bignoniaceae	Dinh thoi	W
13	*Mahonia nepalensis*	Berberidaceae	Di mi	M
14	*Gironniera subaequalis*	Ulmaceae	Ngat	W
15	*Dendrobium crumennatum*	Orchidaceae	Hoang thao	Orchid
16	*Mangifera reba*	Anacardiaceae	Mac trai	F/W
17	*Canarium sp*	Burseraceae	May cham	F/V
18	*Dimocarpus longan*	Sapindaceae	Nhan rung	F
19	*Dendrobium sp.*	Orchidaceae	Phong lan hong	Orchid
20	*Tamarindus indica*	Caesalpiniaceae	Me rung	V/F
21	*Madhuca pasquieri*	Sapotaceae	Sen	W

Note: *W = Wood and fuel, V = Vegetable, F = Fruit, M = Medicine*

3.3.3 Local identification for conservation

According to the Red Book of Vietnam (1996) and Red Lists of IUCN (1994), four species were recorded as group IIA, which refers to valuable species based on decree 48/2002/ND-CP of the Vietnamese Government; they include *Markhamia stipulata, Burretiodendron tonkinense, Chukrasia tabularis* and *Amomum villosum*. Twenty three were recorded in Red Lists of IUCN (1994) including one as Critically Endangered, five as Endangered, eleven as Vulnerable and five as Threatened. Forty six were recorded in Red Book of Vietnam (1996)

including six species as Endangered, 18 Vulnerable, 17 Rare and 5 Threatened. However, IUCN criteria in themselves will not lead to the identification of national or local conservation priorities, and further guidelines are needed to take account of factors such as national threat, local importance of populations, as well as simply the level of threat within country or local areas (Warren *et al.*, 1997). Table 3.8 presents the comparison between local, national and international conservation ranking.

Table 3.8: Local people's, Red Book of Vietnam (1996) and Red Lists of IUCN (1994) classification of endangered species for conservation priorities.

Order	Latin names	Local names	Local	Red Book	IUCN
1	*Adinandra megaphylla* Hu.	Sum la to	-	T	-
2	*Aglaia perviridis* Hiern	Ngau xanh	-	-	VU
3	*Allospondias lakonensis* Pierre	Dau da xoan	T	-	-
4	*Amentotaxus argotaenia* (Hance) Pilg	De tung hoa TH	-	R	VU
5	*Amomum villosum* Roxb.	Sa nhan	T	-	-
6	*Ampelopsis cantoniensis* Michx.	Che day	T	-	-
7	*Annamocarya sinensis* (Dode) Leroy	Cho dai	-	-	EN
8	*Anoectochilus setaceus* Blume.	Kim tuyen	-	E	-
9	*Ardisia silvestris* Pitard.	Khoi tia	-	VU	-
10	*Baccaurea ramiflora* Lour.	Dau da dat	T	-	-
11	*Balanophora laxiflora* Hemsl.	Do dat hoa thua	-	VU	-
12	*Bischofia javanica* Blume.	Nhoi	T	-	-
13	*Burretiodendron tonkinensis* (A.Chev.) Kosterm	Nghien	CR	VU	EN
14	*Caesalpinia sappan* L.	Vang	T	T	-
15	*Calamus platyacanthus* Warb. Ex Becc	Song mat	-	VU	-
16	*Calocedrus macrolepis* Kurz.	Bach xanh	-	E	VU
17	*Canarium album* L.	Tram trang	EN	-	-
18	*Canarium tramdenum* L.	Tram den	T	-	-
19	*Carallia diplopetala* Hand.-Mazz.	Rang ca	-	-	LR/nt
20	*Caryophyllus aromaticus* L.	Dinh huong	EN	-	-
21	*Cephalotaxus hainanensis* H.L.Li	Dinh tung	-	R	EN
22	*Chukrasia tabularis* Juss.	Lat	CR	-	-
23	*Clausena dunniana* Burm.	Quat hong bi	T	-	-
24	*codonopsis javania* (Bl.) Hook.f.	Dang sam	-	VU	-
25	*Colona poilanei* Gagnep.	Co mai nhap la nho	-	-	LR/nt
26	*Cycas balancae* Warb.	Tue da voi	-	R	NT

27	*Dendrobium daoensis* Gagnep.	Hoang thao TD	-	R	-
28	*Dendrobium nobile* Lindl.	Hoang thao lan	T	R	-
29	*Dendrobium sp.* (White)	Phong lan trang	T	-	-
30	*Dendrobium.sp.* (Pink)	Phong lan hong	T	-	-
31	*Dendrocnide urentissima* (Gagnep.)	Han voi	-	-	VU
32	*Deutzianthus tonkinensis* Gagnep.	Mo	-	-	LR/nt
33	*Dimocarpus longan* Lour.	Nhan rung	T	-	-
34	*Dipterocarpus retusus* Blume.	Cho nau	-	-	VU
35	*Dracontomelon duperreanum* Blume	Sau	VU	-	-
36	*Drynaria fortunei* (O.kuntze ex mett.) J.Smith	Bo cot toai	-	T	-
37	*Elaeagnus sp.*	Nhot rung	T	-	-
38	*Elaeocarpus apiculatus* Mast.	Com mui	-	-	VU
39	*Erythropalum scandens* Blume	Bo khai trang	T	-	-
40	*Erythropalum sp.*	Bo khai do	T	-	-
41	*Erythrophleum fordii* Afz.	Lim	CR	-	-
42	*Fallopia multiflora* (Thunb.) Haraldson	Ha Thu o do	-	VU	-
43	*Fernandoa brillettii* (Dop.) Steen.	Dinh	VU	-	-
44	*Ficus semicordata* L.	Mac not	T	-	-
45	*Ficus sp.*	Dua tra	T	-	-
46	*Ficus variegata* L.	Va rung	T	-	-
47	*Fokienia hodginsii* (Dunn.) A.Henry &H.H.T.	Po mu	-	-	LR/nt
48	*Garcinia fagraeoides* A. Chev.	Trai	VU	VU	-
49	*Goniothalamus macrocalyx* Ban.	Mau cau trang	-	-	VU
50	*Heliciopsis lobata* Sleum.	Mung phi	VU	-	-
51	*Hopea odorata* Roxb.	Lo noi hai nam	T	-	VU
52	*Kdsura sp.*	Dau da day	T	-	-
53	*Knema tonkinensis* (Warb.) De Wilde	Mau cho bac bo	-	-	VU
54	*Limnophila rugosa* (Roth) Merr.	Hoi nuoc	-	R	-
55	*Litsea sp.*	Kheng khao cam	T	-	-
56	*Machilus bonii* Nees in Wall.	Khao	T	-	-
57	*Mahonia nepalensis* DC. 1824	Mat gau	CR	VU	-
58	*Mangifera duperreana* L.	Mac trai	T	-	-
59	*Manglietia dandyi* Dandy	Mo vang tam	-	VU	-
60	*Markhamia stipulata* (Roxb.) Seem	Dinh thoi	EN	VU	-
61	*Mazus pumilus* Lour.	Rau dang	T	-	-
62	*Melientha suavis* L.	Ngot rung	VU	T	NT
63	*Michelia balansae* L.	Doi (gioi)	T	-	-
64	*Nageia fleuryi* (Hickel) de Laub.	Kim giao	-	VU	DD
65	*Nephelium sp.*	Vai thieu rung	T	-	-
66	*Ophiopogon tonkinensis* Rodr.	Mach mon bac	-	R	-
67	*P. hangianum* Perner & Gruss.	Lan hai hang	-	E	-

68	*P. henryanum* Graem.	Lan hai henri	-	VU	-
69	*P. hirsutissimum* (Lindl ex Hook)	Lan hai long	-	R	-
70	*P. malipoense* S.C. Chen & Z.H. Tsi	Lan hai xanh	-	R	-
71	*P. mielanthum* T.Tang & F.T.Wang.	Lan hai moc	-	VU	-
72	*P. purpuratum* (Lindl.) Stein.	Lan hai tia	-	E	-
73	*P. tranlienianum* Gruss. & Perner.	Lan hai chan tim	-	E	-
74	*Paphiopedilum concolor* (Bateman) Pfitzer	Hai vang cham nho	-	R	-
75	*Paphiopedilum dianthum* T.Tang &F.T.Wang	Hai hai hoa	-	VU	EN
76	*Paphiopedilum emersonii* Koop. &P.J.Gribb.	Hai enecxon	-	E	CR
77	*Parashorea chinensis* Hwang	Cho chi	VU	R	EN
78	*Pinus kwangtunggensis* Chun ex Tsiang	Thong pa co	-	R	-
79	*Pinus merkusii* Jungh. Et Vriese	Thong nhua	-	-	VU
80	*Platanus kerrii* Gagnep.	Cho nuoc	-	T	VU
81	*Podocarpus neriifolius* D. Don.	Thong tre	-	R	-
82	*Pseudotsuga brevifolia* W.C.Cheng & L.K.Fu.	Thiet sam gia LN	-	R	-
83	*Rauvolfia verticillata* (Lour.) Baill.	Ba gac vong	-	VU	-
84	*Reynoutria japonica* Houtt.	Cu cot khi	-	R	-
85	*S. ceppharantha* Hayata	Binh voi hoa dau	-	VU	-
86	*Similax glabra* L.	Cau vai leng	T	-	-
87	*slausena lansium* L.	Mac mat	T	-	-
88	*Smilax glabra* Wall. Ex Roxb.	Tho phuc linh	-	VU	-
89	*Stephania brachyandra* Diels	Binh voi nhi ngan	-	R	-
90	*Strychnos umbellata* (Lour.) Merr.	Ma tien tan	-	VU	-
91	*Tetrapanax papyriferus* (Hook.) K.Koch	Thong thao	-	T	-
92	*Toona surenii* Reom.	Truong van	T	-	-
93	*Vernonia andersonii* L.	Slay can	T	-	-
	Total	**94**	**46**	**46**	**23**

Note: *CR = Critically endangered, EN = Endangered, VU = Vulnerable, T = Threatened, R = Rare. - = not considered a problem, nt =not considered threatened, LR = Lower risk*

Multidimensional scaling analyses (MDS) showed a significant difference between groups of local identification and Red Book of Vietnam in detecting priorities for conservation of endangered species identified. As can be seen in Figure 3.2 (and also from an analysis of Table 3.8), most species were grouped together; that means they tend to have the same ranking in priorities and have

lower ranks than other species. However, a few species were separated (in this context, their names can be read); these include *Garcinia fagraeoides, Markhamia stipulata* and *Burretiodendron tonkinensis,* which are all species recommended for conservation priorities as Endangered or Critically endangered by local people and the Red Book of Vietnam.

To identify the conservation priorities between local people and Red List of IUCN, Multidimensional scaling (MDS) was also used to compare between their rankings. The results in Figure 3.3 showed that three species separate clearly from others: *Burretiodendron tonkinensis, Parashoea chinenses* and *Paphiopedilum emersonii;* another two species were also slightly separated: *Markhamia stipulata* and *Mahonia nepalensis*; these are the species identified by both categorization processes.

Multidimensional scaling analysis was also used with all three criteria used. In this case, six species come out separately; they are *Markhamia stipulata, Garcinia fagraeoides, Paphiopedilum emersonii, Burretiodendron tonkinensis, Mahonia nepalensis* and *Amentotaxus argotaonia,* other species were grouped together as the same priorities for conservation (Figure 3.4).

Local identification and Red Book of Vietnam

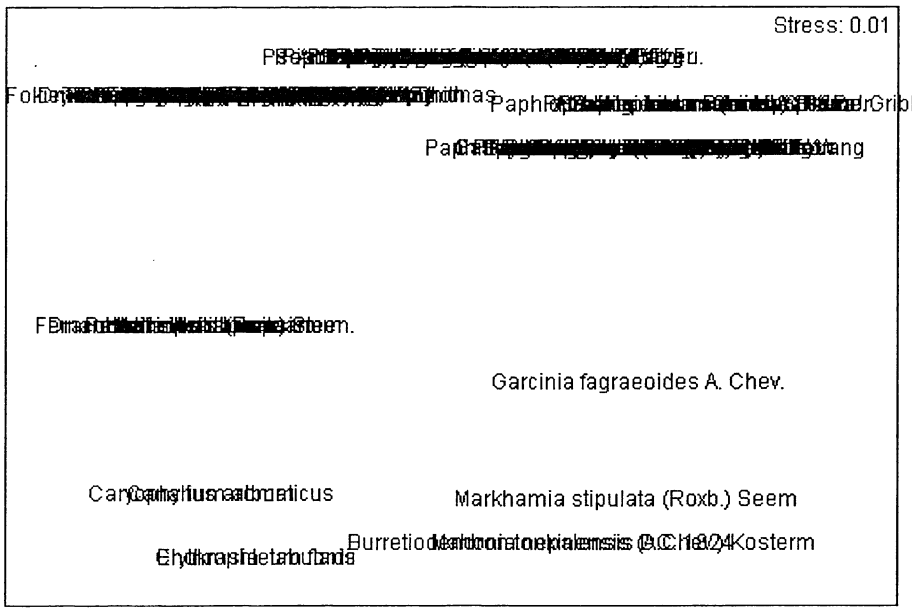


Figure 3.2: Multidimensional Scaling analyses (in Primer program) identifying the priorities for conservation of endangered species in BBNP, comparing between Local people and Red Book of Vietnam criteria.

From the three analyses, we can strongly recommend that seven species (Table 3.4) should be paid special attention for conservation study or propagation in the forest or in specially designated gardens.

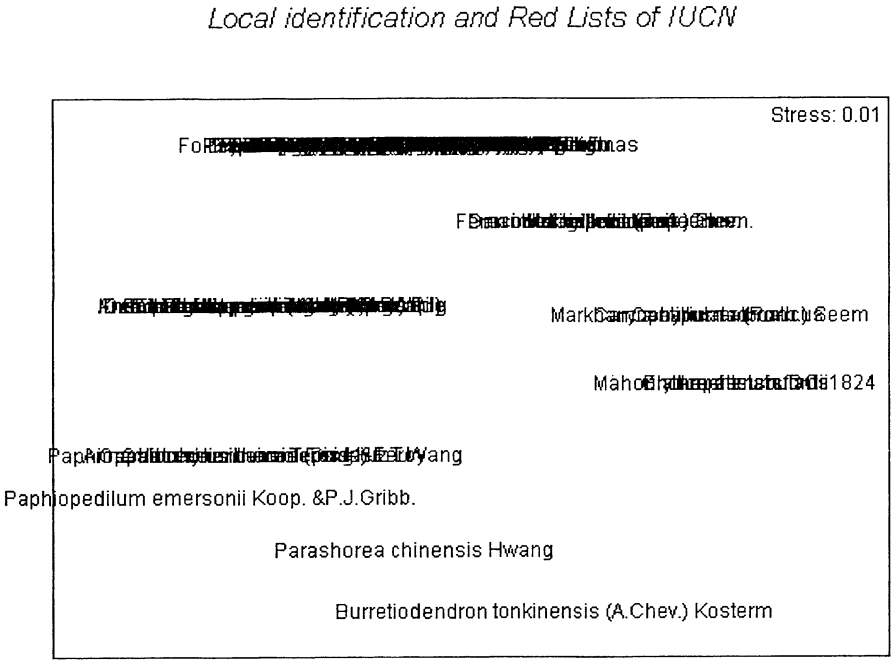


Figure 3.3: Multidimensional Scaling analyses (in Primer program) identifying the priorities for conservation of endangered species in BBNP, comparing between Local people and Red Lists of IUCN criteria.

Local, Red Book of Vietnam and Red Lists of IUCN

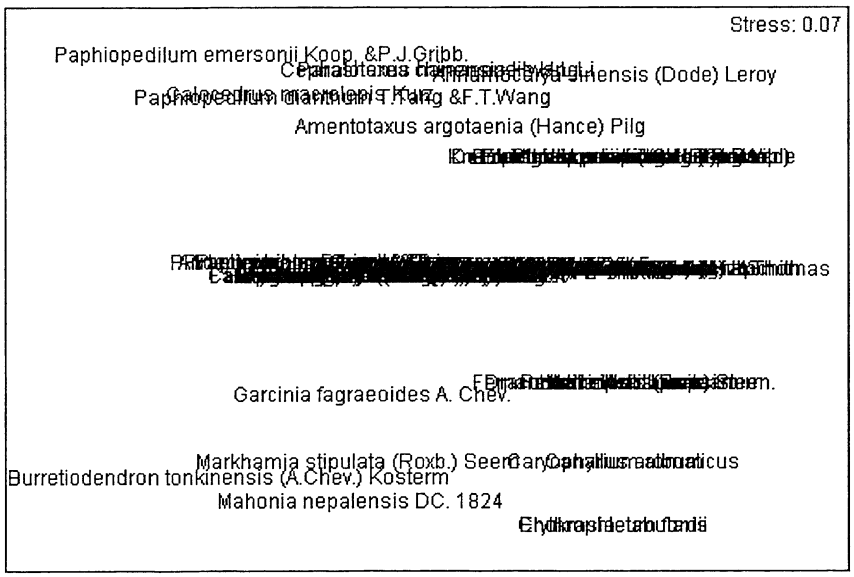


Figure 3.4: Multidimensional Scaling analyses (in Primer program) identifying the priorities for conservation of endangered species in BBNP, comparing between all three criteria of Local people, Red Book of Vietnam and Red Lists of IUCN criteria.

Table 3.9: Seven Endangered species classified by local people, Red Book and Red Lists for highly conservation priorities in BBNP

Rank	Species name	Local	Red Book	Red Lists	Utility
1	***Amentotaxus argotaenia* (Hance) Pilg**	-	R	VU	Wood/Medicine
2	***Burretiodendron tonkinensis* A.Chev.**	CR	V	EN	Wood/Medicine
3	***Mahonia nepalensis* DC. 1824**	CR	V	-	Medicine
4	***Markhamia stipulata* (Roxb.) Seem**	EN	V	-	Wood
5	***Garcinia fagraeoides* A. Chev**	VU	V	-	Wood
6	***Paphiopedilum dianthum* T.Tang &F.T.Wang**	-	V	EN	Flower
7	***Parashorea chinensis* Hwang**	VU	R	EN	Wood

Note: *CR = Critically endangered, EN = Endangered, VU = Vulnerable, T = Threatened, R = Rare.*

3.4 Discussion

3.4.1 Socio-economic studies

Socio-economic studies play a major role in the conservation of forest areas (On *et al.,* 2002; Atari *et al.,* 2008). A greater understanding of the local socio-economic factors help to highlight present and future threats to natural resources, and find solutions to them. However, the most important issue is to involve the local people themselves. This has many advantages in increasing the awareness of local people to problems they and others face, and to extract a large amount of indigenous knowledge which may not be normally available to researchers (Kemp *et al.,* 1994) . With the cooperation and involvement of local people in solving their own problems their future and that of an area, in this case BBNP's, natural resources, is more likely to be sustained.

The method used for research on socio-economic issues in BBNP was Rapid Rural Appraisal (RRA) and secondary data collection. Our interviews were restricted to the village leaders and other important individuals. Many problems they expressed may not be valid for others, especially women and poor families. Information will therefore inevitably be biased. In addition, our studies of ethnic minorities in BBNP must be analysed in the knowledge that no participatory research was conducted. Chan (1994) stated that the use of indigenous knowledge is particularly important here as the people will know what crops are suited for particular areas and what extension methods for the implementation of these changes will help sustain the natural resources of BBNP.

Tay language is used to communicate as a *lingua franca* in BBNP so that for further study Tay interpreters should be considered in order to ensure that information provided is of maximum significance. Six villages were interviewed but the data collected from Tay villages were regarded as more informative than the other villages of Dao and H'Mong people, possibly because they are more frequently exposed (in the lowlands) to the national language.

One important characteristic of BBNP in comparison with most other National Parks is that there are local people living inside the Park (Kemp *et al.,* 1994; Hung, 2002). Farmers' perspectives are key factors that affect adoption and implementation of natural resources management programs (Atari *et al.,* 2009). This study found that forty-six species were classified as threatened to extinction at different levels by local people living in BBNP, four species were classified as Critically Endangered, three as Endangered, six as Vulnerable and thirty as threatened species (Table 3.8). More than 30 of the 46 species were not listed by the national or international agencies and fewer than 10 were. Clearly, there is a perceived need for conservation planning and action on 30 species not recognised as "important" in the Red List or Red Book evaluations.

The total population of the three communes is 9344 people of which 2818 people live inside the Park and most are settled in the buffer zone. However, the pressures upon the Park resources posed by local population living within and around the BBNP, are great (Kemp *et al.,* 1994). Nguyen Thu Huong (2001) stated that high population density is an obstacle for forest protection in BBNP; population density ranged from 43.73 to 77.74 people/km^2. The ethnic composition is different between locations but there are three major different ethnic minority groups in BBNP: Tay people, Dao, and H'Mong.

The people of BBNP are living at a subsistence level, although some live more comfortably than others. The majority of people's resources come from the land and what it can provide. When there is such a close relationship between the people and their land, there is a general realisation of the effect that their population is having on resources, and whether they are in decline; agriculture often cannot provide enough for their needs, and there is little alternative to continuing to exploit other forest resources. This is especially true for the poorer families and villages who have little land of quality on which to grow food.

From the secondary data collected, and observation within the Park, it likely that BBNP natural resources will become depleted at an increasing rate, and greater protection of the resources are needed. Shifting agriculture and unsustainable

methods of harvesting such as cutting whole plants for collecting the edible parts will result in further reduction of forest resources. Moreover, people are largely dependant on the forest resources and damage or exploitation of these are detrimental to their own livelihoods. The realisation of threat of resource depletion is made difficult by different attitudes towards the forest in different ethnic minorities, as some have plentiful local forest resources.

3.4.2 Inventorying the plants and endangered tree species

BBNP is one of the most important national forests of Vietnam; it is an area of high relative biodiversity with many parts of the forest remaining largely intact. Many studies have researched biodiversity of BBNP and listed the species in this area, such as the research of Nguyen Khanh Quac *et al.,* (1999) who recorded 550 species of vascular plants belong to 138 families or a total of 603 species of vascular plant in 137 families found by Hill *et al.,* (1997). The research on useful plants in BBNP of Tran Cong Khanh and Tran Van On (2002) identified 532 species used by local people in BBNP with 427 species identified by scientific name.

Throughout the survey, over 1005 vascular plants were found to be used by local people; only 434 species were identified by the Latin name. This points to a pressing need for detailed systematic study of the plants in the Park. The number of species recorded in this study is higher than in other previous studies. The species list in this study is, however, almost certainly incomplete because of limited time and lack of resources. With additional surveys in this area, the number of species recorded would be increased and therefore a truer reflection of actual biodiversity would be achieved. Further survey work is especially needed in case of some unknown or endemic species, especially those used by local people but not yet identified by the Latin name. Populations of some endemic species only occurred in restricted areas such as *Sinocalamus mucclure* sp (string bamboo). Some valuable species recommended for conservation priority by local people are not identifiable in a formal taxonomic sense and an accurate figure of

their numbers may help emphasize the importance of BBNP and possibly attract more research on natural conservation in this area or for decision makers.

The study identified 27 species were often used by local people in over 50% of household interviews. Many of them were recorded in the Red Book of Vietnam and Red Lists of IUCN such as *Chukrasia tabularis, Melientha suavious, Burretiodendron tonkinensis* and *Amomum subulatum*. Moreover, the study also identified 15 species as needing special protection by local people because they are claimed to be facing reduction of numbers and increasing difficulty in finding them in the Park; a lot of people exploit them and some reported finding them difficult to regenerate or propagate. Many have limited seed dispersal mechanisms.

Many endangered species were used in BBNP for different purposes such as medicine, vegetable, construction, fuel or fruit and many of them were recorded as critically endangered in the Red Book or Red List. The local people said that they have not known that the plants were important or should be protected globally or nationally. This problem reflects the fact that local people were not approached for information needed for the Red Book and Red Lists.

Local people recommended 21 species for propagation because of their needs, most of them used as wood for housing or fuel. The need for housing timbers probably could not be met through propagation in a time frame that is suitable, so education on the use of alternative timbers, such as eucalypts or pines from nearby plantations may be needed.

3.4.3 Identifying priority for conservation

Endangered species were identified using standard Participatory Rural Appraisal (PRA) techniques where local people were encouraged and facilitated to rank a list of regularly used and unknown plant species compiled on the basis of extensive participatory field observations. The study found that this technique is a useful tool for natural conservation, especially for identification of conservation priorities. Forty six species were found as Endangered at different levels by local

people; they understood that these species were faced with high risk of local extinction and in particular, four species could be ranked as Critically Endangered and three as Endangered; those should be urgently conserved. The secondary data was collected according to two other criteria, the Red Book of Vietnam recorded 46 species and the Red Lists of IUCN 23 species as facing risk of extinction at different levels. The different assessments have resulted from differences of criteria and definitions between identification for ranking priorities for conservation.

The criteria of IUCN are clearly quantitative in identifying priorities for conservation at global and national levels (Palmer *et al.,* 1997; IUCN, 2001); the criteria are aimed at identifying species at risk of extinction and placing them accordingly in the Red List categories to combine the criteria A-D (criterion A is built on population reduction, B on small distribution area in combination with fragmentation, decline or extreme fluctuation of the population, C on a small population number in combination with a population decline, and D on an extremely small population (Gardenfors, 2001). Local peoples' identification criteria are more qualitative than quantitative and combine their experiences and knowledge in evaluation of conservation status. The criteria are aimed at identifying the endangered species based on two criteria: rarity and use level (see more detail in section 3.1).

Colyvan *et al.,* (1999) and Gardenfors (2001) emphasized that there are both conceptual and practical obstacles in applying the IUCN Red List criteria at national and local levels. Further discussion and tests of how to evaluate the extinction risk of species used by local people in BBNP are needed. In this study, the priority for conservation of endangered species was recognized at four different levels (46 species), and the results were compared with the Red Book of Vietnam and Red List of IUCN in order to find out the highest ranking for special conservation. One aspect still to be investigated is the effect of scale on risk assessments in a set of geographically small areas; in BBNP that could only be conducted in different locations. Other issues to explore, by using quantitative criteria models for example, would be to establish protocols for application in

small areas, identifying the priority for conservation by local people. Of course, there is also a great need for empirical knowledge including genetic data, dispersal rates and frequency in most taxa (Gardenfors, 2001).

3.5 Conclusion

From the method of combination of three different criteria, the study identified seven species for the highest priority for conservation: *Amentotaxus argotaenia* (Hance) Pilg, *Burretiodendron tonkinensis* A.Chev., *and Mahonia nepalensis* DC. 1824, *Markhamia stipulata* (Roxb.) Seem, *Garcinia fagraeoides* A. Chev, *Paphiopedilum dianthum* T.Tang &F.T.Wang and *Parashorea chinensis* Hwang. A furthe eight species are worthy of attention in this context.

Chapter IV

Vegetation and Environmental Patterns

4.1 Introduction

4.1.1 General context

Vietnam stretches from 23°N to 8° 30'N, supporting a wide range of habitats and biodiversity. The natural vegetation was once dominated by tropical forests, but these have undergone a rapid decline in the past century. In 1943, approximately 44% of the country's land area was forest. By 1983, this had declined to 24% (MacKinnon, 1990; Sung, 1995; Thin and Harder, 1996). The area covered by good-quality natural forests is only around 10% of the land area, and, of this, only around 1% could be described as pristine (Collins *et al.,* 1991).

The natural forest vegetation of lowland Vietnam is dominated by two main types (WWF and IUCN, 1995): tropical wet evergreen (and semi-evergreen) forest, and tropical moist deciduous forest (monsoon forest). Wet evergreen forest is found in areas with a regular, high rainfall (>1500mm per annum), and is largely restricted in Vietnam to the South and Central regions (WWF and IUCN, 1995). Monsoon forests experience a distinct dry season and are dominated by deciduous tree species (Whitmore, 1984). They dominate inland and northern Vietnam, an area classified by Udvardy (1975) as Thailandian Monsoon Forest.

A third major forest formation, forest over limestone, is important in areas of limestone geology and supports a range of herbs (WWF and IUCN, 1995; Hill *et al.,* 1997). At higher altitude (700m and above) lowland forest gives way to montane forest formations, which differ from lowland forests in their distinctive physical structure and floral composition (Whitmore, 1984; Collins *et al.,* 1991; Chan *et al.,* 1994). Ba Be National Park is characterized by limestone monsoon

tropical forest typical of the north of Vietnam (Hill *et al.,* 1997; Quac *et al.,* 1999).

Forests support the greatest part of Vietnam's biodiversity, which includes a high proportion of endangered and endemic plant species (Trung, 1970) and this is so for Ba Be National Park (Dinh, 2003). Two Red Books have been prepared for the flora of Vietnam; volume one was published in 1996, listing 350 plant species and volume two was published in 2004, listing 450 plant species. Several endangered species, including *Burretiodendron tonkinensis, Markhamia stipulata*, and *Melientha suavious* are facing imminent extinction in Vietnam (Thanh, 2006).

Forest degradation and the loss of biodiversity have been caused by a number of factors. These include forest clearing for wood harvest and for shifting agriculture, clearing for broad-scale agricultural crops and urban/village expansion (Dung *et al.,* 2003). Many valuable plants are becoming scarce and some are in danger of extinction. The total of threatened species is high for a single country, reflecting the seriousness of the threats to wild habitat in Vietnam (Quy, 1985; Sang, 1991; Quy, 1997; World Bank, 1995).

The decline in the quality and quantity of Vietnam's native forests was addressed by the Tropical Forest Action Plan for Vietnam (MacKinnon, 1990), which pointed out the lack of adequate management plans or inventories for many of the protected areas in Vietnam. Since this time, the protected areas system has been revised and extended. There are now 87 protected areas in Vietnam, covering 976,000ha (Sung, 2005); this figure includes National Parks, Nature Reserves and Protected Forests. In some areas, biodiversity inventories have been carried out by Vietnam's Forest Inventory and Planning Institute (FIPI) and international organizations. Many projects have been conducted to identify factors affecting structure and vegetation composition of forests which lack basic biodiversity, the presence of endangered species and correlation of forest vegetation and environmental factors (Quy, 2003; Canh, 2006).

The distribution of plant species is widely accepted as a response to a variety of interacting biotic and abiotic factors (Le Broque and Buckney, 1995). Environmental variation often produces modifications in the pattern of vegetation (Aronson and Shmida, 1992; Bertiller *et al.,* 1993; Lyon and Gross, 2004; Bornman *et al.,* 2008). Environmental factors (precipitation, soil texture, soil depth, altitude, landscape form, aspect, and disturbance) have been shown to be strongly related to the cover of vegetation and its composition (Bertiller *et al.,* 1993 and Bornman *et al.,* 2008). The spatial balance of water resulting from the effects of environmental factors such as landforms, soil properties, etc. may also determine small scale changes in plant species distribution (Parker, 1995; Ruedas *et al.,* 2006). Major (1951) and Billings (1952) attempted to describe theoretically, the complex relationship between the distribution of species and the environment. Environmental patterns and plant distribution along a precipitation gradient were analysed by Bertiller *et al.,* (1993), Le Broque and Buckney, (1997), Le Broque and Buckney, (2003), Bornman *et al.,* (2008).

The vegetation of Ba Be National Park has been studied in some detail in the past. Extensive floristic lists for this region have been collected and the distribution of species has been well documented (Kemp *et al.,* 1994; Hill *et al.,* 1997; Dinh, 2003) and attributed mainly to altitude. In terms of community-environment relations, the vegetation of this region has been studied with respect to forest structure and forest types (BBNP, 1997; BBNP, 2001; Trai *et al.,* 2004) and disturbance (Dung *et al.,* 2003); however, few studies have examined the combined effects of multiple environmental factors.

In this study, species composition of vegetation communities was examined in four different forest types (moist sites are sites near the lake, rivers and stream; disturbance 1 sites relate to sites near villages and tracks; disturbance 2 sites relate to sites of secondary forest, and the relatively undisturbed sites relate to the top and middle of the mountains) which differ in the above environmental factors.

4.1.2 Objectives and Hypotheses

As can be seen from the literature review chapter and the above description of studies examining the factors affecting the biodiversity loss and distribution of plant species in Ba Be National Park and elsewhere in Vietnam, much of the current knowledge stems from studies which concentrate on one or a few factors. Topography and general ecological conditions have been particularly regarded as important factors affecting plant species distribution on both regional and local scales (Benson and Howell, 1990; Robinson, 1991; Tozer, 2003; Trai *et al.,* 2004). The possible roles of other factors, particularly other environmental variables, have been largely ignored.

This study examines the ecology of plant communities in Ba Be National Park, an area of relatively undisturbed natural vegetation in the northern mountainous region of Vietnam. Specifically, this study examines the two existing hypotheses that spatial patterns in vegetation attributes of plant communities within the study area can be adequately explained by a single environmental variable, namely altitude (Kemp *et al.,* 1994; Hill *et al.,* 1997) or disturbance (Dung *et al.,* 2003). For the purpose of this study adequacy is defined as the failure of alternative hypotheses to explain significantly more of the variation in vegetation attributes. In this study, the environmental factors were divided into five main groups (Soil data, disturbance factors, vegetation data, physical data, and dominant and endangered species).

The plant communities at a number of sites within Ba Be National Park are described in terms of three vegetation attributes: floristic composition, structural characteristics of vegetation and endangered species richness, and by environmental attributes in order to examine the effects of single environmental factors or vegetation patterns on the distribution of plant species in general and endangered species in particular.

The aim of this study, therefore, was to examine the environmental variables regarding species/endangered species distributions in Ba Be National Park by

determining the patterns and relationships, if any, in the floristic composition and environmental factors affecting vegetation communities. Further, this study examines the relationships between floristic and environmental patterns to determine the major abiotic environmental factors affecting the distribution of forest plant species. As a corollary, this study also examines the extent to which the chosen environmental factors can explain floristic variation.

While it is clearly impossible to examine all possible factors affecting the distribution of species, the identification of major floristic gradients in terms of community composition and major environmental factors can provide a useful point from which other hypotheses may be derived about the causes of any floristic patterns.

Four specific questions were addressed in this study:

i) How does the floristic composition vary spatially between plant communities/forest types, especially regarding endangered species?

ii) Do differences in environmental variables explain a significant proportion of occurrence and abundance of both common species and endangered species?

iii) How do the environmental conditions vary spatially? Are there particular areas in the forest to which endangered species could be transplanted for protection or grown for exploitation? And

iv) What are the relationships between floristic composition and environmental conditions in Ba Be National Park of Vietnam?

4.2 Materials and methods

In this section the rationale of the experimental design and the criteria for choice of study sites are presented; a description of the study area is given. Field surveys were undertaken between September 2005 and November 2006 within BBNP. Australian supervisors and the author participated in both surveys. A specialist in

plant ecology and identification from Thainguyen University of Agriculture and Forestry and staff of Ba Be National Park also assisted with these surveys.

4.2.1 Description of the study area

Study area

The area of ecological study was at 12 sites in Ba Be National Park, which is a strictly protected conservation reserve covered by natural forest approximately 7,610 ha in area. Geographical co-ordinates are 105°34'-105°42'E and 22°21'-22°29'N (See figure 4.1). The site ranges in altitude from 150 to 1,098 m above sea level (asl). The geology of the area is predominantly limestone, with numerous rugged peaks and deep, steep-sided river valleys.

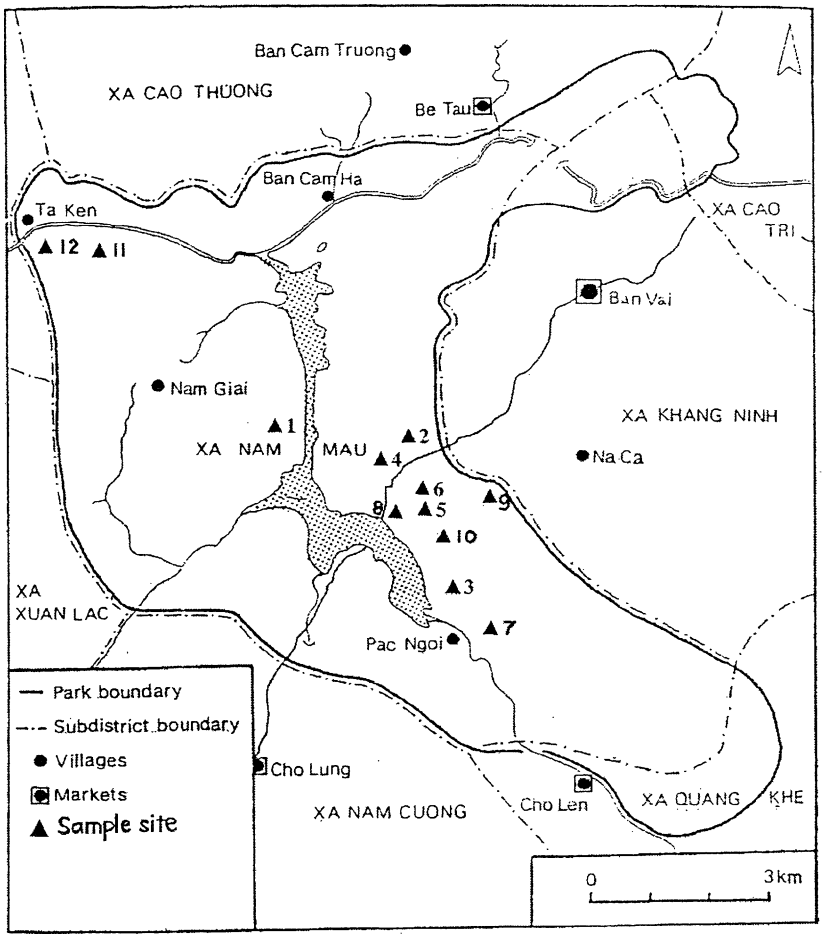


Figure 4.1: Sites where environmental data were collected, in 12 quadrats in Ba Be National Park.

The forest at BBNP can be classified into two main types: limestone forest and lowland evergreen forest. The limestone forest is distributed on steep limestone slopes with shallow soil, and covers a large proportion of the national park. Lowland evergreen forest is distributed on shallow slopes with deeper soils; this forest type has higher tree species diversity than limestone forest and has a richer ground flora (Hill *et al.,* 1997). BBNP is unique amongst Vietnamese protected areas for the diversity of freshwater habitats. This is reflected to some extent in the diversity of phytobenthos species found at the site.

Vegetation Study

Ba Be National Park contains a range of plant community types which have been well documented (Kemp *et al.,* 1994; Hill *et al.*, 1997; Chan and Nguyen, 2003; Loc *et al.,* 2003). The first detailed description of the vegetation in this area was undertaken by the Ministry of Agriculture and Rural Development (1977); it recognized about 504 vascular plant species in 137 families. Later studies, including a floristic classification scheme for the area, have been described by Kemp *et al.,* (1994) and Hill *et al.,* (1997) who recognized a total of 603 species of vascular plants in 137 families, including 10 species listed in the Red Book of Vietnam.

The terrestrial vegetation of BBNP is dominated by lowland tropical forest on limestone. Dominant tree species include *Streblus tonkinensis* (Moraceae), which is an important element of the lower canopy, especially on disturbed rocky slopes and where intensive felling has occurred. *Burretiodendron tonkinensis* (Timaliaceae) is a common upper canopy tree. The lowland forest formations are characterized by a relatively simple canopy structure, low canopy height, and a scarcity of climbing species (Trai *et al.,* 2004). The tree species represented in higher altitude forests differ physiologically from those of lowland tropical rain forest, and plant families which are uncommon, or completely absent at lower altitude form an important component of the canopy, including Lauraceae, Fagaceae and Podocarpaceae (Quac *et al.,* 1999).

The forest formation on the main ridge top of BBNP is composed of mixed coniferous and broadleaf tree species. These ridges support rare conifers such as *Amentotaxus* sp, *Pinus* sp. and especially string bamboo (*Sinocalamus mucclure*), an endemic species that only occurrs in BBNP. The vegetation types within BBNP support valuable habitat for wildlife, in particular for rare and globally endangered primate species.

4.2.2 Experimental Design

Site selection

Twelve sites were chosen within BBNP to cover a wide range of vegetation types existing within the area as identified by Parthasarathy and Karthikeyan, 1997; HELVETAS, (1999); Phon *et al.,* (2000); Khanh *et al.,* (2003) and On *et al.,* (2002). Sites selected were sampled for both floristic and environmental characteristics shown in Table 4.1. Each site was sampled on a single occasion between September 2005 and November 2006. A detailed description of the sites is provided in Table 4.1.

Of the 12 sites, two were near the lake and river, four were near villages and tracks, two were in secondary forest, and three were on the midslope of the mountains and one site on the top of a mountain (Figure 4.1). Vegetation data in different locations were used for comparison analysis. These same sites were double-checked again in November 2007 for more information.

Site criteria

Correlations between vegetation and environmental factors have been examined by Le Brocque and Buckney (1995) in Ku-ring-gai Chase National Park, Australia and On *et al.,* (2001) in Ba Vi and Ba Be National Parks, Vietnam. This study also sampled for both floristic and environmental characteristics shown in Table 4.2. A detailed description of sampling follows.

4.2.3 Data Collection

Site Location

Site identification used topographic maps of the Department of Land Administration in 1992 (Scale 1:25,000), natural resources maps of Ba Be National park in 1993, land-use planning map of BBNP in 2000; slope and aspect data and dominant species recorded in these surveys were used, where possible.

Site location was also checked using vegetation maps of BBNP in 1993, and the maps database of PARC (Creating Protected Areas for Resource Conservation using Landscape Ecology) project. Actual quadrat sampling sites were located after initial surveys of the area based on the above criteria. Site locations are shown in Figure 4.1 and Table 4.1.

Table 4.1: Summary of species data and characteristics of 12 quadrats located in different habitats. Four different forest types were the moist sites near the Lake and river, and in the valley of the mountain (MS), closeness to village and track (DT1), Secondary forest and affected by deforestation (DT2), located in Middle and Top of the Mountain (RU).

Quadrats	Number of Species	Number of Individual plants	Locations			Type of Forest
			Altitude (m)	Longitude	Latitude	
1	58	602	175	105.36.86	22.22.14	MS
2	32	252	250	105.37.86	22.24.98	MS
3	33	331	171	105.37.72	22.24.35	DT1
4	31	350	316	105.37.60	22.24.78	DT2
5	33	277	398	105.37.71	22.24.65	RU
6	29	236	420	105.37.78	22.24.68	RU
7	36	293	224	105.37.86	22.24.14	DT1
8	21	174	254	105.37.71	22.24.54	DT1
9	23	245	624	105.37.97	22.24.68	RU
10	21	174	470	105.37.81	22.24.71	RU
11	26	305	231	105.33.98	22.26.83	MS
12	32	324	230	105.33.55	22.26.25	DT2

Table 4.2: Summary of floristic and environmental variables measured within each quadrat in 12 sites sampled in Ba Be National Park, Vietnam

Soil Data	*Disturbance*
Soil type	Distance to nearest village
Soil pH	Distance to nearest track
Soil depth	Liana cover
Soil moisture	Eroded stone cover
Soil color	Deforestation
Surface water availability	Epiphyte cover
Vegetation Data	*Physical Data*
Litter cover	Location of site
Canopy cover	Degree of visible rock
Green cover	Soil without rock
Brush cover	Altitude
Bamboo cover	Slope
Grass cover	Aspect
Floristic Data	*Dominant species*
Plant frequency	Dominant trees
	Endangered species

Floristic Composition

To determine floristic composition, 12 quadrats were established in different habitats and types of forest, with different topographies: low, middle or top of the mountain. Each quadrat was divided into 40 square sub-quadrats of the same area (i.e. equal square sub-quadrats) (Figure 4.2). Le Brocque and Buckney, (1995); Parthasarathy and Karthikeyan, (1997) and Statzenko, (2002) applied a nested square quadrat system to survey vegetation patterns in Australia but this method was not suitable in BBNP because of topographic factors. In Vietnam, On *et al.*, (2001) used equal square sub-quadrat divisions to research vegetation and environmental patterns in Ba Vi National Park and Khanh *et al.*, (2003) also used this method in BBNP.

The quadrats were selected based on maps of BBNP. The area of each quadrat was 1000 m^2 (20 x 50m), each sub-quadrat was 25 m^2 (5 x 5m). The quadrats

were recognized by measuring tape to begin from the middle of the quadrat and parallel with sea level. The upslope side of each quadrat was adjusted for the slope within it to ensure each quadrat's horizontal projection was the same. The border line was marked by tape measure and paint. Numbers of plants were also counted

The quadrat/subquadrat method used allowed analysis of the data at a number of scales of area by combining data from a selected number of adjacent subquadrats. For this study, three different scales were used: 1000 m^2, 500 m^2 (divided into 2 subquadrats from 1000 m^2) and 200 m^2 (divided into 5 subquadrats from 1000 m^2) as explored in Section 4.3.3 and shown in Figure 4.2.

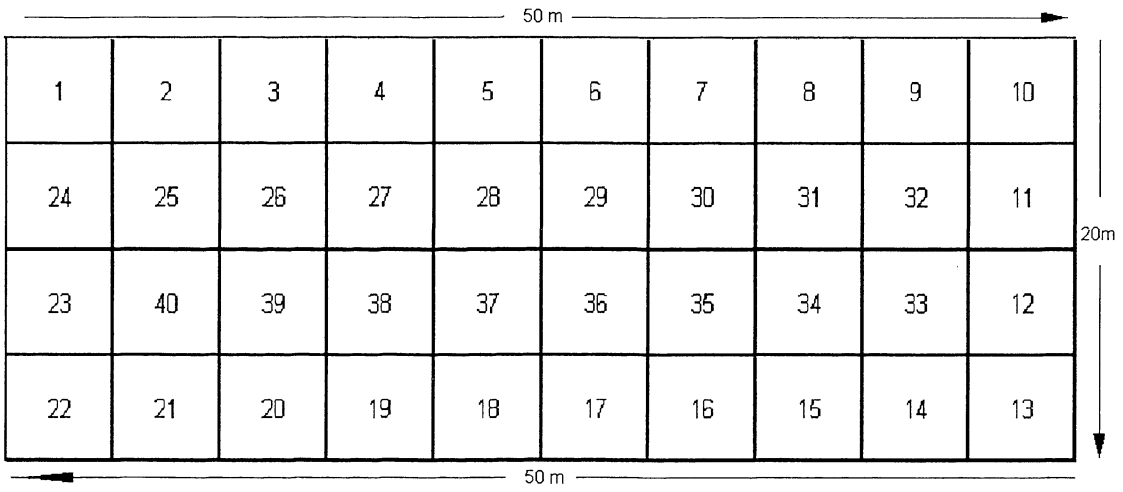


Figure 4.2: Representation of square quadrat and the sequence used to survey the floristic composition (begin from sub-quadrat 1 to the end: sub-quadrat 40) for all 12 quadrats in BBNP.

During the field survey, observations of vegetation composition and plant identity were carried out in areas beyond the quadrats. Informal surveys were also made in other biotopes, in order to identify characteristic and endangered species; in most of these cases, plants were only identified to the genus level.

After collecting general data on the soil, disturbance, vegetation and physical data of each quadrat, botanical specimens were collected throughout the study area in a variety of different (geobotanical) habitats. The survey follows Ho (1993) and FIPI (Vietnam's Forest Inventory and Planning Institute) (1996).

Further taxonomic classification is based on Takhtajan, (1987) for families and genera. Identification of trees and lianas in the field was based on morphological characters: bole color and structure of bark, branching pattern, and canopy construction. Leaves and flowers collected from the ground were compared with those of the canopy with binoculars (7x50). For species which could not be identified in the field, herbarium specimens were collected for later identification.

Our experience has shown that a single cut in the bole can provide much information on tropical woody plants in order to identify the family and genus. The plant identification specialist helped with the implementation of this study. Two to three incisions in branches or buttresses are generally sufficient, but sometimes one to two more cuts may be necessary. The smell of the cut in timber (usually very specific, particularly from Lauraceae, Magnoliaceae, Rosaceae or Meliaceae members), the color, including the rate of changing color and the general aspect are important characters to look for. For instance: milky white sap is characteristic of Asclepiadaceae, Burseraceae, Moraceae etc.; yellow and white sap of Clusiaceae; red and sticky sap of Connaraceae, Vitaceae etc.

Site Physical Characteristics

Site environmental characteristics were chosen to avoid complex and expensive measurements; all were assessed on site or in the laboratory using easily-available equipment and materials.

Within each quadrat site physical characteristics (altitude, slope, aspect, location of the quadrat, degree of visible rock and soil without visible rock) were determined. Altitude was determined by a hand-held altimeter (Casio Alti-Depthmeter, model no. 376DI) and cross checked with 1: 25,000 topographic maps. A clinometer (Suunto Optical Reading Clinometer, Model no. PM-5/360PC) was used to determine the slope, measured as degrees, of the quadrat. Aspect was determined with a compass and reported here as the nominal categories: north, south, east and west. The location of quadrats was identified by

a Geographical Positioning System (Garmin GPS II Plus) and as occurring in valley bottom, down, middle and top of the mountain. Visible rock and soil without visible rock were recorded base on mean percentage of above factors that factors were occurred in each sub-quadrat (from 5-90%).

Site Disturbance Characteristics

The distances to the nearest village and to the nearest track were based on the topographic and land administration maps (from 500-10,000m). Epiphyte and liana cover were divided into 3 levels ($\leq$5% = little; 5-20%= average; $\geq$20% = very much). Eroded stone cover was estimated as the mean percentage that occurred in each sub-quadrat. Deforestation level was identified by visible human effects in the forest (divided into 3 levels: no effect = natural forest; little effect = vegetable/medicine collection; very much = extensive [probably illegal] collection).

Site Vegetation characteristics

All six factors (litter, canopy, green, brush, bamboo and grass cover) were recognized as the mean percentage of them occurring in sub-quadrats. However, the litter cover focused on the degree of decomposition of the vegetation above ground; canopy cover refers to the degree of leaf cover. Green cover is the cover of all of the vegetation cover on the ground and brush cover is the percentage of all bush/brush occurring in the quadrat area. The difference between bamboo cover and grass cover is that bamboo cover is a plant belonging to the Bambusoideae whereas grass cover refers to smaller species occurring near the ground in the Poaceae.

Site Soil Characteristics

Three to five soil samples were collected diagonally from corner to corner and centre in arbitrary points within each quadrat, bulked and sealed in plastic bags. Samples from around obvious active or former ant nests were avoided due to the possible localized changes in soil physical and chemical properties (Carlson and

Whitford, 1991; Clay *et al.,* 2001; Minh, 2007). Where possible, samples were collected using a PVC soil corer (5 cm diameter) to a depth of approximately 10 cm, after brushing aside any surface litter. In sites where the soil was too shallow or rocky to allow use of the corer, samples were collected using a stainless steel trowel.

Soil pH was measured by a Sentix 41 Pocket Meter (model no. pH330i) on three replicate 1:5 soil water extracts after shaking for 1 hour; soil type was recognized by physical components such as humus rich (Hu=1), clay (Cl=2), alluvial land (Si=3) and sandy soil (Sa=4). Depth of soil was identified by digging a profile; color of soil was compared with colorimetric paper. Soil moisture is divided into 4 levels (1=very dry; 2=quite dry; 3=moist; 4=wet). Water availability was divided into five levels (1=water held all year; 2=semi-permanent; 3= seasonal water; 4=semi-dry; 5=dry).

Site dominants and endangered species

The dominant trees in quadrats were identified from the results of the field surveys based on frequencies (detailed result was shown in Table 4.4), and the endangered and endemic species were as classified by the Red Book of Vietnam and Red list of IUCN.

There are a number of potentially confounding effects that could cause artifacts in the results. In the first instance, the use of two different recorders for vegetation and environmental data was a potential source of inconsistency. Both recorders endeavored to be as thorough as possible in collecting data, identifying species and analyzing data. A pro-forma (Appendix 4) was used to enhance uniformity of data collection. Secondly, to avoid potential artifacts due to comparison of different data types, frequency was used in this study for the analysis of dominant species in environmental factors. However, the selection of site location avoided the confounding effects of species and other factors' frequencies on floristic composition (French *et al.,* 2000; Lisa *et al.,* 2006).

It is important that species could be identified in the BBNP to avoid other potential artifacts. Vegetation, endangered species and environmental patterns were readily identifiable at BBNP as has been found by Kemp *et al.,* (1994); Hill *et al.,* (1997) and Khanh *et al.,* (2003). As a further measure, specimens were collected in the field and compared to herbarium specimens collected by the Department of Environmental Sciences at the University of Technology, Sydney and Faculty of Natural Resources and Environment of Thai Nguyen University of Agriculture and Forestry.

4.2.4 Data Analysis

A database for the vegetation and environmental pattern survey was initially established in EXCEL for general statistical information. PRIMER (V5.0) was used to analyse the relationship between floristic composition of quadrats and their relationships to environmental factors.

Univariate statistical analysis of vegetation

For each quadrat a number of indices were calculated: number of species, number of native species and number and percentage of endangered species. Indices were then tested for significant differences between different quadrats in BBNP. The percentage of endangered species was expected to have heterogeneous variance and was analyzed using non parametric tests in SPSS or EXCEL. The number of species and endangered species had homogenous variances and were analyzed using analysis of variance (ANOVA). The number of native species was log transformed to fulfill the assumption of homogeneity of variances and then analyzed using ANOVA.

To test for variation between different habitats, significant differences were tested for between all quadrats. Percentage of endangered species at each quadrat was tested and all other indices were analyzed using ANOVA.

Correlations between indices were conducted using EXCEL and an alpha value of 0.05. The Pearson Product-Moment Correlation was used to compare the

number of species and number of native species after data was log transformed to fulfill the assumption of normality. All other indices were tested with the Spearman Rank Correlation analysis because data could not be transformed to attain normality.

Multivariate statistical analysis of vegetation

Multi-dimensional scaling ordination (MDS; PRIMER) was used to look for patterns in community composition between quadrats. Using frequency data for each species at each quadrat, the Bray Curtis similarity measure was used to construct a similarity matrix. The MDS ordination uses the similarity matrix to define and display the relationship between quadrats based on rank similarities; the relative distances apart of all points are in the same rank order as the dissimilarities of the samples (Clarke and Gorley, 2001; Thorne, 2005). The orientation of an MDS diagram is arbitrary, so no scales are shown on the axes. The SIMPER method or Similarity Percentages procedure (PRIMER V5.0) was used to examine species that most contributed to the patterns shown by MDS analysis. SIMPER assesses which species are good discriminators between groups and which species contribute most to the similarity within groups. MDS ordination was conducted with endangered species and other plant types (lianas, grasses, sedges, fern and shrubs) removed to assess the influence of then on ordination patterns. To compare the similarity of the two ordinations RELATE (PRIMER V5.0) was conducted between the two similarity matrices. Another MDS ordination was conducted on all species as samples to see if there was a pattern of species distribution and if any groups of species commonly occurred together. The least common species were removed from the analysis, including endangered species with very low abundances.

Univariate statistical analysis of environmental patterns

A total of 26 environmental variables or indices were tested for significant differences between different habitats in all quadrats, including soil data, disturbance data, vegetation data, physical data and endemic and endangered

species. To test for variation within different habitats, significant differences in environmental factors were tested for between all quadrats.

Correlations were conducted between all variables using the non-parametric Spearman Rank Correlation analysis because not all indices fulfilled the assumption of normality. Indices that had normal data or could be normalized using transformations were tested using the Pearson Product-Moment Correlation; however, results of several indices were not consistent with the Spearman Rank Correlation results so it was not used.

Multivariate statistical analysis of environmental patterns

A Principal Components Analysis (PCA; PRIMER V5.0) ordination was used to measure dissimilarity/distance of quadrats from each other in terms of environmental variables. Environmental variables are abiotic data and have mixed measurement scales (e.g. Bamboo cover in %, soil depth in m) and therefore a dissimilarity measurement such as Bray-Curtis (used for species data), which assumes a common measurement scale is not appropriate. PCA puts the data on a common, dimensionless measurement scale and uses the Euclidean distance as the dissimilarity measure (Clarke and Gorley, 2001; Thorne, 2005). PCA works best when the data is as near as possible to normal so a Draftsman Plot (PRIMER V5.0) was used to test linearity of relationships. A log transformation was applied to all data to bring it closer to normality before running the PCA. Five different groups of environmental factors were highly correlated together and excluded from the analysis. The PCA reduces the 26 dimensions (number of variables) to a two dimensional graph with two axes that are linear combinations of the input variables. The 2-D plot attempts to capture as much of the variability as possible and the extent to which it is a good reflection of the relationship between the quadrats is summarized by a % variation value (Clarke and Gorley, 2001).

Regressions of vegetation and environmental patterns

Linear regression analysis (SPSS) was used to see how well the different environmental variables could explain variation in the percentage of endangered species at each quadrat (zero percentage quadrats were removed from the analysis).

Multivariate analysis of Vegetation and Environmental patterns

To examine the relationship between environmental variables and floristic composition the BIOENV procedure (PRIMER V5.0) was used. The procedure compares the Bray-Curtis similarity matrix of the species data with the Euclidean matrix of the environmental data through rank correlation. The analysis shows which environmental variables best explain species variation and a Spearman Rank Correlation value is calculated to show the strength of the relationship (Clarke and Gorley, 2001). All environmental data was log transformed, consistent with the PCA analysis. An MDS ordination of quadrats based on combinations of variables identified by BIOENV analysis was constructed using Euclidean distance to construct the matrix. Using RELATE, it was then compared to the vegetation MDS similarity matrix (using Euclidean distance).

4.3 Results

4.3.1 Vegetation analysis

(a) General floristic patterns

A summary of the data on forest plants for all sites is shown in Tables 4.3 and 4.4. The results show that the number of species varies widely from 21 to 58 species for each quadrat, and the number of individual plants also ranged from 174 to 602 individuals per quadrat. Site 1 had the highest number of species and individuals and the lowest number of species and individuals were in sites 8 and 10. The detailed composition of all 12 quadrats is given in Table 4.3 and Appendix 5. The utility of the species is given in Appendix 6.

Table 4.3: Summary of species and individual composition occurred in 12 quadrads in BBNP

Quadrads (sites)	1	2	3	4	5	6	7	8	9	10	11	12
Number of species	59	32	33	31	33	29	36	21	23	21	26	32
Number of individuals	601	252	331	350	277	236	293	174	245	174	305	324

In this study, 161 species, 124 genera and 64 families of flora in 12 sites have been recorded. Magnoliopsida had the highest number and percentage of species (over 79%) compared with other taxa. Dominant limestone species include *Burretiodendron tonkinensis* and *Streblus tonkinensis*; string bamboo (*Sinocalamus mucclure*) is endemic to the region and often found on hill slopes that lie adjacent to the lake.

Table 4.4: Summary of species composition in 12 quadrats in BBNP.

Branch	Family		Genus		Species	
	Number	Ratio (%)	Number	Ratio (%)	Number	Ratio (%)
Fungi – Mycophyta *	1	1.54	1	0.80	1	0.62
Lycopodiophyta	1	1.54	1	0.80	1	0.62
Polypodiophyta - Fern	4	6.25	5	4.00	9	5.56
Magnoliopsida	51	78.46	101	80.80	131	80.86
Liliopsida	8	12.31	17	13.60	20	12.35
TOTAL	65	100.00	125	100.00	162	100.00

** Note: Only one fungus was mentioned by local people as difficult to find; other species were ignored. The percentages of other taxa are little changed if this species is omitted from the Table.*

Sites near the Lake, River and in Valleys (MS: *moist*)

MS included quadrats 1, 2 and 11; this forest on steep slopes was located along lake and river banks (150-300 m asl).

Quadrat 1 was located on the western side of the lake, close to the lake bank (10m). A large proportion of the ridge is composed of rocky outcrops with shallow soil (about 30 cm). The topography was steep, averaging 30-45°, although to make measuring feasible, quadrat 1 was located on medium steep ground with an angle of 40°. The forest showed three distinct layers, the upper

canopy (to 20m), mid-canopy (5-20m), and a ground herb and sapling layer (below 5m). The main species present in the upper canopy was *Burretiodendron tonkinensis*, while the mid-canopy was dominated by *Cleistathus petelotti* and *Polyalthia subcordata.* Some endangered species occurred in this quadrat, including *Burretiodendron tonkinensis, Amomum villosum, Garcinia fagraeoides* and *Stephania sinica* (*sepharantha* Hayata.). as well as string bamboo (*Sinocalamus mucclure*) and *Ficus altissima*, only found in Ba Be National Park.

Quadrat 11 was located on steep karst walls, near the Dau Dang waterfall (North-East side of the lake) on a steep slope (around 16°). The dominant tree was *Streblus tonkinensis* (*ilicifolius* (Vidal) Com.) that occurred in all 40 sub-quadrats. Perhaps due to the dense shade caused by the mid-canopy of *Streblus tonkinensis,* the shrub and ground layers of vegetation contained very few species adapted to permanent existence on the forest floor. Four endangered species were found in this quadrat which are *Burretiodendron tonkinensis, Amomum villosum, Garcinia fagraeoides* and *Melientha suavious.*

Quadrat 2 represents a specific biotope, which experiences year-round high humidity near the Park office. The substratum comprises a 35 cm deep layer of very small limestone karst fragments, developed on a monolithic karst platform. It occurs in a permanent stream valley at 250 m asl supporting a forest formation dominated by the tree species *Streblus macrophyllus.* Four endangered species occurred in this quadrat *Burretiodendron tonkinensis, Stephania sinica* (*sepharantha* Hayata.), *Garcinia fagraeoides* and *Melientha suavious*

***Distance to Nearest Village and Track* (DT1*: disturbance 1*)**

This forest type comprised 3 quadrats (3, 7 and 8), and was located in the East of the Park near the track and Tay village of Pac Ngoi at an altitude of 171 to 254 m asl. It is situated on a steep slope of limestone boulders (the mean slope was 25-45°). The proximity of the village meant that this area was easily exploited for wood and timber. Possibly as a result of human and physical disturbance on the

site, the diversity of species taxa was extremely low, and high value species were rare.

Forest canopy structure consisted of 3 tiers. The main species present in the upper canopy for all 3 quadrats was *Burretiodendron tonkinensis*, whilst the mid-canopy was dominated by *Streblus tonkinensis* and the lower canopy mainly brush and grass covers.

***The secondary forest sites* (DT2: *disturbance 2*)**

DT2 had 2 quadrats: quadrat 4 was located in the southeast area of the park and near the park office. The forest structure is secondary forest on slopes of limestone plateau. The structure of tree stands on slopes of limestone plateaus have changed significantly. Species composition is low and trees are mainly small due to the logging of most large trees. The lower storey is well-developed with the following dominant species: *Celtis sinensis* and *Streblus macrophyllus.* As a result of little shade from the upper storeys, the forest floor has some pioneer trees and big ground herbs such as *Amomum villosum* and *Alangium kurzii.* The upper canopy was *Acer tonkinensis* and this species is also endemic for the north of Vietnam.

Quadrat 12 is located in the north-west area of the park with the secondary forest on clay hills; the soil is a heavy sub-clay. A parental material (schist) is situated at 1-1.5 m in depth. A humus horizon is well developed and has attracted agriculture in this area. As a result of 15 years of cultivation in this quadrat area, upland rice and maize fields are common. The mainly dominant trees are ferns, herbs, grass and shrubs such as *Dicranopteris lineari* and *Musa acuminata.* The floor of the basin had recently been selectively logged, with most of the large trees being removed. The forest on the surrounding slopes was less disturbed.

***The relatively undisturbed sites* (RU:)**

RU was located on the rocky slope of a limestone basin including quadrats 5, 6, 9 and 10, in the south east of the Park near the forest protection station, where

altitude ranged from 398 to 624 m asl. The gradient of these sites was again steep (30-40°). The diversity of woody species present was much higher here than in the other quadrats studied.

Forest composition showed a well developed upper canopy of very tall trees (30-40m). Among the more important families represented in this layer were Tiliaceae (*Burretiodendron tonkinensis*) and Clusiaceae (*Garcinia fagraeoides*). The middle canopy was also highly diverse and *Streblus ilicifolius (tonkinensis)* was the dominant tree. This site also contained a relatively large number of endangered species such as *Markhamia stipulata, Burretiodendron tonkinensis, Garcinia fagraeoides, Stephania sinica* and *Melientha suavious.*

Floristic patterns

A total of 162 species were found in 12 quadrats in BBNP, of which 13 (8.02%) were endangered and endemic species. The highest number of endangered and endemic species found in any quadrat was seven (12.06%), found in one quadrat near the lake (quadrat 1, a moist site). The highest percentage of endangered species in a quadrat was 19.04% in quadrat 8. All four forest types (MS, DT1, DT2 and RU) had an average percentage of endangered and endemic species of 11.72%. All but quadrat 12 had endangered species present.

Only quadrat 1 had species endemic to BBNP of Vietnam, occurring in a small area: *Sinocalamus mucclure* Sp (Le.M.C.) and *Ficus altissima* Bl. The most common species were native species (Table 4.5). The full species list is shown in Appendix 5.

Three endangered species occurred in over 50% of all quadrats: *Burretiodendron hsienmu* was found in [91.66% (11/12)], *Garcinia fagraeoides* [58.33% (7/12)] and *Melientha suanvis* [50.00% (6/12)]. Some endangered species were very common and dense, occurring in nearly all sub-quadrats (more detail in Appendix 5 and 6). Many of them were recorded at nationally and globally levels of threatened extinction in the Red Book of Vietnam and Red List of IUCN; for

Table 4.5: The 13 most common species based on the percentage of total quadrats (12) and the number and percentage of individuals occurring.

Species	Occurrence (% of quadrats)	Number of individual (in 12 quadrats)	Occurrence (% of total individuals)
Burretiodendron hsienmu Chun et How.	91.67	171	4.82
Celtis sinensis Person.	75.00	74	2.09
Cleistathus petelotii Merr. – Ex Croizat.	66.67	117	3.30
Cyclosorus parasiticus (L) Farw.	58.33	78	2.20
Diospyros sylvatica Roxb.	58.33	70	1.97
Diospyros variegata L.	50.00	46	1.30
Garcinia fagraeoides A. Chev.	75.00	114	3.21
Maoutia puya (Wall.) Wedd.	58.33	56	1.58
Meliantha suanvis Pierre.	58.33	49	1.38
Stephania sinica Diels.	50.00	15	0.42
Sterculia lanceolata Cav.	50.00	48	1.35
Streblus ilicifolius (Vidal) Com.	91.67	348	9.81
Tetrastigma planicaule (Hook) gagnep.	58.33	76	2.14

example, *Burretiodendron tonkinensis* was recorded as vulnerable in Vietnam and endangered by IUCN. However, only 38.46% (5/13) of 13 endangered and

Table 4.6: The endangered and endemic species found, in order of frequency of occurrence, expressed as a percentage of total quadrats (12) and the number and percentage of individuals occurring.

Species	Occurrence (% of quadrats)	Number of individual (in 12 quadrats)	Occurrence (% of total individuals)
Anoectochilus setaceus (Blume). Lindl	8.33	22	0.62
Ardisia silvestris Pitard	8.33	4	0.11
Chukrasia tabularis A.Juss (1)	8.33	3	0.08
Cycas balansae L.	8.33	16	0.45
Ficus altissima Bl	8.33	2	0.06
Sinocalamus mucclure Sp. (Le M.C)	8.33	37	1.04
Tetrapanax papyriferus (Hook.) C.Koch	8.33	4	0.11
Markhamia stipulata (Wall.) Seem.	16.67	5	0.14
Hydnocarpus hainania sp	33.33	36	1.01
Stephania sinica Diels	50.00	15	0.42
Meliantha suanvis Pierre	58.33	49	1.38
Garcinia fagraeoides A. Chev	75.00	114	3.21
Burretiodendron tonkinensis Chun et H.	91.67	171	4.82

endemic species were ranked by local people (Chapter 3). Seven of thirteen species were encountered only once (Table 4.6).

(b) Results of univariate statistical analyses

The mean numbers of total species, common species and endangered and endemic species were marginally less at RU sites but the ANOVA analysis showed the differences were not significant (Table 4.7). There was no difference in the percentage of endangered and endemic species.

Table 4.7: Mean values of plant indices at MS, DT1, DT2 and RU sites. Numbers in brackets are standard errors of the mean. No indices are significantly difference ($P > 0.05$).

Sites	Total number of species	Number of common species	Number of endangered and endemic species	Percentage of endangered and endemic species
MS (n=3)	38.66 (8.02)	33.66 (7.14)	3.00 (0.94)	13.08 (1.05)
DT1 (n=3)	30.00 (3.74)	26.00 (3.74)	4.00 (0.00)	19.86 (6.74)
DT2 (n=2)	31.50 (0.35)	29.50 (1.77)	4.00 (1.41)	7.16 (4.06)
RU (n=4)	26.50 (2.38)	23.50 (2.30)	3.00 (0.35)	11.59 (1.41)

(c) Results of Multivariate statistical analyses

The Multi-Dimensional Scaling (MDS) ordination of all quadrats shows clear (stress = 0.01) gradients of floristics among 3 site types (MS, DT1 and RU) [Figure 4.3 (a)]. However, site type DT2 was separated from the other groups and varied. This site type is a secondary forest (after deforestation); it is remote from the main management centre of the Park, while DT1 sites are near the Park offices.

The MDS ordination with liana species removed from the analysis [Figure 4.3 (b)] is similar to the ordination with all species included [in Figure 4.3 (a)]. The Spearman rank correlation coefficient, produced by RELATE, between the two ordinations was 0.115, which was significant (4.2%).

Sequentially, all grass, sedge, ferns and shrub were removed from analysis. Multi Dimensional Scaling (MDS) showed a low stress (0.01) with clear groups of quadrats. As can be seen in Figure 4.3 (c), all quadrats of MS, DT1 and RU were grouped together, even with 1 quadrat of the DT2 site type. In this Figure, only 1 DT2 quadrat was separated; that is quadrat 12, which is still experiencing agricultural activities after deforestation. The other quadrat (4), with no ongoing disturbance migrated to show similarity to the other site types.

Next, all liana, grass, fern, sedge and shrub were removed from analysis [Figure 4.3 (d)]. The figure showed that the result was little different to Figure 4.3 (c) after removing grass, fern, sedge and shrub; the one DT2 site was still separated.

When all trees were removed from the analysis, the vegetation compositions were changed a great deal [Figure 4.4 (b)]. The MDS showed differences between site combinations and the overall picture of the forest was different from forest with all plant species. This shows that tree species contribute a great deal to the similarity between sample sites. With trees removed from the data set, the relatively undisturbed sites appear the most varied group and the two disturbed site groups the least varied, suggesting that disturbance imparts relative uniformity to the understorey.

All endangered and endemic species were removed from analysis [Figure 4.4 (c)] and showed a pattern quite similar to that after removing all the tree species. However, the result was very different to the ordination with all species included. The Spearman rank correlation coefficient, produced by RELATE, between the two ordinations was 0.17 with a significance level of 1.5%.

Finally, all endangered species recognized by local people (result from Chapter III) were removed [Figure 4.4 (d)]. The result from MDS shows that the floristic structure also changed similar to that of removing all endangered species recognized by IUCN and Red Book as given in Figure 4.4 (c).

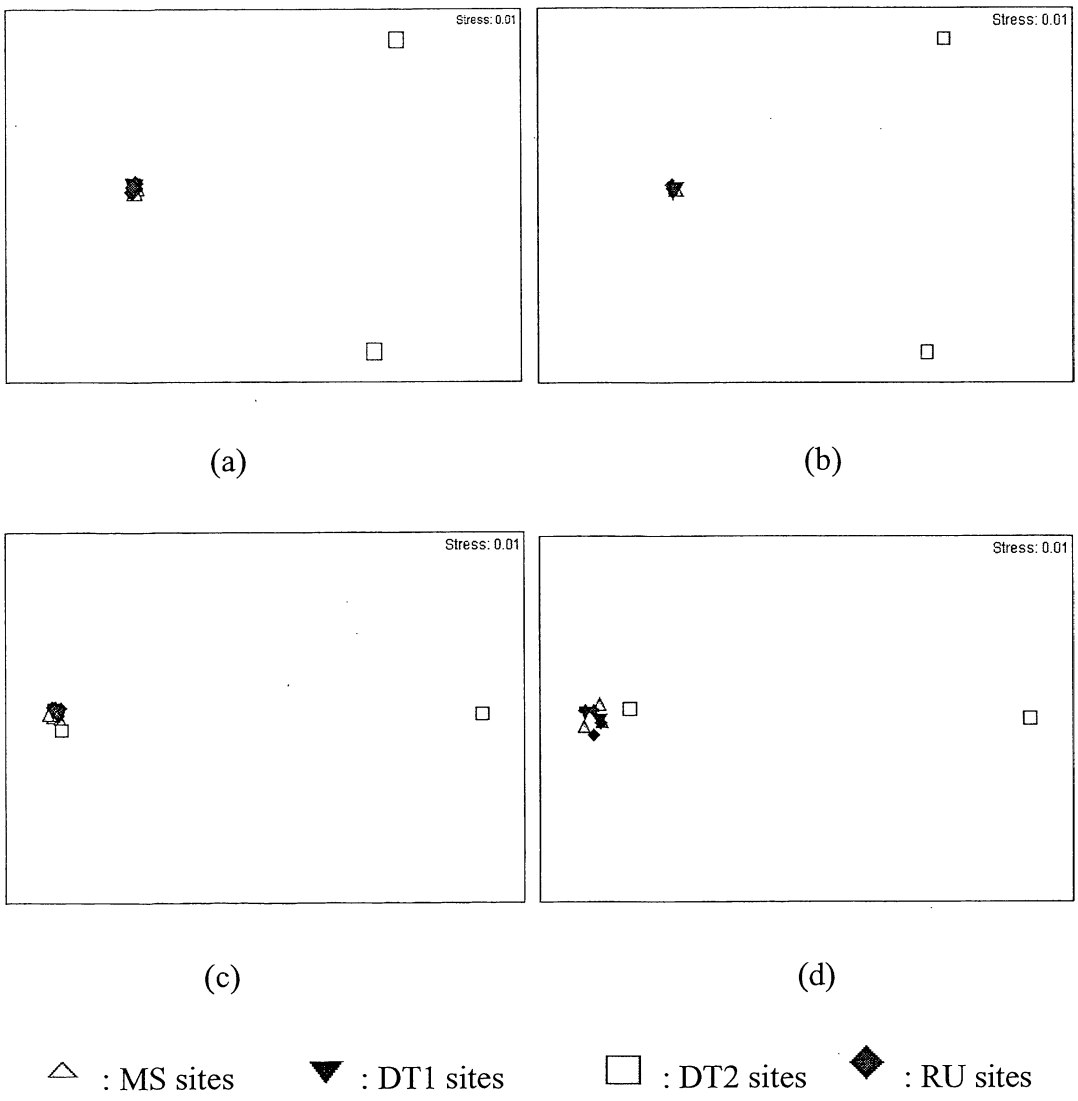


Figure 4.3: MDS (a) ordination of 12 quadrats based on all floristic composition, MDS (b) ordination of 12 quadrats after removing all liana species, MDS (c) ordination of quadrats after removing all grass, fern, sedge and shrub species, MDS (d) ordination of quadrats after removing all liana, grass, fern, sedge and shrub species. MS sites are moisture and near the lake and river, DT1 sites are disturbance, near the village and track, DT2 sites are secondary forest and RU sites are relatively undisturbed .

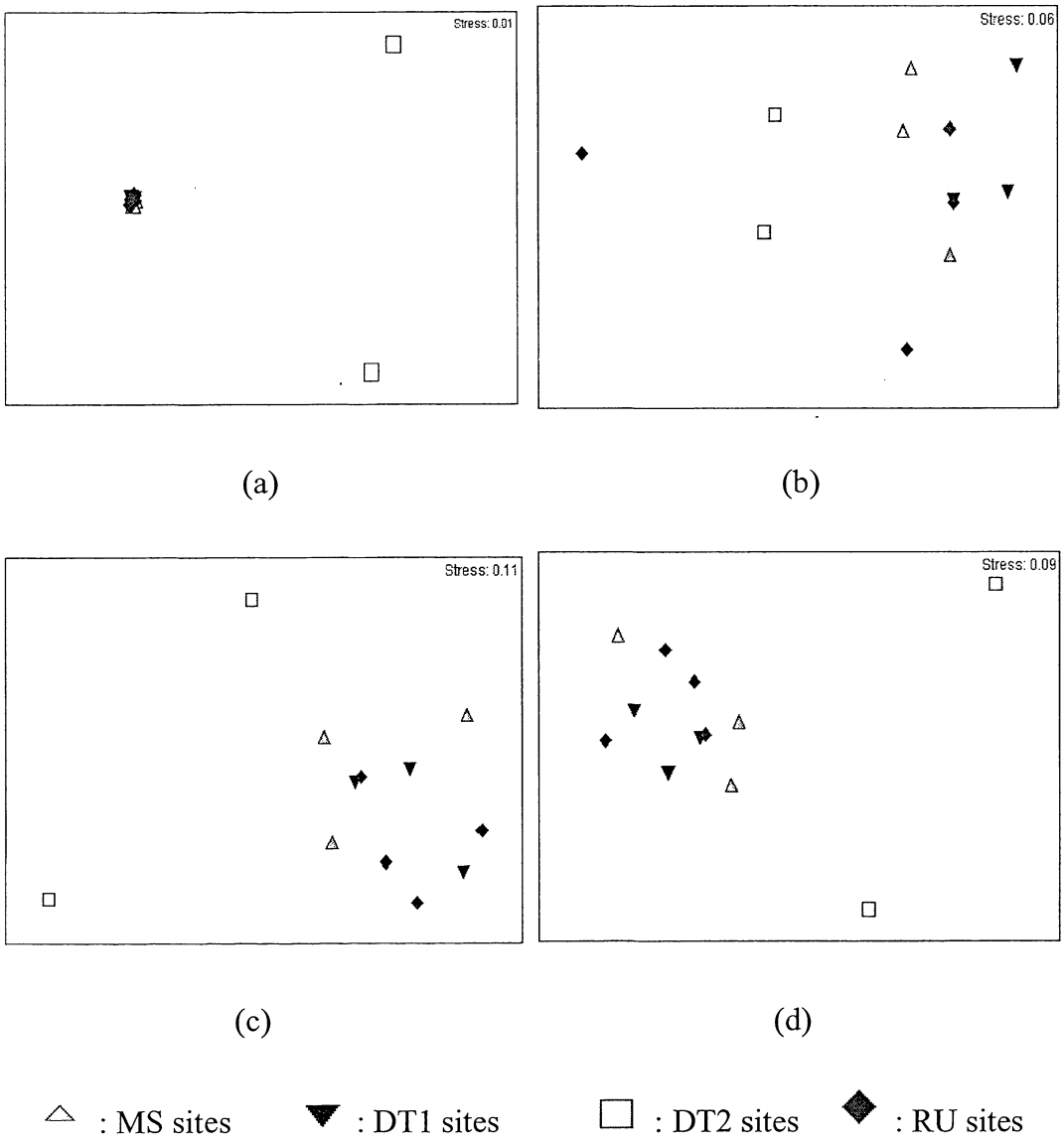


Figure 4.4: MDS (a) ordination of 12 quadrats based on all floristic composition, MDS (b) ordination of 12 quadrats after removing all tree species, MDS (c) ordination of 12 quadrats after removing all endangered and endemic species, MDS (d) ordination of quadrats after removing all endangered species classified by local people. MS sites are moisture and near the lake and river, DT1 sites are disturbance, near the village and track, DT2 sites are secondary forest and RU sites are relatively undisturbed .

Species that contributed up to 50% of the average Bray-Curtis similarity using SIMPER for MS, DT1, DT2 and RU sites are listed in Table 4.8. Average abundance refers to the average presence of the species per quadrat within the site type. Contributive percentage refers to the percentage of species contribution. Cumulative percentage refers to the cumulative influence of each

species to the overall Bray-Curtis value. For example in the MS sites the presence of *Streblus ilicifolius* per quadrat contributes 18.99% of the similarity between quadrats. *Streblus ilicifolius* occurred in nearly all sites with very high abundance. More details are in Appendix 7.

Average dissimilarity ranged from 59.96% to 94.49% between the four site types (Table 4.9). The species of *Streblus ilicifolius* and *Burretiodendron tonkinensis* occur in nearly all analyses.

Table 4.8: Species contributing up to 50% of the average Bray-Curtis similarity (using SIMPER analysis) for each site type.

Species	Average Abundance	Contributive %	Cumulative %
MS Average similarity: 21.33			
Streblus ilicifolius	24.33	18.99	18.99
Garcinia fagraeoides	11.00	11.58	30.58
Celtis sinensis	10.00	9.96	40.54
Maoutia puya	12.00	8.69	49.23
Sterculia lanceolata	9.67	7.85	57.08
DT1 Average similarity: 43.12			
Streblus ilicifolius	38.00	31.89	31.89
Burretiodendron tonkinensis	21.33	12.94	44.83
Diospyros sylvatica	11.00	7.96	52.78
DT2 Average similarity: 9.79			
Microstegium montanum	15.50	42.42	42.42
RU Average similarity: 36.58			
Streblus ilicifolius	38.50	44.44	44.44
Burretiodendron tonkinensis	14.50	13.89	58.33

Table 4.9: Species contributing up to 15% of the average Bray-Curtis dissimilarity (using SIMPER analysis) between MS, DT1, DT2 and RU sites.

Species	Av.Abundance	Av.Abundance	Contributive %	Cumultive.%
Group MS and Group DT1 Average dissimilarity = 67.45				
B. tonkinensis	15.00	21.33	3.66	3.66
S. ilicifolius	24.33	38.00	3.65	7.31
S. macrophyllus	11.33	4.67	3.52	10.83
A. villosum	14.00	0.00	3.14	13.97
Groups MS and DT2 Average dissimilarity = 90.69				
S. ilicifolius	24.33	3.50	3.34	3.34
A. villosum	14.00	20.00	3.16	6.50
M. montanum	0.00	15.50	2.46	8.96
C. petelotii	17.33	0.00	2.41	11.37
S. macrophyllus	11.33	5.50	2.31	13.68
D. lineari	0.00	12.50	2.03	15.71
Groups DT1 and DT2 Average dissimilarity = 93.75				
S. ilicifolius	38.00	3.50	6.22	6.22
A. villosum	0.00	20.00	3.51	9.72
B. tonkinensis	21.33	2.00	3.31	13.04
M. montanum	0.00	15.50	2.77	15.81
Groups MS and RU Average dissimilarity = 72.68				
S. ilicifolius	24.33	38.50	3.60	3.60
S. macrophyllus	11.33	3.00	3.39	6.99
A. villosum	14.00	0.00	3.07	10.06
C. petelotii	17.33	9.00	3.04	13.11
B. tonkinensis	15.00	14.50	2.87	15.98
Groups DT1 and RU Average dissimilarity = 59.96				
H. ilicifolia	2.67	12.50	3.96	3.96
V. quinata	10.33	1.75	3.25	7.21
B. tonkinensis	21.33	14.50	3.15	10.36
G. fagraeoides	11.00	12.00	2.92	13.28
Groups DT2 and RU Average dissimilarity = 94.49				
S. ilicifolius	3.50	38.50	6.59	6.59
A. villosum	20.00	0.00	3.67	10.26
E. odoratum	14.00	0.00	2.63	12.89
M. montanum	15.50	1.50	2.63	15.52

The MDS ordination of 162 species (Figure 4.5) shows some distinct groupings of common species and associated endangered/endemic species. There is a group of common species on the left of the diagram (group 1) and the species found in the mid-mountain condition on the right (groups 5 and 6). Group characteristics are summarized in Table 4.10.

Some endangered and endemic species are closely grouped with groups of common species. Firstly, there are 3 endemic and endangered species in group 2 associated with a group of common species. Secondly, there are three endangered species in group 3 associated with another group of common species. Lastly, only one endangered species is grouped closely with six common species. More detail is in Table 4.10.

However, the MDS ordination of species (Figure 4.5) also shows no distinct groupings of another six endangered species (*Burretiodendron tonkinensis, Markhamia stipulata, Garcinia fagraeoides, Hydnocarpus hainania, Melientha suavious* and *Stephania sinica*). Most of these endangered species are distributed in the centre of the diagram.

Global test by ANOSIM analysis shown that sample statistic (Global R) is 0.443, significance level of sample statistic is 0.3%, number of permutations is 999 (random sample from 138600), and number of permuted statistics greater than equal to Global R is 2. The global R squared value comparing the four forest types shown in Table 4.10.

Table 4.10: Pairwise Tests of general ecological data from 12 quadrads in BBNP (using ANOSIM analysis) between MS, DT1, DT2 and RU sites

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
MS, DT1	0.074	40.	10	10	4
MS, DT2	-0.083	80.	10	10	8
MS, RU	0.481	2.9	35	35	1
DT1, DT2	0.667	10.	10	10	1
DT1, RU	0.481	2.9	35	35	1
DT2, RU	0.893	6.7	15	15	1

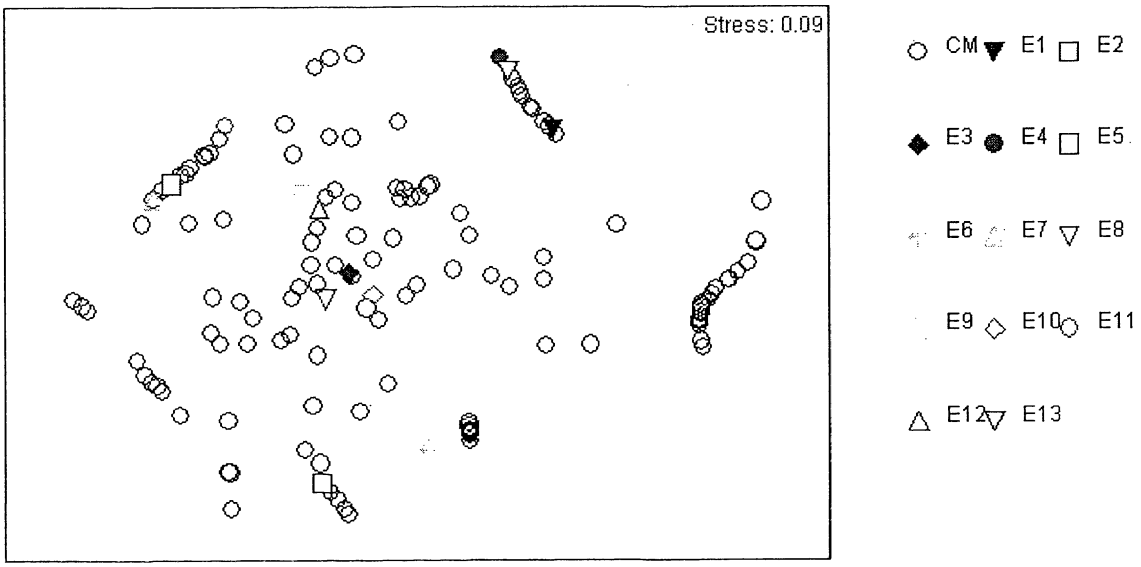


Figure 4.5: MDS ordination of 162 species in BBNP: common species represented by white circles; endangered and endemic species represented by coloured symbols: E1 = *Anoectochilus setaceus*, E2 = *Ardisia silvestris*, E3 = *Burretiodendron tonkinensis*, E4 = *Chukrasia tabularis*, E5 = *Cycas balansae*, E6 = *Markhamia stipulata*, E7 = *Ficus altissima*, E8 = *Garcinia fagraeoides*, E9 = *Hydnocarpus hainania*, E10 = *Melientha suavious*, E11 = *Sinocalamus mucclure*, E12 = *Stephania sinica* and E13 = *Tetrapanax papyriferus*.

Table 4.11: Groups of endangered and endemic species associated with group of common species

Endangered/endemic species	Associated common species
Group 1: *Ardisia silvestris, Ficus altissima* and *Sinocalamus mucclure*	*Jasminum nervsuaviersum, Tetrastigma tuberculatum, Sarcosperma tonkinensis, Ilex cymosa, Pteridium aquilium, Adiantum flabellulatum, Indigofera tinctoria, Idoes ovelis, Pathos chinensis, Andosace umbellata, Bauhinia alba, Adenanhera microsperma, Auricularia auricula, Dioscorea bulbifera, Wrightia tomentosa, Sarcandra glabra, Allospondias lakonensis, Bauhinia purpurea* and *Pavieasia annamnensi*
Group 2: *Anoectochilus setaceus, Chukrasia tabularis* and *Tetrapamax papyriferus*	*Flacontia jangomas, Acer tonkinensis, Cratoxylum polyanthum, Clausena harmandiana, Alangium chinensis, Baccaurea sapida, Anomianthus dulcis, Celtis philippnensis, Alangium Kurzii, Abelmoschus sagittifolius* and *Ficus benjamina*
Group 3: *Cycas balansae*	*Clausena duniana, Cinamomum tonkinensis, Chukrasia tabularia (A), Gmelina arborea, Gossampirus rumphii and Sarcosperma laurina*
Other large group: *Burretiodendron tonkinensis, Markhamia stipulata, Garcinia fagraeoides, Hydnocarpus hainania, Melientha suavious* and *Stephania sinica*	*S.ilicifolius, C.sinensis, D. sylvatica, C. parasitius, D. bonii, S. sinica, A. balansa, D. variegata, D. cerasoides*

4.3.2 Environmental Factors Analysis

(a) General Environmental patterns

All measured environmental factors varied between sites but differences were not significant (Tables 4.11-14).

Table 4.12: Mean values of physical aspect variables. Standard error of mean shown in brackets. DSS is the proportion of exposed rock and SWS is a soil without stone evident.

Site types	Altitude (m als.)	Slope (degree)	Aspect (code)	Position (code)	DSS (%)	SWS (%)
MS	218.66	27.00	2.33	2.00	43.33	17.00
n=3	*(18.38)*	*(7.41)*	*(0.72)*	*(0.47)*	*(16.55)*	*(9.63)*
DT1	216.33	23.33	3.66	2.00	30.33	14.00
n=3	*(19.81)*	*(4.12)*	*(0.27)*	*(0.00)*	*(12.21)*	*(10.61)*
DT2	272.00	15.50	3.00	2.50	2.50	93.50
n=2	*(30.41)*	*(0.35)*	*(0.71)*	*(0.35)*	*(0.35)*	*(1.06)*
RU	478.00	33.75	3.25	4.25	33.75	47.50
n=4	*(44.12)*	*(2.07)*	*(0.41)*	*(0.22)*	*(5.41)*	*(6.49)*

Table 4.13: Mean values of soil data variables. Standard error of mean shown in brackets. WA is surface water availability.

Site types	Soil color (code)	Soil type (code)	Soil pH	Soil moisture (%)	Soil depth (cm)	WA (code)
MS	2.00	3.33	8.00	3.00	50.00	3.00
n=3	(0.47)	(0.72)	(0.24)	(0.47)	(16.33)	(0.82)
DT1	4.00	1.67	7.70	2.33	53.33	3.33
n=3	(0.47)	(0.54)	(0.05)	(0.54)	(7.20)	(0).72
DT2	3.00	4.50	7.30	2.50	75.00	3.00
n=2	(0.70)	(0.35)	(0.35)	(0.35)	(10.60)	(0.00)
RU	3.25	1.75	7.77	1.25	33.75	5.00
n=4	(0.89)	(0.22)	(0.07)	(0.22)	(4.80)	(0.00)

Table 4.14: Mean values of disturbance factor variables. Standard error of mean shown in brackets. DV is distance to the nearest village, DT is distance to the nearest track, DCS is the proportion of eroded rock and DF is a deforestation level.

Site types	DV (km)	DT (km)	DCS (%)	DF (code)	Epiphyte (code)	Liana (code)
MS	3.66	6.80	33.66	2.50	2.33	3.33
n=3	(1.18)	(5.39)	(17.85)	(0.29)	(0.27)	(0.54)
DT1	6.00	0.10	5.33	2.00	2.00	2.67
n=3	(1.25)	(0.00)	(2.13)	(0.00)	(0.00)	(0.54)
DT2	1.40	0.15	2.00	3.00	1.50	2.50
n=2	(0.42)	(0.06)	(0.71)	(0.71)	(0.35)	(1.06)
RU	3.50	0.63	18.75	2.00	2.75	2.25
n=4	(0.56)	(0.13)	(1.08)	(0.35)	(0.41)	(0.65)

Table 4.15: Mean values of vegetation data variables. Standard error of mean shown in brackets.

Site types	Litter cover (%)	Canopy cover (%)	Green cover (%)	Bush cover (%)	Bamboo cover (%)	Grass cover (%)
MS	33.33	80.00	1.00	8.33	14.00	1.00
n=3	(14.96)	(8.49)	(0.00)	(2.72)	(10.61)	(0.00)
DT1	78.33	88.33	1.00	6.66	1.00	1.00
n=3	(8.27)	(5.44)	(0.00)	(1.36)	(0.00)	(0.00)
DT2	67.50	60.00	1.00	15.00	1.00	8.00
n=2	(12.38)	(0.00)	(0.00)	(0.00)	(0.00)	(4.95)
RU	68.75	75.00	2.00	13.75	1.00	2.50
n=4	(3.69)	(6.73)	(0.86)	(3.25)	(0.00)	(0.83)

(b) Multivariate Environmental results

The Principal component analysis (PCA) ordination of environmental variables (Figure 4.6) shows some clear gradients in RU sites and DT2. However, MS sites were not grouped; of 3 quadrats, one was far away from the other two quadrats. The first principal component may be a gradient of increasing altitude.

Multi dimensional scaling analysis (MDS) showed a low stress (0.13), with most of the RU sites grouped together; the DT2 sites also appeared distinctive. DT1 sites are also similar. The two most different sites are MS sites. Ordination of results from multi-dimensional scaling analysis of 4 forest types within BBNP display a distinct vegetation gradient from relatively undisturbed sites (RU) to secondary forest sites (DT2) (left to right; Figure 4.7). Although both secondary forest (DT2 sites; quadrats 12 and 4) were primarily dominated by common species and low canopy, the forest types of the relatively undisturbed sites (RU) were grouped together: quadrats 5, 6, 9 and 10 were associated with vegetation richness and numbers of endangered species. Within the other 2 forest types, a clear distinction between DT1 and MS sites is evident. A gradient within the DT1 sites of forest types is also apparent. This vegetation gradient consists of a gradient between two forest types of MS (quadrat 11) and DT1 (quadrats 3, 7 and 8). However, quadrat 1 was distinctive.

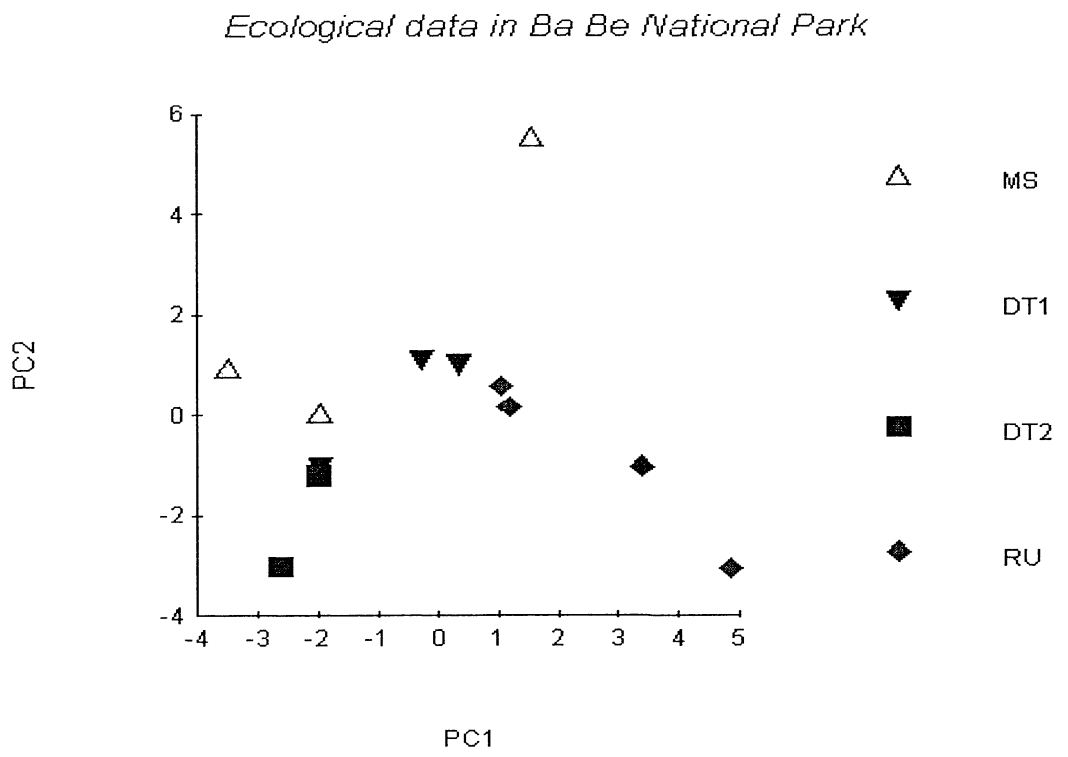


Figure 4.6: Principal components ordination of quadrats based on environmental variables. MS are moist sites, DT1 is disturbance 1 with the quadrats located near the track and village, DT2 is disturbed with the two quadrats located in secondary forest, and RU is undisturbed with the quadrats located near the middle and top of the mountains.

Figure 4.8 shows the overal similarily of sites based on environmental variables, though the vegetation data separates into two groups. As can be seen in Figure 4.8 (and also Appendix 8), all variables were distributed mainly in the central part of the figure. In particular, soil variables were grouped together probably because they were correlated with other environmental factors. Another group of physical variables were grouped in the vertical line and closely correlated with soil variables. Otherwise, disturbance variables were correlated with all environmental variables. However, vegetation variables were widely distributed in the figure, grass, bamboo and green covers were grouped together while litter and canopy covers were separately grouped and canopy cover was closely related to dominant tree variables. In this analysis, endangered species, as a variable, was situated in the middle of figure and closely related to deforestation and physical factors (pH is not shown).

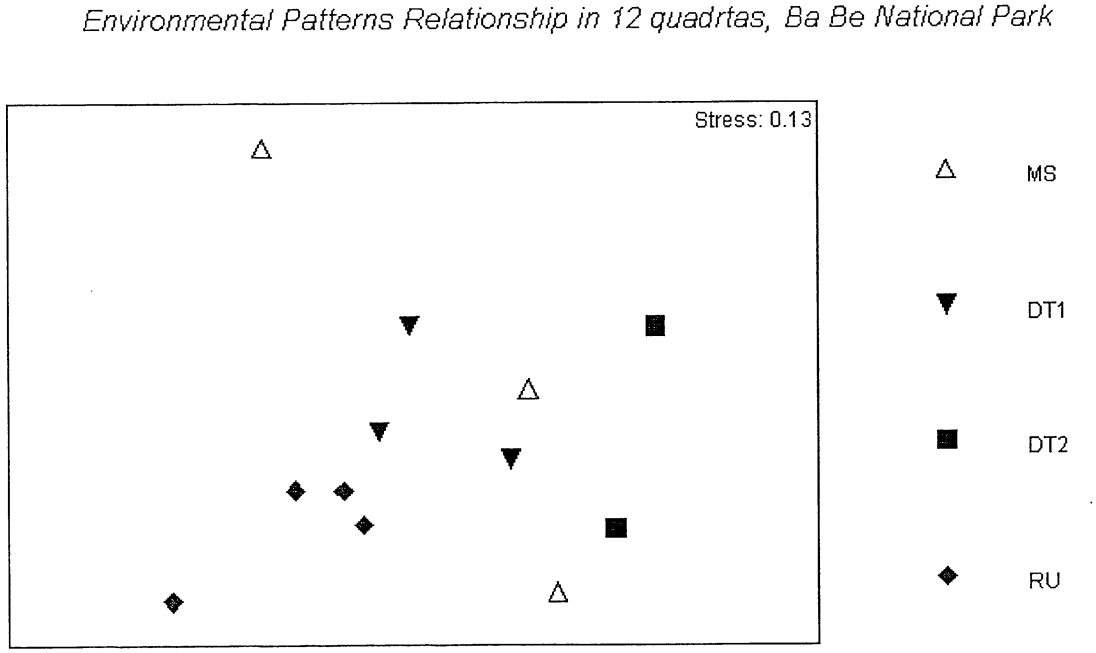


Figure 4.7: MDS ordination of 12 quadrats based on environmental factors. MS represents a moist site, DT1 and DT2 are disturbed 1 and RU is undisturbed.

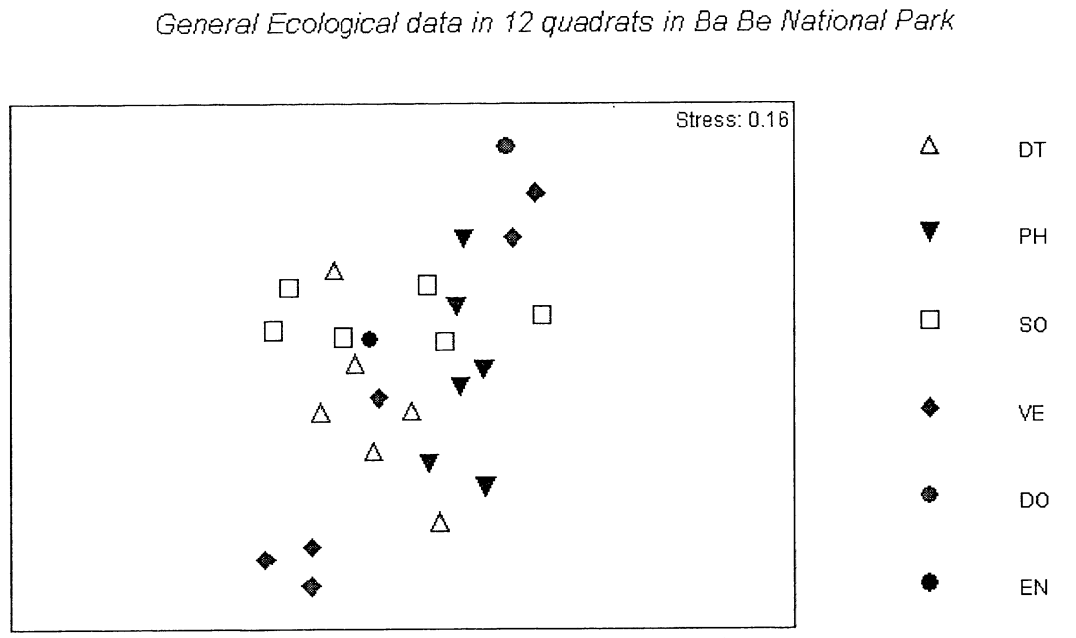


Figure 4.8: MDS ordination of 26 environmental factors. DT is a disturbance factor, PH refers to physical aspects, SO to soil data, VE to vegetation data, DO to dominant trees and EN to endangered plants.

4.3.3 Vegetation and Environmental Relationships

a) BIO-ENV multivariate analysis

The BIO-ENV analysis found 15 environmental variables best correlated with the vegetation patterns, including disturbance factors (deforestation and distance to nearest track), physical aspects (altitude, slope, aspect and soil without rock), soil data (soil type, soil pH and soil moisture), vegetation cover (litter cover, canopy cover, bamboo cover and grass cover) ($r = 0.931$).

The MDS ordination of sites based on the combination of 15 environmental variables (Figure 4.9) selected by BIOENV was highly correlated with the site ordination based on species (Figure 4.3) ($r = 0.921$). This indicates variation in the vegetation is adequately explained by the environmental variables chosen to characterize the sites.

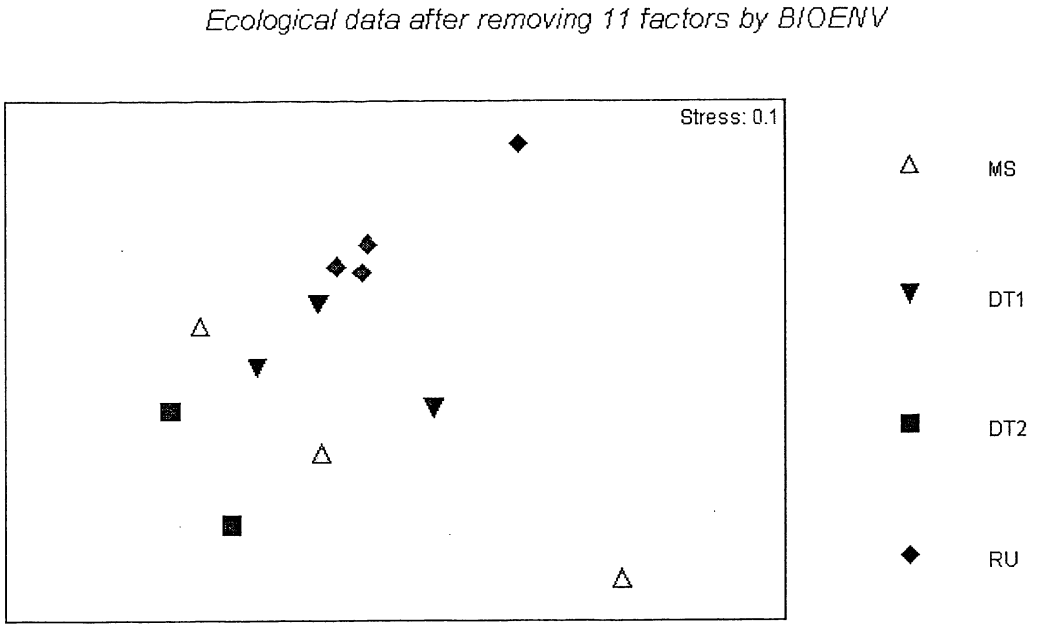


Figure 4.9: MDS ordination of quadrats based on environmental variables selected by BIOENV analysis.

MDS ordination of 12 quadrats based on 15 environmental variables recognized by BIOENV analysis (Figure 4.10) shows that endangered species as a factor are

strongly associated with the factors soil type, deforestation, soil pH and soil moisture.

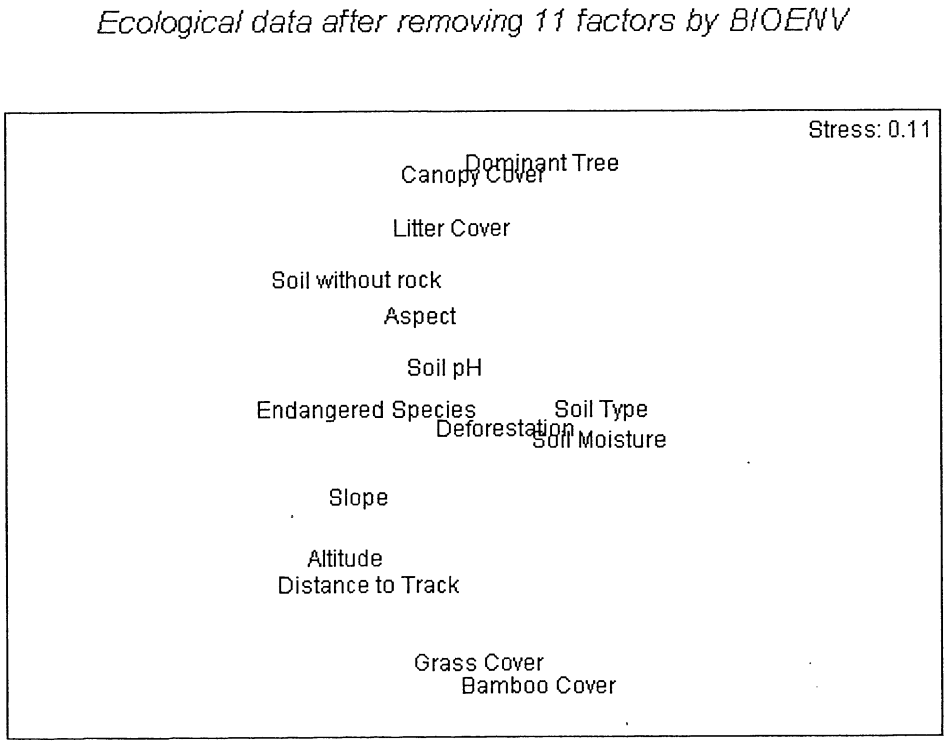
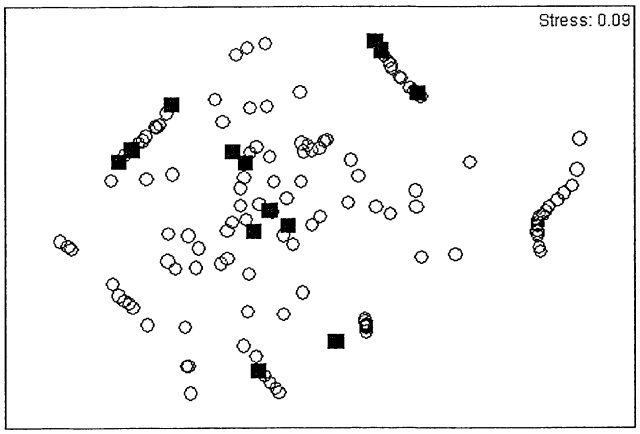


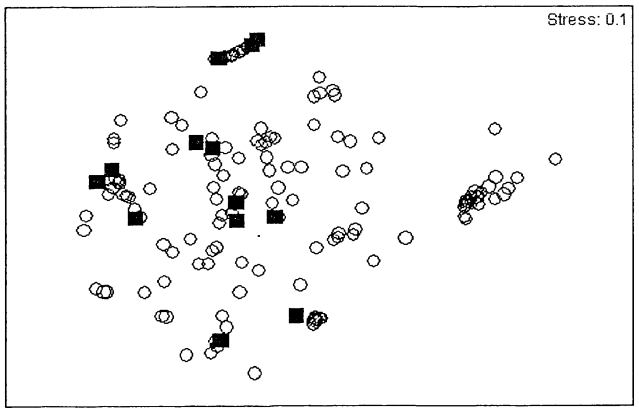
Figure 4.10: MDS ordination of quadrats based on 15 environmental variables selected by BIOENV analysis.

b) Three scales of analysis

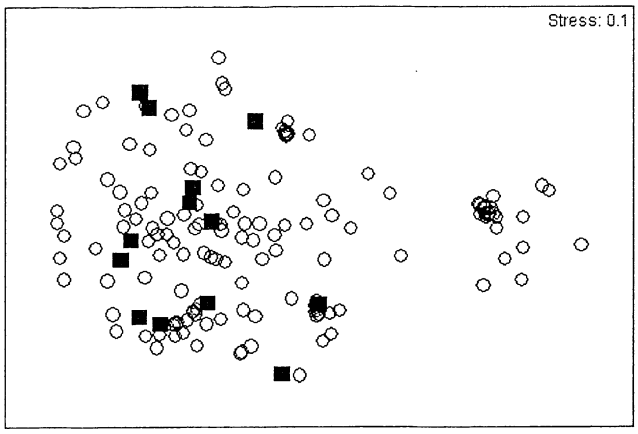
MDS from different three scales of analysis (Figures 4.11-12) shows that the scale of 500 m^2 does not differ greatly from an analysis based on the 1000 m^2 scale, while the scale of 200 m^2 shows differentiation from the other 2 scales. That is not surprising, since one would expect greater variation between samples as the scale becomes smaller. This suggests that sampling at the 500 m^2 scale would have been adequate for this study and would suffice for future studies.



(a)



(b)



(c)

○ : is common species; ■ : is endangered and endemic species

Figure 4.11: (a) is vegetation composition of scale 1 (1000 m^2), (b) is vegetation composition of scale 2 (500 m^2), (c) is vegetation composition of scale 3 (200 m^2) (the result for scale 1 is different to scale 3 (200 m^2)).

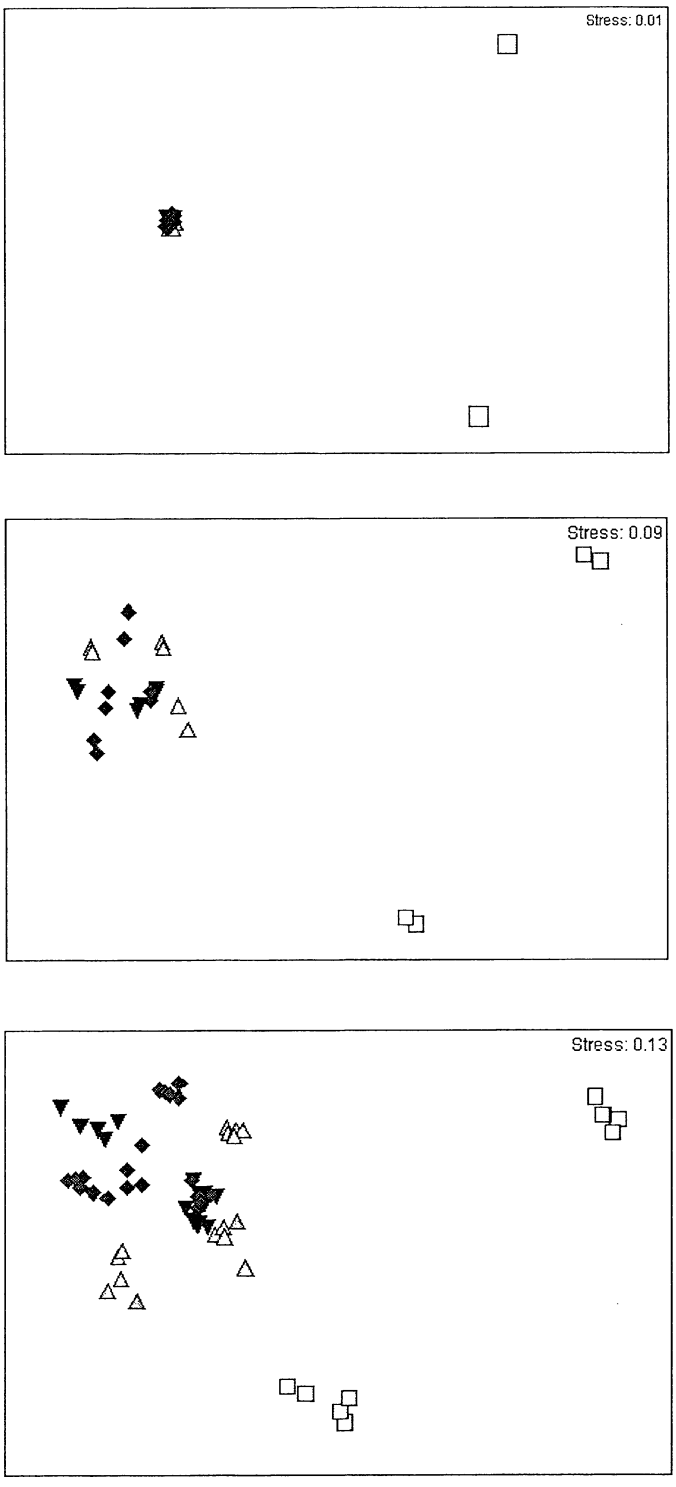


Figure 4.12: (a) MDS of scale 1 (1000sq m) of 12 quadrats based on 4 groups of environmental factors, (b) is MDS of scale 2 (500 sq m), (c) is MDS of scale 3 (200 sq m). Sites/quadrats distribution in scale 3 separated into different sub-groups that are also different from scale 1 and scale 2.

4.4 Discussion

4.4.1 Floristic patterns

Systematic structure is the distribution of species, genera and families based on upper taxa, particularly reserved to each flora. It consists of many criteria, among which the following are often used to compare with floristic attributes: numbers of species, genera, families and upper taxa, the genus coefficient, families coefficient, average species per family and percentage of each plant class compared with other samples (Chan *et al.,* 1999). This study found that a total of 162 species belonging to 125 genera and 65 families occurred in 12 quadrats (1.2ha) in the research area. Magnoliopsida had the highest number and percentage of species 131 (80.86%) and fungi and lycopods had the lowest number and percentage of species 1.0 (0,62%) (Table 4.3). These results agreed with the research of Leigh, (1982), who claimed that the biotic richness of tropical rain forest has been hailed as the highest in the world. In sample plots of 1 hectare of tropical rain forest, up to 100 tree species may be found, compared to only about 10-15, rarely to 35, in a temperate forest (Leigh, 1982).

Four different forest types/structures (moist sites, disturbance 1 sites, disturbance 2 sites, and relatively undisturbed sites) were examined in different locations in Ba Be National Park. The description of the structural characteristics of vegetation (stand structure) has provided a useful adjunct to classifications based on floristic compositional attributes (Le Brocque and Buckney, 1997). In moist sites, vegetation has more species and more abundant plants, especially in quadrat 1 with 602 individuals (Table 4.1). These sites are located near the lake, river or in valleys. In disturbance group 1, all sites were located near a track or village and easily exploited for wood and timber. Probably as a result of human and physical disturbance in the areas, the diversity of species taxa was extremely low, and high value species were rare. There were only 174 individuals of 21 species in quadrat 8 of these sites (Table 4.1). Disturbance 2 sites are sites of secondary forest affected by shifting agriculture of local people for long periods of which the land is left fallow. After natural regeneration the vegetation

composition is changed with lower canopy and monotonous vegetation composition (Appendix 7 and 8). In relatively undisturbed sites, vegetation compositions were relatively undamaged/intact, large trees dominating the upper canopy.

On the other hand, multi-dimensional scaling (MDS) showed that there was no significant difference in vegetation composition between 4 site types (MS, DT1, DT2 and RU) overall, though MS sites were separated from the other 3 site types. Remnants that were more exposed to a high degree of MS site disturbance did not support a higher abundance or percentage of endangered and endemic species than other sites. The MS sites had marginally higher average abundances of common species, but the difference was not significant. Therefore, unlike most studies in BBNP, it cannot be asserted that forest disturbance in BBNP has decreased species richness or abundance.

The MDS ordination [Figure 4.3 (a)] shows no discrete differentiation of MS, DT1 and RU sites. However, it is evident that DT2 quadrats display a greater variation of species composition than the other 3 sites. This is supported by the SIMPER analysis (Table 4.7) that shows DT2 sites have a lower average similarity (9.79) than other sites to MS sites (21.33%), RU sites (36.58%), and DT1 sites (43.12%). However, there were no significant differences between any of the four sites for any of the vegetation indices (Table 4.6).

The SIMPER analysis showed that differences in floristics between all 4 site types were accounted for by variation in the average abundances of species (Table 4.6 and 4.8), rather than the presence of a few dominant species or multiple unique species. There were no endangered species listed as contributing to the differentiation of the 4 site types. This is supported by the high Spearman rank correlation ($r = 0.222$) between the MDS ordination of all species and the MDS ordination without endangered species, tree species etc. (Figure 4.4). Also, Fig 4.4 reveals that if the tree layer is ignored, the two disturbed site types, in particular are far less varied than the undisturbed sites, suggesting that the disturbance regimes represented here result in a simplification of the understorey.

This has implications for biodiversity overall: disturbance tends to decrease variety in the understorey.

MDS ordination of the 162 species in 12 quadrats (Figure 4.5 and see Table 4.10) shows that there is a slight differentiation of species into common species and endangered species groups. The endangered species were distributed regularly in all areas of the diagram, though some appear to be associated with distinct species groupings. This suggests that conservation of these species by propagation in the forest might need to consider the species already present in the propagation area. Moreover, potentially successful propagation areas might be identifiable from the common species already present.

The right side of the diagram in Figure 4.5 has one group of common species that are associated with disturbed habitats; this result is true for all three analyses at different scales (1000m^2, 500 m^2, and 200 m^2) (in particular, *Cryptocarya lenticellata* in quadrat 12 always appears distinctive) [Figure 11(a), (b) and (c)]. This phenomenon probably reflects the low level of abundance of these species overall; only 1 individual of *C. leticellata* occurred in secondary forest. However, the claim that rare and endangered species have lower numbers of individuals and very restricted distribution in the wild, as found in the study of Li *et al.,* (2002); Vaxevanidou *et al.,* (2006), is not supported by this study for BBNP.

Some endangered species listed in the Red Book of Vietnam and the Red List of IUCN were found in nearly all sites (e.g. *Burretiodendron tonkinensis* or *Garcinia fagraeoides*) with high abundance; many were found in higher numbers in quadrats 1, 3 and 7 (Appendix 5). What is more surprising is that the majority of common species examined in MDS were like rare species (about 10 species) (Appendix 5) and four species (*C. lenticellata, P. tavoyana, A. macrorhiza* and *Q. helferiana*) were distinctive in three scaling analyses (Figure 4.5 and 4.11). While the pattern shows that woody tree species in natural areas are associated with endangered species, there is no indication they are invaded and dominated by other species. In fact, as with endangered species, woody tree species were found to be important factors determining vegetation composition in MDS

analysis, as shown when they were removed from the analysis. As stated above, the understorey proved to be very variable (as shown by MDS analysis after removing tree species, Fig 4.4) and this may have repercussions for patterns of exploitation of plants and for the prospects for in-forest propagation of endangered species.

The frequencies of endangered and endemic species were substantially varied from 8.33 to 91.67% (Table 4.6). Compared to total species, this study found only 8.64% of endangered and endemic species, which contrasts with the studies of Hill *et al.,* (1997) and Loc *et al.,* (2003), who reported higher percentages. This is not surprising because Ba Be National Park has complex topography that is difficult to travel over and a lack of studies in a wide range of areas.

There are many possible explanations why vegetation patterns in all four site types in BBNP are not homogeneous, particularly in the understorey. It could be hypothesised that the degree of disturbance (as identified by nearness to village, track and secondary forest) has impacted on vegetation composition to different levels, or the correlation between ecological conditions (particularly in moist sites) and physical effects have not yet reached a point that can impact on vegetation composition. In the case of BBNP, disturbed sites at the same apparent physical and ecological condition differ because the sites located near the office of the BBNP or forest protection station have more endangered species than the other disturbed areas (DT2). This suggests that efforts to increase the perception that illegal gathering will be detected might improve the long-term sustainability of species of interest.

The results from MDS of sites ordination [Figure 4.3 (b), (c) and (d)] shows that after removing herb, shrub,ferns and sedge, the ordination was changed compared with MDS with all species included [Figure 4.3 (a)]. The DT2 site with no ongoing disturbance appeared much more similar to the other site types. This indicates that tree felling without further disturbance can, at least at that site, allow regeneration of something like the original forest types in term of floristic composition; perhaps in time the grasses, sedge, ferns and herbs, which clearly

influence the site's position in Figure 4.3 (a), will disappear as the canopy develops. The other DT2 site, also deforested, but with ongoing agricultural activity, was the only site with no endangered species; suggesting that the agriculture may be more threatening to endangered species than the forestry. However, removing the trees, endangered species (Red Book, Red List) and endangered species classified by local people was very important in affecting the ordination with the modified data set. Further research on epiphytes or lower plants may be necessary to identify their role in affecting composition of vegetation.

The results may indicate that there is no clearly-definable gradient of increasing disturbance across sites. Each site is experiencing disturbance to some degree, in the form of various moisture levels, forest exploitation, different physical conditions, etc, but the categorization of 'disturbed', 'relatively undisturbed sites' and 'moisture' is not precise, rather an evaluation; more precise and more time-consuming measurements of such factors might produce a clearer picture of the ecological patterns than was possible in this study. The influence of past and present National Park management was also detected. For instance, in DT2 sites, the quadrat 12 area is still experiencing logging and illegal collection of forest products by local people, while quadrat 4 is managed strictly because it is near the park office. Therefore it is impossible to say that quadrats 12 and 4 are experiencing the same influence. These issues will be dealt with in greater detail in the general discussion (Chapter VI).

4.4.2 Environmental patterns

The groups of environmental variables (physical aspects, disturbance, soil, vegetation data and endangered and endemic species) did not change between site types according to expectations. In fact, the MS sites have marginally greater spread of environmental variables than the other three site types (Figures 4.7 and 4.9), but the difference was not significant. Many environmental factors obtained a higher value in MS sites (Tables 4.12 to 4.15). PCA ordination (Figure 4.6) and MDS ordination (Figure 4.7) also show no discrete differentiation of all four site

types (MS, DT1, DT2 and RU) based on environmental variables. However, the MS sites display greater variability of environmental properties than DT1, DT2 and RU but most differences were not significant between sites (Table 4.12 to Table 4.15). To compare the MDS of floristic variables analysis, DT2 sites (secondary forest sites) were still distinctive, probably showing their history of shifting cultivation of slash and burn for expanded land area or illegal collection of forest products. This issue may contribute to the variation in vegetation and environmental factors (Le Broque and Buckney, 1995).

A model of the transitions in the vegetation composition has been proposed which includes soil variables, site conditions and the spatial distribution of disturbance (Bertiller *et al.,* 1993). In this study, covers of litter and canopy were very high at all sites and these decrease steadily along the gradient of other vegetation covers while the other species or plant groups increase (Table 4.12). These results are in accordance with previous observations reported by On *et al.,* (2003) and with general patterns of vegetation cover variation described in tropical forest and limestone forest in BBNP (Quac *et al.,* 1999). However the percentage of general vegetation covers are more closely related to other environmental factors. This is an indication that the chosen environmental factors alone might not be the main ones modelling the dominance of different plant species or plant groups in the ecosystems in BBNP. The percentage cover of canopy or other vegetation covers (especially in DT1 sites) are more strongly correlated with the soil data (soil pH, soil moisture or water availability) than disturbance (near the track and village), for example.

With physical factors, MDS analysis showed that environmental factors (altitude, slope, aspect, soil without rock and degree of visible rock) did not strongly correlate together overall, while they strongly correlated with relatively undisturbed sites (Appendix 7). This perhaps reflects the fact that natural sites have been little impacted by human disturbance. On the other hand, disturbance factors (deforestation, distance to track and distance to village) have not had a major influence on vegetation composition, possibly because forest resources were strictly managed by BBNP. However, the other two factors of disturbance

(epiphyte cover and eroded stone cover). were highly correlated with vegetation composition. Hill *et al.,* (1997) and Trai *et al.,* (2004) also found that floristic and environmental factors in BBNP show that the characteristic of limestone forest with the high abundance of epiphyte cover was associated with biodiversity in this area.

The major vegetation gradient from different type of forests (MS, DT1, DT2 and RU) was shown to be correlated with pH and water availability; this is also reported by the research of Le Broque and Buckney, (1995) in drier Australian vegetation. Other soil data (soil depth, soil moisture and soil type) were correlated with the vegetation gradient (Figure 4.8). A further vegetation gradient between four sites was shown to be correlated to green cover, grass cover and bamboo cover and other groups of vegetation data correlated with vegetation composition. Clearly, no single environmental variable adequately explains the major vegetation patterns but the most important ones appear to be soil data and vegetation cover. Further study on floristic composition and environmental variables such as nutrient levels that may contribute to the variation in vegetation in the study area might also prove to form part of a complex of environmental gradients, particularly at the local scale.

4.4.3 Relationships between environment and vegetation

This study found that a combination of environmental variables adequately explained vegetation patterns among the samples investigated in BBNP. The 15 environmental variables selected by the BIO-ENV analysis (Figure 4.9) included disturbance factors (deforestation and distance to track), physical aspects (altitude, slope, aspect and soil without stone), soil data (soil type, soil pH and soil moisture) and vegetation cover (litter cover, canopy cover, bamboo cover and grass cover). The MDS ordination of quadrats based on the combination of 15 environmental variables (Figure 4.10) selected by BIOENV was highly related to the MDS based on species (Figure 4.3) ($r = 0.931$).

4.4.4 Scale of analysis

The principal restriction on sample number was site accessibility, in particular the time needed to reach sites in steep, trackless terrain. Figures 4.11 and 4.12 show that sampling at the 500 square meter scale would have been adequate for this study and this may have allowed more sites to be sampled. Future work in BBNP should include consideration of this point.

4.5 Conclusions

Disturbance is a factor determining floristic composition in BBNP, though degrees of disturbance seem to depend on remoteness and the likelihood that illegal clearing or gathering will be detected. Disturbed site understoreys are less varied than those of other site types and relatively undisturbed understoreys the least varied. Despite this, species abandances and species richness did not vary significantly between site types. These is evidence that tree felling with no ongoing disturbance can result in a vegetation similar to the original forest and be less inimical to endangered species than agriculture.

The chosen environmental variables explained a high proportion of the floristic variation within BBNP, certainly more than any single variable, though the most important ones appear to be soil data and vegetation cover. Endangered species are strongly associated with soil factors and deforestation. The detailed natures of those interactions require further study.

A number of rare/endangered species can be associated with groups of common species whose presence may indicate suitable areas for *in situ* propagation of them.

In future studies, a quadrat size of 500 square meters should be adequate as a sample unit.

Chapter V

Molecular Biology and Genetic Diversity

5.1 Introduction

Molecular makers can be considered very useful tools in conservation genetics of forest plants, and to establish priorities required to be taken for conservation policies and management (Bucci *et al.,* 1997). As a result of the ecological survey in Chapter IV, four plant species present at the sites, *Ethryropalum scandens, Markhamia stipulata*, *Melientha suavious* and *Sinocalamus mucclure,* have been selected for molecular study.

All four species have a distribution restricted to limestone ridges of Ba Be National Park (Khanh *et al.,* 2003). Two of these species are economically important vegetables *(E. scandens* and *M. suavious)* which occur only sporadically in some areas in the north of Vietnam, and their distribution is also restricted to some parts of BBNP. Natural populations of *M. suavious* have recently been targeted as highly vulnerable to habitat loss due to deforestation and overexploitation, and therefore it is important to investigate the distribution and genetic variability in natural populations of *M. suavious* (Prathepha, 2000). On the other hand, *M. stipulata* is a valuable wood tree for construction and furniture, and is also distributed in small areas of the Park. Finally, *S. mucclure* is an endemic bamboo species with its main range in the south of China, and a smaller localised range in the north of Vietnam (Chan & Nguyen, 2003). In the north of Vietnam the range is restricted to only one site near Ba Be lake in the limestone mountainous areas partly situated within Ba Be National Park.

Unfortunately for all four species, their preferred habitat has also been favoured by local tribal people for collection of plant species for medicine or food (see above). Land clearance and over use has led directly to the endangerment of the four species through direct removal of individuals, and the division of previously continuous populations into smaller fragments separated by inhospitable terrain.

The risk of extinction now faced by the remaining populations is compounded by the species own biology; i.e. they require a specialised habitat, they have poor seed dispersal mechanisms, and are slow growing after harvesting (Phung, 1999). These factors make the four species particularly susceptible to inbreeding, with subsequent potential loss of genetic variation, accumulation of deleterious alleles and inbreeding depression (see Chapter II). A number of studies have been performed aimed at gathering sufficient ecological information to enable better conservation management of species within Ba Be National Park (Dien, 2000; MARD, 2001), but to date no genetic diversity studies have been initiated.

Genetic diversity represents the heritable (able to be passed onto offspring) variation that exists between individuals within populations, between populations within species, and between species (New, 2000). Previous studies have found that a loss of genetic diversity decreases the ability of wild populations to survive climatic extremes, pollutants, pests, and disease (Frankham, 1995). Genetic diversity is therefore considered crucial for the long term survival of a species, and according to Hopper and Coates (1990), the maintenance of genetic diversity and heterozygosity in natural populations may provide the best general strategy for ensuring the survival of most organisms. The amount of genetic diversity present in any species may be reduced by chance or natural catastrophes (such as floods and droughts). These smaller populations are more susceptible to stochastic (chance) effects that include inbreeding and loss of genetic variation (Frankham, 1995; Lynch *et el.,* 1995). A number of authors (Dudash, 1990; Agren and Schemske, 1993; Caro and Laurenson, 1994; Hauser and Loeschoke, 1994) have claimed that there is no evidence that populations in the wild suffer from inbreeding depression, and that catastrophes and demographic or environmental stochasticity are more important causes of extinctions that may be incorrectly attributed to non genetic factors alone, when it is the interaction between genetic and non-genetic factors that is important.

A direct way of measuring genetic diversity is by the use of molecular analyses. Such techniques have the potential to reveal an immense number of characters, though they may also vary in the way they resolve genetic differences, in the type

of data they generate, and in the taxonomic levels at which they are best applied (Karp *et al.,* 1996). One method, RAPD-PCR (Random Amplified Polymorphic DNA-Polymerase Chain Reaction) amplifies random genomic DNA sequences using single, short arbitrary primers, and these can be effectively used as genetic markers. The RAPD technique therefore surveys (scans) numerous loci in the genome, which makes this method particularly attractive for analysis of genetic distance and similarity between closely related species (Persson and Gustavsson, 2001; Crockett *et al.,* 2002). A recent method to compensate for some weakness in RAPD-PCR such as inconsistency between samples and dominancy of loci targeted has been developed by using combinations of RAPD and microsatellite primers, called RAMP (Random amplified microsatellite polymorphism)-PCR (Wu *et al.,* 1994). RAMP-PCR has been reported to potentially detect and map co-dominant polymorphisms in DNA without cloning and sequencing, and RAMP-PCR bands were more reliable descriptors of relatedness than RAPD or microsatellite methods by themselves (Panaud *et al.,* 1996). RAMP-PCR has been reported to be more reproducible and better than RAPD-PCR in disclosing genetic relationship in barley cultivars (Sanchez de la Hoz *et al.,* 1996). The method therefore utilizes the ubiquitous and highly polymorphic nature of microsatellites, with the ease of genome scanning supplied by RAPD primers.

In this study three hypotheses will be tested; they can be stated in the form of the following questions.

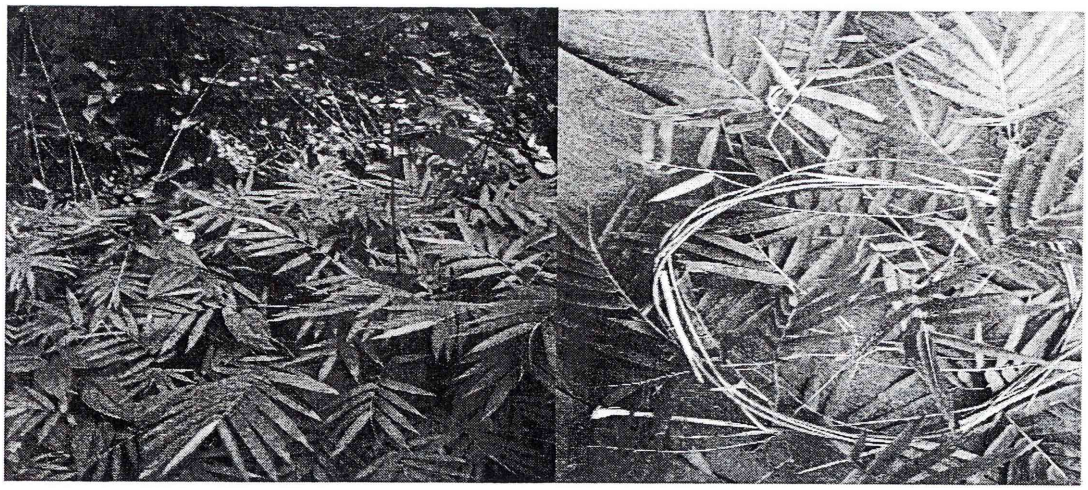
- Firstly, can a multilocus fingerprinting method using a combination of microsatellite and RAPD primers reveal more diversity in the four forest tree species than by using RAPD primers alone?
- Secondly, can the fragmentation of populations on a small scale lead to genetic differences between them?
- Thirdly, which known populations of these species represent the greatest storage of genetic variation?

5.2 Study Plants

This study was designed to determine the genetic diversity of four rare and endangered forest tree species *(Erythropalum scandens, Markhamia stipulata, Melientha suavious* and *Sinocalamus mucclure)* in Ba Be National Park of Vietnam, where these four species were recorded in the Red Book of Vietnam as Rare and Endangered forest plant species (The criteria of the Red Book of Vietnam are generally like those of the Red List of IUCN). Furthermore, the results of an inventory of endangered species in chapter three of this study has identified these four species by local farmers as endangered species that should be conserved and for which they have expressed critical concerns about their numbers.

5.2.1 *Sinocalamus mucclure* (String bamboo)

String bamboo *Sinocalamus mucclure* [sometimes classified as *Ampelocalamus sp.* or *Sinocalamus mucclure* (Chan, 2001; Chan and Nguyen, 2003)] (Figure 5.1) belongs to the family Poaceae, and is a monocotyledon species with healthy root systems, copious branching, and rhizocorms. The stem is long, separated into merostomial parts of 40-50cm and diameter from 0.4-0.6cm. The species is found only in BBNP. It is used for making twine and as a medicinal herb (Long, 2001).



(a) **(b)**

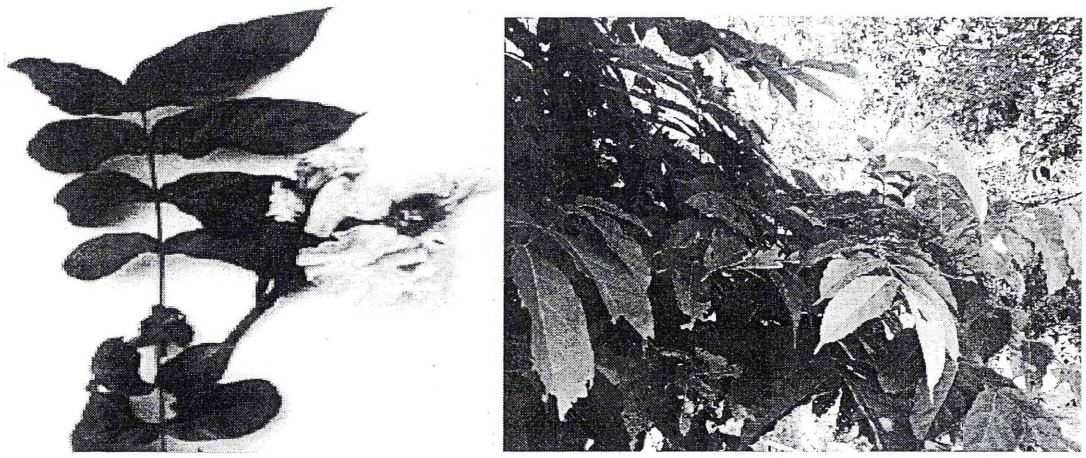
Figure 5.1: Foliage and life-form of String Bamboo (*Sinocalamus mucclure*) (a), and young leaf samples and shoots from which DNA was extracted for this study (b)

5.2.2 *Markhamia stipulata* (Roxb.) Seem.

Markhamia stipulata (Figure 5.2) belongs to the family of Bignoniaceae, and is a tall tree 10-25m high; diameter may be up to 60-80cm.

M. stipulata grows slowly, flowering from November to April, and regenerates from seed. This species is mainly distributed in thick evergreen tropical forests in the north of Viet Nam. This species is extremely vulnerable to extinction owing to the fact that the only remaining populations are on the natural forests in the north, and occasionally in central Viet Nam. *M. stipulata* is under severe threat from possible development, and/or overexploitation (Chan and Huyen, 2000).

M. stipulata has been recognized as vulnerable in the Red List of the IUCN, due to the fact that the species is found in a geographic range to have been estimated to be less than 20,000km^2 (severely fragmented or known to exist at no more than 10 locations; continuing decline, observed, inferred, or projected; extreme fluctuation). Actual population size is estimated to number fewer than 10,000 mature individuals; the populations are all very small or restricted in form; quantitative analysis showing the probability of extinction in the wild is at least 10% within 100 years (IUCN, 2001).



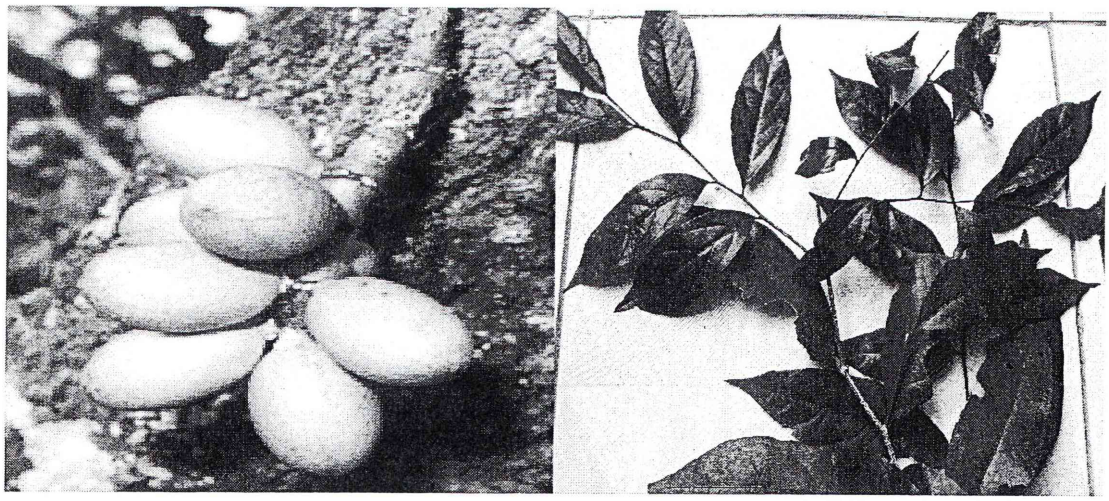
(a) (b)

Figure 5.2: Foliage and inflorescence of *Markhamia stipulata* (Roxb.) (a), and part of a plant in the Botanic Gardens of Ba Be National Park (b)

5.2.3 *Melientha suavis* Pierre.

Melientha suavis (Figure 5.3) is a tree species of the Opiliaceace family, and is a small perennial tree, 4-8m high. *M. suavious* is mainly distributed in Indo-China and the north of Thailand, growing well in limestone forests and on the banks of rivers/streams. In Viet Nam, it is distributed in the north (Chi, 1997; Phung, 1999; Phung, 2001). Fruit is red and yellow and attractive for wild animals, and that is why only a few trees grow in nature (Phung, 2001; Phung, 2003).

This species is classified in the Red Book of Viet Nam in 1996 and 2004 as an endangered species. The Red Book of Vietnam (2004) and Red list of IUCN (2001) give the plant a conservation coding of Near Threatened. It may be true that this taxon is near threatened when strictly evaluated against all criteria, but at present does not qualify for Critically Endangered, Endangered or Vulnerable; however it is close to qualifying for this status, or is likely to qualify for a threatened category in the near future. Natural populations of this species are currently vulnerable to habitat loss due to deforestation and overexploitation (Prathepha, 2000).



(a) (b)

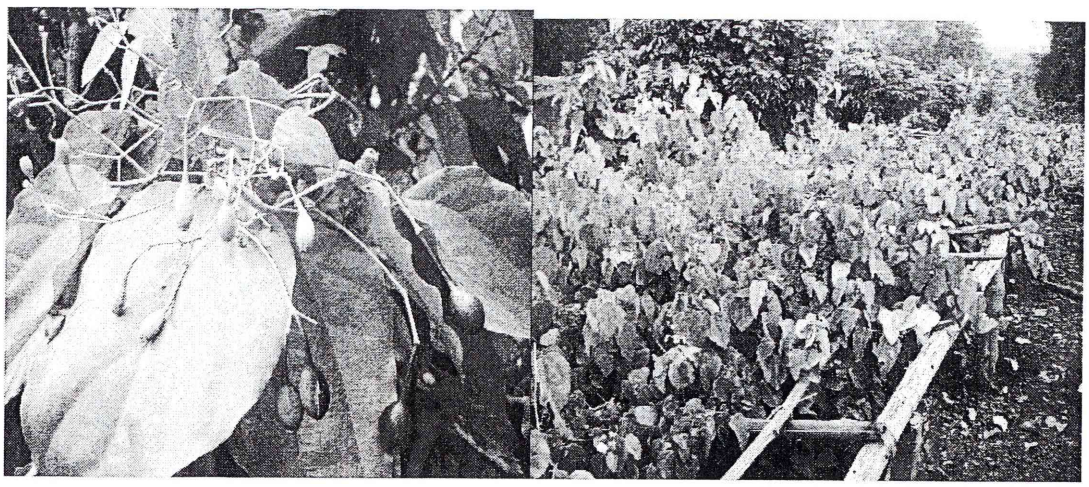
Figure 5.3: Infructescence and developing seeds of *Melientha suavious* Pierre. (a), and the leaves of *Melientha suavious* collected from the Park for DNA extraction (b)

5.2.4 *Erythropalum scandens* Blume.

Erythropalum scandens Blume. (Figure 5.4) is a medium sized shrub with a spreading habit, belonging to the family Olacaceae, that grows to 1 m high in the sun, 5-6 m high in the shade and 3-4 m wide; it is a liana/creeper by cirrus/hapteron, with soft green pendant branches (Phung, 2001).

E. scandens is a wild plant; it is distributed in moist and restoration forests in China, Indo-china, Myanmar and Thailand. In Vietnam, this species occurs in the Northern provinces (Minh, 2007). In its natural state *E. scandens* can adapt to diversified habitats and new surroundings, from the understorey of the canopy of thick forest to well-exposed and open forests (Phung, 2003).

E. scandens was listed in the Red Book of Vietnam in 1992 as being Near Threatened "NT", but this species was taken out the list in the new version of the Red Book in 2004, because of its ease of regeneration and the many cultivation sites in home gardens. However, in nature, overexploitation has reduced this species to low numbers quickly. Local people mainly cut down a whole plant to collect only young leaves for use as a vegetable, and this is also main cause of the reduction in numbers.



(a) (b)

Figure 5.4: Foliage and inflorescence of *Erythopalum scandens* Blume (a), and *E. scandens* growing in the Botanic Garden of Thai Nguyen University of Agriculture and Forestry (b).

5.3 Materials and Methods

5.3.1 Study Site

Samples of the four plant species *(Erythropalum scandens, Markhamia stipulata, Melientha suavious and Sinocalamus macclure)* used in this study were collected from fragmented populations in Ba Be National Park.

The original population of these four species in this area have been gradually fragmented over time by slash and burn agricultural activities, overexploitation for housing, consumption and selling (On *et al.,* 2002; BBNP, 2005). *Erythropalum scandens* and *Melientha suavious* are distributed in all different types of forest in the Park. *Markhamia stipulata* is mostly distributed on the higher limestone forests and *Sinocalamus macclure* only occurs on the one side of Ba Be Lake, at the lower slopes of the limestone forests where soil moisture is consistently high. Samples for this study were collected from areas of fragmented populations in both the buffer zone and restricted areas within the National Park (Figure 5.5)

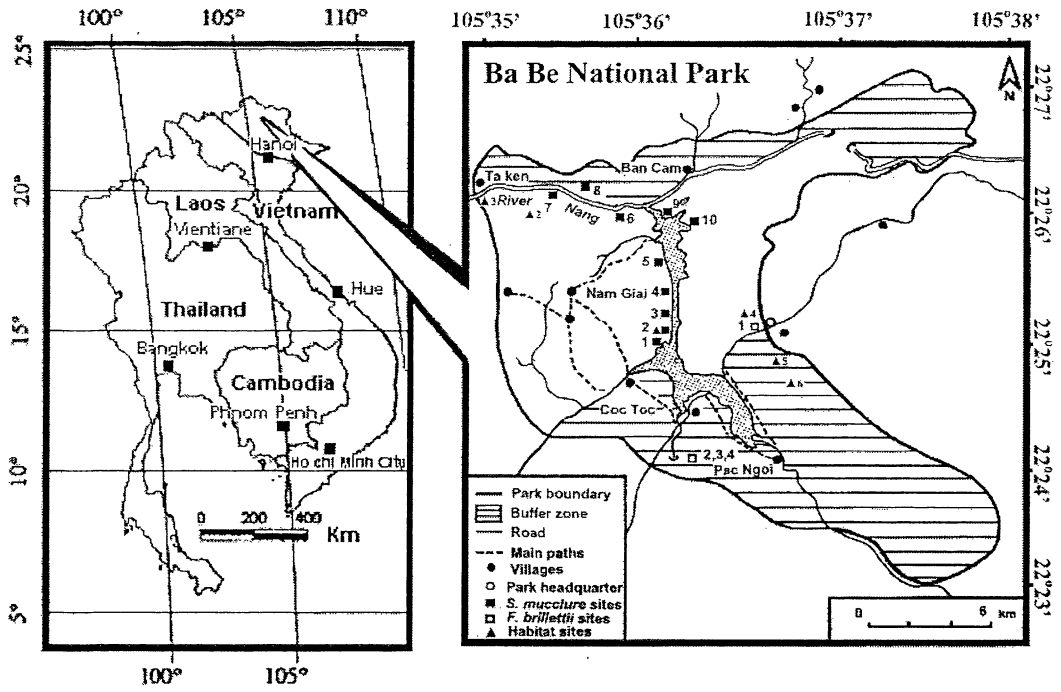


Figure 5.5: Site map for sampling of all four species (*Erythropalum scandens, Markhamia stipulata, Melientha suavious* and *Sinocalamus macclure*) in Ba Be National Park.

5.3.2 Sampling Method

Individual plants within larger populations were selected arbitrarily, providing they satisfied the criteria of healthy growth, but the majority of plants growing (and hence sampled) in each area (a population) were low in numbers. Sampling areas varied in size and so, of necessity, the distances between individual plants were variable, but were always smaller compared to between populations (Figure 5.5). An attempt was made to collect a representative sample of the genetic variation in each area, by using sufficient plant numbers to ensure statistical reliability of results. Locations of the sample sites are presented in Tables 5.1 -5.4

Table 5.1: Origin and description of material of 10 populations of *Sinocalamus mucclure* in BBNP-Vietnam (ranged: latitude from 22'.27° to 22'.25° and longitude from 105'.34° to 105'.35°) collected for RAMP-PCR and RAPD-PCR.

Population (Code: Pop)	Location names (individuals)	Distance to nearest site (km)	Forest situation (Forest)	Topographical types
Pop 1	Ho Hai (S1-S10)	0.5	Natural	Limestone
Pop 2	Ho Hai (S11-S20)	0.8	Natural	Limestone
Pop 3	Ho Hai (S21-S30)	2	Natural	Limestone
Pop 4	Ho Ba (S31-S40)	3	Natural	Limestone
Pop 5	Cuoi Ho Ba (S41-S42)	6	Natural	Limestone
Pop 6	Tham Mu (S43-S44)	2	Natural	S.limestone
Pop 7	Tham Mu (S45-S52)	0.5	Natural	Limestone
Pop 8	Na Lan (S53-S56)	7	Effected	Limestone
Pop 9	Tham Mia (S60)	5	Effected	Limestone
Pop 10	Na Duong (S57-S59)	5	Natural	Limestone

Table 5.2: Origin and description of material of 4 populations of *Markhamia stipulata in* Ba Be National Park -Vietnam (ranged: latitude from 22'26° to 22'24° and longitude from 105'36° to 105'37°) collected for RAMP and RAPD-PCR.

Population (Code: Pop)	Location names	Distance to nearest site	Forest situation	Topographical types
Pop 1	Botanic Garden (Ma10 & Ma11)	20km	Intensive farming	Lowland
Pop 2	Teng Huong 1 (Ma1-Ma3)	20m	N.forest	Limestone
Pop 3	Teng Huong 2 (Ma4-Ma6)	20m	N.forest	Limestone
Pop 4	Teng Huong 3 (Ma7-Ma9)	20m	N.forest	Limestone

Table 5.3: Origin and description of material of 9 populations of *Erythropalum scandens* in BBNP-Vietnam (ranged: latitude from 22'26° to 22'23° and longitude from 105'35° to 105'38°) collected for RAMP and RAPD-PCR.

Population (Code: Pop)	Location names	Distance to nearest site (km)	Forest situation	Topographical types
Pop 1	Nam Cuong (Er1-Er5)	6	Affected	Limestone
Pop 2	Noc Tiep (Er6-Er10)	6	N.forest	Limestone
Pop 3	Coc Toc (Er11-Er15)	6	Affected	S.limestone
Pop 4	Keo Sliu (Er16-Er20)	4	Affected	Near lake
Pop 5	Slam Bac (Er21-Er25)	3	Affected	Limestone
Pop 6	Him Dam (Er26-Er30)	4	Affected	Limestone
Pop 7	Near Office (Er31-Er35)	3	S.forest	S.limestone
Pop 8	Local Garden (Er36-Er40)	5	Intensive farming	Lowland
Pop 9	Rung vau (Er41-Er45)	5	Affected	S.limestone

Table 5.4: Origin and description of material of 9 populations of *Melientha suavious* in BBNP-Vietnam (ranged: latitude from 22'23° to 22'26° and longitude from 105'36° to 105'38°) collected for RAMP and RAPD-PCR.

Population (Code: Pop)	Location names	Distance to nearest site (km)	Forest situation	Topographical types
Pop 1	Nam Cuong (Me1-Me5)	6	Affected	Limestone
Pop 2	Noc Tiep (Me6-Me10)	6	N.forest	Limestone
Pop 3	Coc Toc (Me11-Me15)	6	Affected	S.limestone
Pop 4	Keo Sliu (Me16-Me20)	3	Affected	Near lake
Pop 5	Slam Bac (Me21-Me25)	3	Affected	Limestone
Pop 6	Him Dam (Me26-Me30)	4	Affected	Limestone
Pop 7	Near Office (Me31-Me35)	2	S.forest	S.limestone
Pop 8	An Ma (Me36-Me40)	6	S.forest	Island
Pop 9	Keo Tac Ke (Me41-Me45)	2	N.forest	Near lake

Following previous studies by Langton (2000) tissue samples were taken from those plants originally sampled for RAPD-PCR to enable a direct comparison between the results produced using an alternative RAMP-PCR method. Normally,

more leaf tissue was obtained than needed; the older remaining leaves were omitted due to plant tissue being suitable for DNA extraction (see section 5.3.3 below). To test the hypothesis that genetic variation differs between populations of the four species, the study site was divided into different sampling areas, separated to varying degrees by the type of forest present such as natural forest, secondary forest, the top of the mountain or lowlands, and the different sites of the Park such as in the restricted areas, buffer areas or botanic gardens.

Leaves from 45 individuals of *Erythropalum scandens* were collected from 9 natural populations in the main area and buffer zone of Ba Be National Park (Figure 5.5). In every site, sampling was conducted from 5 individuals for each site. Leaf material of *Markhamia stipulata* was collected from 11 individuals from 3 natural and 1 planted (botanic garden) site (Figure 5.5). Botanic Garden planted material, which had been established more than 7 years previously from local forest wildings was sampled, because almost all naturally occurring trees in the area have been destroyed. Sampled locations covered a wide range of the natural distribution of *Markhamia stipulata*. However, sampling focussed on the locations where the species is most endangered in Ba Be National Park, with 3 individuals per site in the natural populations, and 2 individuals in the Botanic Garden. Individuals were normally a minimum of 5 m apart, although this criterion could not always be fulfilled due to the extreme scarcity in some sampling localities (Dawson & Powell, 1999). Leaves from 45 individuals were also collected from 9 populations of *Meliantha suavious,* with an average 5 individuals for each population in different locations and type of forest in the Park. Finally, the highest numbers of individuals was from the species *Sinocalamus macclure* within 60 individuals in 10 populations. As for populations 1 to 4, leaves were collected from each of 10 individual plants, while for the populations 5 and 6 only 2 individuals were sampled, 8 individuals for population 7, 4 individuals for population 8, 1 individual for population 5 and 3 individuals for population 9 (Bucci *et al.,* 1997).

All samples were labeled by specific and local name, locations, and date of sampling (Do, 2005). Molecular studies were done overseas (i.e. Australia), therefore all samples must be on the list of the Permit to Import Quarantine

Material (the permit Number of this study: 200519682) approved by the Australian Quarantine and Inspection Service (AQIS). The samples were also stored in an Approved Place for Quarantine (Approval No: N1677) in a cold room and/or laboratory at the University of Technology, Sydney (UTS).

5.3.3 Sample Collection and Storage

Previous studies on rare and endangered species (De Filippis, 1996; Langton, 2000; Sommerville, 2001; Hoang, 2002) have found young, expanding leaves and flower buds yielded the best quantity and quality of DNA. This is in agreement with Towner (1991) who noted that unexpanded plant leaves have a high cell density and contain less contaminating polysaccharides and secondary metabolites than mature leaves. To minimise impact on the reproduction of the species for this study, young leaves, slightly expanded and pink in colour were generally collected. However, when no other suitable juvenile material was available on the plant in question, mature leaves were selected.

Leaf samples were removed from each plant using a scalpel sterilised in weak bleach not only to prevent cross contamination in the event that any of the individuals sampled carried pests or disease, but also to ensure adherence to quarantine procedures. To reduce the possibility of contamination of the plant DNA with DNA from other organisms, only healthy leaf samples with no evidence of deformity or pest infestation were collected. Each sample was inspected visually for the presence of external contaminants (such as insects or micro-organisms), then wrapped in aluminum foil and placed in a container of liquid nitrogen for transport back to the laboratory. Plant materials were stored at -80°C before DNA extraction.

5.3.4 DNA Extraction

Total genomic DNA minipreparations were carried out using a modified version of the method described by Doyle & Doyle, (1987) and Magel *et al.,* (2000). This method is based on the use of cetyltrimethylammonium bromide (CTAB), a positively-charged detergent that allows the extraction of DNA from plant material with a minimum of contaminating polysaccharides (Towner, 1991; Sambrook and

Russell, 2001). While many other methods are available for the extraction of plant DNA (Roger *et al.*, 1996), this particular method has been found useful for extracting DNA from woody perennials and yields DNA of a quality suitable for PCR (Magel *et al.*, 2000).

To prevent contamination from foreign DNA, all solutions (other than heat labile or flammable compounds) and equipment used in the following extraction method were first sterilised by autoclaving (121°C, 104kPa for 20 minutes), or by washing (mortar and pestle only) in 10% sodium dodecyl sulfate (SDS), prior to beginning the extractions. Fresh CTAB buffer [2% (w/v) CTAB, 20mmol/L EDTA, 100mmol/L Tris-HCl, pH 8.0, 1.4mol/L NaCl, 1% (v/v) 2-mercaptoethanol (BME), 1% (w/v) polyvinylpyrrolidone PV-40 (PVP)] was prepared on the day of each extraction.

To begin the extraction, a mortar and pestle were pre-cooled in liquid nitrogen for several minutes before use. Approximately 100mg of leaves were ground to a fine powder in liquid nitrogen, in the pre-cooled mortar and pestle. A 450µl aliquot of CTAB buffer was then added to, and ground together with, the powdered sample. This mixture was allowed to thaw before adding a further 450µl CTAB buffer.

The resulting slurry was transferred to a 2ml microcentrifuge tube using a wide-bore pipette, and heated at 65°C for 5 minutes in a dry heat block. The tube was then incubated at 60°C in a water bath for 30 minutes, with occasional inversion to mix the contents. Following incubation, 6µl of 20mg/ml proteinase K (Promega) was added to the reaction mix, and the tube further incubated in a water bath at 37°C for 90 minutes with occasional inversion.

Proteins, pigments, and other contaminating organic compounds were extracted by adding 900µl chloroform:isoamyl alcohol (24:1) to the slurry. The resulting mixture was gently inverted 8 – 10 times to maximize DNA yield and the microtube was then centrifuged at 12,000g for 5 minutes at room temperature. The resulting aqueous supernatant (approximately 500 – 700µl, containing the DNA) was carefully transferred to a fresh 1.5ml microtube using a wide-bore pipette.

The DNA in the supernatant was precipitated with two thirds the volume of cold isopropanol. The tube contents were gently mixed, then centrifuged at 12,000g for 2 minutes at room temperature to pellet the precipitate. The isopropanol was decanted, and replaced with 1ml chilled 70% (v/v) ethanol. The DNA pellet was gently flattened with the side of a pipette tip to maximise the surface area available for washing.

The DNA was re-pelleted by centrifugation at 12,000g for 10 minutes at room temperature. The ethanol was then decanted, and the DNA pellet was allowed to dry at room temperature for a maximum of 15 minutes, but the pellet was not allowed to completely dry, before being resuspended in 50µl sterile TE buffer (10mmol/L Tris-HCl, 1mmol/L EDTA, pH 8.0). A further 30 minutes incubation in a water bath at 37°C was required to help the DNA pellet dissolve fully in the TE buffer or it was left overnight at 4° C to dissolve fully.

When the pellet had dissolved, 2µl of 10mg/ml RNAase A (Sigma) was added, and the tube was incubated in a water bath at 37°C for 30 minutes to destroy any contaminating RNA. The DNA solution was then analysed by spectrophotometry and finally stored at -20°C for later use.

5.3.5 Quantitation of DNA

The quantity and quality of extracted DNA was estimated using a Pharmacia GeneQuant DNA/RNA calculator. Absorbance readings were taken at wavelengths of 230, 260 and 280nm. The purity of the DNA was then estimated by the ratio of readings taken at 260:280nm and 260:230nm (pure DNA having a 260:280 ratio of 2.0). The calculator automatically estimated DNA yield by multiplying the absorption at 260nm by 50µg/ml (an OD_{260} of 1 corresponds to ~50µg/ml of double-stranded DNA).

5.3.6 Polymerase Chain Reaction

DNA polymorphisms in the genome of the four selected forest tree species (i.e. *Erythropalum scandens* Blume., *Markhamia stipulata* Steem., *Meliantha suavious* Pierre., and *Sinocalamus mucclure* sp.) were amplified through the use of the

Polymerase Chain Reaction (PCR), and a variety of RAPD primers and microsatellite primers. Due to time constraints *E. scandens* and *M. suavious* were only amplified with the RAPD-PCR method, and the other two species (*M. stipulata* and *S. mucclure*) were assessed with both RAPD-PCR and RAMP-PCR methods. Each PCR was performed in a final volume of 25µl containing 1 x Fisher Biotech Reaction Buffer (67mM Tris-HCl – pH 8.8, 16.6mM $[NH_4]_2SO_4$, 0.45% Triton X-100, 0.2mg/ml gelatin), 1M betaine, 2mM Fisher Biotech mixed dNTPs, 0.1µg/ml RNase A, and varying amounts of primer/s, $MgCl_2$, Fisher Biotech Taq DNA Polymerase, genomic DNA, and sterile double distilled water. PCR reactions were carried out using a Biometra Personal Cycler.

5.3.7 PCR Preparation

To prevent contamination of the PCR reaction mixture with exogenous DNA, and to prevent cross-contamination of template DNA, the following precautions were taken (recommended by Kwok and Higuchi, 1989):

1. All equipment used in PCR preparation (PCR tubes, pipette tips, master mix tubes, and solutions) were autoclaved;
2. Laminar flow cabinet, pipettes and gloves were sterilised by irradiation with UV light prior to sample preparation;
3. Reaction components were assembled in the laminar flow cabinet;
4. Gloves were worn, and were changed periodically, during PCR preparation;
5. Reagents were pre-mixed, prior to dividing into aliquots, with template DNA added last, and
6. A negative control (containing all components except template DNA) was included in each series of reactions to ensure no contaminating DNA was present in any of the reagents.

Test reactions were performed in duplicate to ensure the reproducibility of the results.

5.3.8 Primer Selection and Optimization of PCR

Primer selection and optimisation of the PCR is described in Appendix 9

Final reaction conditions

PCR was carried out on each of 60 samples for String bamboo, 11 samples for *Markhamia stipulata*, 45 samples for each of *M. suavis* and *E. scandens* with RAPD primers. DNA samples were also assessed using 2 combinations of 2 microsatellite primers (MS1: 5' CAACACACACACAC 3') and (MS2: 5' TGACACACACACAC 3') with various RAPD primers (OPB10, and OPD2). Each reaction was performed in a final volume of 25µl containing 1 x Fisher Biotech Reaction Buffer, 1M betaine, 2mM Fisher Biotech mixed dNTPs, 0.1µg/ml Rnase A, 2.5 mM $MgCl_2$ (3.0 mM for RAMP-PCR), 1.0 units Taq DNA Polymerase (1.5 unit for RAMP-PCR), 40ng genomic DNA, and 12pmol of each primer. Reactions were carried out in a Biometra Personal Cycle using the following temperature profile: 46 cycles of denaturation at 94°C for 1 minute, primer annealing at 92 °C for 1 minute, 35°C for 1 minute, 72 °C for 1 minute and extension at 72°C for 5 minutes and cooling to 2 °C.

5.3.9 Gel Electrophoresis

The products of the above PCRs were analysed by electrophoresis on agarose gels.

(a) Gel preparation

Agarose gels of 2% (w/v) and 3% (w/v) were prepared using Sigma Type I (low EEO) Agarose dissolved in 0.5 X TBE buffer (5.4 g/L Tris base, 2.75 g/L boric acid, 2 ml/L (0.5 mol/L) EDTA pH 8). Each gel was cast and run in a Biolad Mini-Sub® Cell electrophoresis tank. The gels were loaded with 15µl of each PCR product combined with 2µl of bromophenol blue loading dye (0.2% (w/v) bromophenol blue and 50% (v/v) glycerol in TE buffer). A molecular weight marker (either Hyper Ladder I - Biotech or pGEM Marker - Promega) was added to one lane to determine the approximate sizes of the PCR products. Electrophoresis was carried out at 90V, in 0.5 X TBE buffer, for 2 to 3 hours till the dye had reached the edge.

(b) Gel Staining and Photography

Agarose gels were stained in a solution of ethidium bromide (10µl of 10µg/ml ethidium bromide per 100ml of double-deionised water) for 15 minutes on a shaker and de-stained in double-deionised water for 20 minutes. The gels were then viewed on a Uvitec Transilluminator (M020616, Integrated Sciences) and photographed using a Kodak camera (EDAS 290) connected to a computer. Images were printed in black and white using a Kodak image program (Kodak camera tools DC 290).

5.3.10 Band Scoring

The presence or absence of bands was determined by examining each gel photograph. Photographs for band scoring were printed in black and white using a Laser printer. Observed bands were marked in ink on one of two photographs taken of each gel to obtain a permanent record for later evaluation. Only those bands that were unambiguous were scored.

5.3.11 Data Analysis

Each reproducible band was visually scored '1' for the presence and '0' for the absence of bands, and the binary data used for statistical analysis. The band sizes were determined by comparison with a 100 bp DNA molecular weight ladder (Promega), and faint bands of doubtful reproducibility were ignored; see Figure 5.6 and Figure 5.7 for examples of variations in band intensity. Data was analysed with PopGen Version 1.31 (Yeh *et al.,* 1999), a Microsoft Windows-based freeware program for population genetic analysis and PRIMER Version 5 (Clark and Gorley, 2001) (Pymouth Routines In Multivariate Ecological Research- v5) for Windows Version 5.2.7. G-statistic (G_{st}), multi-dimensional scaling (MDS) and cluster analysis were used to estimate genetic differences between the sites (populations) and individual. The G-statistic estimates genetic differentiation and reduction in the number of heterozygote loci based on Nei's regular and unbiased genetic measures (Yeh *et al.,* 1999). The Mantel test statistic (r) was used to determine correlation between geographic and genetic distances using the program IBD Isolation by Distance Version 1.52 (Mantel, 1967). MDS was used to understand patterns of

variation within and amongst populations by converting a set of variables into a few dimensions so that individual variations are condensed into a set of limited axes. Such graphical analysis helped to identify the individuals and primers which tend to cluster together. Cluster procedure was an average linking one, and all similarities used were Bray-Curtis to produce dendrograms (Clark and Gorley, 2001).

5.4 Results

5.4.1 DNA Extraction

The total genomic DNA minipreparations were carried out using a modification of the CTAB-DNA extraction method of Doyle and Doyle, (1987) for this study. DNA extracted from young meristematic leaf material ground in liquid nitrogen was better in quantity and quality than that from mature leaves, as previously found by De Filippis *et al.,* (1996); Langton, (2000); Hoang, (2002). The advantages of using young leaf material over mature leaves of the four different species, in terms of providing high yield and much higher quality of DNA is shown in Table 5.5. The bamboo leaf material was more difficult to extract DNA from because it is hard fibrous material. Statistical analysis showed a significant difference (P= 0.05) between DNA yields and age of tissue material. Yields of DNA from young leaves were significantly higher than from tissue that was at times only slightly more mature.

Young leaf materials not only provided a higher yield of DNA, but also better quality, as indicated by the 260:280 ratio and a more constant 260:230 ratio. DNA from young leaves had an average 260:280 ratio of 1.8, while that of the mature materials were approximately 1.9 (see Table 5.3). The ratios of absorbance at 260 to 230 nm were just lower in DNA extracted from young leaves than that from mature leaves. Young leaves having an average 260:230 ratio of 1.98 and mature leaves having a ratio of around 2.08, but with overlapping SE. However, the quality of the DNA from different tissues was not as variable as the yield. The DNA extracted from fully expanded leaves was generally contaminated with polysaccharides. But, this level of contamination did not affect PCR in our

situation, as reproducible profiles have also been obtained using DNA with ratios of 260:280 nm as low as 1.48 (De Filippis and Magel, 1998).

DNA extracted from four different species in liquid nitrogen were found to be different when compared with one another (see Table 5.8). *E. scandens* and *M. suavious* are favourite vegetables with soft leaves, the leaves of *M. stipulata* have more deposits and leaf hairs on leaves, and especially the leaf of *S. macclure* is hard and more fibrous than the others. The DNA extracted from the four species were somewhat variable in quality, though the lowest average 260:280 ratio was for *M. stipulata* (1.286) but on experimentation indicated sufficient purity for using in PCR-based applications for this study. Hence, the quality of the DNA from different tissues, although variable was not as variable as the yield; the DNA yield ranged between 550.8 and 956.6 µg DNA/g F.W.

Table 5.5: Quality and quantity of DNA extracted from young and old leaf of String Bamboo *(Sinocalamus macclure)*. Yields and ratios were estimated using a Genequant DNA/RNA calculator. The 260:230 and 260:280 refer to the ratio of absorbances measured by spectrophotometry at 230 nm, 260 nm and 280 nm respectively.

Species	Type of leaf	260:230 ratio			260:280 ratio			DNA yield (µg/g F.W. tissue)		
		Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.
Sinocalamus macclure (String Bamboo)	young ± SE	1.659	2.389	1.981 0.061	1.689	2.026	1.801 0.027	1058.0	1329.0	1202.8 29.5
	old ± SE	0.829	3.226	2.086 0.201	1.559	2.203	1.905 0.067	124.0	575.0	318.3 46.8

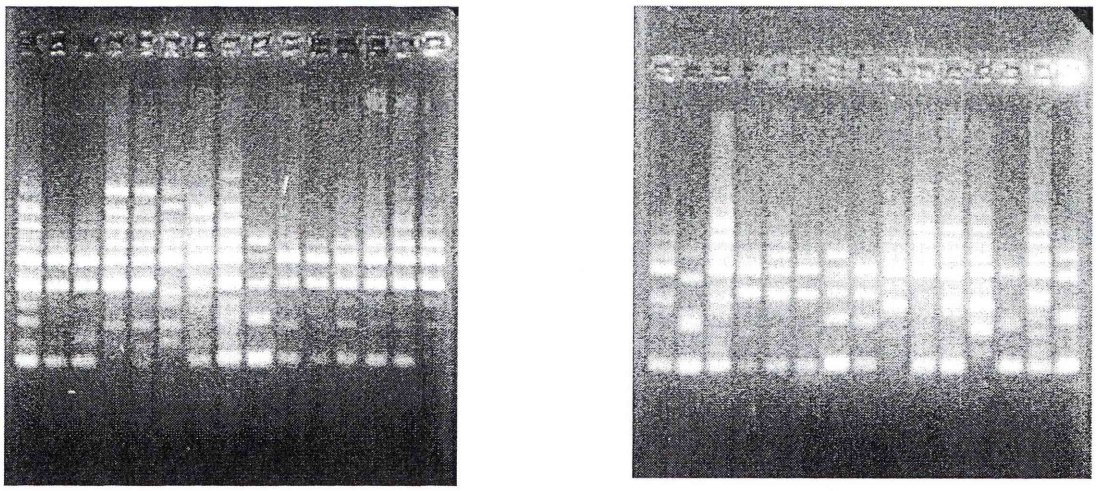
Table 5.6: Quality and quantity of DNA extracted from difference 4 species of *Erythropalum scandens*, *Markhamia stipulata*, *Melientha suavious* and *Sinocalamus macclure*. Yields and ratios were estimated using a Genequant DNA/RNA calculator. The 260:230 and 260:280 refer to the ratio of absorbances measured by spectrophotometry at 230 nm, 260 nm and 280 nm respectively.

Species	260:230 ratio			260:280 ratio			DNA yield (µg/g F.W. tissue)		
	Min.	Max.	Avg. ± SE	Min.	Max.	Avg. ± SE	Min.	Max.	Avg. ± SE
Erythropalum scandens	-0.040	8.566	2.702 0.405	0.838	1.846	1.506 0.039	15.5	1499.0	942.3 89.5
Markhamia stipulata	1.000	1.574	1.262 0.066	1.000	1.539	1.286 0.065	171.0	1181.0	757.4 105.3
Melientha suavious	0.044	10.580	1.443 0.586	1.033	2.000	1.606 0.036	27.5	1801.0	550.8 62.2
Sinocalamus macclure	0.560	3.681	1.750 0.132	0.722	30.330	2.277 0.476	15.0	1490.5	965.8 63.2

5.4.2 PCR optimisation

(a) $MgCl_2$

The optimum amount of $MgCl_2$ required in each PCR reaction can vary according to the particular primer combinations. In this experiment, 2.5mM of $MgCl_2$ was found suitable and produced strong and consistent banding patterns for the RAPD primers used. For RAMP combinations, at a ratio of 2:1, a concentration of between 2.5 and 3.0 mM $MgCl_2$ was found to be suitable for producing consistent banding patterns (Figure 5.5). At concentrations of $MgCl_2$ lower than this amount (about 2.5 mM) bands were faint and difficult to record. Higher concentrations of $MgCl_2$ (approximately 4.0 mM or more) showed no further improvement on the pattern and strength of the bands obtained, or on their reproductivity (Figure 5.5).



(a) (b)

Figure 5.6: Example of a RAPD-PCR profile among *Sinocalamus mucclure* individuals. (a) are from individuals in population 1 and (b) are individuals in population 2, showing similarity and diversity of band patterns.

(b) Taq polymerase

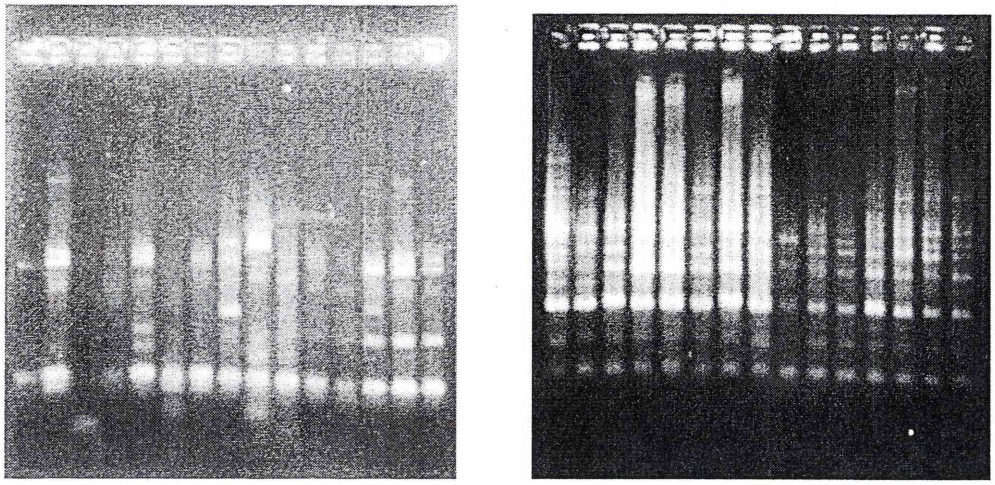
An amount of 1.0 unit of *Taq* polymerase was found optimum for the RAPD primers tested. Previously, there was no discernable difference between a concentration of 1.0 and 1.5 units of *Taq* polymerase, however using 1.0 unit was more economical (Hoang, 2002). In contrast, the amount of *Taq* polymerase

required for PCR can be greater for combinations of primers than for single primers (Swanson, 1999); the amount of 1.5 units *Taq* polymerase was found the best for the RAMP primers tested. The use of 1.5 units of *Taq* polymerase produced stronger and more consistent bands than was the case with 1.0 unit. Higher concentrations of *Taq* were not tested since 1.5 units is already at the upper limit of concentrations generally used in PCR and the enzyme is somewhat expensive.

The concentration of 12pmol per primer was used for this study. The RAMP primer ratio of 1:2 (RAPD:microsatellite) was found to yield a broader range of band sizes and good banding patterns; it also meant that the stocks of RAPD primers were not depleted too rapidly. Both MS1 and MS2 primers, in combination with the RAPD primers produced complex banding patterns, and these primer combinations produced more bands than RAPD primers alone. The band patterns produced by MS1 and MS2 were not identical, though appeared to be stronger with primer combinations using MS1 than in those with MS2.

For reproducibility, fingerprints produced using our optimised reaction conditions were found to be reproducible within experiments and, for the most part, reproducible between experiments conducted on the four different species. Small differences and inconsistencies between experiments may have resulted from the use of DNA samples that had been through too many freeze/thaw cycles and subsequent degradation of the DNA, and remedied by preparing fresh aliquots from the original concentrated stock DNA solutions.

Of the six genomic DNA concentrations tested (12ng, 25ng, 40ng, 50ng, and 70ng), 25ng of genomic DNA produced the strongest and most consistent bands in both RAPD and RAMP (Figure 5.6). The use of 50 and 70ng of DNA also produced strong and consistent banding patterns, however the patterns obtained were no better than those obtained with 25ng DNA. Concentrations of genomic DNA lower than 25ng produced inconsistent bands in both RAPD and RAMP-PCR (Figure 5.7).



(a) (b)

Figure 5.7: PCR performance with different amounts of genomic DNA in 4 species with other PCR components optimised ($MgCl_2$, *Taq* polymerase and temperature profile). PCR was carried out with combination of MS1 and RAPD primer D5.

The most suitable thermal profile for RAPD-PCR in this study was determined as: denaturation at 94°C for 4 minutes, followed by 46 cycles of denaturation at 92°C for 1 minute, annealing at 35°C for 1 minute and extension at 72°C for 1 minute, with a final round of extension at 72°C for 2 minutes and waiting for the temperature to reduce to 2°C.

Gel Electrophoresis was tested with different amount of agarose gels 2.5% with 0.8g and 3% with 1.2g; and the PCR products obtained were separated in 2.5% (w/v) and 3% (w/v) agarose gels. We found that the 2.5% (w/v) agarose gels were as good as 3% (w/v) agarose gels at separating bands in this study. With the ethidium bromide staining 20 min and destaining (in autoclaved water), the quality of bands were affected by the time of staining. Staining for 20 min and destaining for 15 min produced the clearest bands while staining for longer periods (e.g. 30 and 30 mins) did not increase the strength of the bands and sometimes produced fainter bands. All final PCR products were analysed on 2.5% agarose gels stained with ethidium bromide for 20 minutes and destained for 15 minutes.

5.4.3 *Sinocalamus mucclure*

(a) RAPD-PCR

Sixty individuals of *Sinocalamus mucclure* were sampled in the field study in 10 populations (Table 5.5). As with other species, the number of individuals of each population was different because of lack of samples in certain for collection areas and some populations were isolated; with other population groups only 1 individual occurred there.

String Bamboo was tested with 4 RAPD-primers (OPB-10, OPB-12, OPC-19 and OPD-02). The total number of bands scored was 68, of which 22 were generated by OPB-10, 15 bands for OPB-12, 14 bands for OPC-19 and 17 bands for OPD-02. In particular, the number of individuals in each of ten populations varied from 1 to 10 depending on availability at the sites. In fact, site 9 (population 9) had only 1 individual occurring on an isolated island of the Lake and other sites were not available for collection of a full complement of 10 (like from site 1 to 4) because of geographical distance between individuals. The number of polymorphic bands varied; populations 1 to 4 had 17-33 polymorphic bands, while population 9 had the lowest result (0), and this has reflected in % polymorphism of 0-48.5 (Table 5.7)

Table 5.7: DNA polymorphism between 10 populations of *Sinocalamus mucclure* detected by RAPD-PCR. 11 RAPD primers were used (see Table 5.1 for sequences of primers). Results are for duplicate PCR and only consistent bands were recorded. Pop is population.

Parameter	Pop1	Pop2	Pop3	Pop4	Pop5	Pop6	Popp7	Pop8	Pop9	Pop10
Number of individuals	10	10	10	10	2	2	8	4	1	3
Number of polymorphic bands	28	33	17	25	6	7	23	14	0	18
Percentage of polymorphism	41.18	48.53	25.00	36.76	8.82	10.29	33.82	20.59	0.00	26.47

The UPGMA dendrogram is in Figure 5.8

The UPGMA dendrogram separated into 2 main groups well; the separation of populations 1 to 6 from populations 7 to 10. The reason the ten populations separated into 2 groups in the dendrogram is probably due to the low number of

samples collected, geographic distance and the high degree of differentiation in ecological conditions between groups and populations. In the first main group, populations 2 and 3 were geographically close (800m), population 1 and 2 were close (500m), populations 3 and 4 were 2km apart, and 3km between population 4 and 5; all were surrounded by similar vegetation types and had similar isolation barriers. However, population 6 was far from these others (6km) but all on the same side of Ba Be Lake and all six populations shared the same ecological conditions. In the other group of four, population 8 and 10 were grouped together; their geographical separation was far (about 13 km) but they had the same vegetation and ecological types. Population 7 was located on the other side of the river but is very near population 8 (300m), while population 9 was isolated from other populations (on the island), with only 1 individual.

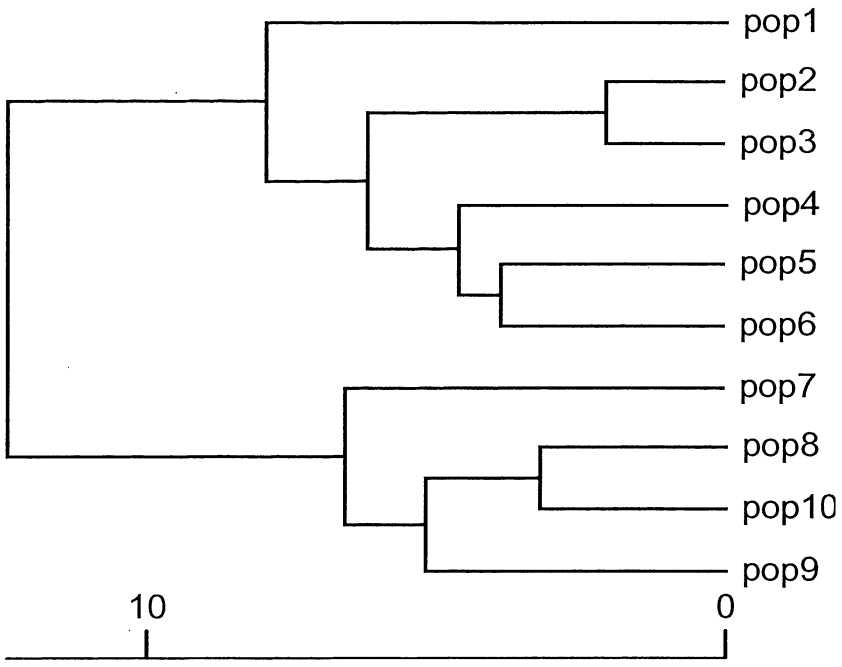


Figure 5.8: UPGMA Dendrogram of nine population of *Sinocalamus mucclure* in Ba Be national Park – Vietnam. The result was analysed by Popgen/Treeview program with RAPD-PCR data.

The result obtained from multi-dimensional scaling (MDS) (Stress 0.16) was informative. Individual Tham Mia (population 9) was separated from the two individuals grouped in the analyses. As well, individuals from 46 to 60 were

consistently grouped together (Figure 5.9), from population 8, 9 and 10 with the similar ecological conditions. Similarity appeared to be greater in individuals from 1 to 45, they were also grouped together; and all belonged to populations 1 to 6 and close relative proximity to one another. Overall, the result reflected the same relationship as the dendrogram in Figure 5.9 (a). The most informative primers were OPB12 and OPB10 from Figure 5.9 (b).

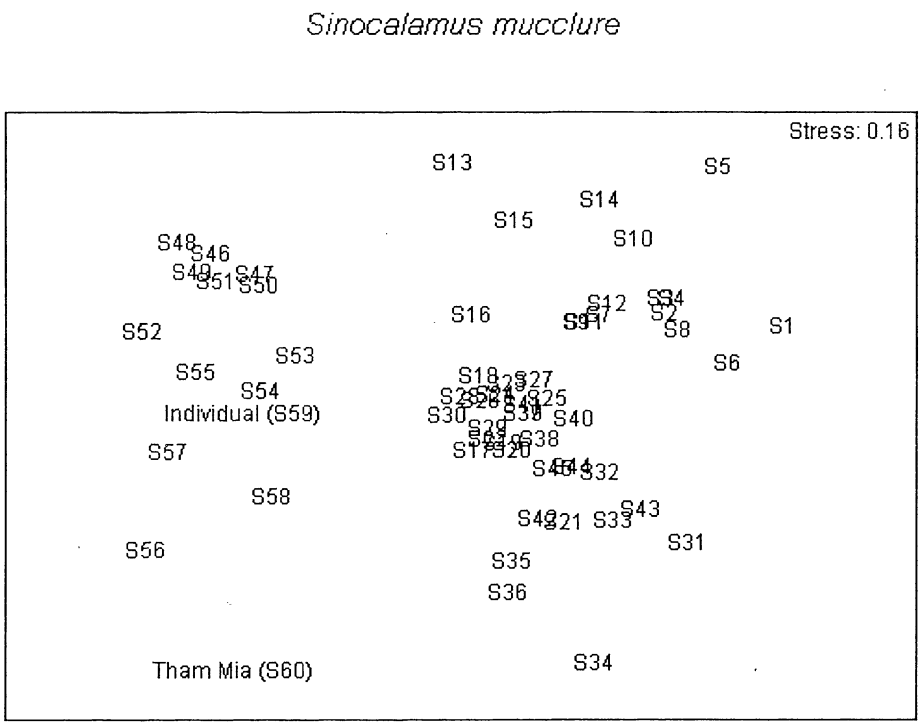


Figure 5.9: (a) Multi dimensional scaling (in Primer program) ordination of individuals of *Sinacalamus mucclure* based on a genetic distance matrix generated from pairwise comparison of DNA fingerprints based on the presence and absence of bands in RAPD-PCR.

Sinocalamus mucclure

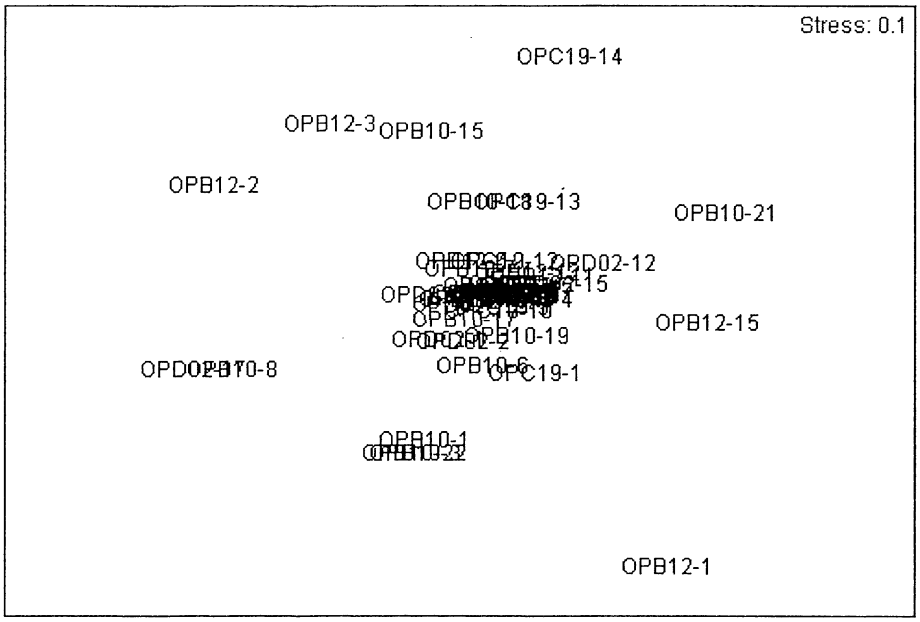


Figure 5.9: (b) Multi dimensional scaling (in Primer program) ordination of *Sinacalamus mucclure* separating the informative RAPD primers from those that produced no information in RAPD-PCR based on on the presence and absence of bands.

(b) RAMP-PCR

The UPGMA dendrogram of RAMP-PCR separated into 3 main groups; the separation of populations 1 to 3 from populations 4 to 8. The reason the ten populations separated into 2 groups in the dendrogram is probably due to the low number of samples collected, geographic distance and the high degree of differentiation in ecological conditions between groups and populations (Figure 5.10).

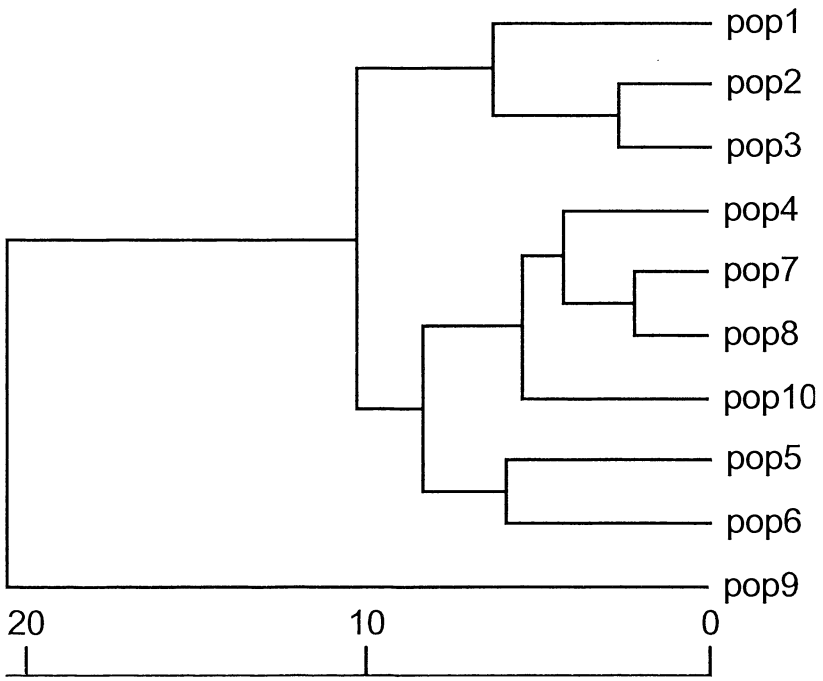


Figure 5.10: UPGMA Dendrogram by RAMP-PCR of nine population of *Sinocalamus mucclure* in Ba Be national Park – Vietnam. The result was analysed by Popgen/Treeview program with RAMP-PCR data.

The result obtained from multi-dimensional scaling (MDS) (Stress 0.14) was informative. Individual in Tham Mia (S60) (population 9) was separated from the rest of the individual grouped in the analyses. Overall, the result was reflected by the same relationship as the dendrogram in Figure 5.11 (a). The most informative primers were MS1-OPD12 and MS2-OPB10 from Figure 5.11 (b).

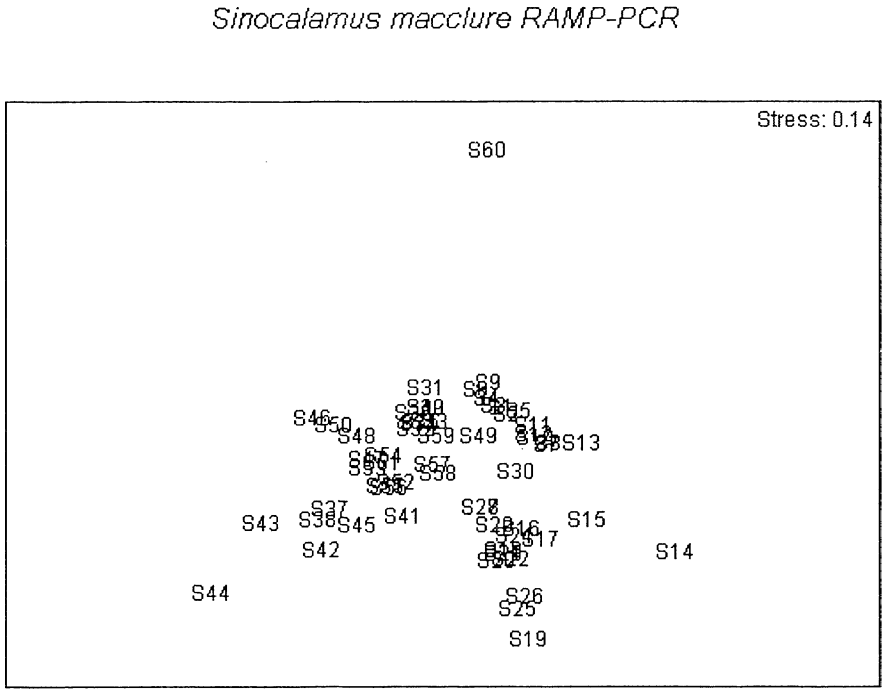


Figure 5.11: (a) Multi dimensional scaling (in Primer program) ordination of individual of *Sinacalamus mucclure* based on a genetic distance matrix generated from pairwise comparison of DNA fingerprints based on the presence and absence of bands in RAMP-PCR.

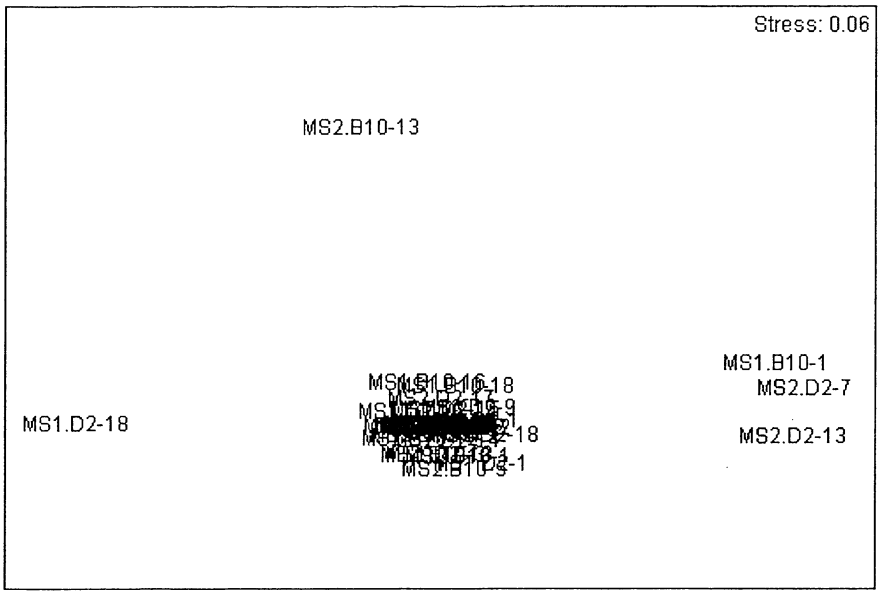


Figure 5.11: (b) Multi dimensional scaling (in Primer program) ordination of *Sinacalamus mucclure* separating the informative RAMD primers from those that produced no information in RAMP-PCR based on on the presence and absence of bands.

5.4.4 *Markhamia stipulata*

(a) RAPD-PCR

Eleven individuals of *Markhamia stipulata* were sampled in 4 populations (Table 5.1). The criteria for using only 4 populations was similar to those for *Erythropalum scandens* . However, this species is in limited numbers in the Park and very rare, so the number of individual and population was fewer than for other species.

Markhamia stipulata was investigated with 5 RAPD primers (OPA-19, OPB-10, OPB-12, OPD-02, and OPF-15). The number of polymorphic bands generated by RAPD primers within 4 populations is given in Table 5.8. All of the RAPD primers tested in this study produced a different pattern of bands within populations, some primers in some populations generated more polymorphic bands (16-32) than in the botanic garden plant (10). In other words, very high polymorphisms were detected within site group populations, but in contrast polymorphisms between site group populations were about 9-33% (Table 5.8). The number of polymorphic loci within the species is between 15 and 47.

Table 5.8: DNA polymorphism between 4 populations of *Markhamia stipulata* detected by RAPD-PCR. 11 RAPD primers were used (see Table 5.1 for sequences of primers). Results are for duplicate PCR and only consistent bands were recorded. Pop is population.

Parameter	Pop1	Pop2	Pop3	Pop4
Number of individuals	2	3	3	3
Number of polymorphic bands	10	16	16	32
Percentage of polymorphism	14.71	23.53	23.53	47.06

The UPGMA dendrogram of population frequency data based on Nei's genetic distance (Figure 5.12) indicated that population 1 (botanic garden) material was more similar to population 3 than to populations 2 and 4.Population 4 was

separated from these others, however it was relatively close by distance to populations 2 and 3 (20-50m).

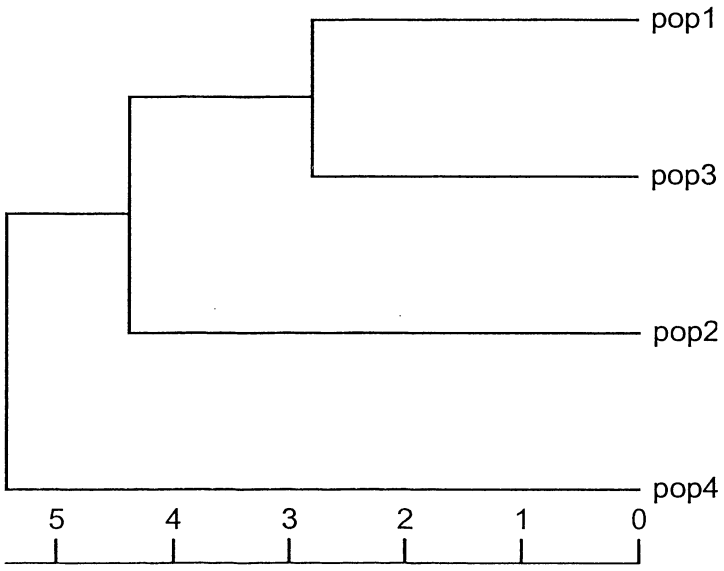


Figure 5.12: UPGMA Dendrogram of four population of *Markhamia stipulata* in Ba Be national Park – Vietnam. The result was analysed by Popgen/Treeview program with RAPD-PCR data.

MDS confirmed differences between grouping of sites and populations in detecting polymorphic bands differences (Figure 5.13). Individuals 10 and 11 were separated. Another grouping consisted of individuals 1 to 9. Individuals 9, 10 and 11 belonged to population 4, and in analysis by MDS, they are also highly separated, indicating that they are also distinct from one another; and as distinct they are to populations 1, 2 and 3.

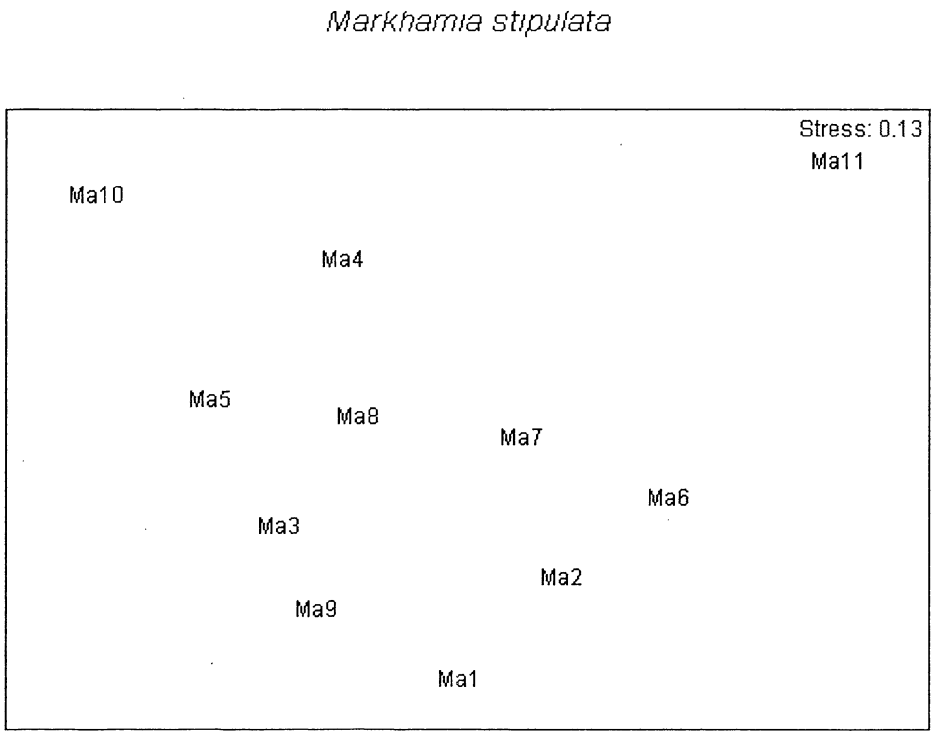


Figure 5.13: Multi dimensional scaling (in Primer program) ordination of individuals of *Markhamia stipulata* based on a genetic distance matrix generated from pairwise comparison of DNA fingerprints based on the presence and absence of bands in RAPD-PCR.

(b) RAMP-PCR

The Number of bands in four populations of *Markhamia stipulata*, generated by combinations of MS1 and MS2 and 2 RAPD primers, are shown in Table 5.9. The number of bands scored in each fingerprint ranged from 16 to 21. The combination of MS1 and MS2 with RAPD primers produced more bands per fingerprint for this species than the respective RAPD primers alone, and these results agreed with Sommerville's (2001) research in the endangered species *Grevillea caleyi* R.Br in Sydney. In addition, in this study, MS2 combinations generated more bands than MS1 combinations with the same 2 RAPD primers OPB-10 and OPD-02.

Table 5.9: Number of bands of *Markhamia stipulata* produced with different combinations of microsatellite (MS1) and (MS2) with RAPD primers and RAPD primers alone. The results are for duplicate PCR, and only consistent bands were recorded.

Species	MS1+OPB10	MS1+OPD02	MS2+OPB10	MS2+OPD02	RAPD-OPB10	RAPD-OPD02
Markhamia stipulata	19	16	21	18	18	15

The UPGMA dendrogram resulting from the presence and absence of bands generated by MS1 and MS2 and RAMP-PCR primers indicates a difference in relationship between population 1 and the other 3 populations as well (Figure 5.14). In fact, The first division in population 1 separated one group in the botanic garden of the Park and it was at a great distance to other groups (20km). Populations 2 and 3 were grouped together with very close distance of 20m, and population 4 had a geographic distance of 20m to populations 2 and 3. These results are not in agreement with the results using RAPD-PCR alone. Therefore, we conclude that the combination of MS1, MS2 and RAPD primers appeared more useful than RAPD primers alone when detecting polymorphism between populations, based on distance between plants.

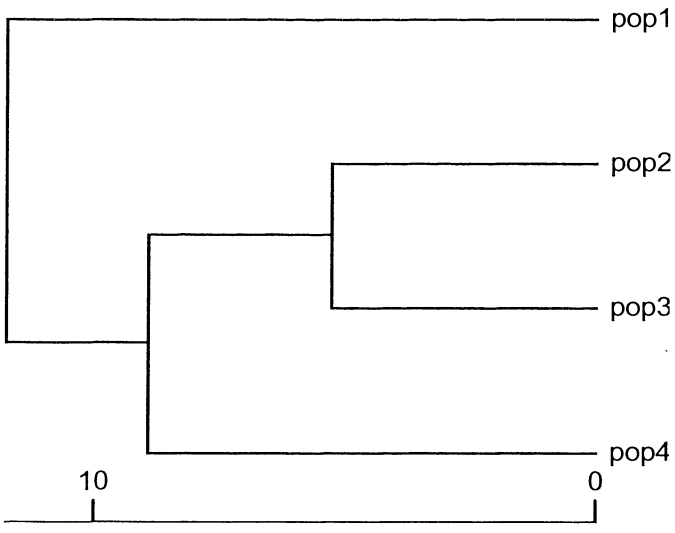


Figure 5.14: UPGMA Dendrogram of four population of *Markhamia stipulata* in Ba Be national Park – Vietnam by RAMP-PCR analysis. The result was analysed by Popgen/Treeview program with RAMP-PCR data.

As with RAPD primers, the individuals from the four different populations were grouped by MDS analysis according to their level of informativeness (Figure 5.15).

Two individual Ma-1 and Ma-11 were separated widely from the rest. It is likely that these two were mainly responsible for the separation of populations 1 and 4 because of the low numbers of individuals.

Two combinations of primers produced polymorphic bands in the comparisons of 11 individuals of *Markhamia stipulata*, and two combinations of RAMP primers generated polymorphic bands between individuals. As with RAPD primers, the different combinations were grouped by MDS analysis according to their level of informativeness (Figure 5.16). MS2+B10 combination was the best of those tested in terms of detecting bands that were present in the population but absence in individual. Combinations of MS1+D2 and MS2+D2 were able to generate bands that distinguished between populations as well.

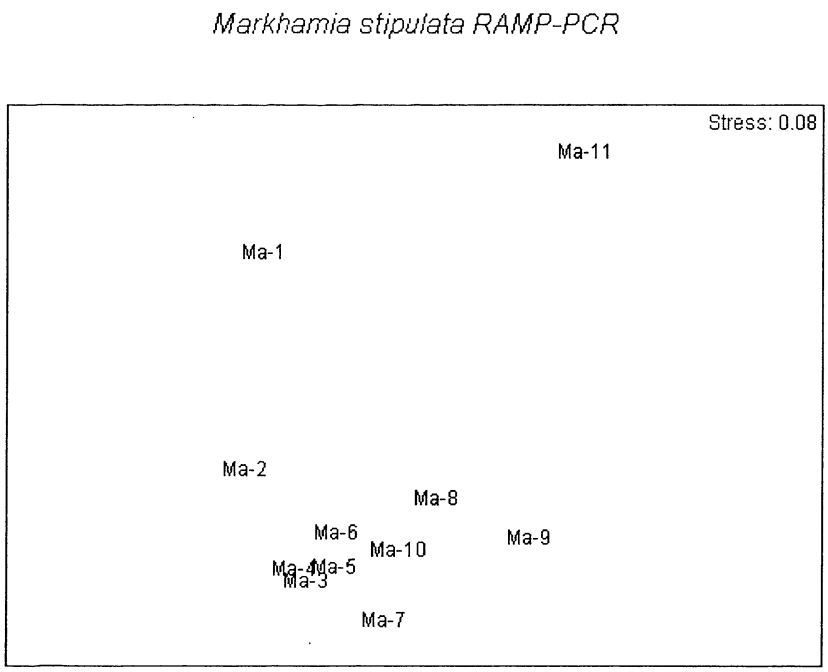


Figure 5.15: Multi-dimensional scaling analysis of 11 individual of Markhamia stipulata in Ba Be National Park of Vietnam in RAMP-PCR.

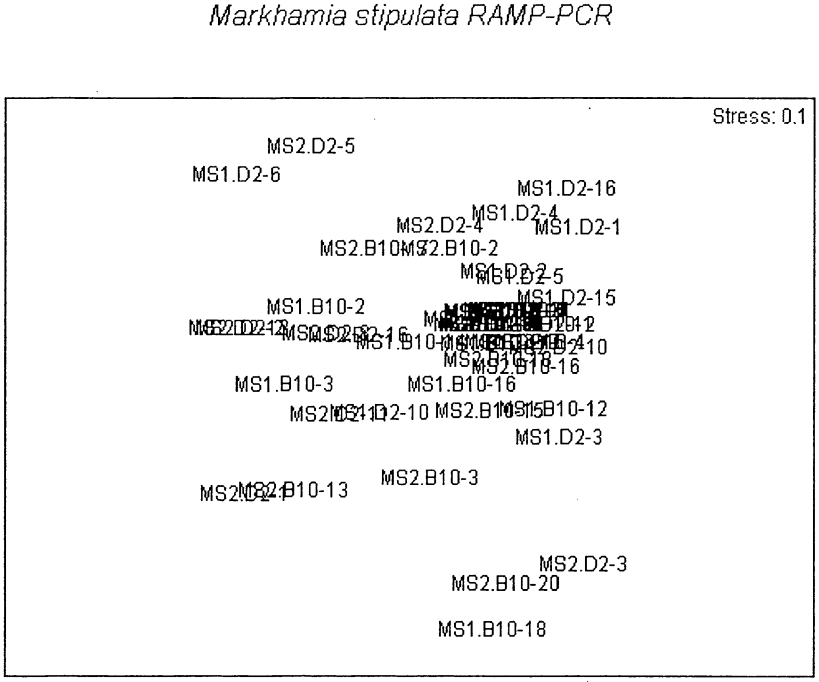


Figure 5.16: Multi dimensional scaling (in Primer program) ordination of *Markhamia stipulata* separating the informative RAMD primers from those that produced no information in RAMP-PCR based on on the presence and absence of bands.

Time constraints prevented the RAMP-PCR analysis of the remaining two species

Summary of RAMP-PCR versus RAPD-PCR

A summary of the number of polymorphic bands generated by combinations of MS1 and 7 RAPD primers, is shown in Table 5.6. There were about 57 different bands detected in comparison of populations by RAMP-PCR. In other words, 71% polymorphisms were found in the populations present (Table 5.10). The combination of MS1 and RAPD primers produced more bands per fingerprint than the respective RAPD primers alone, but combinations of MS2 and RAPD primers produced fewer bands than combinations of MS1 and RAPD primers. However, combinations of MS2 and RAPD primers appeared to produce not as many low molecular weight bands as did the combination of MS1 and RAPD primers, or RAPD primers alone (Figure 5.8). MDS showed clear differences between

individuals and groupings of site populations from the RAMP polymorphic bands data (Figure 5.9). Among *Sinocalamus mucclure* populations 7, 8 and 10 were grouped together. Another grouping consisted of populations 1 to 6. However population 9 appeared not to be grouped with any other population (Figure 5.10). This group division was confirmed when a dendrogram of the data was constructed (Figure 5.11). In *Markhamia stipulata* only populations 2 and 3 were grouped together. Two other wide apart groupings consisted of populations 1 and 4 (Figure 5.12). This group division was clearly evident when a dendrogram of the data was constructed (Figure 5.14).

Table 5.10: Summary of DNA polymorphism, population statistics and Mantel test. Results were from duplicate PCR reactions, where only consistent reproducible bands were included from 7 RAPD primers (total of 87 bands) or 2 RAMP primer combinations (total of 76 bands). G-statistic is identical to the F-statistic where only two possible alleles are scored at any locus, or where analysis of presence or absence of bands is conducted. G-statistic however does not require knowledge of genotype frequencies, and is a measure of the reduction in the numbers of heterozygote loci and genetic differentiation. Mantel statistic (r) was used to determine correlation between geographic and genetic distance.

Parameter	*Sinocalamus mucclure*		*Markhamia stipulata*	
	RAPD	RAMP	RAPD	RAMP
Number of individuals	60	60	11	11
Number of population	10	10	4	4
Number of polymorphic bands	55	50	44	53
Percentage of polymorphism	76.47	71.43	64.71	71.62
G-statistics (G_{st})	0.62	0.57	0.67	0.53
Mantel r test (probability)	0.19(0.25)	0.40(0.008)	0.37(0.02)	0.68(0.002)

5.4.5 *Erythropalum scandens*

(a) RAPD-PCR

Forty-five individuals of *Erythropalum scandens* were sampled in 9 populations (Table 5.11), and an average of 5 individuals per population. The reasons for selecting 9 populations were based on the geographical distance between individuals and populations in order to estimate the genetic flow between populations. Moreover, forest situations were included to ensure that differentiation may lead to indications of genetic diversity of each population as affected by the

different situations of the natural forest, secondary forest and forest affected by humans. Finally, there was a focus on the different terrains such as limestone forest, semi-limestone forest, island or near the lake, that might relate to the isolation of the populations.

Erythropalum scandens was investigated with 5 RAPD primers (OPA-08, OPA-19, OPB-10, OPC-19, and OPD-02). The number of polymorphic bands generated by RAPD primers within populations is given in Table 5.11. All of the RAPD primers tested in this study produced a different pattern of bands within populations. However, as expected, some primers and populations generated more bands than others. In other words, very high polymorphisms were detected within site group populations, and polymorphisms between site group populations were 33-59% (Table 5.11). MDS confirmed differences between grouping of sites and populations in detecting polymorphic band differences (Figure 5.17). Populations 7, 8, and 9 were grouped together. Another grouping consisted of populations 2, 3, 4, 5, and 6. However, population 1 was separated from the other 2 groups.

Table 5.11: DNA polymorphism between 9 populations of *Erythropalum scandens* detected by RAPD-PCR. 11 RAPD primers were used (see Table 5.1 for sequences of primers). Results are for duplicate PCR and only consistent bands were recorded. Pop is population. G_{st} is G-statistic calculated using Popgen program.

Parameter	Pop1	Pop2	Pop3	Pop4	Pop5	Pop6	Pop7	Pop8	Pop9
Number of individual	5	5	5	5	5	5	5	5	5
Number of polymorphic bands	33	50	31	45	55	24	51	47	49
Percentage of polymorphism	35.48	53.76	33.33	48.39	59.14	25.18	54.84	50.54	52.69
G-statistic (G_{st})	0.69								
Mantel r test (prob.)	0.25 (0.14)								

Analysis of distance of population showed that the dendrogam separated the 9 populations of *Erythropalum scandens* in Ba Be National Park very well. The separation of population 1 was expected, as polymorphisms are one of the lowest between different populations. The reason for the grouping of populations in the dendrogram may be also due to low band scoring. This result may also reflect that the location of this population is situated far and between the border of the Park

and village, or that the primers used in this experiment are not necessarily primers that will be useful to distinguish between populations (Brummer *et al.*, 1995).

The first division showed that population 1 was separated from the others; this population is located quite far from other groups, the distance between the nearest to furthest groups being from 6 to 20km, and another point is that this is between the border of the park and a local village. The second division separated populations 2 to 6 form populations 7-9; populations 2 and 4 were grouped together and geographically close (about 6 km), surrounded by similar vegetation types and had similar isolation barriers, though population 4 was distinct from populations 2 and 3 possibly because it is on a different side of the Lake even though geographic distance is not great (7km). Populations 5 and 6 are distant from the others but very close (3.5km) to each other with the same vegetation types and topography. The other division consists of populations 7, 8 and 9 together; all shared the same side of the Lake and on the track from the lake to the village. Population 8 is near the park office with the same distance to the two other populations (about 3 km). Population 9 is from a local garden and the fact that it was grouped with population 7, may be that it was collected from population 7 or nearby for propagation (Figure 5.5).

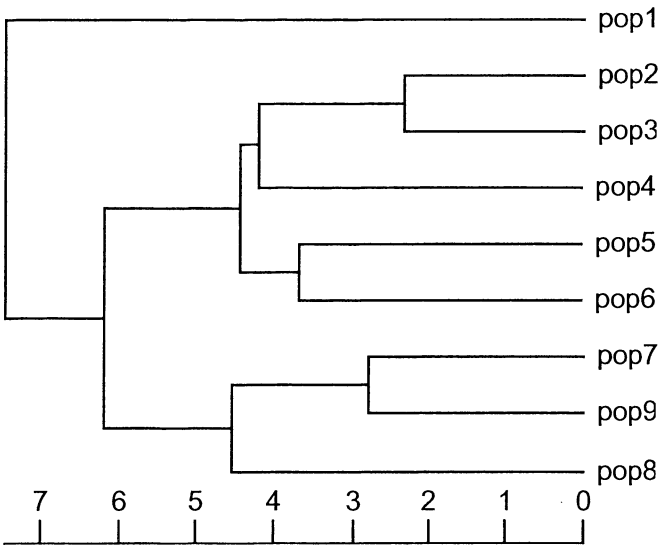


Figure 5.17: Genetic relationship between 9 populations of *Erythropalum scandens* determined by RAPD-PCR. Analysis was based on the presence and absence of bands produced by RAPD primers using the Popgen 32/treeview program with RAPD-PCR data.

Multi dimensional scaling analyses (MDS) showed a significant difference (stress = 0.19) between individuals of species, and sample statistic (global R) is 0.343, significance level is 0.1%. As can be seen in Figure 4.18, and individual Er32 was about the only separation, other separation of individuals were probably not significant and in a large cluster. G_{st} was high (0.69) and mantel statistic showed no correlation of genetic diversity with high distance (Table 5.11).

Erythropalum scandens

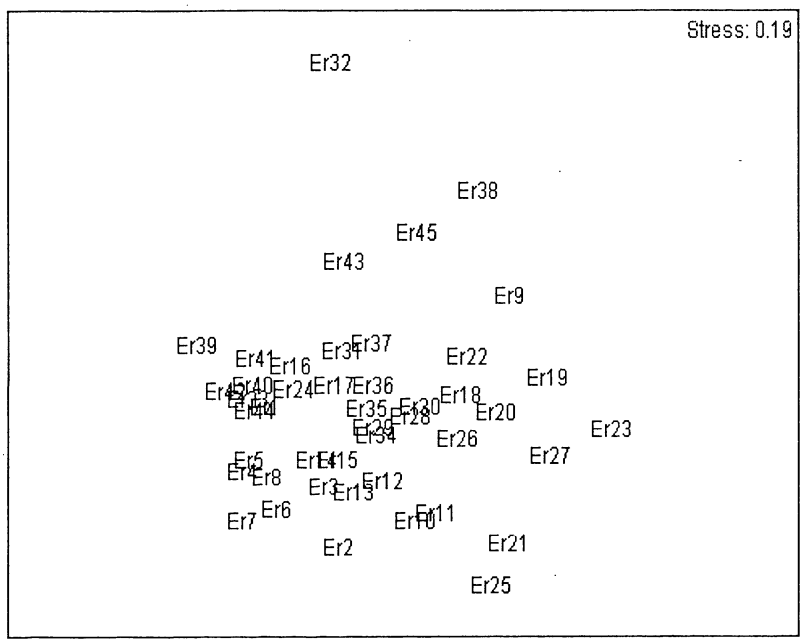


Figure 5.18: Multi dimensional scaling (from Primer program) separating the informative RAPD primers from those that produced no information in RAPD-PCR based on the presence and absence of bands.

5.4.6 *Melientha suavious*

(a) RAPD-PCR

Forty-five individuals of *Melientha suavious* were sampled from 9 populations (Table 5.13), an average of 5 individuals per population. The collection sites were like those for *Erythropalum scandens,* but two sites were different (Local Garden and Rung Vau).

Of fourteen RAPD primers, all but five (OPA-8, OPA-19, OPB-10, OPC-19, and OPD-02) generated scorable fragments which detected polymorphism between *Melientha suavious* individuals. All five primers produced complex patterns that proved difficult to interpret and some were eliminated from the analysis. The summary of genic variation statistics for all loci showed that the number of polymorphic bands generated by RAPD primers within 9 populations was between 45.56 and 75.56. Some primers and populations generated more polymorphic bands than others, such as population 7 (63) and population 8 (68). Very high polymorphisms were detected between site group populations and these were 38.89% (Pop3) to 75.56 (Pop8) given in Table 5.14. Estimates of G_{st} was high at 0.62 and Mantel statistic showed no relationship between genetic data and distance from populations (Table 5.12).

Table 5.12: DNA polymorphism between 9 populations of *Melientha suavious* detected by RAPD-PCR. 11 RAPD primers were used (see Table 5.1 for sequences of primers). Results are for duplicate PCR and only consistent bands were recorded. Pop is population. G_{st} is G-statistic calculated using Popgen program.

Parameter	Pop1	Pop2	Pop3	Pop4	Pop5	Pop6	Popp7	Pop8	Pop9
Number of individual	5	5	5	5	5	5	5	5	5
Number of polymorphic bands	41	58	35	56	55	45	63	68	43
Percentage of polymorphism	45.56	64.44	38.89	62.22	57.78	50.00	70.00	75.56	47.78
G-statistic (G_{st})	0.62								
Mantel r test (prob.)	0.21	(0.10)							

The UPGMA dendrogram of population data based on Nei's genetic distance (Figure 5.19) indicated that population 7 and 8 are separated. Population 8 is located in the island of the lake but it has the same grouping with population 7 near the Park office; this may reflect the fact that the park office species was taken to the island for propagation, because after cultivation of casava on the island ceased, vegetation developed as secondary forest and now includes this species. The second group was separated population 9 near the shore of the Lake with surrounding natural forest; it was isolated from other populations. All other groups were not well separated and had different vegetation types around and they were geographically distant (6-10km) and different topography from one another.

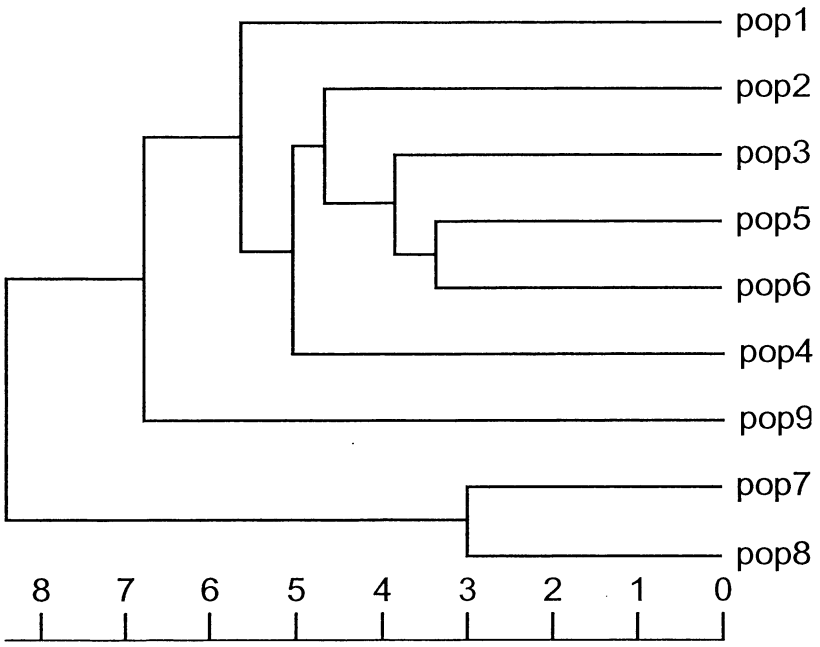


Figure 5.19: UPGMA Dendrogram of nine population of *Melientha suavious* in Ba Be national Park – Vietnam. The result was analysed by Popgen 32/treeview program with RAPD-PCR data.

Multi dimensional scaling analyses (MDS) showed significant differences (stress = 0.2) between the forty-five individuals in terms of polymorphic bands, and sample statistic (global R) is 0.278, significance level is 0.1%. The result is given in Figure 5.20, most individuals were grouped together, suggesting high relative similarity between them; some individuals were distinctive and grouped apart, such as Me6, Me35, Me 18, Me 8, Me31, Me39, Me38, Me37 and Me15. G_{st} was high (0.62) and mantel statistic showed no correlation of genetic diversity with high distance (Table 5.12). The result reflects a sporadic separation of individuals virtually in every population.

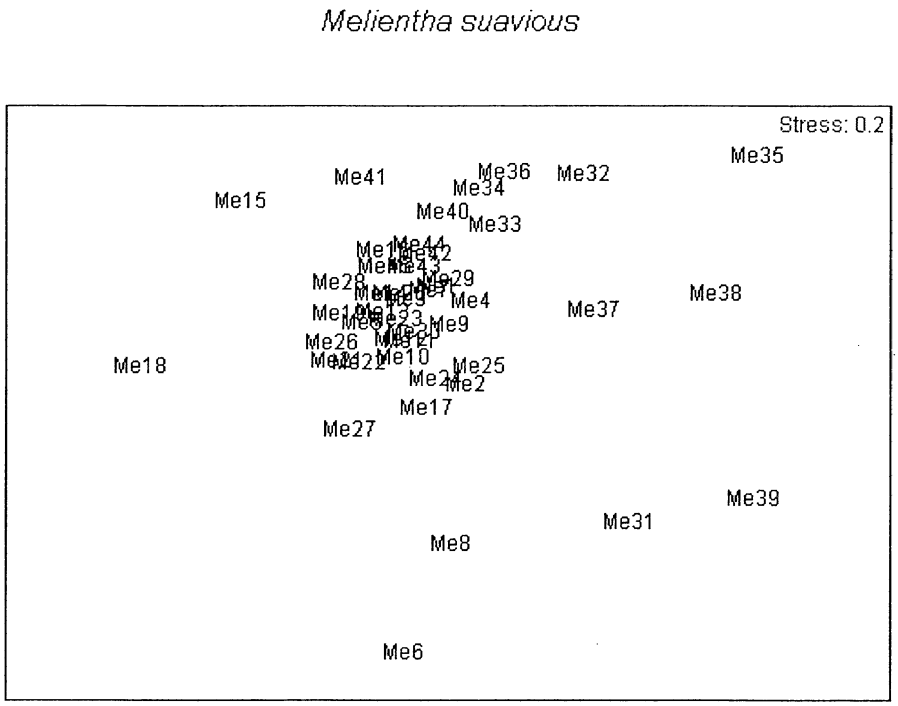


Figure 5.20: Multi dimensional scaling (from Primer program) separating the informative RAPD primers from those that produced no information in RAPD-PCR based on the presence and absence of bands.

5.4.7 Overall result for four species

Four rare and endangered forest tree species [*Erythropalum scandens* (Er), *Markhamia stipulata* (Ma), *Meliantha suavious* (Me) and *Sinocalamus macclure* (Sm)] were used in RAPD-PCR. All of the RAPD primers produced a very different pattern of bands in the 4 species. However, as expected, most primers tested generate a high number of bands in all species, except for primer F15. The number of bands generated by individual RAPD primers is noted in Table 5.13, the number of bands scored in each fingerprint ranged from 5 to 23. Primer C19 with *Erythropalum scandens* produced the greatest number (23) in any one species. All of the primers except primer F15 produced acceptable band numbers. Maximum number of bands in comparison with all species was 78 with primer B10. *E. scandens* and *M. suavious* produced a total of over 90 scorable bands (Table 5.15)

Table 5.13: Number and size range of bands produced by RAPD-PCR of genomic DNA extracted from 4 rare and endangered forest tree species in Ba Be National Park of Vietnam (see Appendix 9 for primer sequences). Experiments were performed in duplicate and only consistent bands were recorded.

RAPD primers	*Erythropalum scandens*	*Markhamia stipulata*	*Melientha suavious*	*Sinocalamus macclure*	Total bands
OPA-08	17	-	20	-	37
OPA-19	18	15	15	-	48
OPB-10	20	18	18	22	78
OPB-12	-	15	-	15	30
OPC-19	23	-	19	14	46
OPD-02	15	15	18	17	65
OPF-15	-	5	-	-	5
Total for species	93	68	90	68	-

The summary percentage polymorphism between *E. scandens, M. stipulata, M. suavious* and *S. mucclure*, as determined by RAPD-PCR, is shown in Table 5.15. There were large differences between the four different species in the number and size of bands generated by RAPD-PCR. However, there was difference in intensity of bands between 4 species; For example some bands were very strong in Er, Me, Sm but weak in the Ma.

Polymorphism between the populations of 4 different species was very different, *Melientha suavious* showed the highest percentage polymorphism (98.89%), and *Markhamia stipulata* yielded the lowest percentage (64.71 %). The number of polymorphic bands G_{st} value and even Matel test showed a high level of genetic differentiation and in *E. scandens, M. suavious* and *S. mucclure* there was no relationship between genetic data and distances between populations. Only in *M. stipulata* was there a relationship between genetic diversity and distance between individual in populations.

Table 5.14: DNA Polymorphism of 4 rare and endangered forest tree species detected by RAPD-PCR. 11 RAPD primers were used (see Table 3.1 for sequences of primers). Results are for duplicate PCR and only consistent bands were recorded. G_{st} is the G-statistic calculated using PopGen program.

Parameter	*Sinocalamus macclure*	*Markhamia stipulata*	*Erythropalum scandens*	*Melientha suavious*
Number of individuals	60	11	45	45
Number of populations	10	4	9	9
Number of bands	68	68	93	90
Number of polymorphic bands	55	44	84	89
Percentage polymorphism	76.47	64.71	90.32	98.89
G-statistic	0.62	0.67	0.69	0.62
Mantel r test (probability)	0.19 (0.25)	0.37 (0.02)	0.25 (0.14)	0.21 (0.10)

5.3 Discussion and Conclusions

5.3.1 DNA extraction

The CTAB method (Doyle and Doyle, 1987) used for DNA extraction from leaf tissue for the four forest tree species from Ba Be National Park in this research was effective, but variable as has also been reported by Magel *et al.,* (2000). The yield of DNA obtained from young tissue for the four species was similar to those from leaves of *Eucalyptus microcorys, Grevillea* hybrids and *Grevillea caleyi* R.Br. using the same method (Chen and De Filippis, 1996; Sommerville, 2001). The similarity in yields may be because the same type of plant material was used, and with likely similar leaf characteristics. Nevertheless, the results showed that even within the one species, the yields of DNA can vary between individuals sampled.

The yield of DNA extracted from the same species was highly dependent on the age of tissue. Younger tissue usually provides a higher DNA yield in comparison to older tissue. Doyle and Doyle, (1990) also reported that the DNA yields depended

on the age and the quality of the tissue used for extraction. Unexpanded leaves with high cell density would be superior material for DNA extraction than older leaves with lower numbers of dividing cells (Tower, 1991).

According to Sambrook and Russell, (2001) pure DNA should have a 260:280 ratio of 2.0, values lower than this indicate contamination with proteins and other substances, while higher values may indicate the presence of single stranded DNA, but more likely significant amounts of RNA (pure RNA has a 260:280 ratio of 2.0). The 260:230 ratio represents an indication of polysaccharide and other colloidal contamination (Magel *et al.,* 2000). DNA from four younger tissue of *Erythropalum scandens, Markhamia stipulata* and *Melientha suavious* had a 260:280 ratio of lower than 1.8 (1.50, 1.28 and 1.60) and this means some protein containation or carry-over. A ratio of 260:230 over 2 suggested little contamination by polysaccharides. In this study, the result of DNA quality ratios even if they looked unaceptably low for some samples extracted did not cause problems in PCR amplification. However, all samples had to be diluted at least by a factor of 10 which meant that contaminants present would also be diluted by this factor before PCR; and this was perhaps the main reason for low 260:280 ratios not being relevant.

Although there was variation in yields of DNA between four species using the CTAB method, all DNA extracted using this method was still far too high for DNA analysis by PCR (i.e. RAPD-PCR and RAMP-PCR) and had to be dilluted. Moreover, the yield of DNA obtained in any given extraction from the four species, although variable, was consistent enough and fairly homogeneous among for all species tested. Therefore, one could strongly recommend that the CTAB method for DNA extraction used in this study is suitable for adoption for a number of woody forest species.

From experiences of DNA extraction, overseas samples should be stored carefully and all samples were kept in the freezer at -80^0C all the times, during DNA extraction care must be specially taken in the chloroform:isoamyl alcohol step, since the supernatant containing the final DNA is transferred to a fresh tube at the end of this step. If part of the layer between the two aqueous phases is also

transferred, the quality of DNA could be poor due to contamination by proteins and other organic compounds.

5.3.2 PCR optimization

The success or failure of a PCR depends upon the optimization of conditions for the PCR. Different primers in PCR may have different optimal conditions, including the optimization of Mg^{2+} concentrations, amount of DNA template and the annealing temperature of primers; all these factors can affect the yield of the PCR product (Birt and Baker, 2000).

The thermal profile for PCR amplification is an important factor to consider in a successful PCR. Within each profile, the annealing temperature is the most critical factor for any PCR reaction (Birt and Baker, 2000). The thermal profiles of the RAMP/RAPD program was a simple one as used in this study, and this program was used for both RAMP and RAPD-PCR. This program was tested before and used an annealing temperature of 35^0C, which is suitable for RAPD-PCR and may suggest that the short RAPD primers would have been inhibited by a higher temperature, allowing perhaps only some amplification by the microsatellite primer. In addition, the RAMP-PCR method benefitted by the use of a higher ratio of microsatellite primers compared to random decamer (RAPD) primers (2:1); and this was another important feature in reproducibility of molecular data, especially in RAMP-PCR where a combination of the two primers were used.

An optimum amount of $MgCl_2$ according to Park and Kohel, (1994) usually lies between 1.5 and 4.5 mM in the PCR reaction mixture. We found the best concentration of Mg^{2+} for producing strong and consistent bands to be 2.5 mM for RAPD-PCR, and 3.0 mM for RAMP-PCR (depend on the microsatellite primer used). At concentrations of $MgCl_2$ lower than this amount (e.g. 2.5 mM) bands were faint and difficult to record. Perhaps low concentrations of Mg^{2+} impaired the extension reaction, as most DNA polymerase requires Mg^{2+} as a co-factor (Kidd and Ruano, 1995), therefore faint bands would result. In contrast, at higher concentrations of $MgCl_2$ (4.0 mM), no further improvement in either the pattern strength or reproducibility of bands was obtained. According to Kidd and Ruano

(1995), high concentrations of Mg^{2+} stabilize double-stranded DNA and inhibit complete denaturation of the product early in the cycle, hence reducing yield.

These results appear to agree with Park and Kohel, (1994), who have stated that the optimum concentration of Mg^{2+} for PCR is dependent on the specific primers used; and also support the suggestion of Swanson (1999) that multiplex PCR reactions (using two or more primers simultaneously) require more magnesium than single primers alone.

Interestingly, all combinations of MS1 and MS2, and the nine RAPD primers tested had an optimum Mg^{2+} concentration of 3 mM. The results imply that in combinations with microsatellite and RAPD primers, the RAPD primers appear not to determine the amount of Mg^{2+} required. In other words, the amount of Mg^{2+} required is more dependent on the microsatellite primer used than on the particular combination of microsatellite and RAPD primers (Sommerville, 2001). Although, in this study we used the same microsatellite (MS1) utilised by Sommerville (2001), the RAPD primers used in combination with the microsatellite were different. Despite this, the optimum amount of Mg^{2+} required was found to be the same as that determined by Sommerville, (2001); Hoang, (2002).

Genomic DNA concentration is also one of the primary variables to optimise in order to obtain a successful PCR. Swanson, (1999) suggested that the amount of template DNA should be in a range of 10 - 500ng/reaction. In the present study we found that of the six genomic DNA concentrations tested (10ng, 25ng, 40 ng, 50ng, 70 ng and 100 ng), 50 ng of genomic DNA was the best for producing strong and consistent bands in both RAPD and RAMP (see section 1). This amount of DNA is within the range that has been successfully used by many researchers (Williams *et al.,* 1990; Park and Kohel, 1994; Somerville, 2001; Hoang, 2002).

Optimization in the concentration of the enzyme *Taq* DNA polymerase in the PCR reaction mixture is also important to gain reproducible PCR products. This enzyme is generally used in PCR at a rate of 0.5 to 1.5 units per reaction. In this study, we found a different requirement for *Taq* DNA polymerase between the RAPD-PCR and RAMP-PCR. Although the total concentration of primers was equal in RAPD and RAMP PCR, more *Taq* polymerase was required in RAMP-PCR than in

RAPD-PCR (see section 4.3.2). A possible explanation is perhaps that multiplex PCR reactions require more *Taq* polymerase than single primers alone, as has been suggested by Swanson (1999). These results also provide an explanation for the greater amount of Mg^{2+} required for RAPM-PCR than for RAPD-PCR. It is known that magnesium plays an essential role in the activity of *Taq* DNA polymerase (Swanson, 1999), therefore the use of more Taq DNA polymerase would require the use of more Mg^{2+}.

5.3.3 RAPD-PCR

RAPD-PCR is a useful technique applied in large genomes where the short primers used to amplify the DNA scan the genome for polymorphisms or changes in different parts of the DNA. These changes are scored simply as presence or absence in these segments of the DNA targeted. The RAPD-PCR technique is easy to use, it is a very good method to detect genetic changes only within the same species or at best very closely related species. No information about region amplified is possible with RAPD-PCR, but it is likely that mildly repetitive or highly repetitive DNA is primarily targeted (De Filippis and Magel, 1998; Persson and Gustavsson, 2001). RAPD markers can provide an efficient assay for polymorphisms, which should allow rapid identification and isolation of chromosome-specific DNA fragments (Williams *et al.,* 1990). The ease of using RAPD markers makes it a very popular method, and RAPD-PCR has been used for a variety of purposes in plant genetic analysis (Cabrita *et al.,* 2001). Therefore, RAPD-PCR was selected as a possible technique which had the potential to detect genetic diversity and genetic differences between individuals and populations of four rare and endangered forest tree species *E. scandens, M. stipulata, M. suavious* and *S. mucclure* in BBNP of Vietnam which have been isolated or disturbed over a period of time and distance, and this has also been reported for other plants (Cabrita *et al.*, 2001; Heider *et al.*, 2006). These results must be considered and evaluated with some caution since the nature of the RAPD-PCR method means that normally it overestimates genetic differences. This overestimation appears consistent with this study where RAPD-PCR was able to detect a large number of

polymorphic band differences between population sites (Wu *et al.*, 1994; Prathepha, 2000).

Analysis of variation in RAPD fragments revealed a moderate to high level of variation among individuals and populations of four species and a high level of overall diversity represented by the percentage of polymorphic loci found. For two vegetable species the percentage of polymorphism of *E. scandens* (90.32%) and *M. suavious* (98,89%) through all nine populations collected in BBNP were considerably higher than the variation observed in previous RAPD studies using similar materials and similar species. Prathepha (2000) reported polymorphism ranged from 6.52 to 58.70% across ten populations of *M. suavious* (the same species in Thailand), Langton, (2000) and Sommerville, (2001) found a high of 87.5% in the endangered species *Grevillea caleyi* while with the same method Hoang, (2002) reported an average 10.8% of polymorphism in rice. The high percentage of polymorphism found in our study is consistent with an analysis of genetic diversity of *Flemingia macrophylla* (95%) collected from different locations in the North of Vietnam by Heider, (2007). This result could reflect the degree of outcrossing within and among species. Hamrick and Godt, (1996) stated that inbreeding species tend to be less diverse within, but more differentiated among populations while outbreeding species are characterized by high levels of intra-population diversity and low differentiation between populations. In the current situation all four species can not be simply put into these two categories and makes this MPE of differentiation hard to compare.

The average percentage of polymorphism of the two species *M. stipulata* (64.71%) and *M. mucclure* (76.47%) were lower than for *E. scandens* (90.32%) and *M. suavious* (98.89%). With *M. stipulata*, all four populations had a quite low percentage of polymorphism within the populations (14.71% to 47.06%); the results indicated that these species may be inbreeding. However in one case (*E. scandens*) these were lower numbers than other species and in this species a possible reason for the reduced rate of polymorphism within populations, and in general the genetic diversity (differentiation) of this species being high. Within populations, tropical woody species tend to exhibit high levels of diversity (White

and Powell, 1997; Collevatti *et al.,* 2001). The results showed that where the populations with low density of individuals occurred and far from the main groups with perhaps higher density, a reduced percentage of polymorphism occurred, though the number of samples may also be the reason for this reduction. Loss of genetic variation has been reported to accompany a reduction in population size (Van Treuren *at al.,* 1991; Prober and Brown, 1994). Genetically depleted populations are generally considered less likely to respond to environmental stress by adaptation to changing environments and may be more prone to local extinction (Ellstrand, 1992).

UPGMA dendrograms grouped populations of four species but only in one (*M. stipulata*) was this related to geographic distance. Within the environmental conditions in BBNP, all populations of the four species occurred as isolated patches, being frequently separated by natural barriers such as rivers, lake, forest or mountain ranges. Moreover, BBNP is characterized by diversity of ecological conditions such as forest situation types, limestone forest and sloping land forest generate vegetation diversity (Dien, 2005). The dendrogram of *S. mucclure* showed that the first grouping was from populations 1 to 6, this was a useful result because this group is located in one side of Ba Be lake with the same aspect, vegetation types and other ecological conditions, while the other group, populations 7 to 10, are located on the other side of the lake and the ecological factors are quite different. The other three species showed some correlation between populations such as distance or similar vegetation cover but this could not explain clearly how they were grouped together.

The correlations between and within species and populations should be targeted for further research and other methods should be explored to identify the relationships between genetic diversity and ecological factors.

5.3.4 RAMP-PCR

The RAMP-PCR technique used various combinations of a number of short RAPD primers and a number of microsatellite primers, and is harder to use than RAPD-PCR, but is also a suitable method to detect genetic changes across species. This technique was first published in 1994 by Wu *et al.* and soon after that Ramser *et*

al., (1997) used RAMPs (they called the method by other name; RAMPO or random amplified microsatellite polymorphisms) along with another three molecular techniques to determine relationship among 21 accessions of *Guinea yam*.

The results from MDS analyses (see section 5.4) showed that RAMP was able to generate some polymorphic bands that RAPD primers alone were not, and also detected polymorphic bands that were detected by RAPD primers. In fact, in seven RAPD primers tested, two primers appeared more informative than the other five primers in detecting polymorphism in the DNA of the four species. The study therefore used these two informative random primers for RAMP-PCR studies (see section 5.3.8). The dendrogram based on RAMP-PCR data analysis showed that RAMP, especially with microsatellite MS2 not only presented a relationship between populations of species, but also disclosed a very close genetic relationship between them. These results are in agreement with Wu *et al.,* (1994), Sánchez de la Hoz *et al.*, (1996) and Ramser *et al.*, (1997) who concluded that RAMP-PCR is a useful technique for disclosing genetic relatedness between more distantly related species and also between sub-populations.

Comparison of MS1 and MS2 with slightly different anchored bases demonstrated that each had different abilities to target sites on DNA. It is likely that the ability of a microsatellite to amplify a sequence in target DNA may also depend on how abundant the microsatellite is in that sequence. Differences in the frequency of repetition of dinucleotide microsatellites have been reported in other species of plants (Whelan *et al.,* 2000; James and McDougall, 2007). There is evidence in the literature that RAMP, and other multi-locus microsatellite-fingerprinting methods, capture only some of the polymorphisms associated with microsatellites (Hayden and Sharp, 2001).

The results of RAMP primers of *S. mucclure* also detected lower polymorphic bands than that were detected by RAPD primers alone. For example, average RAMP primers polymorphic bands of *S. mucclure* were only 50, while that generated 55 in RAPD primers alone. These results conflicted with previous study by Sommerville (2001) in which the combination of mcrosatellite and RAPD

primers produced more bands than the RAPD primers alone but the result is consistent with Langton's (2000) study in which the number of bands and polymorphisms detected were much less than those using RAPDs alone. RAMP-PCR therefore may not just capture polymorphisms associated with microsatellites as suggested by Hayden and Sharp, (2001), but may also detect polymorphisms generated by RAPD primers.

The UPGMA dendrogram based on Nei's genetic distance showed that population 1 of *M. stipulata* was clearly separated and is explained by the fact that this population is in a botanic garden with different ecological conditions to compared with the other 3 populations; its origin from the wild is unknown. Moreover, population 1 has been isolated from the others by mountains and the lake, the geographical distance is about 20 km. Therefore in some cases molecular genetic data separated populations with distinct isolation and physical and environmental charateristics.

5.3.5 Species Comparison

Some results appear contradictory to studies by Sommerville, (2001) and Langton, (2000) using similar PCR techniques. There are two possible explanations for this inconsistency. Firstly, the length of agarose gels used was insufficient to resolve all bands present, as has been suggested by Sommerville (2001). We used 3% (w/v), 9 cm long agarose gels to resolve both RAPD-PCR and RAMP-PCR products, however it may still be possible that some high molecular weight bands generated by a combination of microsatellite and RAPD primers have not been resolved successfully. Secondly, the lower annealing temperature used in RAPD-PCR may introduce mis-priming. According to Birt and Baker, (2000) and Sambrook and Russell, (2001) reducing the annealing temperature in a PCR reaction reduces the stringency of the reaction, the lower the temperature, the more likely it is that primers will bind to sections of DNA that do not completely match the primer sequence. Therefore, RAPD primers alone were able to produce more bands than combinations of MS2 and RAPD primers. The lower number of bands generated by RAMP in comparison to RAPD in *Grevillea caleyi* R.Br. has also been reported by Sommerville (2001).

Sánchez de la Hoz *et al.*, (1996) reported a higher percentage of polymorphisms detected by RAPD primers alone than by RAMP on barley cultivars. In this project, the percentage polymorphisms recorded for nine single RAPD primers were greater than those detected by combinations of MS1 or MS2 with nine RAPD primers. These results are in agreement with Sánchez de la Hoz *et al.,* (1996) who found that the arbitrary RAPD oligonucleotides used as single primers produced a large number of fragments slightly more polymorphic than those generated in combination with microsatellites.

The G-statistic demonstrated that both all four species tested contained moderately large genetic differentiation. RAMP-PCR always showed higher G-statistic values than RAPD-PCR. Similarities detected between individuals at any one site in this study were low and suggested that significant genetic differences were present between individuals. Even the similarity between what might have been more unrelated/distant sites were low (De Filippis *et al.,* 1996). In summary, results from the molecular data showed that a considerable amount of genetic variation between populations was present at the fragmented sites sampled.

Our data was in agreement with the findings of Kelly *et al.,* (2000) who discovered that small populations of New Zealand mistletoe (with less than 10 individuals) did not show significantly reduced diversity compared with larger populations (up to 200 individuals). Similarly, Fleishman *et al.,* (2001) noted that small populations of *Cordylanthus palmatus* were just as genetically diverse as larger populations. Care should be taken in drawing conclusions from the latter study, however, since it is not known how many of those seedlings sampled would have eventually reached maturity (Lesica and Allendorf, 1991).

A significant correlation was observed between populations in *Markhamia stipulata* and geographic distance as determined by the Mantel test, and appears to be a major contributing factor to genetic diversity. This relationship was apparent also for *Sinocalamus mucclure*, although using RAPD-PCR data for *Sinocalamus mucclure* this relationship was not present (Table 5.10). Plants from the Botanic Garden site for *Markhamia stipulata* (population 1) had the highest genetic variation, but were also correlated to distance, and may reflect a method of

temporal genetic transfer amongst closely related populations (Falconer and Mackay, 1996; Schneller, 1998).

Chapter VI

Discussion and Conclusion

6.1 Prioritisation of Species for Conservation

6.1.1 Socio-economic studies

Socio-economic studies should play a major role in the conservation of forest areas (On *et al.,* 2002; Atari *et al.,* 2008). A good understanding of the local socio-economic factors helps to highlight present and future threats to natural resources, and find solutions to alleviate them. However, the most important issue is to involve the local people themselves. This has many advantages in increasing the awareness of local people to problems they and others face, and to extract a large amount of indigenous knowledge which may not be normally available to forest researchers (Kemp *et al.,* 1994). With the cooperation and involvement of local people in solving their own problems their future and that of the natural resources that they use are more likely to be sustained.

In this study, the method used for research on socio-economic studies was Rapid Rural Appraisal (RRA) and secondary data collection. Our interviews were largely restricted to people at home at the time, tothe village leaders and other prominent individuals. Many problems they identified may not be valid for others, especially women and poor families. Information will therefore inevitably be biased. In addition, our studies with ethnic minorities in BBNP must be analysed in the knowledge that no participatory research had been conducted. Chan (1994) stated that the use of indigenous knowledge is particularly important here as the people will know what crops are suited for particular areas and what extension methods for the implementation of changes will help sustain the natural resources of BBNP. Tay language is used to communicate as a *lingua franca* in BBNP so that for further study, as in this one, Tay speakers should be involved in order to ensure that information provided is of maximum clarity. Six

villages were interviewed but the data collected from Tay villages were more informative than other villages of Dao and H'Mong.

The total population of the three communes is 9344 people of which 2818 people live inside the Park and most of them are settled in the buffer zone of the Park. However, the pressures upon the Park resources posed by local populations living within and around BBNP are great (Kemp *et al.,* 1994). Huong, (2001) stated that high population density is an obstacle for forest protection in BBNP; the results of this study showed that the population density ranged from 40 to 70 people/km^2. The ethnic composition is different between locations but there are three major ethnic groups in BBNP: Tay, Dao, and H'Mong people, each of which utilizes the forest in different ways.

The people of BBNP are living at a subsistence level, although some live more comfortably than others (for example, some households have members who work in urban areas nearby). The majority of people's resources come from the land. When there is such a close relationship between the people and their land, there is a general realisation of the effect that their population is having on resources, and whether they are in decline. Agriculture activities often cannot provide enough for their needs, and there is little alternative to continuing to exploit forest resources. This is especially true for the poorer families and villages that have little land of quality on which to grow food.

From the secondary data collected particularly information on the high birth rates, and observation within the Park, it is likely that BBNP resources will become depleted at an increasing rate and greater protection of the resources will be needed. Shifting agriculture and unsustainable methods of harvesting such as felling whole trees to collect the edible parts will result in further reduction of forest resources. Moreover, people are largely dependant on forest resources and damage or overexploitation of these is detrimental to their own livelihoods. The realisation of the threat of resource depletion is made difficult by different attitudes towards the forest in different ethnic minorities, as some have plentiful

local forest resources, according to their needs. A more detailed exploration of the different cultural attitudes to forest resource use would be beneficial.

6.1.2 Inventorying the plants and endangered tree species

BBNP is one of the most important national forests of Vietnam; it is an area of high relative biodiversity with many parts of the forest remaining largely intact. Many studies have researched biodiversity of BBNP and identified the species in this area; Quac *et al.,* (1999) recorded 550 species of vascular plants belong to 138 families and a total of 603 species of vascular plants in 137 families were found by Hill *et al.,* (1997). Khanh and On (2002) identified 532 species used by local people in BBNP with 427 species identified by scientific name.

The number of species recorded in this study is higher than in other previous studies. Throughout the survey, over 1005 vascular plants were found or mentioned and the number of species not identified by scientific name was small. The species lists shown in this study are, however, almost certainly incomplete because of limited time and lack of resources. With additional surveys in this area, the number of species recorded would be increased and therefore a truer reflection of actual biodiversity would be achieved. Further survey work is especially needed in the case of some unknown species or endemic species, especially some species used by local people but not identified by scientific name yet. Populations of some endemic species only occurred in restricted areas (such as *Sinocalamus mucclure* [string bamboo]) and some valuable species recommended for conservation priority by local people are hitherto unknown, scientifically (or at least unidentifiable from the local name) and an accurate figure of their numbers may help emphasize the importance of BBNP and possibly attract more research on natural conservation in this area or attention from decision makers. The more remote areas of the Park may harbour yet more species.

The study showed that 27 species were used by local people in over 50% of households interviewed. Many of them were recorded in the Red Book of

Vietnam and Red List of IUCN; they include *Chukrasia tabularis, Melientha suavious, Burretiodendron tonkinensis* and *Amomum subulatum*. Moreover, local people also identified 15 species as needing special protection because they are detecting reduction of numbers and/or difficulty finding them in the Park.

Many endangered species were used in BBNP for different purposes such as medicine, vegetable or fruit and some of those were recorded in the Red Book or Red Lists. The local people said they did not know that those plants were important or should be protected globally or nationally. This problem reflects the fact that local people have not been appraised of the information in the Red Book and Red Lists. Meanwhile, 21 species were recommended for propagation because of their needs, most of them used as wood for housing or fuel.

6.1.3 Identifying priority for conservation

Endangered species were identified using standard Participatory Rural Appraisal (PRA) techniques where local people were encouraged and facilitated to produce lists of regularly used and endangered species compiled on the basis of their extensive field observations and experiences. The study found that this technique is a useful tool for natural conservation, especially for identification of conservation priorities. Forty six species were perceived as Endangered at different levels by local people; they recommended that four species regarded as Critically endangered and three as Endangered should be urgently conserved. The secondary data was collected by the other criteria of the Red Book of Vietnam, which listed 46 species and 23 by the Red Lists of IUCN as facing risk of extinction at different levels. However, their assessments have resulted from criteria and definitions for ranking priority for conservation that are different to those of the local people.

The criteria of IUCN are clearly quantitative in identifying priorities for conservation at global and national levels (IUCN, 2001), and are aimed at identifying species at risk of extinction and placing them accordingly in the Red List categories to combine the criteria A-D, built on population reduction, small

distribution area in combination with fragmentation, decline or extreme fluctuation of the population, on a small population number in combination with a population decline, and on an extremely small population respectively (Gardenfors, 2001). Local peoples' identification criteria are more qualitative than quantitative and combine their experiences and knowledge in evaluation of conservation status. The criteria are aimed at identifying endangered species based on two criteria: Rarity and Use Level or demand (see more detail in section 3.1). Therefore, it is not surprising that the priority lists are somewhat different.

Colyvan *et al.,* (1999) and Gardenfors, (2001) emphasized that there are both conceptual and practical obstacles in applying the IUCN Red List criteria at national and local levels. Those issues are dealt with in Chapter III. Further discussion and tests of how to evaluate the extinction risk of species used by local people in BBNP are needed. In this study, the priority for conservation of endangered species was recognized at 4 different levels (46 species), and the results were compared with Red Book of Vietnam and Red List of IUCN in order to find out the highest ranking for special conservation. One aspect to be investigated is the effect of scale on risk assessments in a set of geographically small areas; in BBNP that could only be conducted in different locations. Other issues to explore, by using quantitative criteria models for example, would be to establish protocols for application in small areas, and identifying the priority for conservation by local people. Of course, there is also a great need for empirical knowledge including genetic data, dispersal rates and frequency in most taxa (Gardenfors, 2001). From the method of combining three different criteria, the study identified seven species for the highest priority conservation, all regarded as *threatened* or worse:

Amentotaxus argotaenia (Hance) Pilg.,
Burretiodendron tonkinensis A.Chev.,
Mahonia nepalensis DC. 1824,
Markhamia stipulata (Roxb.) Seem.,
Garcinia fagraeoides A. Chev.,
Paphiopedilum dianthum T.Tang &F.T.Wang.,

Parashorea chinensis Hwang.

The above list represents the species perceived to be at greatest risk of local disappearance and could easily be expanded to include a number of other species (Chapter III lists 15 such species) based on the same ranking process; the cutoff for prioritization was arbitrary. Moreover, given the high birth rates among the local people, other species – not yet perceived to be at great risk of disappearance would be expected to appear on such a list in the future. Thus, an important outcome from this study should be the realization that priority lists, however compiled, are likely to be unstable and that, consequently, they should be reviewed periodically.

6.1.4 Summary

- The currently-used national and international schemes for identifying species at risk of extinction are of limited use in the local context;
- Study of the taxonomic status of some species is required, because scientific names could not be applied in all cases;
- Local people are, to varying degrees, ignorant of techniques which might alleviate the perceived shortage of useful or essential plant species, indicating a need for education in such techniques;
- Seven plant species were identified for urgent, high-priority conservation action in BBNP;
- Priorities for conservation effort are likely to change over time and should be reviewed from time to time.

6.2 Vegetation and Environmental Patterns

6.2.1 Floristic patterns

In terms of overall conservation value, the high species diversity, together with the presence of some endangered species recorded in the Red List of IUCN and the Red Book of Vietnam, and species endemic to BBNP such as string bamboo (*Sinocalamus mucclure*), and several native species at the northern limit of their

distribution, such as *Burretiodendron tonkinensis* and *Celtis sinensis* (Hill *et al.,* 1997; Trai *et al.,* 2004) distinguish BBNP's limestone forest component from other similar sites in the northern mountainous region of Vietnam. This study found that a total of 162 species belonging to 125 genera and 65 families occurred in 12 quadrats (1.2ha total) in the research area. Magnoliopsida had the highest number and percentage of species (131, 80.86%) and fungi and lycopods had the lowest number and percentage of species (1, 0.62%) (Table 4.3). These results agreed with the research of Leigh, (1982), who claimed that the biotic richness of tropical rain forests has been hailed as the highest in the world.

Hill *et al.,* (1997) reported that ten of the species found at BBNP are recorded in the Red Book of Vietnam and Red List of IUCN. However, this study found that thirteen of the species in 12 quadrats are listed in the Red Book of Vietnam and Red List of IUCN, which describes species threatened with extinction nationally and globally (Table 4.5). Only five of these were classified as endangered species by local people (*Burretiodendron tonkinensis, Chukrasia tabularis, Markhamia stipulata, Garcinia fagraeoides* and *Melientha suavious*); that is, there probably is insufficient data available on the distribution/status to help the local people to participate in broader conservation effort at national and global scales. This again points to a need for education in these matters among the local people; in short, local people have not become aware of their potential responsibility beyond their day-to-day needs. Of the remaining eleven species classed as threatened, two are endemic to the park (*Sinocalamus mucclure* and *Ficus altissima*).

Hill *et al.,* (1997) claimed that two major threats to individual plant species in BBNP are the over-exploitation of high value timber species, and the collection of plants for use in traditional medicine. In this study, species exploited for timber include *Burretiodendron tonkinensis, Chukrasia tabularis, Markhamia stipulata,* and *Garcinia fagraeoides*. However, some other species are not perceived as endangered species by local people or even by authorities in the research area. Others are threatened by forest loss, in combination with collection as ornamental plants (Hill *et al.,* 1997) such as *Cycas balansae,* encountered in this study.

Kemp *et al.,* (1994) and Hill *et al.,* (1997) described the forest types in BBNP as tropical moist evergreen forest and tropical evergreen limestone forest. The vegetation composition varies with ecological factors such as geography, topography, geology, hydrology and local climate conditions. Furthermore, based on the topography and geography, Trai *et al.,* (2004) described the forest formations in BBNP in different places as limestone karst ridges, limestone karst slopes, permanent stream valleys, gentle slopes or sheltered slopes. However, to evaluate the conservation status and the risk to endangered species, in this study, the forest types were categorised by ecological/environmental factors and simultaneous combination of the level of human disturbance with habitat types in order to improve the knowledge of the park in terms of natural resources and to evaluate the conservation value of the area. After exploration throughout the park, four site types were chosen which reflected the major vegetation types found. The sites chosen had the following characteristics.

In moist sites, vegetation tends to have more species and more abundant plants (Table 4.1). These sites are located near the lake, river or in valleys with high levels of permanent moisture. This climate condition seems to be particularly suitable for species growth and development. The forests bordering the lake appear to be intact (Hill *et al.,* 1997; Quac *et al.,* 1999). Soil moisture was one of the factors found to be strongly associated with presence of endangered species (Figure 4.10).

This study incorporated a comparision between two disturbed site types and other undisturbed site types. In disturbance group 1, all sites were located near a track or village and easily exploited for wood and timber. Probably as a result of that human and physical disturbance in the areas, the diversity of species taxa was low, and high value species were rare. Many roads and tracks cross through the vegetation and are used by the local people for grazing cattle. Moreover, the national park authorities have allowed local people to collect the plants and medicine for their own subsistence, but not for trading. So the differing disturbance regimes of the remnants will have influenced vegetation in distinct ways. Permission has been given even for vegetation and medicine collection of

some species in the tree strata, exposing the shrub layer to direct physical disturbance, increased insolation and an increase in the litter cover loss. The removal of the main sources of organic matter can also alter nutrient cycles (Hopmans *et al.,* 2005).

With disturbance group 2, timber extraction occurs on a relatively small scale (e.g. quadrat 12), but clearance and degradation of previously forested areas for agricultural purposes is extensive (e.g. for all sites of this forest type). Human disturbance has had a particularly disruptive influence on forest cover (Hill *et al.,* 1997); much of the flatter land has been cleared to enable cultivation and steeper slopes are clothed with poor secondary forest and vegetation cover. Two sites of disturbance group 2 (quadrats 4 and 12) are secondary forest with a history of shifting agriculture, and quadrat 12 is part of an area of high continuing human disturbance and has limited management, while quadrat 4 is located nearer the national park office and forest protection station and still has some endangered species and higher species abundance than the other overall. Removal of open-space-adapted species from the data set Figure 4.3 (a, c) showed that this quadrat had many species in common with the other site types. This also suggests that on going agriculture after tree harvest, as in quadrat 12 is the factor primarily responsible for the absence of endangered species at the site. This difference between these two sites points to the importance of a visible regulatory regime. It may also suggest that the local people are broadly aware of the land use restrictions, but ignore them when they can!

In relatively undisturbed sites, the forest type has been less exploited by man in the past. These forest types display the characteristics of primary forest and are located far from the villages and tracks; this agrees with the conclusion of Hill *et al.,* (1997) that the best forest areas are some distance from settlements. Vegetation cover and composition were relatively undamaged/intact and large trees dominated the upper canopy. However, vegetation composition and cover is affected by topography.

BBNP's four forest types, as chose in this study, are floristically and structurally distinctive, at least in the understorey. There are differences in growth form composition between the four areas. The secondary forest (disturbance 2) area is structurally simplified, with very few big tree or upper canopy species. There is little difference in total species number between quadrats of the same forest types and fern and shrub species numbers appear to make a greater contribution to overall species composition at the expense of tree and endangered species on secondary forest types (disturbance 2). The ability of ferns to be an important component of forest structure and to prevent soil erosion has been described by Huyen and Toan, (2003). Chan and Nguyen, (2003) described bamboo as an important component of forest structure in BBNP. The results of this study seem to contradict this suggestion. The MDS analysis after removing all fern, shrub, lianas etc. (Figures 4.3 to 4.5) provides a possible explanation: fern, shrub, liana, sedge and grass are not factors that greatly influence composition for all sites in BBNP. In moist and relatively undisturbed sites, trees dominated the upper canopy with very little fern and shrub. Alternatively, in high human disturbance areas such as secondary forests the number of endangered species may be reduced. Upper canopy trees, generally sheltered locations and associated suitable environmental conditions are required for endangered and endemic species. The results of MDS analysis showed that tree and endangered species are an important influence on floristic composition of BBNP (Figure 4.6 and 4.7), the relatively undisturbed sites showing greatest variety in the understorey.

To assess the status of rare and endangered species, and to prioritize among conservation approaches, we must first understand the factors that affect the numbers of individuals within species (Schemske *et al.,* 1994). Plants may pose challenges to conservation efforts that are quite distinct from human disturbance and management efforts. Unique disturbance characters include distance to tracks and villages and nearness to the management stations. However, at some spatial scale, most plant species are patchily distributed due to their sedentary habit and spatial heterogeneity of the environment (Levin and Kerster, 1974; Holland and Jain, 1981; Hanski, 1985; Platt and Weiss, 1985; Horvitz and Schemske, 1986).

The results of this study suggest that this patchiness is apparent at about 200 m^2 or smaller scales.

This study found that some endangered and endemic species were associated with groups of common species in conformity with ecological conditions (Figure 4.8 and Table 4.10). For example, group 1 has three endangered species associated with nineteen common species and group 2 has another three endangered species associated with twelve common species; all species in group 1 were common species but they related closely with the ecological factors in quadrat 12.

Considering the importance of asexual propagation in the standard methods for promotion of endangered species and their special range of dependent environmental variables, attention should be paid to protecting and creating favourable environmental conditions for target species (On et *al.*, 2001; Schippmann *et al.,* 2004; Liu *et al.,* 2007). The *in situ* conservation method has been adopted as an important means for conserving rare and endangered species. The first option of conservation is to define conservation areas free from significant disruption for the most genetically diverse populations (because asexual propagation tends to reduce genetic diversity) and the preferred habitat (Liu *et al.,* 2007). Considering the population size, habitat conditions (and taking into account genetic diversity and variation), *in situ* conservation appears suitable for the populations of groups 1, 2, 3 and 4 in this study (Fig 4.10), namely:

Ardisia sylvestris
Ficus altissima
Sinocalamus mcmclure
Anoectochilus setaceous
Chukrasia tabularis
Tetrapanax papyriferus
Cycas balansae
Burretiodendron tonkinensis
Markhamia stipulata

Garcinia fagraoides
Hydocarpus hainania
Melientha suavious and
Stephania sinica.

For some other endangered species, the population size is so small that one single catastrophic event (e.g. forest products collection or logging) can destroy the entire population; scattered distribution of species that reflects the habitat fragmentation similarly creates vulnerability. Augmentation in size and viability of such populations with plant fragments seem to be one possibility for their preservation. This conservation strategy can maintain most of its resources and genetic diversity. To date, Ba Be National Park has not established conservation processes for most of these particular species. This study suggests that growing endangered species in their suitable ecological conditions (identified in part by the occurrence of associated common species) in BBNP will help to reduce the risk of extinction and biodiversity loss. *Ex situ* conservation will, undoubtedly, be necessary also.

This study found that some endangered species had very high numbers of plants (such as *Burretiodendron tonkinensis* or *Garcinia fagraeoides*) that occurred in almost all sites. However, some expectedly common species appeared only once (such as *C.lenticellata*, *P. tavoyana, A. macrorhiza, Q. helferiana* or *S. mucclure*). For future conservation, these latter species should be considered for propagation before they, too, become at risk of local extinction, even though they have viable populations elsewhere.

On a broader conceptual scale, the reassessment of BBNP's conservation value may be argued for on the following basis: that the presence of a diverse array of communities, arranged in a relatively small, isolated area that possesses only a small amount of connectivity with other near-pristine areas, is worthy of attention for both management and research objectives, if not for its own intrinsic value. In terms of research, BBNP's limestone forest could be viewed as an entire ecological unit, with limited boundary effects and the potential for studies

in a considerable variety of vegetation types in this area is high. The diversity of vegetation and high species numbers also suggest that, for management, BBNP may serve as a seed bank, or store of genetic material in a relatively small area, perhaps to aid restoration of nearby areas.

6.2.2 Environmental patterns

To further explore BBNP's vegetation, the field and analytical results must be brought together to form an overall snapshot of the ecological processes that are responsible for it. Little data exist on vegetation-environment relationships in Vietnam, and particularly in BBNP. At the international scale, there is a substantial body of research on analogous tropical forest vegetation described in the literature, but most studies to date have been correlative in tropical forest in general rather than in tropical limestone forest in particular. There is a lack of understanding of small scale processes such as ecological conditions in the limestone karst slopes forest, together with inconsistent results across different disturbance regimes. Therefore, the correlative analyses in this study are in a local context, and focus on identifying and describing the specific processes likely to be occurring in BBNP. This approach restricts the study's universality when considering general concepts, such as the role of endangered and endemic species in influencing, and being influenced by, floristic composition and environmental conditions. Conversely, the restriction of analysis to one site such as BBNP minimizes variation in some environmental factors, such as climate, geology and disturbance patterns (Adam *et al.,* 1989). By reducing the number of factors that need consideration, it is possible to arrive at a better understanding of the role of factors that are variable. Such results may be built upon in future work, when suitable data at other sites becomes available. A particular instance of this emerged during the study:

Two broad disturbance types were chosen – timber tree harvesting and subsequent gathering (DT2 sites) and agriculture/grazing/gathering. It would be helpful to study the impacts of each of the detailed activities (and recovery from

them). Local people probably could identify areas used for each in the past (and when), but no longer used.

To assess the status of rare and endangered species, and to prioritize among conservation approaches, one must first understand the factors that affect the numbers of individuals within species (Schemske *et al.,* 1994).

Several different data collection and analytical approaches were adopted in the hope that variation in the collected vegetation and environmental data would be more comprehensive enough to display meaningful patterns and relationships, that the different methods would provide varied perspectives on ecological processes, and to allow an evidence approach to be used when forming conclusions. The chosen methods complement each other and provide a broader picture of the ecology of the study area. Therefore, the groups of environmental variables (physical aspects, disturbance, soil, vegetation data and endangered and endemic species) were collected and analysed in order to gain an understanding of the influence of environmental factors on vegetation composition and endangered species in particular in BBNP.

To identify the likely causal environmental factors for the observed vegetation composition, the several results must be considered together. Although MDS and PCA are based on different underlying algorithms, the gradients calculated for both ordinations are largely in agreement with respect to their direction in relation to the floristic compositions. The constrained ordination suggests that the most important environmental factors for likely development of these vegetation compositions include groups of physical aspects, and soil data. Other important factors include disturbance, and vegetation and endangered species data. All of these group factors display significant between group differences across the entire dataset. Individual factors, for example altitude, soil pH or aspect, also display a high level of correlation with each other. However, the multiple sources of variance leave open the possibility that different environmental processes are the primary influence on determining different vegetation compositions, particularly in the understorey. In other words the relationships between

vegetation and environment may be community specific, constrained by changes in other environmental factors and as a result, spatially heterogeneous. To explore this possibility requires analyses with subsets of site data, effectively reducing the number of variables by holding certain factors constrained, making the identification of limiting environmental factors more likely. More costly and time-consuming analyses (e.g. nutrient levels, site histories) would be needed for this.

The analyses of groups in the dataset largely follows the points of interest discovered in the analyses of vegetation, namely the separation of understrey species in four different site types: MS, DT1, DT2 and RU. The causes of distinctive compositional profiles in different forest types, influences on the distribution of the vegetation and endangered species in different quadrats, and the environmental factors influencing vegetation and endangered species composition on the same forest types needs further detailed study. The conclusions are based initially on SIMPER results (Appendices 7 and 8) and supported by observed MDS ordination patterns.

The physical data included location of site, degree of visible rock, soil without rock, altitude, slope and aspect. Cluster analyses showed that (Appendix 8) all these factors were slightly associated with the distribution of vegetation, while aspect and soil without rock, altitude and location of quadrat, and slope and degree of visible rock are more closely related to the distribution of the vegetation component. This is an indication that the chosen group of physical data alone might not be the main factor modeling the dominance of different endangered plant species or groups of plants in the research area. However, we found that string bamboo, that is endemic to BBNP, occurs only in one site near Ba Be lake (located in quadrat 1 in the west site of the lake). This phenomenon may be explained by the aspect factor, which would affect the evaporative demand through the amount of incident energy received (Bertiller et al., 1993). The Simper analysis showed that almost all sites have average similarity to each other ranging from 73 to 85.19%. So, further studies focussing on individual species' relations to environmental factors should be conducted.

The role of particular soil data in the vegetation of BBNP is not well documented. With the group of soil data that include soil pH, soil type, soil color, soil moisture, soil depth and surface water availability in the research area, the role of soil data appears to be of little significance overall, though endangered species and soil type were associated (Figure 4.10), with results suggesting that the critical variables are more likely to be related to non-soil data. The results support findings by Minh (2005); Minh (2007) that the relationship between the location of plant communities and associated soil properties in the northern mountainous areas of Vietnam is unclear, as crop species such as tea contribute significantly to soil properties and nitrogen levels through litter production, whereas forest tree species do not. In the case of limestone forest in BBNP, Hill *et al.,* (1997) reported that the influence of soil properties and natural disturbance are extremely difficult to evaluate compared to other types of tropical forest. Cluster analysis (Appendix 8) shows that there are 2 groups of soil factors: group 1 is soil type, soil moisture and soil depth and another group is soil pH, surface water availability and soil color. In fact, the average pH for all sites is very high (7.7), especially MS sites (8.0). Khanh *et al.,* (2003) demonstrated that the pH levels in BBNP vary between 7.5 and 8.0, this is suitable for growth and development of forest species in BBNP. However, this study found that in some areas the pH level varied highly and inhomogeneously such as in quadrat 12, where it was lower than in other sites (6.3) presumably because of disturbance. However, with the MDS sites analysis, most sites did not correlate closely to vegetation composition with all factors and only some factors associated with distribution of species. For future work, soil data research on this area should focus on comparison between different types of soil and its relationship to vegetation composition.

With disturbance data (including epiphyte cover, eroded stone cover, liana cover, deforestation, distance to village and distance to track), MDS analysis indicates that epiphyte cover and eroded stone cover are more closely correlated with the vegetation composition than other variables (Figure 4.8), while other factors such as deforestation levels, distance to village or track were slightly related to the

species distribution and vegetation composition. In BBNP complex topography associated with different management regimes may lead to this differentiation. On the other hand, MDS site analysis showed that there are no locations where disturbance data can explain clearly the vegetation composition or endangered species distribution, apart from the fact that disturbance results in a relatively homogeneous understorey. However, in disturbance sites (DT1 and DT2), Simper analysis indicated that deforestation and distance to village are two main factors affecting the vegetation composition of these sites. The other two site types are quite different. With MS sites, liana cover may greatly affect the vegetation composition because of their ability to reduce light availability in the understorey. With RU sites, the distance to the nearest track contribute up to 23.64% of the pattern, which may be explained by the fact that areas near tracks may experience more control from forest protectors. As outlined above, groups of disturbance such as human disturbance and physical disturbance should be separated for future study to identify the root of disturbance.

With the group of vegetation data (including litter cover, canopy cover, green cover, bush cover, bamboo cover and grass cover), MDS and Cluster analysis showed that canopy cover and litter cover are, not surprisingly, associated, suggesting they play a major role in shaping the vegetation as well.

Focussing on the four forest types (MS, DT1, DT2 and RU) in BBNP, the results strongly suggest that the not homogeneous topography and different levels of disturbance lead to the different vegetation compositions and endangered and endemic species distribution in the four distinctive stands. In secondary forest sites (DT2 sites), the history is of 'slash and burn' for agricultural activities or forest products collection for subsistence, and the sites are located near the villages and tracks. During the course of surveys at BBNP, knowledge of the vegetation types around this site type was accumulated. The disturbance levels were also noted. The results can be seen in Figure 4.7 and Appendix 6. Disturbance is not evenly distributed within these areas of disturbance and even in some sites of relative undisturbance the endangered species and common species are still unevenly distributed. For the future conservation of these areas, it

will be important to build up a picture of some forest plant species (especially endangered species) succession, based on areas where disturbance was known to have occurred in the past and in where there is still primary forest.

With the sites of relative undisturbance (RU site), the MDS analysis showed that the sites were very similar. The sites were located over 400m higher than most other sites. The structure of forest includes a tall three-tiered canopy. The trees present in the upper canopy were very large, often reaching over 40m, and had a strong influence upon the ordinations. The patterns observed here are typical of mature stage primary forest with no or little human disturbance. The numbers of endangered species and valuable plants were highest of all quadrat groups, indicating that this is a complex and diverse forest type. The upper canopy was dominated by *Burretiodendron tonkinensis* and *Garcinia fagraeoides* these are also two endangered species listed in red list of IUCN and local peoples' identification. However, under management these species still occurred as dominant trees with high numbers of individuals. The middle canopy layer contained species of *Streblus ilicifolius,* regarded as an invasive species. Based on the Simper analyses, this species occurred at highest frequency in all quadrats of this site type (Table 4.6). From this point of view, future research should focus on the invasion strategies of this species and the influence on other species' distribution. The lower canopy contained components of the upper canopy species but was not as dense as in other sites. However, the herb layer was not dense because most of the area was dominated by rocks and litter cover. A large number of species found within the quadrats were only encountered a few times such as *Stephania sinica* and *Cycas balancae* and many were rare with specific habitat requirements, [especially evident in quadrat 9, located at the highest altitude (624m)]. This site was by far the most diverse forest system studied in terms of all plants species and indicates a pristine forest environment.

The influence of general environmental factors on MS sites (moisture sites) are less clearly defined by Primer than at the other three site types because of overlapping species distribution and different levels of physical/human disturbance. Therefore, variance between the structurally classified groups,

disturbance, physical, soil and vegetation data, was analysed. Both PCA and MDS indicate that quadrat 1 was always separated in the analyses; for this quadrat (1), the tree density was higher than all other quadrats , as was the basal area, due to the larger stature of the trees. Diversity (species and structure) in this undisturbed area was high and the forest was a complex mixture of habitat types and string bamboo only occurred in this quadrat. In general, MS sites have high diversity of species (average 38.66) and endangered species (average 3.0). Two endemic species to the Park only occurred in quadrat 1 of this site type; those are *Sinocalamus mucclure* and *Ficus altissima*. The results suggested a strong positive correlation between aspect and pH for this quadrat. If the areas near the lake and river/valley are considered, it appears that the significant input of moisture to this site, together with higher levels of solar radiation and associated evaporation from the soil on some different aspects, may create a moisture differential, reducing rates of leaching and transport of solutes on the site (Statzenko, 2002). Thus, the effect of aspect and pedology may be a reason that higher species numbers occurred in quadrat 1 as well as two endemic species. It follows that in delineation between the four sites (MS, DT1, DT2, and RU), water availability, pH and differences in soil moisture and associated leaching probably refelect topography. Further analysis of vegetation data (litter, canopy, green, brush, bamboo and grass cover) may provide evidence of this process.

Meanwhile, there are less significant environmental differences within DT1 sites. Variation in disturbance factors appears significant. Individual disturbance levels do not express the patterns of variation detected between sites and quadrats. In the case of the highest number of endangered and rare species in this site type, the results from table 4.7 show that the endangered species in DT1 were distributed almost evenly across all quadrats with a high percentage (19.86) compared with other sites. Because of management from the Park, the influence of human disturbance was not greatly affecting species distribution and endangered species. The most significant deviations in this site type may be the result of soil factors (soil type, soil pH, soil depth etc.) or physical data (slope, location of site, soil without rock, degree of visible rock etc.). Three endangered

species, *Burretiodendron tonkinensis, Garcinia fagraeoides* and *Meliantha suavious* were present at all quadrats of this site type, where the disturbance factors are less significant than in DT2. These species could be cultivated in these locations where ecological conditions are suitable for them and monitoring of human activity is readily available.

The analyses described in this study point to several relationships between the environment and the vegetation of BBNP, the nature and extent of which is primarily influenced by difference in locations and physical/human disturbance. Not homogeneous topography seems to leads difference of floristic composition. For example, quadrat 9 is located on the top of the mountain within lowest human disturbance, and this site also was affected by other environmental factors such as surface water availability.

In the case of BBNP, some endangered species such as *Burretiodendron tonkinensis* have a high percentage of occurrence (91.67%) (Table 4.3). Some common species were not recorded in the Red Book but are at very low numbers and could become locally extinct such as *C. lenticellata* or *P. tavoyana*. On the other hand, in three site types MS, DT1 and RU, Simper analyses indicated that the common invasive species of *Streblus ilicifolius* contributed highest to similarity (over 50%). This result suggests that the BBNP could accept that the local people can exploit this species for their subsistence.

Overall, the results point to a combination of measured environment factors acting together to influence the vegetation patterns in BBNP, with processes of interaction between the physiographic and climatic variables. The close correlation of groups of environmental factors suggests they could be used to define the influences on the vegetation, including endangered and endemic species. The MDS ordination analyses of sample sites on the different locations in BBNP supports this notion, the tight clustering of sites with different types of forest does not indicate the presence of gradients, and suggests that if individual environmental parameters alone explain the floristic variation, then endangered and endemic species are as likely to be found in positions where they currently

do not exist. As this is not the case, it follows that multiple physiographic elements must be significant determinants of observed variation.

In the case of floristic and structural variation within the types of forest, again, the results suggest that it is the physiographic influence that plays the ultimate role in the observed variation, particularly in the understorey. Observations during fieldwork suggest that endangered species were distributed widely in all types of the Park, except quadrat 12 with its influence of high disturbance and deforestation. However, other environmental factors affecting species distribution in BBNP, such as nutrient factors should be the focus of further study, as mentioned above.

6.2.3 Relationships between environment and vegetation

This study found that the chosen group of environmental variables was adequate in explaining vegetation patterns in BBNP. The fact that the 15 environmental variables selected by the BIO-ENV analysis accounted for over 90% of floristic variation implies that the 15 environmental variables are very important factors in determining vegetation composition (detailed in section 4.3.3 in Chapter IV). However, others factors not examined in this study, such as soil productivity, site history, management regimes or frequency and intensity of human activities may contribute to the variation in vegetation in the study area. This result agrees with researches in Argentina and Australia of Bertiller *et al.,* (1993), Le Broque and Buckney, (1994) and Thorne, (2005) that there is a complex of environmental factors operating on distribution of vegetation and no single environmental variable adequately explains the major vegetation patterns.

6.2.4 Summary

Perhaps the most important outcome of the study was that more sample sites were needed ; this is indicated by the site-specific nature of the outcomes of the analysis (Section 4.). Despite this deficiency, it was possible to identify common species with which endangered ones were well correlated and to identify the

apparently important role of topographic variation in determining vegetation and environmental patterns.

Another outcome was that the sample units were probably larger than necessary. This suggests that further study can be conducted a little more quickly than the current one was.

While the chosen set of environmental variables (mainly physical ones) were satisfactory in accounting for much of the variation in vegetation, closer analyses within site types indicated that other factors must be influential in determining local patterns in the vegetation. Further study on the influence of soil nutrients in determining small-scale vegetation patterns probably would yield useful information on the requirements of endangered species in the Park. In particular, soil moisture factors and absence of disturbance seem important

Indications that the proximity of formal management activities reduced the level and impact of illegal activities suggests that more extensive patrolling by Park staff might usefully reduce the risk to the endangered species in the Park.

6.3 Genetic Diversity and Molecular Biology

6.3.1 Methodological consideration

A primary objective of conservation genetics is to estimate the level and distribution of genetic variation in endangered species (Lacy, 1988; Fritsch and Rieseberg, 1996; Cardoso *et al.,* 1998). Accurate estimates of diversity are very useful for optimizing sampling strategies and for conserving and managing plant genetic resources (Hamrick *et al.,* 1991; Schaal *et al.,* 1991; Chalmers *et al.,* 1992). Genetic information is particularly helpful when only a subset of the current populations can be protected and the identification of areas of maximum genetic diversity is a priority for the establishment of short-term conservation strategies (Schemske *et al.,* 1994).

Based on the Red List of IUCN, Red Book of Vietnam, local people's priorities, and recommendation from authorities, four endangered forest tree species from

BBNP (*E. scandens, M. stipulata, and M. suavious* and *S. mucclure*) were chosen for genetic diversity analysis. Two species, *M. stipulata* and *M. suavious* are listed in the Red Book in 2006 as endangered species, while *E. scandens* was recorded in the Red Book in 2004 but this has been highly impacted on by extensive human activities and was overexploited during this period (Phung, 2004). As a result, the species has become endangered and today its total population size is very restricted, especially in the Park. The three species above were also highly recommended for critical conservation by local people living in BBNP (detailed results in Chapter III in this study). Finally, *S. mucclure* is endemic to BBNP only, and has a narrow distribution in the park; this species was highly recommended for further study by Vietnamese scientists and local authorities. Furthermore, the relationship between all four species and their environmental requirements, including associations with more common species, has been conducted in Chapter IV of this study.

For understanding high genetic differentiation among and within remnant populations and individuals of these species, molecular markers were used to examine the distribution of genetic variation between natural populations and to determine whether differences were attributable to differences between geographical locations.

The degree of polymorphism revealed by RAPD and RAMP analysis in all populations in BBNP was high. RAPD analysis is of relevance when working with geographically restricted plant species expected to yield low levels of genetic variability (Hamrick *et al.,* 1991; Smith and Pham, 1996), while RAMP analysis was better than RAPD analysis at disclosing genetic changes between individual plants that were more closely related, or grouping of sites (populations) which might have been similar (De Filippis, 1996).

6.3.2 RAPD-PCR

All four endangered species collected in this study were studied by RAPD-PCR. The results suggest that RAPD-PCR was able to identify genetic differences between distantly related individuals or populations which have been isolated

over a long period of time and in different locations, and this has also been reported for other plants (Cabrita *et al.,* 2001). The nature of the RAPD-PCR method means that normally it overestimates genetic differences. In this study, RAPD-PCR was able to detect a low number of polymorphic band difference between individuals at any one sites. A plausible reason for the low degree of polymorphism in sites detected is that RAPD markers are usually genetically dominant (Wu *et al.,* 1994) and the degree of polymorphism detected as a result can be low.

Firstly, in common with other species of the family Bignoniaceae, *Markhamia stipulata* is expected to be primarily outcrossed (Chan and Huyen, 2000). Apart from the seed dispersal mechanism, which appears to be the main determinant of distribution, very little is known about the reproductive biology of the species. However, some morphological features of its flowers indicate that it is vector dependent. Together, those observations would lead us to expect the species to retain most variation within population as in other outscrossing, woody, long-lived plants (Chan and Huyen, 2000). However, this study found only (64.71%) polymorphism between sites for this species; that is lower than the other three species studied in this research but consistent with a specific vector mediated reproductive system.

These observations suggest that, with the exception of the botanic garden group, there is a limited extent of gene migration between the groups (Table 5.8). To test this hypothesis, a more direct measure of gene flow utilizing a codominant marker system might be needed. Other authors have suggested this should be employed when comparing isozymes with RAPD data, although population studies that have considered both RAPDs and allozymes have shown similar patterns (Aargaard *et al.,* 1995; Cardoso *et al.,* 1998) in the partitioning of the genetic variation. Furthermore, recent studies based on RAPD markers with outcrossing species (Nesbitt *et al.*, 1995; Rosseto *et al.,* 1995; Wachira *et al.,* 1995) have shown that they retain most variability within populations, confirming isozyme data. Previous studies of partitioning of RAPD variation with outcrossing and selfing plants have also demonstrated that it is clearly

dependent on the patterns of geographical distribution and the mating systems of the species (Nesbitt *et al.,* 1995). The partitioning observed in *M. stipilata* could therefore suggest that the species may tolerate a degree of inbreeding. Hamrick (1990) suggested inbreeding could be due to the mating between relatives, such as half-sibs, rather than to selfing. In addition, there is evidence that many tree species with bisexual flowers seem to have at least limited self-compatibility (Bawa and Ashton, 1991). Because *M. stipulata* population sizes are restricted, some levels of inbreeding and also genetic drift could have occurred. As different populations may lose different alleles, a large number of alleles can still be maintained among all the populations as a whole (Neigel, 1996).

The observation that the genetic variability is not evenly distributed throughout individuals, from different populations, indicates that these forest fragments might not be the result of a once continuous system fragmented exclusively in BBNP. Although this fragmentation has been greatly enhanced by overexploitation by the local people, there is strong evidence that most local people used the wood of this species for housing or making furniture (result in Chapter III). The main cause of biodiversity loss in BBNP is deforestation that causes habitat loss (Quy, 2007). *M. stipulata* has restricted distribution in other areas of Vietnam (Chan and Huyen, 2000). The results from Chapter IV indicated that *M. stipulata* has occurred only once (in quadrat 9 on the top of the mountain) with only one individual and the result from MDS showed it was isolated from other species (Figure 4.9). The population 1 (botanic garden) was associated with population 3 (natural site) but separated from population 4. Geographical isolation together with some degree of inbreeding may have been important factors in the genetic differentiation observed between the analysed populations.

Overall there would appear to be high levels of population differentiation and these results indicate that, in this case, provenance is important for the establishment of conservation strategies. Populations representing the different locations where the species is naturally found should be protected. This study

found (in Chapter IV) how this species is associated with other species and their suitable ecological conditions

Endemic and geographically limited plant species generally posses low variation due to genetic drift and restricted gene flow (Karron, 1991; Hamrick and Godt, 1996; Zhang *et al.,* 2006). However, this study found that the percentage of polymorphisms of string bamboo (*S. mucclure*) at the population level is higher than that observed from RAPD analysis in another endangered species in this study, e.g. 64.9% in *M. stipulata.* The results in this study suggest that fragmentation is not necessarily a good predictor of genetic diversity for *M. stipulata.* Recent analysis of genetic variation has emphasized the importance of considering environmental factors or geographic distribution. Chan and Nguyen, (2003) revealed that geographical factors may lead to loss of genetic diversity for string bamboo in BBNP because of the inhomogeneous topography of limestone forest. Results in Chapter IV indicated that the aspect factor may be one of the main factors in this species' distribution because this species occurred on one side of Ba Be lake (in the west site of the lake).

Compared with genetic structure based on RAPD analysis of other populations of Poaceae, the level of population differentiation observed in *S. mucclure* is higher than that with *Oryza sativa* (Hoang, 2002), which is under 20%. High diversity and low population partitioning in rare plants have previously been attributed to a number of factors (Zawko *et al.,* 2001), including insufficient length of time for genetic diversity (Zhang *et al.,* 2006), ecological factors (Van Tienderen *et al.,* 2002) or a natural reduction in population size and isolation; adaptation of genetic system to small population conditions; recent fragmentation by human disturbance of a once continuous genetic system and extensive gene flow (Maguire and Sedgley, 1997). For *S. mucclure*, the number of polymorphic bands and percentage of polymorphism between 10 populations sampled were very different. The percentage of polymorphic bands for the species was 70.5% , while the percentage of polymorphic bands for a single population ranged from 10.29 to 48.53% (except population 9 because this site has only 1 individual). The UPGMA dendrogram (Figure 5.10) showed that there are 2 groups

separated, the first group (population 1 to population 6) is located in 1 site near the lake and another group (population 7 to 10) all are situated in another site near the river. Consequently, migration of this species should be considered in this case to overcome the diversifying effects of random drift. Our preliminary field observations indicated that this species is mainly reproduced by protogenesis/bud reproduction. Animal pollination and seed dispersal by wind may have facilitated extensive gene flow and are likely responsible for the present structure of genetic variation. However, *S. mucclure* flowers after 20 years so that other factors should be paid more attention when considering this phenomenon (Chan, 2004).

Knowledge of the levels and distribution of genetic diversity is important for designing conservation strategies for threatened and endangered species (Hamrick and Godt, 1996). Despite restricted geographical range, a relatively high level of genetic variation within populations and considerable gene flow among populations were detected in *S. mucclure*. Thus, recent fragmentation (human disturbance) may be the main factor leading to a decrease in population size. From Chapter III, we know this species is collected for medicinal purposes and shifting agriculture in this area is also causing habitat loss and population decline. A single means of preventing genetic deterioration of this endemic species in this area is to stop deforestation and to protect its suitable habitats (Zhang *et al.,* 2006). As determined in Chapter IV, this species is grouped with some other relatively common species which can help to define its suitable habitat (detailed in table 4.9 in Chapter IV), but it should be possible to also use *ex situ* conservation for further genetic conservation of this important species. Source material should come from each of the two main groups.

Nine populations of the endangered wild species *M. suavious* were sampled for RAPD analysis. According to our study, this species had higher genetic diversity compared with a study of the same species in Thailand by Prathepha, (2000). However, these species populations were of low genetic diversities compared to other threatened and endangered long lived plants. The genetic diversity of populations 7 (70%) and 8 (75.56%) were higher than other populations with

restricted geographical isolation. Genetic variability and isolation have been considered important factors for the survival of a population or species, particularly in a changing environment. A small population in isolated areas would lose its genetic variation if its numbers remained low and it decreases dramatically in size; only a few individuals remain in its location after habitat fragmentation. *M. suavious*, is a favored vegetable for local people and for the market and a valuable medicinal plant, and has been faced with overexploitation. Other factors leading to genetic variation are geographical isolation because population 8 is situated on An Ma island of Ba Be lake and population 7 is situated on a limestone hillside. All of the sites have different fire histories and experience of shifting agriculture.

The results indicate that there are two groups of populations separated from the nine sampled (Figure 5.5). Differentiation may reflect either the geographical or ecological isolation of this species, but indicates a need to ensure that propagation material is derived from both groups.

To our knowledge, the data presented here represent the first significant study of molecular genetic variation in any Vietnamese *M. suavious*. Further and more detailed studies on other endangered forest tree species in BBNP are required before general models for endangered species in BBNP can be developed. Apart from providing a genetic input into the management of *M. suavious* for conservation purposes, the data have implications for evaluation of the species in provenance trials. It is anticipated that future molecular analysis will focus on a wider range of populations within different locations in Vietnam in order to further develop genetic management strategies at a national level. Phung (2004) suggests that the emphasis for the conservation of *Melientha suavious* should be on providing alternative sources of supply of useful products outside core areas, through cultivation. Considerable planting of this species is already underway in Thainguyen University of Agriculture and Forestry, although the origin of this material is unknown and probably of a narrow genetic base. Therefore, an evaluation of germplasm currently being used in planting programs, to assess both origin and genetic diversity, is also necessary.

With *E. scandens*, analysis of variation in RAPD-PCR revealed a moderate level of variation among populations and a high level of overall diversity represented by the percentage of polymorphic loci found (90.32%) across all populations in the different locations in BBNP. However, the level of diversity is quite different between populations and lower than the average of the whole species as sampled in this study. This phenomenon might be attributable to a higher than expected degree of outcrossing. Inbreeding species tend to be less diverse within but more differentiated between populations while outcrossing species are characterised by high levels of intra-population diversity and low differentiation within populations (Hamrick and Godt, 1996). The need for careful selection from genetically diverse populations may be less pressing for this species than for others.

The result from Chapter V also indicates that the high percentage polymorphism along with other analysis suggests that the partitioning of genetic diversity among *E. scandens* populations was not strongly differentiated to suspect population genetic bottlenecks. Current gene flow in the *E. scandens* populations might be high enough to prevent stronger differentiation though the high level of variability detected, and might reflect historical population variation indicating that the populations from which samples were collected have not been isolated long enough yet for genetic drift or selection to affect allelic composition (Ellstrand, 1992). As no historic data is available, it is not possible to determine if and to which degree genetic erosion due to human interference has already had impact on the genetic diversity of this species in BBNP. However, the fragmentation of previously interlinked habitats could result in population isolation and decreasing gene flow (Young *et al.*, 1996). As BBNP is affected by overexploitation of natural resources (result from Chapter III) and consequently by environmental degradation (result from Chapter IV), it is very likely that *E. scandens* populations underwent fragmentation and reduction of population sizes.

E. scandens in BBNP presently exhibits a relatively high degree of genetic variation at genotype level. Moderate differentiation observed among populations indicates that the detrimental effects of genetic erosion are not of immediate

concern. *E. scandens* was recorded in the Red Book of Vietnam as an endangered species, but currently it is not threatened by extinction in Vietnam because propagation has been successfully applied, even extensively in some areas; though the genetic provenance of these plants is largely unknown. However, habitat fragmentation and further reduction of genetic diversity by genetic drift should be avoided to ensure the maintenance of genetic diversity over time.

In order to capture the ecological and geographic ranges of *E. scandens* in BBNP (and elsewhere), future sampling collection should target populations at larger distances and ecological conditions that are diverse.

If no particular conservation aim is defined, a common principle of *ex situ* conservation of the four species should be to maximize genetic diversity within the stored collections, or plants growing in local gardens to help reduce the pressure on natural resources. The ideal *in situ* protection concept covering the range of genetic variation represented in each target taxon would involve large areas comprising the natural geographic and ecological range –within Vietnam- of each species (Margules and Pressey, 2000; Heider *et al.,* 2007). In this study, *in situ* conservation was considered in Chapter IV; the analysis also indicated where the ecological conditions are likely to be suitable for each species.

6.3.3 RAMP-PCR

Two endangered species were studied using RAMP-PCR: *Sinocalamus mucclure* and *Markhamia stipulata.* Overestimation of diversity appears consistent with this study where RAPD-PCR was able to detect a large number of polymorphic band differences between population sites (Wu *et al.,* 1994; Prathepha, 2000); the percentage of polymorphic bands detected by RAMP-PCR was also high. The results from MDS analysis showed that RAMP was able to generate some polymorphic bands that RAPD primers alone were not.

In summary, results from the molecular data showed that a considerable amount of genetic variation between populations was present at the fragmented sites sampled. Similar results were found in a study of the legume *Flemingia*

macrophylla in North Vietnam in which the authors discovered that the genetic composition of lowland accessions differed significantly from those in upland regions (Heider *et al.,* 2007).

A significant correlation was observed between populations and geographic distance as determined by the Mantel test, and appears to be a major contributing factor to genetic diversity. This relationship was apparent for both species, although using RAPD-PCR data for *Sinocalamus mucclure* this relationship was not present (Table 5.16). Plants from the Botanic Garden site for *Markhamia stipulata* (population 1) had the highest genetic variation, but were also correlated to distance, and may reflect a method of temporal genetic transfer amongst closely related populations (Falconer and Mackay, 1996; Schneller, 1998). This temporal genetic transfer is entirely possible in view of the biology and past collections of *Markhamia stipulata*. However this situation is in contrast to the report of Castineiras *et al.,* (2007) who found no correlation with distance in cultivated accessions of lima beans in Cuban home gardens.

The results from this study suggest that small population fragments of *Sinocalamus mucclure* and *Markhamia stipulata* in BBNP are well worth conserving as part of an overall strategy to maintain genetic diversity in both species. Management to ensure better conservation of both species, however, must be more proactive than at present. A first step is to present this information to the management of the National Park and make sure that they understand the significance of the findings. The second step might be to propagate from all populations of *Sinocalamus mucclure* not in the buffer zone, to be within the buffer zone of the park so that there is more monitoring and protection. A third step would be to educate the indigenous population not to collect material from the park, and develop a plan to invest in methods of propagation that will allow growing of these valuable species in domestic situations. Domestic plants could be harvested with ease and without the need for wild collections, as well as to eventually provide a wider genetic basis for both species. Finally, the conservation of both these endangered plants would benefit considerably by

interconnecting the present fragmented populations via corridors to help guarantee continuing genetic exchange.

6.4 Conclusion and Recommendation

BBNP is an area of high relative biodiversity with many parts of the forest remaining largely intact (Hill *et al.,* 1997). Throughout the survey of local people, over 1005 species were found to be used by local residents for their subsistence belonging to 107 families, 251 genera and 434 species identified by scientific name, including 232 species used for medicine, 88 for vegetable, 72 for fruit, and 150 for wood products; 46 species are marketed. The results generated higher numbers of taxa than other previous studies in BBNP, highlighting the value of local knowledge.

The research used were Rapid Rural Appraisal (RRA) and Participatory Rural Appraisal (PRA) methods. Our interviews were limited to the village chiefs and other prominent individuals and many problems they expressed may not be valid for others, especially women and the poorer families. Information is therefore biased (Kemp *et al.,* 1994; Chambers, 1995; Biggs and Matsaert, 1999). In addition to this, our studies of the ethnic minorities in BBNP must be analysed in the knowledge that no previous participatory research was conducted. Historically, decisions were made by outsiders with preconceptions about problems and solutions and the results were not discussed further with the local people. This is very difficult to address and is a common problem with short-duration socio-economic survey work. A very objective view is needed in order that these biases are not reinforced, and these aspects should be brought into consideration when analysing the conclusions. However, the PRA and RRA methods used highlight certain problems and areas for future study. Informal interviews were implemented within local leaders and park's authority people.

A follow-up to this study should include sessions in which the findings are conveyed to the broadest possible group of forest users.

The people of BBNP are living at a subsistence level, although the standard of living may be starting to improve in terms of agriculture extension and environmental education for many villages to participate in nature conservation. The majority of the peoples' resources come from the land and what it can provide. Agriculture cannot provide for all their needs, and there is little alternative to continuing to exploit other resources. This is especially true for the poorer families and villages. Short-term solutions to problems will continue to be applied until alternatives become available.

From the data collected, and observations within the Park, it is likely that BBNP's natural resource depletion will continue at an increasing rate, and greater protection of the resources are needed. Park policy is to resettle those villages within the protected area to areas outside the Park boundaries. Dao and H'Mong villages from protected areas have already been moved to outside such as to Don Den village (where they were interviewed for this study). The H'Mong villages of Nam Dai and Khau Qua have been settled from 1979 and the Park is now preventing further settlement or clearance, and waiting until the villagers move on. This alleviates some pressure on the park's natural resources, but increases the pressure outside the park. Greater numbers of people will therefore come into the Park, as it can provide needed resources. Thus, more sustainable farming is urgently needed in the Park. There are no plans to move people within the buffer zone.

> **Agricultural and environmental extension activities, applying modern intensive farming practices, and conservation and environmental education should be implemented for the local people to develop sustainably.**

Local people should be taken into account before the implementation of any forestry protection policies. People are largely dependant on the forest resources, and damage to or exploitation of these are detrimental to their own livelihoods (as would be strict banning of traditional forest uses). The realisation of the threat of resource depletion is made difficult by different attitudes towards the forest in

different minorities. There appears to be lack of commitment to sustainable use of the *government* land on which the people have settled.

> **Increased ownership and lease-holding of land may encourage people to look after their resources. Local people could also be involved in the protection of the resources (including employment as park guards or guides for tourists).**

In the face of the population pressures, increased yields from land are needed but this need not involve expansion of agricultural land area and encroachment into the Park forests. Access to new technologies and information on agricultural methods will help to achieve this increase in yield. Modern methods, which need not be expensive, such as improved irrigation, new seed strains and a better understanding of fertilizer use, would relieve future pressure on the forests of BBNP. Alternative land use such as agroforestry schemes and replantation of useful forest tree species could supply a local resource and a possible surplus for sale in the markets. Communal woodlots have had varied success in Vietnam with mass planting of fast growing trees such as *Eucalyptus* or *Acacia* since 1975 (Vui, 2006; Hai *et al.,* 2007) and may prove beneficial to the villages as whole. The villages are close-knit communities and communal resources may well be distributed equally in some villages.

Paddy expansion is not necessarily the only answer in the fragile upland environment and many other methods of agriculture exist (Kemp *et al.,* 1994; Hill *et al.,* 1997). The use of indigenous knowledge is particularly important here as the people will know what crops or forest tree species are suited for particular areas. Extension methods for the implementation of these changes will help sustain the natural resources of BBNP.

> **Policies of expansion of rice paddies and other agricultural uses for the low land areas should be revised, particulaly with a view to evaluating potentially more productive crops and methods, before implementation in the mountainous regions.**

The classification of species with respect to their conservation status using the IUCN criteria is an important process in many countries, providing a guide for setting conservation priorities (Colyvan *et al.,* 1998; Coe, 2001; Martin, 2008). As the recommendation above, this study listed all endangered forest tree species in BBNP by IUCN criteria, the result found 23 species recorded at different levels from Critical to Vulnerable rankings. A total of 46 species met the criteria of Red Book of Vietnam recorded in this study. However, the state of conservation and conservation priorities are different concepts which are commonly confused (Munton, 1987; De Grammont and Cuaron, 2006). The IUCN criteria are designed to identify global states of conservation (Butchart *et al.,* 2005), but when it comes to considering distributional ranges they are based on absolute thresholds which are not equally applicable to all taxonomic groups, nor are they consistent with the size of the distribution ranges of the species at small scales as in BBNP. This impedes the classification of the species in a way which reflects the real urgency for local conservation. Recent advances have resulted in several approaches to dealing with uncertainty in data used to rank species. These methods demand an unambiguous and transparent logical structure for the criteria. This study also suggested some changes to the ways in which the criteria are represented that correct inconsistencies and which may serve to avoid important errors when uncertainty in the data is considered. This approach was to begin with the indigenous people living in the research area and identified 46 endangered forest plant species ranked at different levels based on 2 criteria (use level and rarity level). Twenty-one species were identified for propagation and cultivation, 15 were identified by local people as needing special protection. The result from MDS analysis indicate that seven species should be highly recommended for priority conservation based on comparison from three different criteria of IUCN, Red Book, and local people identification.

Priority action should focus on those seven species initially and be expanded to the 15 species perceived as needing special protection locally.

Ba Be National Park supports a flora of high value to Vietnam. Typical tropical forest types with high biodiversity values and the presence of valuable and rare species are all to be found within the Park, and although much of this forest is disturbed to some extent it plays an important role of supporting fauna and of landscape protection. In order for the forest to continue these roles it is important to protect those areas with little or no disturbance as these support the richest diversity of species. However, all areas support wildlife and some areas of regenerating forest are showing encouraging signs of recovery. Some disturbed sites in this study had greater species richness than others

It is important to exercise effort in the regulation of these areas from encroachment by the human population within and around the Park.

Conversely,

Studies into the effects of different disturbance types and regimes on species richness and regeneration of valued species should be made a priority by Park management.

The vegetation composition varies with different forest types (MS, DT1, DT2, and RU sites). Multivariate analysis showed some discrete differentiation of vegetation patterns in some sites. The relatively undisturbed sites (RU) did not support a higher number and abundance of common and endangered species compared to disturbed sites, though their understoreys were more varied. Endangered and endemic species and tree species play an important role in vegetation composition in BBNP at all MDS analyses. Continued management of the Park for species conservation can include both "pure" and strict protection and regulated exploitation. The sites that had been cleared for tree harvest (DT2) gave evidence that tree harvest *per se* did not prevent regeneration of the forest, including some endangered species, but that on going agriculture did.

Park management plans should recognize and evaluate both the value and the threats of human exploitation.

Forestry authorities, perhaps in conjunction with conservation agencies and others, should develop stricter post-forestry restrictions on the use of harvested forest.

Thirteen endangered and endemic species were found in four site types; there are four groups of endangered species associated with common species and ecological conditions, and one group of common species was separated from analysis.

***In situ* and *ex situ* conservation of valuable species should incorporate knowledge of the apparent optimal environmental conditions for the target species.**

Many plants are difficult to grow outside of their natural forest habitats and so over time have become less well known and relied upon (Kemp *et al.,* 1994). A knowledge of their preferred habitat conditions is essential for their effective conservation.

Both further ecological investigation and physiological studies of sensitive species is necessary.

The genetic analysis in this study amplified relatively few polymorphisms in four endangered forest plant species in BBNP, but detected more diversity in the species when using RAMP-PCR. The result suggests that both RAPD and RAMP-PCR are usefully informative. However, the results also show that PCR reaction conditions, electrophoresis and staining methods may be more responsible for the apparent poor performance of the markers than the markers themselves.

Comparison of RAMP-PCR with the results of RAPD-PCR run under the same conditions indicated that RAMP-PCR was more informative than RAPD-PCR, and that it should generate the same or a greater genetic diversity index under identical conditions. The ability of the markers to distinguish between sub-populations of four endangered species indicates that RAMP-PCR has potential for use in conservation genetics with further development.

Molecular marker analysis of genetic variation within four endangered forest plant species revealed a high level of genetic variability and moderate levels of differentiation among accessions, while detecting a significant differentiation between accessions collected in different locations in the park. This study provides genetic information for further and more detailed analysis of genetic diversity of all four species. To link with priority species for conservation and ecological conditions, it serves as guidance for the delineation of *ex situ* and *in situ* conservation approaches. The generated baseline data are valuable for follow-up research and for future decision making processes associated with management and conservation of genetic resources.

Further molecular genetic studies of the identified target species are needed in BBNP (and elsewhere) to help inform decisions on conservation strategies.

Analysis of sub-populations of the four endangered forest plant species in BBNP demonstrated that there was a significant difference in genetic variation between all four groups of species. The sources of the differences appeared to lie in corresponding differences in the human and physical disturbance of the sites, rather in fragmentation, and suggested that the genetic differences observed represented temporal, rather than spatial, genetic variation.

In the case of BBNP, this study is the first report providing basic genetic information on four endangered forest plant populations. When these results are compared to published results, it appears that the distribution patterns obtained from this study agrees with the findings of several authors, based on RAMP and RAPD variation in plant species. Thus, it is suggested that molecular markers could be successfully applied for detecting genetic variability in natural populations of these forest species. Furthermore, analysis carried out in this study can also be considered a helpful tool in conservation genetics of endangered forest plant species in establishing priority to be taken for conservation policies and management of these species in BBNP.

Molecular genetic studies should form an integral part of the development of conservation priorities and strategies.

Responsibility for the implementation of the above recommendations lies with a variety of agencies, international, national, regional and local. A significant challenge for these agencies will be to discriminate between actions that are best conducted at each such level. A particular challenge emerged during this study:

> It will be difficult to convince an indigenous forest user of the necessity to constrain use of a species that is highly abundant in his/her local area (but endangered elsewhere) and for which continued exploitation appears necessary for the improvement of their living conditions and prospects for their family.

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APPENDICES

Appendix 1: The list of local people interviewed in 3 commune of Ba Be National Park.

Order	Household	Age	Gender	Education	Level of household	Ethnic groups	Income	Low land	Forest land	Villages	Communes
1	Giang A Tu	20	1	1	4	3	3	2000	8000	Don Den	Khang Ninh
2	Giang A Chanh	24	1	0	4	3	5	2000	8000	Don Den	Khang Ninh
3	Duong Van Quan	33	1	1	4	3	3	2000	8000	Don Den	Khang Ninh
4	Thao Van Minh	26	1	1	4	3	4	2000	8000	Don Den	Khang Ninh
5	Duong Van Tu	32	1	0	4	3	5	2000	8000	Don Den	Khang Ninh
6	Hau Van Phing	42	1	0	4	3	3	1000	3000	Don Den	Khang Ninh
7	Duong Van Bao	60	1	2	4	3	3.5	1000	6000	Don Den	Khang Ninh
8	Giang A Lenh	53	1	0	4	3	5	1000	3000	Don Den	Khang Ninh
9	Duong Van Chong	41	1	1	4	3	3	1000	5000	Don Den	Khang Ninh
10	Hau Van Bang	26	1	1	4	3	2	1000	3000	Don Den	Khang Ninh
11	Duong Van Dia	39	1	1	4	3	5	3000	2000	Don Den	Khang Ninh
12	Hua A Va	51	1	0	4	3	5	2000	8000	Don Den	Khang Ninh
13	Giang A Vu	50	1	1	4	3	5	2000	8000	Don Den	Khang Ninh
14	Giang Chu Pao	46	1	0	4	3	2	1000	5000	Don Den	Khang Ninh
15	Sung A Sy	29	1	0	4	3	3	2000	8000	Don Den	Khang Ninh
16	Ly Van Dia	24	1	1	4	3	3	1000	3000	Don Den	Khang Ninh
17	Hau Van Vang	22	1	1	4	3	2	2000	3000	Don Den	Khang Ninh
18	Giang A Lu	31	1	0	4	3	3	2000	8000	Don Den	Khang Ninh
19	Giang A Vu	33	1	0	4	3	4	2000	6000	Don Den	Khang Ninh
20	Giang Sinh Pao	38	1	1	4	3	2	2000	5000	Don Den	Khang Ninh
21	Giang A Dinh	30	1	0	4	3	7	1000	3000	Don Den	Khang Ninh

Order	Household	Age	Gender	Education	Level of household	Ethnic groups	Income	Low land	Forest land	Villages	Communes
22	Ly Van Tinh	24	1	1	4	3	1.5	2000	8000	Don Den	Khang Ninh
23	Vang A Tu	28	1	1	4	3	2	1000	3000	Don Den	Khang Ninh
24	Duong Van Pao	19	1	2	4	3	4	2000	8000	Don Den	Khang Ninh
25	Vang A Vu	20	1	0	4	3	2	2000	8000	Don Den	Khang Ninh
26	Sung A Cau	30	1	1	4	3	3	2000	8000	Don Den	Khang Ninh
27	Duong Van Giang	31	1	1	4	3	4	2000	8000	Don Den	Khang Ninh
28	Thao Van Cha	33	1	1	4	3	8	4000	5000	Na Ban	Nam Mau
29	Hoang Van Dinh	46	1	0	3	3	12	6000	3000	Na Ban	Nam Mau
30	Sung Van Tu	42	1	0	4	3	6	5000	4000	Na Ban	Nam Mau
31	Duong Van Giang	24	1	0	4	3	4	2000	2000	Na Ban	Nam Mau
32	Lau Van Kheo	34	1	0	4	3	7	2000	7000	Na Ban	Nam Mau
33	Ly A Than	20	1	3	3	3	9	8000	30000	Na Ban	Nam Mau
34	Vu Van Tu	48	1	1	3	3	10	6000	4000	Na Ban	Nam Mau
35	Duong Van Tu	54	1	2	4	3	12	2000	6000	Na Ban	Nam Mau
36	Hoang Van Pa	47	1	1	4	3	5	5000	4000	Na Ban	Nam Mau
37	Truong Thi Dinh	72	2	0	4	3	8	4000	6000	Na Ban	Nam Mau
38	Truong Van Hau	43	1	0	4	3	4	1000	2000	Na Ban	Nam Mau
39	Hoang Van Khinh	34	1	1	4	3	4	3000	5000	Nam Dai	Nam Mau
40	Hoang Van Thang	36	1	1	4	3	3	2000	5000	Nam Dai	Nam Mau
41	Ly Van Su	39	1	1	4	3	8	10000	5000	Nam Dai	Nam Mau
42	Ly Thi Sie	60	2	0	4	3	3	2000	3000	Nam Dai	Nam Mau
43	Ly Van Lau	40	1	0	4	3	3	1500	2000	Nam Dai	Nam Mau
44	Hoang Minh Tam	30	1	1	3	3	15	10000	15000	Nam Dai	Nam Mau
45	Hoang Minh Tam	31	1	2	4	3	9	10000	12000	Nam Dai	Nam Mau
46	Hoang van Tung	42	1	2	3	3	8	10000	60000	Nam Dai	Nam Mau
47	Ly Thi Vang	18	2	1	3	3	3	3000	3000	Nam Dai	Nam Mau

Order	Household	Age	Gender	Education	Level of household	Ethnic groups	Income	Low land	Forest land	Villages	Communes
48	Vang Van Rong	56	1	0	4	3	7	3000	2000	Nam Dai	Nam Mau
49	Ly Van Hong	36	1	2	3	3	7	5000	2000	Nam Dai	Nam Mau
50	Linh Thi Mai	31	2	0	4	3	10	2000	1000	Nam Dai	Nam Mau
51	Trieu Tien Minh	47	1	2	3	2	11	7000	5000	Na Vai	Quang Khe
52	Ly Nguyen Khuyen	45	2	2	3	2	6	5000	3000	Na Vai	Quang Khe
53	Trieu Thanh Bao	32	1	1	1	2	12	4500	5000	Na Vai	Quang Khe
54	Trieu Duc Bao	42	1	1	4	2	8	4000	2000	Na Vai	Quang Khe
55	Trieu Thi Son	26	2	1	4	2	7	2000	3000	Na Vai	Quang Khe
56	Trieu Tien Ngan	34	1	1	4	2	8	4000	5000	Na Vai	Quang Khe
57	Trieu Duc Thanh	41	1	2	3	2	12	3000	2500	Na Vai	Quang Khe
58	Hoang Xuan Dinh	38	1	0	3	2	12	4000	2000	Na Vai	Quang Khe
59	Trieu Thi Phuong	24	2	1	4	2	4	5000	2000	Na Vai	Quang Khe
60	Trieu Huu Dinh	56	1	1	4	2	10	6000	3000	Na Vai	Quang Khe
61	Trieu Thi Bao	35	2	1	3	2	8	3500	3500	Na Vai	Quang Khe
62	Trieu Khai Chiu	50	1	1	3	2	8	4500	7000	Na Vai	Quang Khe
63	Trieu Sinh Phu	40	1	1	3	2	13	5400	6000	Na Vai	Quang Khe
64	Trieu Tien Vinh	41	1	2	3	2	10	4000	15000	Na Vai	Quang Khe
65	Trieu Sinh Thanh	40	1	1	3	2	8	7000	14000	Na Vai	Quang Khe
66	Trieu Duc Tien	43	1	2	3	2	12	7000	10000	Na Vai	Quang Khe
67	Trieu Khai Tien	36	1	0	4	2	6	5000	700	Na Vai	Quang Khe
68	Trieu Thanh Ngan	41	1	2	4	2	7	5000	5000	Na Vai	Quang Khe
69	Trieu Duc Son	26	1	1	4	2	7	3000	3500	Na Vai	Quang Khe
70	Trieu Thi Thai	34	2	1	4	2	3	1000	1800	Na Vai	Quang Khe
71	Trieu Sao Hoa	34	1	2	3	2	10	4000	5000	Na Vai	Quang Khe
72	Trieu Thi Lan	43	2	1	1	2	17	3200	2000	Na Vai	Quang Khe
73	Hoang Xuan Hung	38	1	1	3	2	10	4000	6000	Na Vai	Quang Khe

Order	Household	Age	Gender	Education	Level of household	Ethnic groups	Income	Low land	Forest land	Villages	Communes
74	Trieu Duc Oanh	35	1	3	3	2	22	4000	4000	Na Vai	Quang Khe
75	Trieu Khai Thang	50	1	2	3	2	17	7000	3000	Na Vai	Quang Khe
76	Trieu Dinh Phu	62	1	0	3	2	6	6000	2000	Na Vai	Quang Khe
77	Trieu Thanh Ly	34	1	2	3	2	16	6000	20000	Na Vai	Quang Khe
78	Trieu Khai Long	41	1	1	4	2	5	5000	5000	Na Vai	Quang Khe
79	Trieu Duc Chu	35	1	0	4	2	5	5000	5000	Na Vai	Quang Khe
80	Trieu Duc Phu	35	1	0	3	2	10	9000	5000	Na Vai	Quang Khe
81	Trieu Trieu Hin	58	1	1	2	2	20	0	250000	Khuoi Luong	Khang Ninh
82	Vang Thong Kiem	24	1	0	4	2	4	5500	0	Khuoi Luong	Khang Ninh
83	Ban Thi Kieu	33	2	0	4	2	6	6000	3500	Khuoi Luong	Khang Ninh
84	Dang Phu Dao	48	1	1	4	2	4	6000	5000	Khuoi Luong	Khang Ninh
85	Dang Van Lai	28	1	0	4	2	3	5000	5000	Khuoi Luong	Khang Ninh
86	Ban Van Tuan	24	1	1	4	2	5	1000	0	Khuoi Luong	Khang Ninh
87	Ly Van Phay	48	1	1	4	2	5	3414	225	Khuoi Luong	Khang Ninh
88	Luc Sanh Phuc	43	1	1	4	2	4	4000	20600	Khuoi Luong	Khang Ninh
80	Luc Sinh Hien	40	1	0	4	2	5	2000	2000	Khuoi Luong	Khang Ninh
90	Luc Chan Hin	27	1	1	4	2	5	3000	2000	Khuoi Luong	Khang Ninh
91	Luc Sanh Piao	34	1	0	4	2	5	2000	1000	Khuoi Luong	Khang Ninh
92	Ly Thi Voi	35	2	1	3	2	10	2300	0	Khuoi Luong	Khang Ninh
93	Ban Dun Choi	46	1	0	4	2	15	2500	10000	Khuoi Luong	Khang Ninh
94	Ban Van Lu	54	1	1	3	2	10	2000	10000	Khuoi Luong	Khang Ninh
95	Dang Dao Quyen	46	1	0	3	2	7	6000	20000	Khuoi Luong	Khang Ninh
96	Hoang Muoi Quay	37	2	0	3	2	8	5000	0	Khuoi Luong	Khang Ninh
97	Trieu dao Lua	29	2	0	4	2	3	3000	20000	Khuoi Luong	Khang Ninh
98	Dang Giao Quyen	45	1	0	4	2	6	2000	6000	Khuoi Luong	Khang Ninh
99	Dang Dao Nan	32	1	1	4	2	7	1400	3000	Khuoi Luong	Khang Ninh

Order	Household	Age	Gender	Education	Level of household	Ethnic groups	Income	Low land	Forest land	Villages	Communes
100	Ban Nhu Can	46	1	2	4	2	4	3000	68800	Khuoi Luong	Khang Ninh
101	Hoang Thi Khang	45	2	2	4	1	3	700	0	Pac Ngoi	Nam Mau
102	Nguyen Su	36	1	2	3	1	13	5000	10000	Pac Ngoi	Nam Mau
103	Nong Van Giam	34	1	3	3	1	6	2000	0	Pac Ngoi	Nam Mau
104	Hoang Van Duc	34	1	2	4	1	2.5	2400	0	Pac Ngoi	Nam Mau
105	Hoang Van Sy	27	1	1	4	1	4	2100	3000	Pac Ngoi	Nam Mau
106	Hoang Van Long	60	1	2	3	1	6	5000	0	Pac Ngoi	Nam Mau
107	Hua Duc Hop	56	1	3	3	1	15	5000	3000	Pac Ngoi	Nam Mau
108	Trieu Van Vuong	54	1	2	4	1	2.3	7000	0	Pac Ngoi	Nam Mau
109	Hua Van Mui	41	1	2	3	1	6	4000	0	Pac Ngoi	Nam Mau
110	Duong Thi Lan	47	2	2	3	1	3	5000	0	Pac Ngoi	Nam Mau
111	Nong Thi Lan	42	2	2	3	1	5	5000	0	Pac Ngoi	Nam Mau
112	Gia Thi Hien	30	2	3	3	1	10	5000	0	Pac Ngoi	Nam Mau
113	Nong Van Duy	45	1	2	4	1	10	1000	0	Pac Ngoi	Nam Mau
114	Nong Van Danh	28	1	2	3	1	10	3000	0	Pac Ngoi	Nam Mau
115	Trieu Duy Tho	40	1	2	2	1	30	14000	0	Pac Ngoi	Nam Mau
116	Hua Van Tuyen	44	1	2	4	1	4	4000	23000	Pac Ngoi	Nam Mau
117	Ma Van Tue	34	1	3	3	1	15	5000	40	Pac Ngoi	Nam Mau
118	Ma Van Thang	48	1	1	3	1	4.5	2000	8000	Pac Ngoi	Nam Mau
119	Nong Xuan Hoa	45	1	2	4	1	9	1000	0	Pac Ngoi	Nam Mau
120	Dong Van Thiep	35	1	2	4	1	12	2000	0	Pac Ngoi	Nam Mau
121	Hoang Van Chinh	39	1	2	3	1	7	2000	0	Pac Ngoi	Nam Mau
122	Hoang Van Hop	52	1	3	3	1	5	10000	1000	Pac Ngoi	Nam Mau
123	Nguyen Van Sau	32	1	2	3	1	10	6000	40000	Pac Ngoi	Nam Mau
124	Duong Van Chan	45	1	2	3	1	8	6500	3000	Pac Ngoi	Nam Mau
125	Ngon Van Toan	59	1	2	2	1	12	10000	40000	Pac Ngoi	Nam Mau

Order	Household	Age	Gender	Education	Level of household	Ethnic groups	Income	Low land	Forest land	Villages	Communes
126	Nguyen Van Toan	34	1	1	3	1	5	4000	6000	Pac Ngoi	Nam Mau
127	Hoang Van Luyen	35	1	3	3	1	6	2000	0	Pac Ngoi	Nam Mau
128	Hoang Van Le	40	1	2	3	1	5	2000	0	Pac Ngoi	Nam Mau
129	Duong Van Thuan	30	1	2	3	1	4	2600	0	Pac Ngoi	Nam Mau
130	Hoang Van Trang	35	1	3	3	1	6	2000	3000	Pac Ngoi	Nam Mau
131	Tran Van Tuan	38	1	2	3	1	5	3200	0	Pac Ngoi	Nam Mau
132	Mach Van Dung	45	1	3	3	1	3.5	7000	2000	Pac Ngoi	Nam Mau
133	Duong Van Han	23	1	2	3	1	2.4	1500	0	Pac Ngoi	Nam Mau
134	Duong Van Hoi	49	1	2	3	1	20	4500	2000	Pac Ngoi	Nam Mau
135	Hoang Van Chuyen	35	1	3	3	1	5	2000	3000	Pac Ngoi	Nam Mau
136	Nong Van Thao	45	1	2	3	1	4	5000	0	Pac Ngoi	Nam Mau
137	Hua Van Cam	50	1	2	3	1	3	5000	0	Pac Ngoi	Nam Mau
138	Trieu Duc Luat	60	1	3	3	1	24	9000	4000	Pac Ngoi	Nam Mau
139	Hua Duc Giap	30	1	2	3	1	10	8000	5000	Pac Ngoi	Nam Mau
140	Hoang Van Doan	42	1	1	4	1	3	1000	0	Pac Ngoi	Nam Mau
141	Hoang Van Sy	27	1	2	4	1	4	2100	3000	Pac Ngoi	Nam Mau
142	Hoang Van Duoc	28	1	2	4	1	4	2000	3000	Pac Ngoi	Nam Mau
143	Duong Van Dang	50	1	2	3	1	20	2800	0	Pac Ngoi	Nam Mau
144	Trieu Quang	80	1	2	3	1	10	10000	0	Pac Ngoi	Nam Mau
145	Hua Van Tham	47	1	2	3	1	15	6000	20000	Pac Ngoi	Nam Mau
146	Ma Van Gioi	38	1	2	3	1	4	1000	40000	Pac Ngoi	Nam Mau
147	Trieu Thi Oanh	37	2	2	3	1	100	11000	50000	Pac Ngoi	Nam Mau
148	Hoang Thi Khoe	52	2	2	4	1	2	25000	0	Pac Ngoi	Nam Mau
149	Duong Van Thin	53	1	2	3	1	12	6000	30000	Pac Ngoi	Nam Mau
150	Trieu Van Hung	47	1	2	3	1	8	2200	0	Pac Ngoi	Nam Mau
151	Duong Thi Oanh	32	2	2	3	1	8	700	0	Ban Nam	Khang Ninh

Order	Household	Age	Gender	Education	Level of household	Ethnic groups	Income	Low land	Forest land	Villages	Communes
152	Ma Thi Oanh	35	2	2	3	1	6	2000	2000	Ban Nam	Khang Ninh
153	Nguyen Thi Tuyen	52	2	1	3	1	3	1500	1000	Ban Nam	Khang Ninh
154	Hoang Van Pao	36	1	2	4	1	2	1500	0	Ban Nam	Khang Ninh
155	Duong Van Bong	32	1	3	3	1	7	1200	4000	Ban Nam	Khang Ninh
156	Hoang Duong Cat	50	1	2	3	1	2	600	2000	Ban Nam	Khang Ninh
157	Nguyen Van Dao	41	1	3	3	1	15	4000	30000	Ban Nam	Khang Ninh
158	Nong Thi Thanh	37	2	1	3	1	8	6000	6000	Ban Nam	Khang Ninh
159	To Thi Huong	35	2	1	4	1	2	700	1000	Ban Nam	Khang Ninh
160	Nguyen Van Tue	38	1	2	2	1	10	7000	3000	Ban Nam	Khang Ninh
161	Nguyen Khac Duoc	47	1	2	2	1	15	2500	2000	Ban Nam	Khang Ninh
162	Nguyen Long Can	50	1	2	3	1	10	5000	20000	Ban Nam	Khang Ninh
163	Duong Van Chuong	54	1	2	3	1	8	3000	10000	Ban Nam	Khang Ninh
164	Duong Van Thuy	74	1	3	3	1	10	4000	20000	Ban Nam	Khang Ninh
165	Hoang Ngoc Nia	22	1	3	4	1	4	3000	20000	Ban Nam	Khang Ninh
166	Hoang Van Cu	26	1	2	4	1	4	2000	12000	Ban Nam	Khang Ninh
167	Duong Van Vang	60	1	2	4	1	10	4000	6000	Ban Nam	Khang Ninh
168	Nguyen Van Nieu	64	1	1	3	1	9	600	0	Ban Nam	Khang Ninh
169	Nguyen Thi Cuc	30	2	2	3	1	5	2000	2000	Ban Nam	Khang Ninh
170	Tran Thi Mon	32	2	2	3	1	10	2000	5000	Ban Nam	Khang Ninh
171	Duong Van Vong	38	1	3	3	1	20	2500	30000	Ban Nam	Khang Ninh
172	Hoang Thi Chanh	34	2	3	2	1	10	3000	4000	Ban Nam	Khang Ninh
173	Nguyen Van Thuy	74	1	2	2	1	30	7000	10000	Ban Nam	Khang Ninh
174	Hoang Thi Khuyen	24	2	3	4	1	5	3000	3000	Ban Nam	Khang Ninh
175	Duong Thi Net	27	2	3	3	1	5	6000	0	Ban Nam	Khang Ninh
176	Duong Thi Be	44	2	1	3	1	10	2000	3000	Ban Nam	Khang Ninh
177	Duong Van Vuc	48	1	3	1	1	30	2000	50000	Ban Nam	Khang Ninh

Order	Household	Age	Gender	Education	Level of household	Ethnic groups	Income	Low land	Forest land	Villages	Communes
178	Nguyen Van Cam	41	1	2	3	1	3	2000	0	Ban Nam	Khang Ninh
179	Duong Van Bong	39	1	2	3	1	5	2000	0	Ban Nam	Khang Ninh
180	Duong Van Thuyet	43	1	3	4	1	3	1200	20000	Ban Nam	Khang Ninh
181	Nong Thi Thue	37	2	2	3	1	4	1000	0	Ban Nam	Khang Ninh
182	Duong Thi Non	42	2	2	3	1	5	3000	0	Ban Nam	Khang Ninh
183	Duong Thi Thuc	54	2	1	3	1	5	2000	0	Ban Nam	Khang Ninh
184	Nguyen Van Phoi	27	1	2	3	1	4	2000	0	Ban Nam	Khang Ninh
185	Duong Van Tuyen	42	1	2	3	1	6	2000	0	Ban Nam	Khang Ninh
186	Nguyen Van Hoan	53	1	3	3	1	5	5000	0	Ban Nam	Khang Ninh
187	Nguyen Van Cao	44	1	3	3	1	20	1200	5000	Ban Nam	Khang Ninh
188	Duong Van Duy	42	1	3	3	1	6	2000	3000	Ban Nam	Khang Ninh
189	Nguyen Duc Quynh	62	1	3	4	1	3	3000	20000	Ban Nam	Khang Ninh
190	Duong Van Tinh	60	1	1	4	1	3	2800	30000	Ban Nam	Khang Ninh
191	Luong Van Ngo	61	1	2	3	1	5	2400	20000	Ban Nam	Khang Ninh
192	Dao Van Que	38	1	2	3	1	10	2000	10000	Ban Nam	Khang Ninh
193	Hoang Thi Chuyen	40	2	2	3	1	5	2000	0	Ban Nam	Khang Ninh
194	Duong Ngoc Xuat	53	1	2	3	1	5	3000	0	Ban Nam	Khang Ninh
195	Nguyen Van Ty	38	1	2	3	1	4	2500	0	Ban Nam	Khang Ninh
196	Trinh Thi Huyen	40	2	2	3	1	5	3000	0	Ban Nam	Khang Ninh
197	Nguyen Van Tai	42	1	3	3	1	5	1500	0	Ban Nam	Khang Ninh
198	Nguyen Van Duong	24	1	1	4	1	2	1000	0	Ban Nam	Khang Ninh
199	Nguyen Van Thuoc	47	1	2	3	1	12	3000	0	Ban Nam	Khang Ninh
200	Dao van Nghien	35	1	2	3	1	10	3000	1000	Ban Nam	Khang Ninh

Appendix 2: Questionaire for local people interview used in survey of identification endangered species and local people participated in natural conservation.

University of Technology, Sydney
Faculty of Science – Department of Environmental Sciences

Questionnaire

Endangered forest tree species

For households living in Ba Be National Park (BBNP)

The purpose of this survey is to identify the endangered forest tree species, vegetation cover, ecological conditions, and species distributions in the evaluation of the conservation status and risk for some endangered forest tree species project in Ba Be National Park. In the other hand, this program will fine out the effective conservation solutions for these species. Filling in accurate information will help to protect precious natural resources and improve to the living of communities.

I. Household information

Full name:

Age:

Gender: ☐ Male ☐ Female

Level of instruction:
☐ Primary ☐ Secondary ☐ High

Economic status/main income:
☐ Rich ☐ Intermediate ☐ Middle ☐ Poor

Ethnic:

Income:

Position in the community:

Total housing land and agricultural land:

Total forest land

Village: Commune: District: Province: Bac Kan

II. List of forest species

2.1. List all forest trees are used as medicinal plants by your family collected from (BBNP)

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2.2. According to you, which medicinal plants you think they will be rare or in endangered now.

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2.3. List all edible plants are used as vegetables in your family

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2.4. According to you, which edible plants will be rare or in endangered risk

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2.5. List all fruits are often collected by your family from BBNP.

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2.6. According to you, which fruit plants are or will be rare and in endangered risk up to date.

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2.7. List all woody species, fuel trees are used by your family collected from BBNP.

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2.8. According to you, which woody trees have become rare and in endanger risk.

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2.9. List all forest products are used as market goods by your family.

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2.10. According to you, which forest products have become rare and difficult to find out in BBNP.

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2.11. According to you, which forest plants should be preserved.

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Thank you for your cooperation.

Appendix 3: The List of species used by local people for medecine (Me), vegetable (V), market (Ma), fruit (F), and wood purposes (W). (this is 167 species were identified scientific name in total 1005 species used by local people in Ba Be National Park.

Order	Latin Name	Local name	Family name	Usage
1	*Glochidion velutinum*	Ba Se	Euphorbiaceae	Me
2	*Fissistigma thorelli*	Ba beo	Annonaceae	Me
3	*Morinda officinalis*	Ba Kich	Rubiaceae	Me
4	*Stemona tubelosa*	Bach bo	Stemonaceae	Ma
5	*Stemona saxorum*	Bach bo	Stemonaceae	Me/Ma
6	*Lindera sp.*	Bach quan	Lauraceae	Me
7	*Klanchoe integra*	Bang beo	Crassulaceae	Me
8	*Ardisia silvestris*	bang toc	Myrsinaceae	Me
9	*Cucurbitamaxima*	Bi do	Cucurbitaceae	Me
10	*Taraxacum sp*	Bo cong anh	Asteraceae	V
11	*Styrax tonkinensis*	Bo de	Styraceae	W
12	*Erythropalum sp.*	Bo khai do	Erythropalaceae	Me
13	*Erythropalum scandens*	Bo khai trang	Erythropalaceae	Me/V/Ma
14	*Flacourtia jamgomas*	Bo quan	Flacourtiaceae	Me
15	*Thysanolaena maxima*	Bong chit	Poaceae	Ma
16	*Garcinia oblonggifolia*	Bua	Clusiaceae	F
17	*Acronychia pedunculata*	Buoi	Rutaceae	Me
18	*Citrus grandis*	Buoi	Rutaceae	Me/F
19	*Aconychia sp*	Buoi bang	Rutaceae	Me
20	*Solanum incanum*	Ca rung	Solanaceae	F
21	*Rorippa nasturtiumaquaticum*	Cai song	Brassicaceae	V/Ma
22	*Blumea lacera*	Cai troi	Asteraceae	V
23	*Brassica juncea*	Cai xanh	Brassicaceae	Me
24	*Citrus aurantiacum*	Cam	Rutaceae	Me
25	*Ormosia sp*	Cam chi	Fabaceae	W/Ma
26	*Betula alnoides*	Cang lo	Betulaceae	W
27	*Hedyotis capitellata*	Cao da cam	Rubiaceae	Me
28	*Similax glabra*	Cau vai leng	Similaceae	Me/Ma
29	*Similax sp.*	Cau vai leng	Similaceae	Me
30	*Merremia bimbim*	Cay bim bip	Convolvulaceae	Me
31	*Indigofera galegoides*	Cay cham	Fabaceae	W
32	*Morus alba*	Cay dau	Moraceae	Me
33	*Illicium difengpi*	Cay hoi	Illiciaceae	Ma
34	*Artocarpus sp*	Cay may khoai	Moraceae	W
35	*Colocasia sp.*	Cay mon	Araceae	Ma
36	*Nervilia fofdii*	Cay mot la	Orchidaceae	Me/Ma
37	*Ficus racemosa*	Cay sung	Moraceae	Me
38	*Vernonia sp.*	Cha tao	Asteraceae	Me

Order	Latin Name	Local name	Family name	Usage
39	*Toona sp.*	Cham khach	Meliaceae	Me
40	*Toona sp.*	Cham may cha	Meliaceae	W
41	*Citrus limon*	Chanh	Rutaceae	F
42	*Atalantia citroides*	Chanh rung	Rutaceae	Me/F
43	*Desmodium triangulare*	Che ba	Rutaceeae	Me
44	*Ampelopsis cantoniensis*	Che day	Vitaceae	Me/V
45	*Camellia vervosa*	Che gan*	Theaceae	Me
46	*Camelia sp*	Che khau	Theaceae	Me
47	*Camelia forrestii*	Che rung	Theaceae	Me/V
48	*Camelia sp.*	Che thau	Theaceae	Me
49	*Camellia sinensis var.assamica*	Che tuyet	Theaceae	Ma
50	*Camellia sinensis*	Che xanh	Theaceae	Me
51	*Engelhardtia serrata spicata*	Cheo	Juglandaceae	W
52	*Engelhardtia serrata var.cambodica*	Cheo tia	Juglandaceae	W/Ma
53	*Zanthoxylum sp.*	chieu phiong	Rutaceae	Me
54	*Parashorea chinensis*	Cho chi	Diptercarpaceae	W
55	*Phyllanthus amarus*	Cho de	Euphorbiaceae	Me
56	*Phyllanthus urinaria*	Cho de	Euphorbiaceae	Me
57	*Phyllanthus sp.*	Cho de	Euphorbiaceae	Me
58	*Nephelium chryseum BI*	Chom chom rung	Sapindaceae	Me
59	*Aphanamixis grandiflora*	Chu	Meliaceeae	F/W
60	*Musa acuminata*	Chuoi	Musaceae	Me/V/F/Ma
61	*Ensete glaucum*	Chuoi (babana)	Musaceae	Me/V/F/Ma
62	*Musa sp.*	Chuoi hoa do	Musaceae	Me
63	*Musa sp.*	Chuoi lon	Musaceae	W
64	*Musa sp.*	Chuoi lon	Musaceae	W
65	*Musa coccinea*	Chuoi rung	Musaceae	F
66	*Musa sp.*	Chuoi rung	Musaceae	Me/V/F/W/M
67	*Musa paradisiaca*	Chuoi tieu rung	Musaceae	Me/F
68	*Livistona cochinchinensis*	Co	Arecaceae	F
69	*Imperata cylindrica*	Co danh	Poaceae	Me
70	*Amomum sp*	Co neng	Zingiberaceae	Me
71	*Eupatorium odoratum*	Co nhat	Asteraceeae	Me
72	*Justicia gendarussa*	Co sleng slua	Acanthaceae	Me
73	*Arenga pinnata*	Co tao	Arecaceae	V
74	*Cassia sp.*	Coc be	Fbaceae	Ma
75	*Alocasia adora*	Cu day	Araceae	Me
76	*Dioscorea hemsleyi*	Cu mai	Dioscoreaceae	Me/V
77	*Dioscorea cirrho*	Cu nau	Dioscoreaceae	Ma
78	*Curcuma longa*	Cu nghe	Zingiberaceae	Me

Order	Latin Name	Local name	Family name	Usage
79	*Alocasia sp.*	cu ray	Araceae	F
80	*Aglaomorpha coronans*	Cun cut	Polypodiaceae	V
81	*Ficus sp.*	Da rung	Moraceae	W
82	*Blumea balsamifera*	Dai bi	Asteraceae	Me
83	*Prunus persica*	Dao (peach)	Rosaceae	Me/F/W/Ma
84	*Prunus sp.*	Dao dai	Rosaceae	F
85	*Baccaure ramiflora*	Dau da dat	Euphorbiaceae	Me/F/Ma
86	*Kdsura sp.*	Dau da day	Schisandraceae	Me/F/Ma
87	*Allospondias lakonensis*	Dau da xoan	Anacardiaceae	Me/F/W
88	*Allospondias sp*	Day dan*	Anacardiaceae	Me/W
89	*Alocasia sp.*	Day lon	Araceae	W
90	*Castanopsis chinensis*	De	Fagaceae	W
91	*Cinnamomum obtusifolium*	De	Lauraceae	W
92	*Castanopsis sp*	De	Fagaceae	F/W/Ma
93	*Lithocarpus hemisphaericus*	De	Fagaceae	W
94	*Lithocarpus ducampii*	De do	Fagaceae	
95	*Castanopsis sp.*	De rung	Fagaceae	W
96	*Mahonia nepalensis* DC. 1824	Di mi	Berberidaceae	Me/W/Ma
97	*Houttuynia cordata*	Diep ca	Saururaceae	V
98	*Markhamia stipulata*	Dinh	Bignoniaceae	W
99	*Dysoxylum sp*	Dinh huong	Meliaceeae	Me/W/Ma
100	*Markhamia brilleti*	Dinh thoi	Bignoniaceae	F/W/Ma
101	*Cratoxylum pruniflorum*	Do Ngon	Hypericaceae	W
102	*Garcinia multiflora*	Doc	Clusiacece	F
103	*Alocasia odora*	Doc mung	Araceae	V
104	*Michelia balansae*	Doi	Magnoliaceae	W/Ma
105	*Trevesia palmata*	Du du	Araliaceae	Me/V/F/Ma
106	*Carica papaya*	Du du	Caricaceae	**F**
107	*Ficus.sp*	Dua cay	Moraceae	W
108	*Ficus.sp*	Dua cay	Moraceae	W
109	*Broussonattia papyrifera*	Duong	Moraceae	Me
110	*Sonchus arvensis*	Fhiac bao	Asteraceae	V
111	*Amanthus spinosus*	Fhiac da	Amaranthaceae	V
112	*Piper lolot*	Fhiac fat	Piperaceae	V
113	*Loranthus sp.*	Fhiac may ngen	Loranthaceae	Me
114	*Loranthus sp.*	Fhiac may sla	Loranthaceae	Me
115	*Loranthus sp.*	Fhiac vay	Loranthaceae	V
116	*Boehmeria nivea*	Gai	Urticaceae	Me
117	*Gnetum formosum*	Gam	Gnetaceae	F
118	*Bombax malabarica*	Gao	Bombaceae	Me/W/Ma
119	*Alpinia conchigera*	Gieng	Zingiberaceae	Me/Ma

Order	Latin Name	Local name	Family name	Usage
120	*Alpinia sp*	Gieng	Zingiberaceae	Me/Ma
121	*Manglietia sp*	Gioi vang	Magnoliaceae	W
122	*Michelia mediocris*	Gioi xanh	Magnoliaceae	W
123	*Zingiber rubens*	Gung do	Zingieraceae	Me
124	*Zingiber sp*	Gung rung	Zingiberaceae	Me
125	*Streptocaulon griffithii*	Ha thu o trang	Asclepiadaceae	Me
126	*Lportea violacea*	Han linh	Urticaceae	Me
127	*Alocasia longiloba*	Ho hac	Araceae	W
128	*Illicium verum*	Hoi	Illiciaceae	Me
129	*Adinandra lienii*	Hong	Ebenaceae	Me
130	*Flacourtia rukam*	Hong quan	Flacourtiaceeae	Me
131	*Trema sp*	Hu	Ulmaceae	W
132	*Trema Orientalis*	Hu day	Ulmaceae	W
133	*Trema sp*	Hu dinh	Ulmaceae	W
134	*Sargentodoxa cuneata*	Huyet dang	Sargentodoxaceae	Me
135	*Makhamia sp*	Ke duoi cao	Bignoniaceeae	Me
136	*Makhamia cauda-felina*	Ke duoi dong	Bignoniaceeae	Me
137	*Makhamia sp*	Ke lan	Bignoniaceeae	Me
138	*Vernonia sp.*	Khan non	Asteraceae	Me
139	*Machilus bonii*	Khao	Lauraceae	W
140	*Cinnamomum balansae*	khao huong	Lauraceae	W/Ma
141	*Litsia cubeba*	Khao khinh	Lauraceae	W
142	*Machilus sp*	Khao nhot	Lauraceae	W
143	*Cinnamomum pathenoxylon*	Khao thom	Lauraceae	W
144	*Schima sp*	Khao xu ma	Theaceae	W
145	*Argireia acuta*	Khau cat	Convolvulaceae	Me
146	*Peraria aff. Montana*	Khau cat khao	Fabaceae	Me
147	*Stephania hermandifolia*	Khau hen	Menispermaceae	V
148	*Spatholobus sp*	Khau luot	Fabaceae	Me
149	*Srgentodoxa sp*	Khau luot	Sargentodoxaceae	Me
150	*Spatholobus sp*	Khau luot	Fabaceae	Me
151	*Desmodium sp.*	Khau mau	Fabaceae	Me
152	*Pottsia sp*	Khau ping	Apocynaceae	Me/Ma
153	*Thunbergia Sp*	Khau thuong	Acanthaceae	Me
154	*Illigera sp*	Khau tuon	Hernandiaceae	
155	*Averrhoa carrambola*	Khe	Oxalidaceae	Me/F/W
156	*Averrhoa sp.*	Khe (star fruit)	Oxalidaceae	Me/V/F
157	*Disporopsis longifolia*	Khing	Convallariaceae	Me
158	*Heterosmilax gaudichaudiana*	Khuc khac	Smilaceae	Me
159	*Similax ferox*	Kim cung	Smilaceae	Me
160	*Phrynium dispermum*	La rong	Maranthaceae	Ma
161	*Simbopogon citratus*	La sa rung	Poaceae	V

Order	Latin Name	Local name	Family name	Usage
		(lemongrass)		
162	*Chukrasia tabularis*	Lat	Meliaceae	W/Ma
163	*Peltophorum sp.*	Lim	Caesalpiniaceae	W
164	*Peltophorum sp.*	Lim	Caesalpiniaceae	W
165	*Peltophorum tonkinensis*	Lim	Caesalpiniaceae	W/Ma
166	*Ganoderma sp.*	Linh chi	Ganodermataceae	Ma
167	*Pterospermum truncatolobatum*	Long mang	Sterculiaceae	Me
168	*Cinnamomum camphora*	Long nao	Lauraceae	Me
169	*Garcinia sp*	Mac bua	Clusiaceae	F
170	*Alpinia sp*	Mac ca	Zingiberaceae	F
171	*Cleistocalyx operculatus*	Mac cha	Myrtaceae	W
172	*Mangifera duperreana*	Mac chai	Anacardiaceae	F
173	*Dracontomelon sp*	Mac chu	Anacardiaceae	V/F/W/Ma
174	*Pyrus sp.*	Mac cot	Rosaceae	F
175	*Canarium album*	Mac cuom	Burseraceae	V/F/W/Ma
176	*Aeculus assamica*	Mac ken	Hippocastanaceae	F
177	*Phyllanthus emblica*	Mac khan	Euphorbiaceae	F
178	*Hodgsonia macrocarpa*	Mac kich	Cucurbiaceae	F
179	*Pandanus sp*	Mac la	Pandanaceae	Me/Ma
180	*Pandanus urophyllus*	Mac lai keo*	Pandanaceae	Me
181	*Pandanus tonkinensis*	Mac lai keo*	Pandanaceae	Me
182	*Eleagnus sp.*	Mac lot dong	Elaeagnaceae	Me
183	*Alpinia sp*	Mac luot	Zingiberaceae	F
184	*Prunus salisina*	Mac man (plum)	Rosaceae	Me/F/Ma
185	*slausena.sp*	Mac mat	Rutaceae	Me/V/F
186	*slausena sp*	Mac mat dong	Rutaceae	F
187	*Artocarpus heterophyllus*	Mac mi (jack fruit)	Moraceae	Me
188	*Choerotpondias axillaris*	Mac mia	Anacardiaceae	F
189	*Ficus sp*	Mac ngoa	Moraceae	F
190	*Ficus sp.*	Mac ngoa	Moraceae	F
191	*Sterculia sp*	Mac ngoang	Sterculiaceae	F
192	*Amomum verspertilio*	Mac nieu	Zingiberraceae	F
193	*ficus semicordata*	Mac not	Moraceae	F
194	*Psidium guajava*	Mac oi (guava)	Mirtaceae	Me/F/Ma
195	*Lischi sinensis*	Mac pai	Sapindaceae	Me/F/W
196	*Bambusa sp*	Mac phay	Bambusoideae	W/Ma
197	*Kdsura sp.*	Mac phay khau	Schisandraceae	Me
198	*Micromelum minutum*	Mac phet dong	Rutaceae	Me
199	*Prunus armeniaca*	Mac phung (appricot)	Rosaceae	Me
200	*Citrus sp*	Mac puc	Rutaceae	Me/F

Order	Latin Name	Local name	Family name	Usage
		(pomelo)		
201	*Melastoma sp*	Mac tac	Melastomaceae	F
202	*Microcos paniculata*	Mac thuot	Tiliaceae	F
203	*Garcinia sp*	Mac toc	Clusiaceae	F
204	*Uvaria sp.*	Mac vy	Annonaceae	F
205	*Momordica sp.*	Man bung dong	Cucurbitaceae	Me
206	*Momordica sp*	Man dong	Cucurbitaceae	V
207	*Ampelocalamus patellaris*	Mang giang	Poaceae	V
208	*Dendrocalamus giganteus*	Mang mai	Poaceae	Ma
209	*Neohouzeana dulloa*	Mang nua	Poaceae	V/W/Ma
210	*Bambusa spinosa*	Mang tre	Poaceae	V
211	*Phyllostachys pubecens*	Mang truc	Poaceae	V/Ma
212	*Sinobambusa sat*	Mang vau	Poaceae	V/F/W/Ma
213	*Bambusa Sp*	Mang vau	Poaceae	V/W/Ma
214	*Stephania sinica*	Mau ca tom*	Menispermaceae	Me
215	*Calamus tetradactylus*	May	Arecaceae	Ma
216	*Amomum mengtzense*	May ca	Zingiberraceae	Me
217	*Alangium chinensis*	May cap pa	Alangiaceae	W
218	*Toona sp*	May cham	Meliaceae	W
219	*Garuga pinnata*	May cham	Burceraceae	W
220	*Castanopsis indica*	May co	Fagaceae	W
221	*Castanopsis cerebrinus*	May co	Fagaceae	W
222	*Quecus chrysocalyx*	May co	Fagaceae	F/W
223	*Ficus tinctoria*	May da	Moraceae	W
224	*Ficus sp.*	May da	Moraceae	W
225	*Ficus nervosa*	May da	Moraceae	W
226	*Lingnania sp.*	May din	Poaceae	F/Ma
227	*Ficus sp.*	May dua booc	Moraceae	Me
228	*Ficus sp*	May dua cay	Moraceae	Me
229	*Ficus sp*	May dua cay	Moraceae	Me
230	*Ficus sp*	May dua tra	Moraceae	me
231	*Dendrocalamus sp.*	May hoc	Poaceae	W
232	*Wendlandia sp*	May khao quang	Rubiaceae	W
233	*Coix sp.*	May khuong	Poaceae	Me
234	*Macaranga denticulata*	May la nen	Euphorbiaceae	W
235	*Aleurites moluccana*	May lai	Euphorbiaceae	Me
236	*Hodgsonia sp*	May lai	Cucurbiaceae	Me
237	*Melia sp*	May len	Meliaceae	W
238	*Quisqualis indica*	May lin	Combretaceae	W
239	*Saraca sp*	May ma	Caesalpiniaceae	Me
240	*Lycidce rodosteria*	May my	Caesalpiniaceae	W

Order	Latin Name	Local name	Family name	Usage
241	*Imperata sp.*	May nay	Poaceae	Me
242	*Bombax sp*	May nghin	Bombaceae	
243	*Bischofia javanica*	May phat	Euphorbiaceae	Me/W
244	*Moschocarpus sp.*	May phoong	Sapindaceae	W
245	*Tetrameles nudiflora*	May pop dong	Datiscaceae	W
246	*Diospiros sp.*	May sich	Ebenaceae	W
247	*Mallotus barbatus*	May tau	Euphorbiaceae	W
248	*Mallotus sp.*	May tau	Euphorbiaceae	W
249	*Mallotus sp*	May tau	Euphorbiaceae	F/W
250	*Streblus macrophyllus*	May teo	Moraceeae	Me/W
251	*Alstonia scholaris*	May tin pet	Apocynaceae	Me
252	*Allospondias sp*	May tram	Anacardiaceae	W
253	*Phyllantus sp*	Me	Euphorbiaceae	F
254	*Costus tonkinensis*	Mia do	Costaceae	Me
255	*Artocarpus rigidus sp*	Mit rung	Moraceeae	F
256	*Paederia scandens*	Mo long	Rubiaceae	Me
257	*Caryota urens*	Moc	Arecaceae	V
258	*Caryota.sp*	Moc	Arecaceae	V
259	*Auricularia sp.*	Moc nhi	Auriculariaceae	V
260	*Auricularia auricula*	Moc nhi	Auriculariaceae	Me/V/Ma
261	*Auricularia sp.*	Moc nhi (mushroom)	Auriculariaceae	V
262	*Colocasia sp.*	Mon	Araceae	Me
263	*Colocasia sp.*	Mon lon	Araceae	W
264	*Colocasia esculenta*	Mon thom	Araceae	Me
265	*Basella sp.*	Mong tay	Basellaceae	Me
266	*Basella rubra*	Mong toi	Basellaceae	V
267	*Diospyros mun*	Mun	Ebenaceae	W
268	*Heliciopsis lobata (Merr.) Sleum*	Mung phi	Proteaceae	Me/Ma
269	*Rhus chinensis*	Muoi	Anacardiaceae	W/Ma
270	*Momordica sp.*	Muop dang rung	Cucurbiaceae	V
271	*Artemisia sp*	My ngoi	Asteraceae	Me
272	*Kadsura coccinea*	Na rung	Schisandraceae	Me/F
273	*Panus rudis*	Nam	Pleurotaceae	V
274	*Termitomyces albuminosa*	Nam dat	Tricholomataceae	V
275	*Termitomyces sp.*	Nam dat	Tricholomataceae	V
276	*Lentinus edodes*	Nam huong	Pleurotaceae	Me/V/Ma
277	*Lentinus sp.*	Nam thuong	Pleurotaceae	Ma
278	*Blumea sp.*	Nat deng	Asteraceae	Me
279	*Pluchea indica*	Nat nam	Asteraceae	Me
280	*Elephantopus scaber*	Net ti	Asteraceae	Me/Ma

Order	Latin Name	Local name	Family name	Usage
281	*Artemisia vulgaris*	Ngai cuu	Asteracae	Me
282	*Gironniera subaequalis*	Ngat	Ulmaceae	
283	*Excentrodendron tokinense*	Nghien	Tiliaceae	W
284	*Ficus fulva*	Ngoa	Moraceae	F
285	*Melientha suavis*	Ngot rung	Opiliaceae	Me/V/Ma
286	*Acanthopanax trifoliatus*	Ngu da bi	Araliaceae	Me
287	*Marsdenia tinctoria*	Nguon can	Asclepiadaceae	Me
288	*Lamia sp.*	Nha khi mu heo	Lamiaceae	Me
289	*Ageratum conyzoides*	Nha meo	Asteraceae	Me
290	*Limnophila rugosa*	Nha pa cop	Scrophulariaceae	Me
291	*Dimocarpus longan*	Nhan	Sapindaceae	F
292	*Diospyros apiculata*	Nho noi	Ebenaceae	Me
293	*Elaeagnus latifolia*	Nhot	Elaeagnaceae	F
294	*Elaeagnus sp.*	Nhot rung	Elaeagnaceae	Me
295	*Ficus sp.*	Nom nao	Moraceeae	Me
296	*Oroxylum indicum*	Nuc nac	Bignoniaceeae	Me
297	*Streblus ilicifolius*	O ro	Moraceeae	W
298	*Psidium guajava*	Oi	Myrtaceae	Me
299	*Micromelum sp.*	Ot	Rutaceae	Me
300	*Micromelum minutum*	Ot rung	Rutaceae	Me
301	*Loranthus ligustina*	Pac lac	Loranthaceae	Me
302	*Loranthus robinosnii*	Pac may lin	Loranthaceae	Me
303	*Loranthus cochinchinensis*	Pac may ngheng	Loranthaceae	Me
304	*Loranthus sp.*	Pac may noang	Loranthaceae	Me/F/W
305	*Loranthus parasitica*	Pac may sa	Loranthaceae	Me
306	*Caliptereris esculenta*	Phac cut	Aspidiaceae	V
307	*Clerodendrum cyrtophyllum*	Phac kham	Verbenaceae	V
308	*Loranthus sp*	Phac khi	Loranthaceae	V
309	*Loranthus sp*	Phac may dua	Loranthaceae	Me
310	*Loranthus sp.*	Phac may hu	Loranthaceae	Me
311	*Loranthus sp.*	Phac may mau	Loranthaceae	Me
312	*Loranthus sp*	Phac may tau	Loranthaceae	Me
313	*Loranthus sp*	Phac pai	Loranthaceae	V
314	*Duabanga sonneratioides*	Phay	Sonneratiaceae	W/Ma
315	*Plygonum alatum*	Phec lieu	Polygonaceae	Me
316	*Enydra Sp.*	Phjac au	Asteraceae	V
317	*Acanthopanax sp.*	Phjac ca	Araliaceae	Me
318	*Brassica juncea*	Phjac cat	Brassicaceae	V
319	*Brassica sp.*	Phjac cat	Brassicaceae	V
320	*Geophila sp.*	Phjac chan	Rubiaceae	V

Order	Latin Name	Local name	Family name	Usage
321	*Gnaphalium polycaulon*	Phjac chen	Asteraceae	V/Ma
322	*Eryngium foetidum*	Phjac chi	Aspiaceae	V
323	*Gnaphalium sp.*	Phjac da	Asteraceae	V
324	*Neptunia oleracea*	Phjac phan	Mimosaceae	V
325	*Phasalys peruviana*	Phjac pop	Solanaceae	V/Ma
326	*Dendrobium sp.*	Phong lan	Orchidaceae	Ma
327	*Cymbidium aloifolium*	Phong lan do	Orchidaceae	Ma
328	*Dendrobium.sp.*	Phong lan hong	Orchidaceae	Me/Ma
329	*Aerides falcata*	Phong lan tim	Orchidaceae	Ma
330	*Dendrobium sp.*	Phong lan trang	Orchidaceae	Ma
331	*Dendrobium lindleyi*	Phong lan vang	Orchidaceae	Ma
332	*Garcinia sp.*	Qua bua rung	Clusiaceae	F
333	*Duchesnea indica*	Qua dau rung	Rosaceae	F
334	*Garcinia obtusifolia*	Qua doc	Clusiaceae	F
335	*Pyrus sp.*	Qua le	Rosaceae	F
336	*Tamarindus indica*	Qua me	Caesalpiniaceae	V/F/W
337	*Melastoma candium*	Qua mua	Melastomaceae	F/W
338	*Rhodomyrtus tomentosa*	Qua sim	Myrtaceae	F/W/Ma
339	*Ficus auriculata*	Qua va	Moraceae	F
340	*Clausena dunniana*	Quat hong bi	Rtaceae	F
341	*Clausena lancium*	Quat hong bi	Rtaceae	Me/F
342	*Cinnamomum cassia*	Que	Lauraceae	
343	*Cinnamomum sp.*	Que rung	Lauraceae	W
344	*Citrus sp.*	Quyt rung	Rutaceae	F
345	*Aerva sanguinolenta*	Rau chua	Amaranthaceae	Me
346	*Mazus pumilus*	Rau dang	Scrophulariaceae	V
347	*Callipteris esculenta*	Rau don	Aspidiaceae	V
348	*Pentaphragma sp.*	Rau luoi ran	Campanulaceae	V
349	*Geophila repens*	Rau ma	Rubiaceae	V
350	*Sagittaria sagittifolia*	Rau mac	Alismataceae	V
351	*Chenopodium album*	Rau moi	Chenopodiaceae	V
352	*Elatostema balansae*	Rau pa	Urticaceae	V
353	*Polygonum odoratum*	Rau ram	Polygonaceae	V
354	*Amaranthus sp.*	Rau ren	Amaranthaceae	V
355	*Portulaca oleracea*	Rau sam	Portulacaceae	V
356	*Crassocephalum crepi-dioides*	Rau tau bay	Asteraceae	Me/V
357	*Crassocephalum sp.*	Rau tau bay	Asteraceae	V
358	*Vernonia andersonii*	Ruot nguoi	Asteraceae	Me
359	*Amomum xanthioides*	Sa nhan	Zingiberaceae	Me/F
360	*Wedelia chinensis*	Sai dat	Asteraceae	Me
361	*Dracaena angustifolia*	Sam cau	Dracaenaceae	Me
362	*Panax sp*	Sam rung	Araliaceae	Me

Order	Latin Name	Local name	Family name	Usage
363	*Pueraria montana var.chinensis*	San day	Fabaceae	V
364	*Sterculia sp,*	Sang trau	Sterculiaceae	F
365	*Hopea chinensis*	Sao	Dipterocarpaceae	W/Ma
366	*Dracontomelon duperreanum*	Sau	Anacardiaceae	Me/V/F/W/Ma
367	*Madhuca alpinia*	Sen	Spotaceae	W
368	*Ficus stricta*	Si	Moraceae	Me/W
369	*Dillenia scabrella*	So	Dilleniaceae	F
370	*Alsonia sp*	Sua	Apocynceae	Me
371	*Antiaris toxicaria*	Sui	Moraceae	W
372	*Ficus sp*	Sung	Moraceae	Me/F
373	*Ficus sp.*	Sung	Moraceae	F
374	*Ficus sp.*	Sung	Moraceae	F
375	*Pseudodrynaria coromans*	Tac ke	Polypodiaceae	Ma
376	*Panax sp*	Tam that	Araliaceae	W
377	*Panax stipulialatus*	Tam that	Araliaceae	Ma
378	*Panax sp.*	Tam that day	Araliaceae	Me
379	*Schefflera octophylla*	Tang to	Araliaceae	Me
380	*Paliurus ramosissimus*	Tao	Rhamnaceae	Me
381	*Zizyphus oenoplia*	Tao rung	Rhamnaceae	Me
382	*Vatica diospyroides*	Tau	Dipterocarpaceae	W
383	*maoutia puya*	Teng tang	Urticaceae	Ma
384	*Phyllanthus reticulatus*	Teng thau	Euphorbiaceae	Me
385	*Schefflera sp.*	Teng to deng	Araliaceae	Me
386	*Cratoxylum polyanthum*	Thanh nganh	Hypericaceae	W
387	*Coelogyne sp*	Thanh thao	Orchidaceae	Me
388	*Cenna tora*	Thao quyet minh	Caesalpiniaceae	Me
389	*Dendrocalamus sp.*	Thau muoi	Poaceae	Me
390	*Vitis balansaeana*	Thau pau	Vitaceae	Me
391	*Pottsia sp.*	Thau pinh deng	Apocynaceae	Me
392	*Aporosa vililosaceae*	Thau tau	Euphorbiaceae	W
393	*Tetrastigma sp.*	Thau tep	Vitaceae	Me
394	*Streptocaulon juventas*	Thay can	Asclepiadaceae	Me
395	*Acer tokinensis*	Thich	Aceraceae	W
396	*Pinus massoniana*	Thong	Pinaceae	
397	*Canavalia cathartica*	Thua meo	Fabaceae	Ma
398	*Nicotiana rustica*	Thuoc lao	Solanaceae	Me
399	*Perilla frutescens*	Tia to	Lamiaceae	Me
400	*Perilla sp.*	Tia to dai	Lamiaceae	Me
401	*Perilla sp.*	Tia to do	Lamiaceae	Me
402	*Perilla sp.*	Tia to rung	Lamiaceae	Me/V

Order	Latin Name	Local name	Family name	Usage
403	*Allium sativum*	Toi (galic)	Liliaceae	Me
404	*Aspidistra typica*	Toi rung	Convallariaceae	Me
405	*Amorphophallus sp*	Tong mu	Araceae	Me/W
406	*Garcinia fagraeoides*	Trai li	Clusiaceae	F/W
407	*Canarium bengalense*	Tram ba cacnh	Burseraceae	F/W
408	*Canarium tramdenum*	Tram den	Burseraceae	V/F/W/Ma
409	*Aquilaria crassna*	Tram huong	Thymelaceae	Me
410	*Vernicia montana*	Trau	Euphorbiaceae	Ma
411	*Mimosa pudica*	Trinh nu	Mimosaceae	Me
412	*Parashorea stellata*	Tro chi	Dipterocarpaceae	W/Ma
413	*Parashorea sp.*	Tro da	Dipterocarpaceae	
414	*Dipterocarpus pilosus*	Tro nau	Dipterocarpaceae	Me/W
415	*Toona surenii*	Truong van	Meliaceae	W
416	*Caesalpinia sappan*	Vang	Caesalpiniaceae	Me/W
417	*Saraca dives*	Vang anh	Caesalpiniaceae	W
418	*Homanomena occulta*	Vat huong	Araceae	Me
419	*Pothos sp.*	Vat veo	Araceae	Me
420	*cleistocalyx operculatus*	Voi	Myrtaceae	Me/W
421	*Schima argenta*	Xam lam	Theaceae	W
422	*Melia aredazach*	Xoan (meliacea)	Meliaceeae	W/Ma
423	*Melia sp.*	Xom deng	Meliaceeae	W
424	*Opuntia dillenii*	Xuong rong	Cactaceae	Me
425	*Zanthoxylum nitidum*	Xuyen tim	Rutaceae	Me
426	*Aidia pycnantha*	Găng núi	Rubiaceae	
427	*Leea rubra*	Goi hac	Leeaceae	
428	*Da tura netel*		Solanaceae	
429	*Zingiber zerumbet*	Gung rung	Zingiberaceae	
430	*Toxicodendron succedanea (L.)*		Anacardiaceae	
431	*Artocarpus sp*		Moraceae	
432	*Mallotus sp*		Euphorbiaceae	
433	*Ficus hirta*		Moraceae	
434	*Ficus sp.*		Moraceae	
435	*Rhamnus SP*		Rhamnaceeae	
436	*Dioscorea alata*		Dioscoreaceeae	
437	*Clausina sp*	Quat dai	Rutaceae	
438	*Sinobambusa bacanensis*		Poaceae	
439	*Dalbergia SP*		Fabaceae	
440	*Quecus SP*		Fagaceae	
441	*Arenga sp*	May tao	Arecaceae	
442	*Choearospondias sp*	Lat xoan	Anacardiaceae	
443	*Aphananthe lissophylla*	Lat ruoi	Ulmaceae	

Order	Latin Name	Local name	Family name	Usage
444	*Aphananthe sp*	Lat ruoi nham	Ulmaceae	
445	*Eberhardtia tonkinensis*	Kong sua	Apocynaceeae	
446	*Artocarpus styracifolis*	Vo khoai do	Moraceae	
447	*Portulaca trichosperma*	Muong khao	Tiliaceae	
448	*Mallotus apelta*	Bui bui	Euphorbiaceae	
449	*Dipterocarpus sp*	Cho	Dipterocarpaceae	
450	*Tsoongiodendron odorum*		Magnoliaceae	
451	*Paramichiria sp*		Magnoliaceae	
452	*Anamocarya sinensis*	Cho dai	Juglandaceae	
453	*Wrigtia laevis*		Apocynaceeae	
454	*Hymenodiction oricence*	Vo rut	Rubiaceeae	
455	*Ficus sp.*		Moraceae	
456	*Tatrastigma sp*	Vac	Vitaceeae	
457	*Artemisia lactiflora*		Asteraceae	
458	*Curcuma sp*	Nghe den	Zingiberaceae	
459	*Sida rhombifolia*	Ke hoa vang	Malvaceae	
460	*Dischidia acuminata*	Hat bi	Asclepiadaceae	
461	*Solannum nigrum*	Lu lu	Solanaceae	
462	*Phasalys angulata*	Lu lu cai	Solanaceae	
463	*Clerodendrum jponicum*	Mo man sam	Verbenaceae	
464	*Polygonum sp*		Polygonaceae	
465	*Memecylon sp*	Sam si	Myrtaceae	
466	*Trema sp*	Hu den	Ulmaceae	
467	*Canthium parvifolium*	Mo qua	Moraceae	

Appendix 4: The questionaire for ecological study used 12 quadrats in Ba Be National Park

The University of Technology, Sydney
Faculty of science, department of environmental sciences

Questionnaire

of vegetation cover and ecology of endangered forest tree species in Ba Be National park

Date.....month.....year 2005 Place of plot.....

1- Plot number.....
2- Plot co-ordinate
3- ravage of deforestation level
4- Altitude
5- Slope
6- Direction of expose
7- Place of plot
8- Type of soil
9- pH value
10- Humidity of soil
11- Depth of soil
12- Surface water regulation
13- Distance to the Villege
14- The nearest distance to the footnote
15- Degree of showing stone's face
16- Degree of carved stone cover
17- Degree of rubbe stone cover
18- Soil without stone
19- Rotten cover level
20- Canopy level
21- Green cover level
22- Brush cover
23- Bamboo cover value
24- Grass cover value
25- Medlar tree value
26- Liana value

Table 2: Dominant trees in the research quadrat

1.................................... 2..
3.................................... 4..
5.................................... 6..
7.................................... 8..
9.................................... 10..

Table 3: Endangered tree species or vulnerable and which should be conserved

(For instance: Medicinal plant, vegetable, fruit, fire-wood, wood and market products…)

Code	Name of species	Frequency	Code	Name of species	Frequency

Appendix 5: The list of 162 species occurred in 12 quadrats (sites) in Ba Be National Park, surveyed from 9/2005 to 10/2006 and double checked in 11/2007. For lifeform: SH is shrub, T is tree, G is grass, SE is sedge, F is fern, H is herb, and LI is liana; for distribution: T is tropical, E is endemic to Ba Be scale, and V is endemic to Vietnam.

Order	Latin name	Family	Lifeform	Distribution	Vietnamese	site 1	site 2	site 3	site 4	site 5	site 6	site 7	site 8	site 9	site 10	site 11	site 12
1	*Abelmoschus sag×ttifolius* (Kurz) Merr.	Malvaceae	SH	T	Sam Bo chinh	0	0	0	17	0	0	0	0	0	0	0	0
2	*Acer tonkinensis* Lecomte	Aceraceae	T	I/E	Thich Bac bo	0	0	0	25	0	0	0	0	0	0	0	0
3	*Achyranthes aspera* L.	Amaranthaceae	G/SE	T	Co xuoc	0	0	0	0	0	0	0	0	0	0	0	4
4	*Adenanthera microsperma*	Mimosaceae	S/SE	T	Muong gan	7	0	0	0	0	0	0	0	0	0	0	0
5	*Adiantum cernuum* L.	Adiantaceae	F/SE	T	Toc than ve nu	14	0	0	0	0	0	0	0	0	0	0	0
6	*Adiantum flabellulatum* L.	Adiantaceae	F/SE	T	Rau Don Den	3	0	0	0	0	0	0	0	0	0	0	0
7	*Alangium chinense* (lour.) – Harms	Alangiaceae	T	T	Thoi ba	0	0	0	7	0	0	0	0	0	0	0	0
8	*Alangium kurzii* Craib	Alangiaceae	T/SE	T	Thoi ba la day	0	0	0	20	0	0	0	0	0	0	0	0
9	*Alchornea trewioides* –(Benth.) Muell-Arg.	Euphorbiaceae	SH/SE	T	Dom dom	0	0	0	0	0	0	0	0	0	0	0	17
10	*Aleurites moluccana* Willd	Euphorbiaceae	T	T	Lai	0	0	0	0	0	4	0	0	0	0	0	0
11	*Allospondias lakonensis* (Pierre.) Stapf	Anacardiaceae	T	T	Dau da xoan	5	0	0	0	0	1	0	0	0	0	0	0
12	*Alocasia macrorrhiza* (L) Schott	Araceae	SE	T	Day	0	0	0	0	0	0	0	0	0	0	5	7
13	*Amesiodendron chinensie* – (Merr.) Hu	Sapindaceae	T	T	Truong 3 la	12	0	0	0	0	0	0	11	7	0	0	0
14	*Amomum vespertilio* Gagnep	Zingiberaceae	SE	T	Sa Nhan thien	0	0	0	8	0	0	0	0	0	0	0	0
15	*Amomum villosum* Lour.	Zingiberaceae	SE	T	Sa nhan	18	0	0	40	0	0	0	0	0	0	24	0
16	*Amorphophallus – rivieri* Dur	Araceae	SE	T	Khoai nua	0	0	0	0	0	7	0	0	0	0	7	0
17	*Andosace umbellata*	Primulaceae	H	T	Tim Lan	3	0	0	0	0	0	0	0	0	0	0	0
18	*Anoectochilus setaceus* (Blume). Lindl	Orchidaceae	H/SE	T	KimTuyen	0	0	0	22	0	0	0	0	0	0	0	0
19	*Anomianthus dulcis* (punal) Sinclair	Annonaceae	SH	T	Dat la dai	0	0	0	0	0	0	0	6	0	0	0	0
20	*Antiaris toxicaria* Pers. –Lesch.	Moraceae	T	T	Sui	0	0	0	0	0	1	4	0	0	0	0	0
21	*Aprosa mycrocalyx* Hassk.	Euphorbiaceae	T	T	Thau tau	0	0	0	6	0	0	0	0	0	0	0	11
22	*Archidendron balansa* (Oliv.) – I. Nielsen	Mimosaceae	T	T	Cut Ngua	10	2	5	0	1	0	8	0	0	0	0	0
23	*Ardisia silvestris* Pitard	Myrsinaceae	H	T	Khoi rung	4	0	0	0	0	0	0	0	0	0	0	0

Order	Latin name	Family	Lifeform	Distribution	Vietnamese	site 1	site 2	site 3	site 4	site 5	site 6	site 7	site 8	site 9	site 10	site 11	site 12
24	*Arenga pinata* (Wurmb) Merr	Arecaceae	SE	T	Dao	0	0	0	0	0	0	0	0	0	0	13	0
25	*Argyreia acuta* Lour.	Convolvulaceae	LI	T	Bac Thau	0	7	11	0	0	0	0	0	0	0	0	9
26	*Argyreia capitata*(Vahl) Choisy	Convolvulaceae	LI	T	Bac thau tia	0	13	8	0	4	0	14	0	0	0	0	0
27	*Aspidistra lurida* ker-Gawl	Liliaceae	SE	T	Toi rung	19	0	0	0	0	0	0	2	0	0	0	0
28	*Asplenium nidus* L.	Asplenniaceae	F	T	To Dia	8	0	0	0	0	10	0	0	0	0	11	0
29	*Atalantia citroides* Pierre ex- Guilaum.	Rutaceae	T	I	Cam rung	1	0	0	0	0	3	0	7	8	0	0	0
30	*Auricularia auricula* (L) Underw	Auriculariaceae	SE	T	Moc nhi	1	0	0	0	0	0	0	0	0	0	0	0
31	*Baccaurea sapida* (Roxb.) – Muell.-Arg	Euphorbiaceae	T	T	Dau da dat	0	0	0	6	0	0	0	0	0	0	0	0
32	*Bauhinia alba* Hamilt	Caesalpiniaceae	LI	T	Mong Bo (hoa trang)	4	0	0	0	0	0	0	0	0	0	0	0
33	*Bauhinia malabaria* L.	Caesalpiniaceae	LI	T	Mong bo do	0	0	0	0	0	3	0	0	0	0	0	0
34	*Bauhinia purpurea* L.	Caesalpiniaceae	LI	T	Day Mong bo lua	6	0	0	0	0	0	0	0	0	0	0	0
35	*Bischofia javanica* Blume	Euphorbiaceae	T	T	Nhoi	0	0	0	12	0	0	0	0	0	0	0	0
36	*Boea megellanica* Lamk	Gesneriaceae	LI	T	Day bac thau	0	0	0	0	0	0	0	0	0	0	0	5
37	*Brenia fruticosa* (L.) Hook. F.	Euphorbiaceae	SH	T	Bo cu ve	0	0	0	0	0	0	0	0	0	0	0	12
38	*Bridelia ovata*	Euphorbiaceae	T	T	Tho rung	0	0	0	0	0	0	0	0	0	0	8	0
39	*Broussonettia papyrifera* (L) – Lher.ex Vent.	Moraceae	T	T	Duong	0	0	0	0	0	0	0	0	0	0	0	12
40	*Buddleja americana* L (?)	Buddlejaceae	LI	T	Chia Voi	0	2	4	7	11	0	4	0	0	0	0	0
41	*Burretiodendron hsienmu* Chun et How	tiliaceae	T	T/E	Nghien	35	4	29	4	20	15	24	11	8	15	6	0
42	*C.harmandiana* Pierre.	Solanaceae	H	T	Ot Rung	0	0	0	0	0	0	0	0	0	6	0	0
43	*Caryota mitis* Lour.	Arecaceae	T	V	Moc dinh dinh	0	0	0	0	0	0	0	0	0	0	11	0
44	*Castanopsis chinensis* A.chev.	Fagaceae	T	T	De gai	0	0	0	0	0	0	0	0	0	0	0	14
45	*Celosia cristata* L.	Amaranthaceae	H	T	Mao ga	0	0	0	0	0	0	0	0	0	0	0	5
46	*Celtis philippinensis* Blanc	Ulmaceae	T	T	Seu Long	0	0	0	11	0	0	0	0	0	0	0	0
47	*Celtis sinensis* Person	Ulmaceae	T	T	Seu	13	7	7	18	3	0	5	0	5	6	10	0
48	*Chaetocarpus pungens* Thwaites	Euphorbiaceae	T	T	Da nau	0	0	0	0	0	2	0	0	0	0	0	0
49	*Chukrasia tabularis* A.Juss	Meliaceae	T	T	Lat	0	0	0	0	0	0	0	0	6	0	0	0

Order	Latin name	Family	Lifeform	Distribution	Vietnamese	site 1	site 2	site 3	site 4	site 5	site 6	site 7	site 8	site 9	site 10	site 11	site 12
50	*Chukrasia tabularis* A.Juss *attopenensis* Pierre	Meliaceae	T	T	Lat hoa	0	0	0	3	0	0	0	0	0	0	0	0
51	*Cinamomun tonkinense* (Lecomte) –A. Chev	Lauraceae	T	T/V	De xanh	0	0	0	0	0	0	0	0	12	2	0	0
52	*Cissus modeccoides* Planch	Vitaceac	LI	T	Day chia Voi	0	0	0	0	0	0	3	0	0	0	0	0
53	*Clausena duniana Levl.*& Fede	Rutaceae	T	T	Hong bi rung	0	0	0	0	0	0	0	0	25	7	0	0
54	*Clausena harmandiana* Pierre.	Rutaceae	SH	T	Ot Rung	0	0	0	8	0	0	0	0	0	0	0	0
55	*Clausena wampi* Olive	Rutaceae	T	T	Quat hong bi rung	1	0	0	8	0	0	0	0	0	0	0	0
56	*Cleistanthus myrianthus* Kur	Euphorbiaceae	T	T	Coc rao la to	9	1	0	0	28	0	0	0	0	0	0	0
57	*Cleistathus petelotii* Merr. – Ex Croizat	Euphorbiaceae	T	T	Coc dao	36	16	6	0	0	18	15	8	15	3	0	0
58	*Crassocephalum crepidioides* –(Benth.) S.Moore	asclepiadaceae	H	T	Rau tau bay	0	0	0	0	0	0	0	0	0	0	0	3
59	*Cratoxylum polyanthum* – Korth	Clusiaceae	T	T	Thanh ngach	0	0	0	6	0	0	0	0	0	0	0	0
60	*Cryptocarya lenticellata* H. Lec	Lauraceae	T	T	Nanh chuot	0	0	0	0	0	0	0	0	0	0	0	1
61	*Cycas balansae*	Cycadaceae	SH	T	Thien Tue	0	0	0	0	0	0	0	0	16	0	0	0
62	*Cyclosorus parasiticus* (L) Farw	Adiantaceae	F/SE	T	Duong xi thuong	19	5	14	0	11	11	0	0	0	5	0	13
63	*Dendrobium nobile* Lindl	Orchidaceae	SH	T	Hoang Thao	0	0	0	0	0	1	0	0	0	0	0	0
64	*Deutzianthus tonkinensis* – Gagnep	Euphorbiaceae	T	E	Cay Mo	0	0	0	0	0	0	0	8	0	4	0	0
65	*Dicranopteris lineari* (Burm. Underw)	Gleicheniaceae	F/SE	T	Guot	0	0	0	0	0	0	0	0	0	0	0	25
66	*Dimerocarpus brenieri* Gagnep	Moraceae	T	T/V	May teo	0	0	0	0	0	0	3	0	0	0	0	0
67	*Dimocarpus fumatus ssp. Indochinensis* Leenh	Sapindaceae	T	T/V	Nhan Rung	0	0	0	0	0	0	0	8	17	7	10	0
68	*Dioscorea bulbifera*	Dioscoreaceae	LI	T	Khoai dai	27	0	0	0	0	0	0	0	0	0	0	0
69	*Diospyros Sylvatica* Roxb.	Ebenaceae	T	T	Thi rung (den)	1	0	0	0	0	0	0	0	0	7	0	0
70	*Diospyros sylvatica*	Ebenaceae	T	T	Thi Do	17	4	9	0	5	0	9	15	11	0	0	0
71	*Diospyros variegata*	Ebenaceae	T	T	Thi La rung to	22	1	6	0	8	5	4	0	0	0	0	0
72	*Diplazium esculentum –(Rets) J.Smith*	Athyriaceae	F/SE	T	Rau ron	0	0	0	0	0	0	0	0	0	0	0	8
73	*Dracaeana angustifolia*	Liliaceae	SH	T	Bau bau	0	0	0	0	0	0	0	0	0	0	0	11
74	*Dracontomelon- duperreanum* Pierre	Anacardiaceae	T	T	Sau	0	3	11	6	1	0	7	0	0	0	0	0

Order	Latin name	Family	Lifeform	Distribution	Vietnamese	site 1	site 2	site 3	site 4	site 5	site 6	site 7	site 8	site 9	site 10	site 11	site 12
75	*Drynaria bonii* Christ	Polypodiaceae	F	T	Tac Ke da	4	2	8	0	5	0	17	0	0	0	0	0
76	*Dunbaria heynei* Wight & Arn	Fabaceae	LI	T	Dau gai (dai)	0	0	0	0	0	0	0	0	0	0	8	0
77	*Elaeocarpus dubius* A.Dc	Elaeocarpaceae	T	T	Com Tang	0	5	7	0	2	0	4	0	0	0	0	0
78	*Endospermum chinense* Benth	Euphorbiaceae	T	T	Vang trung	0	0	0	0	0	0	0	0	0	0	0	13
79	*Entada phseoloides* (L.) Merr	Fagaceae	LI	T	Day bam bam	5	0	0	0	0	6	0	9	0	0	10	0
80	*Epatorium odoratum* L.	asclepiadaceae	SH	I	Co Nhat	11	0	0	13	0	0	0	0	0	0	0	15
81	*Erythrina stricta* Roxb	Fabaceae	T	T	Vong Nem	0	0	6	0	19	1	4	0	3	0	0	0
82	*Erythropalum scandens* Blume	Erythroxylaceae	LI	T	Bo khai	0	0	0	0	0	0	0	0	0	0	17	0
83	*Fagraea fragans* Roxb	Loganiaceae	T	T	Trai	0	0	0	0	0	5	0	0	0	0	0	0
84	*Fernamdoa Brilletii (Markhamia stipulata)*	Bignoniaceae	T	T	Dinh Thoi	0	0	0	0	0	0	0	0	1	0	4	0
85	*Ficus altissima* Bl	Moraceae	T	E	Da Ba Be	2	0	0	0	0	0	0	0	0	0	0	0
86	*Ficus bÑnjamina* L.	Moraceae	T	T	Si	0	0	0	3	0	0	0	0	0	0	0	0
87	*Ficus lacor* Buch. Ham.	Moraceae	T	T	Sung	0	0	0	0	0	0	0	0	0	0	0	9
88	*Ficus semicordata*	Moraceae	T	T	Mac not	0	0	0	0	0	0	0	0	0	0	0	10
89	*Ficus vasculosa* Wall. Ex Miq.	Moraceae	T	T	Mit Rung	6	0	0	0	0	0	0	0	0	0	0	0
90	*Flacoutia jangomas* (Lour.) Raeusch	Flacourtiaceac	T	T	Bo Quan	0	0	0	5	0	0	0	0	0	0	0	0
91	*Garcinia fagraeoides* A. Chev	Clusiaceae	T	T	Trai Li	13	8	20	0	13	0	3	10	16	19	12	0
92	*Gmelina arborea*	Verbenaceae	T	T	Loi tho	0	0	0	0	0	0	0	0	9	0	0	0
93	*Gossampinus rumphii* Schott & Endl.	Malvaceae	T	T	Gao	0	0	0	0	0	0	0	0	3	0	0	0
94	*Guihaia grossefibrosa* (Gagnep) Dransf.,S	Arecaceae	LI	T	Heo	0	0	0	0	0	0	0	0	0	0	8	0
95	*Hydnocarpus anthelminthica* – Pierre ex Gagnep	Kyggelariaceae	T	T	Dai Phong tu	0	6	11	0	8	6	5	0	0	0	0	0
96	*Hydnocarpus hainania* sp	Flacourtiaceac	T	T	Nang trung Hai Nam	2	12	0	0	0	0	17	5	0	0	0	0
97	*Hydnocarpus ilicifolia* King	Kyggelariaceae	T	T	Nang trung	13	0	8	0	13	31	0	0	0	6	0	0
98	*Idoes ovelis* Blume.	Icacinaceae	LI	T	Tac Khe (Moc thongta)	4	0	0	0	0	0	0	0	0	0	0	0
99	*Ilex cymosa*	Aguifoliaceae	T	T	Nhua Sang	13	0	0	0	0	0	0	0	0	0	0	0

Order	Latin name	Family	Lifeform	Distribution	Vietnamese	site 1	site 2	site 3	site 4	site 5	site 6	site 7	site 8	site 9	site 10	site 11	site 12
100	*Indigofera tinctoria* L	Fabaceae	T	T	Cham la nho	1	0	0	0	0	0	0	0	0	0	0	0
101	*Ipomeoea angustifolia* Jacq	Convolvulaceae	LI	T	Day bim bim	0	0	0	0	0	0	0	0	0	0	15	0
102	*Jasminum nervsuaviersum* Lour	Oleaceae	LI	T	Nhai day	4	0	0	0	0	0	0	0	0	0	0	0
103	*Lygodium .flexuosum* (L.) Sw	Schizaeaceae	F	T	Bong bong	0	0	0	0	0	0	0	0	0	0	0	15
104	*Lygodium Jiaponnicum* (Thunb.) Sw	Schizaeaceae	F	T	Bong bong nhat	0	0	0	0	0	0	0	0	0	0	0	4
105	*Livistona humilis* R. Br.	Lauraceae	T	T	Ke	0	0	0	0	0	0	1	0	0	0	0	0
106	*Macaranga denticulata denticulata* –lune) Muell.- Arg	Euphorbiaceae	T	T	La neu	0	0	0	0	0	0	0	0	0	0	0	9
107	*Machilus oreophyla*	Lauraceae	T	T	Nhi Khao	14	0	0	0	0	0	0	0	0	0	0	0
108	*Mallotus glabriusculus auct., -non (Kurz) Pax & Hoffm.*	Euphorbiaceae	SH	T	Nhot vang	7	0	0	0	0	15	0	8	0	0	0	0
109	*Manglietia glauca* Auct	Magnoliaceae	T	T	Mo la tron	0	0	0	17	0	0	0	0	0	0	0	0
110	*Maoutia puya* (Wall.) Wedd	Urticaceae	SH	T	Ta me	21	6	6	0	7	2	5	0	0	0	9	0
111	*Markhamia Cauda-felina Hance*	Bignoniaceae	T	T	Ke Duoi dong	0	0	0	0	0	0	0	0	0	0	8	0
112	*Melientha suanvis* Pierre	Oleaceae	T	T	Ngot rung (Rau sang)	0	7	10	0	2	2	10	0	0	7	11	0
113	*Microstegium montanum* Nees ex Steud.	Poaceae	G	T	Co rac	0	0	0	17	0	0	0	0	6	0	0	14
114	*Mimusops elengi L.*	Sapotaceae	T	T	Sen nong	0	0	0	0	0	1	0	0	0	0	0	0
115	*Musa acuminata* **Coll.**	Musaceae	SE	T	Chuoi rung	0	0	0	0	0	0	0	0	0	0	0	23
116	*Ophiopogon reptans* Hook. f.	Liliaceae	LI	T	Cao Cang	0	9	12	0	1	0	4	0	0	0	0	0
117	*Oplismenus compositus* (L.) Beauv.	Poaceae	G/SE	T	Co la tre	0	0	0	0	0	0	0	0	0	0	0	16
118	*Pavieasia annamensis* Pierre	Sapindaceae	T	T/V	Truong 5 la (mat/ken)	6	0	0	0	0	0	0	0	0	0	0	0
119	*Phoebe tavoyana* (Meisn.) – Hook.f.	Lauraceae	T	T	Su la to	0	0	0	0	0	0	0	0	0	3	0	2
120	*Polyal thia petelotii* Merr	Annonaceae	T	T	Nhoc den (la to)	0	2	0	0	0	0	0	0	2	0	0	0
121	*Polyalthia cerasoides* Benth & Hook	Annonaceae	T	T	Nhoc da	5	0	8	0	6	0	13	7	0	0	0	0
122	*Polyalthia petelotii* Merr	Annonaceae	T	T	Nhoc den (trai khop)	0	0	0	0	0	0	0	0	0	0	12	0
123	*Polyalthia subcordata* Blume	Annonaceae	T	T	Nhoc	32	0	0	0	0	0	0	0	11	11	0	0

Order	Latin name	Family	Lifeform	Distribution	Vietnamese	site 1	site 2	site 3	site 4	site 5	site 6	site 7	site 8	site 9	site 10	site 11	site 12
124	*Polygomum multiflorum* Thunb	Polygonaceae	LI	T	Ha thu o do	0	0	0	0	0	0	0	0	0	0	0	2
125	*Pothos cattheartt* Schott (1)	Araceae	LI	T	Ray leo la nho	0	0	12	0	0	0	0	0	0	0	0	0
126	*Pothos cattheartt* Schott (2)	Araceae	LI	T	Ray leo	0	0	0	0	0	0	0	2	0	0	0	0
127	*Pothos chinensis* (Raf.)	Araceae	LI	T	Day leo la nho	1	9	0	0	1	0	0	0	0	0	0	0
128	*Pteridium aquilium* L.	Adiantaceae	F	T	Quyet Duong xi	1	0	0	0	0	0	0	0	0	0	0	0
129	*Pterospermum – heterophyllum* Hance(1)	Sterculiaceae	T	T	Long Mang xanh	0	0	0	0	0	20	0	0	0	0	0	0
130	*Pterospermum heterophyllum* Hance	Sterculiaceae	T	T	Long mang 1	0	0	0	0	0	0	3	0	0	0	0	0
131	*Pterospermum truncatolobatum Gagnep*	Sterculiaceae	T	T	Long mang tia	0	7	11	0	20	12	0	0	0	0	0	0
132	*Quescus helferiana* A. DC.	Fagaceae	T	T	De (qua bet)	0	0	0	0	0	0	0	0	0	1	0	0
133	*Saraca diver* pierre	Caesalpiniaceae	T	T	Vang Anh	0	13	5	6	5	0	8	0	0	0	0	0
134	*Sarcandra glabra* (Thumb) Nakai	Euphorbiaceae	SH	T	Soi rung	16	0	0	0	0	0	0	0	0	0	0	0
135	*Sarcosperma laurina*	Sarcospermaceae	T	T	Sen nong	0	0	0	0	0	0	0	0	4	0	0	0
136	*Sarcosperma tonkinensis* H. Lec	Sarcospermaceae	T	T	Cay Bac long	6	0	0	0	0	0	0	0	0	0	0	0
137	*Schefflera octophylla* Harms.	Araliaceae	T	T	Dang du	0	0	0	12	0	0	0	0	0	0	0	0
138	*Selaginella Doederleinii* Hieron.	Selaginellaceae	SH	T	Quyen ba	0	0	0	0	0	0	0	0	0	0	0	14
139	*Sinocalamus mucclure* SP (Theo L^{a} Méng Ch©n.)	Bambusoideae	SH	E/I	Truc day	37	0	0	0	0	0	0	0	0	0	0	0
140	*Stephania sinica* Diels	Menispermaceae	LI	T	Binh Voi	2	2	2	0	2	0	3	4	0	0	0	0
141	*Sterculia lanceolata* Cav.	Sterculiaceae	T	T	Sang	0	15	1	0	8	0	6	0	0	4	14	0
142	*Streblus ilicifolius* (Vidal) Com	Moraceae	T/SE	T	O ro	20	13	40	7	40	34	34	40	40	40	40	0
143	*Streblus macrophyllus* BL.	Moraceae	T	V	May Teo	0	34	14	11	12	0	0	0	0	0	0	0
144	*Streptocaulon wallichii* Wight	asclepiadaceae	LI	T	Ha thu o trang	0	0	0	0	0	0	0	0	0	0	0	2
145	*Syzygium cuminii* (L.) Skeels	Myrtaceae	T	T	Cham tia	1	0	0	0	0	7	0	0	0	6	0	0
146	*Syzygium formosum* (wall) matsam	Myrtaceae	SH	T	Mau Don Da	8	0	0	0	0	0	0	0	0	0	0	0
147	*Tetrameles nudiflora* R. Br.	Datiscaceae	T	T/V	Thung	0	0	18	0	1	0	2	3	0	0	0	0
148	*Tetrapanax papyriferus* – (Hook.) C.Koch	Araliaceae	T	T	Thong thao	0	0	0	4	0	0	0	0	0	0	0	0
149	*Tetrastigma planicaule* (Hook.f.) gagnep.	Vitaceac	LI	T	Day quoai ba lo 5 la	27	0	13	0	4	9	6	2	0	0	15	0

Order	Latin name	Family	Lifeform	Distribution	Vietnamese	site 1	site 2	site 3	site 4	site 5	site 6	site 7	site 8	site 9	site 10	site 11	site 12
150	*Tetrastigma strumarum* gagnep.	Vitaceac	LI	T	Day Quoai ba lo 3 la	11	12	0	8	0	0	0	0	0	0	0	0
151	*Tetrastigma strumarum* gagnep. (1)	Vitaceac	LI	T	Den 3 la	0	0	0	0	0	0	0	0	0	8	0	0
152	*Tetrastigma tuberculatum*	Vitaceac	LI	T	Day rat nui da	2	0	0	0	0	0	0	0	0	0	0	0
153	*Toona sureni* (Blume) Merr	Meliaceae	T	T	Truong Van	0	0	0	13	4	0	12	0	1	0	7	0
154	*Turpinia sp*	Staphylliaceae	T	T/V	Coc Dao la nho	0	0	0	0	0	0	8	0	0	0	0	0
155	*Vatica tonkinensis* A.Chev	Dipterocarpaceae	T	T/V	Tau mat	0	0	0	0	0	0	0	4	0	0	0	0
156	*Vatica diospyroides* Symingt	Dipterocarpaceae	T	T	Tau Muoi	0	0	0	0	3	0	2	4	18	0	0	0
157	*Vernonia arborea* Ham	Asteraceae	T	T	Bong bac	0	0	0	0	0	0	0	0	0	0	0	7
158	*Vitex agnus-castus* L.	Verbenaceae	T	T	Den (1)	0	0	0	0	0	0	0	0	0	0	10	0
159	*Vitex farviflora* Juss	Verbenaceae	T	T	Den 5 la	0	0	5	0	2	0	0	0	0	0	0	0
160	*Vitex quinata* Will.	Verbenaceae	T	T	Den 5 la (1)	0	25	5	0	7	0	26	0	0	0	0	0
161	*Wrightia tomentosa* (Roxb.) –Roem. & Schult.	Apocynaceae	T	T	thung muc	0	0	0	0	0	0	0	0	0	0	0	12
162	*Wrightia tomentosa* Roem var *cochinchinensis* Pitard	Apocynaceae	T	T	Thung Muc long	8	0	0	0	0	0	0	0	0	0	0	0

Appendix 6: Checklist of vegetations of localized plots in the protection area of Ba be national –Viet Nam, arranged by class, family and species name. Me is medicine, Ve is vegetable, Wo is wood, Bo is bonsai, Co is construction, Fr is fruit and An is for animal food

Checklist of vegetations of localized plots in the protection area of Ba be national -Viet Nam

(From plot number 1 to 12)

Fungi - Mycophyta

Order	Latin name and order of family	Vietnamese name	Form of life	Pheno--logy	Utility
	1.Auriculariaceae	**Ho moc nhi**			
1	*Auricularia auricula* (L) Underw	Moc nhi	5		Me,Ve

Lycopodiophyta

Order	Latin name and order of family	Vietnamese name	Form of life	Pheno--logy	Utility
	1. Selaginellaceae	Ho quyen ba			
1	*Selaginella delicatula* (Desv.) Alston	Quyen ba nho	4		
2	*Selaginella Doederleinii* Hieron.	Quyen ba	4		

Fern - Polypodiophyta

Order	Latin name and order of family	Vietnamese name	Form of life	Pheno--logy	Utility
	1. Adiantaceae	Ho toc ve nu	4		
1	*Adiantum cernuum* L.	Toc ve nu (Toc than ve nu)	4		Bo
2	*Cyclosorus parasiticus* (L) Farw	Duong xi thuong			
	2. Asplenniaceae	Ho to dieu			
3	*Asplenium nidus* L.	To dieu			
4	*Blechnum orientale* L	Quyet la dua	4		B,Me
	3. Athyriaceae	**Ho don**			
5	*Diplazium esculentum* – (Rets) J.Smith	Rau don			
	4. Gleicheniaceae	Ho guot			

6	*Dicranopteris lineari* (Burm. Underw)	Guot	3		
	5.Polypodiaceae	**Ho rang de**			
7	*Drynaria bonii* Christ	Tack e da			
	6. Schizaeaceae	**Ho Bong bong (Rang ngon)**			
8	*Lygodium microphyllum* (cav.) R.-BR	Bong bong la nho	1.5		Me
9	*L.flexuosum* (L.) Sw	Bong bong	1.5		Me
10	*L.Jiaponnicum* (Thunb.) Sw	Bong bong nhat	1.5		Me

Angiosperm - Angiospermae

Dicotyledon - Dicotyleledoneae

12	Latin name and order of family	Vietnamese name	Form of life	Phenology	Utility
	1. Aceraceae	**Ho thich**			
1	*Acer laurinum* Hassk	Thich 10 nhi	1.1		
2	*Acer tonkinensis* Lecomte	Thich Bac bo	1.2		Wo,B
	2. Alangiaceae	**Ho thoi ba**			
3	*Alangium chinense* (lour.) – Harms	Thoi ba	1.3		Wo,Me
4	*Alangium kurzii* Craib	Thoi ba la day			
	3. Amaranthaceae	**Ho rau den**			
5	*Achyranthes aspera* L.	Co xuoc	5		Th
6	*Celosia cristata* L.	Mao ga trang	5		Me
	4. Anacardiaceae	**Ho ®ao lon hot**			
7	*Allospondias lakonensis* (Pierre.) Stapf	D©u da xoan	1..2		B,W,Fr
8	*Dracontomelon- duperreanum* Pierre	Sau	1.1		W,Fr
	5. Annonaceae	**Ho na**			
9	*Xylopia vielana* Piere	den (Den, sai)	1.3		Wo,Me
10	*Polyalthia subcordata* Blume	Nhoc			Wo
11	*Polyalthia cerasoides* Benth & Hook	Nhoc ®a			
12	*Polyalthia petetolii* Merr	Nhoc ®en (trai khop)			
	6. Apocynaceae	**Ho truc ®ao**			

13	*Wrightia tomentosa* (Roxb.) – Roem. & Schult.	Thung muc (long mem)	1.3		Wo,Me
	7. Araliaceae	**Ho chan chim**			
14	*Schefflera octophylla* Harms.	Dang	1.4		Me
15	*Tetrapanax papyriferus* – (Hook.) C.Koch	Thong thao (§uoi dong)	1.4		Me
	8. asclepiadaceae	**Ho thien ly**			
16	*Dischidia acuminata* Cost.,	Tai chuot	1.5		Bo
17	*Crassocephalum crepidioides* – (Benth.) S.Moore	Rau tau bay	5		Ve, Me
18	*Epatorium odoratum* L.	Co lao (co nhat)	5		Me
19	*Streptocaulon wallichii* Wight	Ha thu o trang			
	9. Asteraceae	**Ho cuc**			
20	*Vernonia arborea* Ham.	Bong bac	1.3		Wo,Me
	10. Bignoniaceae	**Ho dinh**			
21	*Fernamdoa Brilletii* (dop.) – Steen	Dinh thoi	1..2		Wo
22	*Markhamia Cauda-felina* – (Hance) Benth et Hookf.	Ke duoi dong	1.3		Wo,Me
23	*Markhamia stipulata* (Roxb.) Seem.	Dinh	1..2		Wo
	11. Buddlejaceae	**Ho bo cho**			
24	*Buddleja Americana* L	Chia voi			
	12. Caesalpiniaceae	**Ho vang**			
25	*Bauhinia purpurea* L.	Mong bo hoa tim (Lua)	1.5		Bo,Me
26	*Bauhinia alba* Hamilt	Mong bo hoa trang			
27	*Bauhinia divaricata* L.	Mong bo			
28	*Saraca diver* pierre	Vang anh	1..2		Wo,Bo
	13. Clusiaceae	**Ho mang cut**			
29	*Cratoxylum polyanthum* – Korth	Thanh ngach (Lanh ngach)	1.3		Wo,Me
30	*C. prunifolium* (Jack) Benth. – & Hook.f.ex Dyer	§o ngon	1.3		Wo
31	*Garcinia fagraeoides* A. Chev	Trai ly			
32	*Garcinia oblonggifilia* Champ. – Ex Benth.	Bua	1.3		Wo,Me
	14. Convolvulaceae	**Ho khoai lang**			
33	*Argyreia acuta* Lour.	Day bac thau	1.5		Me
34	*Argyreia capitata*(Vahl) Choisy	Bac thau tia			

35	*Merremia hederamia* (Burm.f.) Hall.f.(Evolvulus hederaceus Burm.f.)	Bim bim hoa vang	1.5		Me
36	*Ipomoea angustifolia* Jacq	Bim bim			
	15. datiscaceae	**Ho thung**			
37	*Tetrameles nudiflora* R. Br.	Thung (§ang)	1.1		Wo
	16. Dilleniaceae	**Ho so**			
38	*Dillenia turbinata* Fin Gagnep.	Long bang	1.3		Wo,Me
	17. Dipterocarpaceae	**Ho qua hai canh** (ho dau)			
39	*Vatica diospyroides* Symingt	Tau muoi	1..2		Wo
	18. Ebenaceae	**Ho thi**			
40	*Diospyros sp3*	Thi ®o			
41	*Diospyros Sylvatica* Roxb.	Thi rung	1.3		Wo
42	*Diospyros sp4*	Thi rung la to			
	19. Elaeocarpaceae	**Ho com**			
43	*Elaeocarpus dubius* A.Dc	Com tang	1.3		Wo,Bo
	20. Erythroxylaceae (olacaceae)	**Ho bo khai**			
44	*Erythropalum scandens* Blume	Bo khai			*
	21. Euphorbiaceae	**Ho ba manh vo**			
45	*Alchornea trewioides* – (Benth.) Muell-Arg.	Dom dom (Dom dom qua nhan)	1.4		Me
46	*Antidesma acidum* Retz	Da nau (Choi moi chua)	1.4		Me
47	*Aleuritis moluccana* (L.) Willd	Lai			
48	*Aprosa mycrocalyx* Hassk.	Thau tau	1.3		Wo,Me
49	*Baccaurea sapida* (Roxb.) – Muell.-Arg	Giau da dat	1.3	*	Fr, Me
50	*Bischofia javanica* Blume	Nhoi	1..2		W,B, Me
51	*Brenia fruticosa* (L.) Hook. F.	Bo cu ve	1.4		Me
52	*Cleistathus petelotii* Merr. – Ex Croizat	Coc rao	1.4		Wo
53	*Cleistathus myrianthus* Kur	Coc rao la to			
54	*Deutzianthus tonkinensis* – Gagnep	Mo	1.3		Wo
55	*Endospermum chinenses* Benth	Vang trung			
56	*Macaranga denticulata denticulata* – (lune) Muell.- Arg	La nen	1.3		Wo,Me

57	*Mallotus glabriusculus auct., -non* (Kurz) Pax & Hoffm.	Nhot vang			
58	*Sarcandra glabra* (Thumb) Nakai	Soi rung			
	22. Fabaceae	**Ho dau**			
59	*Dunbaria heynei* Wight & Arn	Dau gai			
60	*Erythrina stricta* Roxb	Vong nem	1.1		Wo,Me
61	*Indigofera tinctoria* L.	Cham (nhuom)			
62	*Pueraria Phaseooloides* (Roxb)- Benth.	San day rung	1.5		Fi, Me
	23. Fagaceae	**Ho de**			
63	*Castanopsis chinensis* A.chev.	De gai (Ca oi trung hoa)	1..2		Wo,Co
64	*Entada phseoloides* (L.) Merr	Bam bam			Me,Co
65	*Quescus helferiana* A. DC.	De qua bet	1..2		,Wo,Me
	24. Flacourtiaceac	**Ho nang trung (Bo quan)**			
66	*Flacoutia jangomas* (lour.) Raeusch. (F. cataphracta. Roxb . ex Willd.).	Bo quan			
67	*Hydnocarpus venenata* Gaerta	Nang trung			
68	*Hydnocarpus hainamia*	Nang trung hai nam			
	25. icacinaceae	**Ho moc thong**			
69	*Idoes ovelis* Blume.	Day moc thong ta	1.5		Me
	26. Kyggelariaceae	**Ho chum bao**			
70	*Hydnocarpus anthelminthica* – Pierre ex Gagnep	§ai phong tu	1.3		Wo, Me
71	*Hydnocarpus ilicifolia* King	Nang trung			Wo
	27. Lauraceae	**Ho re**			
72	*Cinamomun tonkinense* (Lecomte) – A. Chev	Re xanh			
73	*Cryptocarya lenticellata* H. Lec	Nanh chuot			
74	*Lindera tonkinensis* Lecomte	O duoc	1.4		Me
75	*Litsea cubeba* (lour.) Pers.	Mang tang	1.3		Oil,Me
76	*Phoebe tavoyana* (Meisn.) – Hook.f.	Khao nhot (Su la to)	1.3		Wo
	28. Liliaceae	**Ho hanh**			
77	*Aspidistra lurida* Ker-Gawl	Toi rung			
	29. Loganiaceae	**Ho ma tien**			

78	*Fagraea fragans* Roxb	Trai			
	30. Malvaceae	**Ho bong**			
79	*Abelmoschus sag×ttifolius* (Kurz) Merr.	Sam bo chinh			
80	*Sida rhombifolia* L.	Ke hoa vang			
81	*Urena lobata* L.	Ke hoa dao			
	31. Magnoliaceae	**Ho moc lan**			
82	*Manglietia glauca* Auct.	Mo (la tron)			
	32. Meliaceae	**Ho xoan**			
83	*Chisocheton paniculata* – (Roxb.) Hiern	Quech tia	1.3		Wo
84	*Chukrasia tabularis* A.Juss	Lat hoa	1..2		Wo
85	*Melia azedararach* L.	Xoan	1.3		Wo
86	*Toona sureni* (Blume) Merr	Truong van			Wo,Me
	33. Menispermaceae	**Ho tiet de**			
87	*Stephania sinica* Diels	Binh voi	4		Me
	34. Mimosaceae	**Ho trinh nu**			
88	*Adenanthera microsperma* – Teysm. & Binn	Muong rang rang (trach quach)	1.3		Wo
89	*Archidendron balansa* (Oliv.) – I. Nielsen	Cut ngua	1.3		Wo
	35. Moraceae	**Ho Dau tam**			
90	*Antiaris toxicaria* Pers. – Lesch.	Sui (Thuoc ban)	1.1		Wo,Me
91	*Broussonettia papyrifera* (L) – Lher.ex Vent.	Duong	1.3		Me
	Dimerocarpus brenieri Gagnep	May teo			
92	*Ficus auriculata* L.f.	Va	1.3		Wo,Me
93	*Ficus bÑnjamina L.*	si xanh			
94	*Ficus lacor* Buch. Ham.	Sung rung qua nho (de man)	1.4		Fr, Bo
95	*Ficus championi* Benth	Da qua xanh			
96	*Ficus vasculosa* Wall. Ex Miq.	Mit rung (Mit ma)	1.3		Wo
97	*Ficus altissima* Bl	Da tia (Da ba be)			
98	*Ficus semicordata*	Mac not			
99	*Streblus ilicifolius* (Vidal) Com	O ro			
100	*Streblus macrophyllus* BL.	May teo (ruoi)			

	36. Myristicaceae	**Ho mau cho**			
101	*Horsfiedia amygdalina* – (Wall.) Warb.	Mau cho la to (sang mau)	1..2		Me,Wo
	37. Myrsinaceae	**Ho don nem**			
102	*Ardisia silvestris* Pitard	La khoi	2		Me
	38. Myrtaceae	**Ho sim**			
103	*Syzygium chanlos* (Gagnep.)-Merr.& Perry	Tram voi	1.4		Wo
104	*Syzygium cuminii* (L.) Skeels	Tram tia	1.3		Wo
105	*S. wghtianum* Wall. ex-Wight & Arn.	Tram trang	1..2		Me, Fr
	39. Oleaceae	**Ho nhai**			
106	*Jasminum nervsuaviersum* Lour	Nhai day	1.5		Me
107	*Melientha suanvis* Pierre	Rau sang (Rau ngot rung)	1.3		
	40. Orchidaceae	**Ho lan**			
108	*Anecochilus setaceus* Blume	Kim tuyen			
109	*Denrobium nobile* Lindl	Hoang thao			
	41. Polygonaceae	**Ho rau ram**			
110	*Polygomum muliflorum* Thunb	Ha thu o ®o			
111	*Aidia pycnantha* (Drake) – Tirveng.	Mai tap	1.4		Wo
112	*Wendlandia paniculata* – (Roxb.) A. DC.	Hooc quang	1.4		Me
	42. Rutaceae	**Ho cam**			
113	*Atalantia citroides* Pierre ex-Guilaum.	Cam rung (Ban than bat toai)	1.4		Me
114	*Clausena duniana Levl.*& Fede	Hong bi rung	1.4		Me,Fr
115	*C.harmandiana* Pierre.	Trung sao (ot rung)	1.4		Me
	43. Sapindaceae	**Ho bo hon**			
116	*Amesiodendron chinensie* – (Merr.) Hu	Truong sang ba la	1.4		Wo
117	*Dimocarpus fumatus ssp. Indochinensis* Leenh	Nhan rung			
118	*Pavieasia annamensis* Pierre	Truong mat (5 la)			
	44. Sarcospermaceae	**Ho sen dat**			
119	*Sarcosperma laurina*	Sen nong	1..2		Wo,Fr
120	*Sarcosperma tonkinensis* H. Lec	Bac (long)			
	45. Sonneratiaceae	**Ho ban**			

121	*Duabanga grandiflora* – (Roxb.ex DC.) Walt.	Phay	1..2		Wo, Bo
	46. Sterculiaceae	**Ho trom**			
122	*Pterospermum* – *heterophyllum* Hance	Long mang xanh	1..2		Wo
123	*Pterospermum jackianum* Wall	Long mang tia			
124	*Sterculia lanceolata* Cav.	Sang	1.4		Wo, Me
	47. tiliaceae	**Ho day**			
125	*Burretiodendron hsienmu* Chun et How	Nghien			Wo
	48. Ulmaceae	**Ho du**			
126	*Celtis sinensis* Person	Seu			
127	*Celtis phippinensis* Blanc	Seu rung			
	49. Urticaceae	**Ho gai**			
128	*Maoutia puya* (Wall.) Wedd	Ta me			
	50. Verbenaceae	**Ho tech**			
129	*Vitex farviflora* Juss	Chan chim (Den)			
130	*Vitex quinata* Will.	Chan chim thuoc (Den 5 la)	1.4		Bo
131	*Vitex triforlia* Will	Den 3 la			
	51. Vitaceac	**Ho nho**			
132	*Cissus modeccoides* Planch	Day chia voi			
133	*Tetrastigma planicaule* (Hook.f.) gagnep.	Day quai ba lo			
134	*Tetrastigma strumarum* gagnep.	Day quai ba lo 3 la			
	Monocotyledoneae	**Monocotyle-don**	**Form of life**	**phenology**	**Utility**
	1. Araceae	**Ho ray**			
1	*Alocasia macrorrhiza* (L) Schott	Ray	1.5		Me
2	*Amorphophallus* – *campanulatus* Blume	Cay ray dai (Nua (Nua chuong))	5		Me
3	*Amorphophallus – rivieri* Dur	Cay khoai nua			
4	*Pothos cattheartt* Schott	Ray leo	1.5		Me
	2. Arecaceae	**Ho cau**			
5	*Arenga pinata* (Wurmb) Merr	Dao			
6	*Caryota mitis* Lour.	Dung dinh (Mdd)	1.4		Fi, Me
7	*Caryota urens* L.	Moc	1.3		Bo,

					Me
8	*Guihaia grossefibrosa* (Gagnep) Dransf.,S.K.Lee & F.N.Wei	Heo			Co
9	*Livistona humilis* R. Br.	Ke			
	3. Bambusoideae	**Phan ho tre nua**			
10	*Sinocalamus mucclure* SP (By L[a] Méng Ch©n.)	Truc day			
	4. Liliaceae	**Ho cao cang**			
11	*Ophiopogon reptans* Hook. f.	Cao cang			
	5. Musaceae	**Ho chuoi**			
12	*Musa acuminata* Coll.	Chuoi rung	1,6		Ve
	6. Orchidaceae	**Hä lan**			
13	*Dendrobium daoense* Reichb..f.	Hoang thao	1.7		Bo
	7. Poaceae	**Ho hoa thao**			
14	*Chrysopogon aciculatus* – (Retz.) Trin	Co may	3		An
15	*Imperata cylindrica* (L) Beauv.	Co tranh	5		Me
16	*Microstegium montanum* – (Nees ex Steud.) A. camus	Co rac nui	5		An
17	*Oplismenus compositus* (L.) Beauv.	Co la tre	5		An
	8. Smilacaceae	**Ho cam cang**			
18	*Smilax glabra* Wall. Ex Roxb	Cam cang (Tho phuc linh)	1.5		Me
	9. Stemonaceae	**Ho bach bo**			
19	*Stemona tuberosa* Lour	Bach ho (day ba muoi)	1.5		Me
	10. Zingiberaceae	**Ho gung**			
20	*Amomum villosum* Lour.	Sa nhan	3		Me
21	*Amomum vespertilio* Gagnep	Sa nhan thien			
22	*Zingiber purpureum* Rosc	Gung da			Me

Appendix 7: SIMPER analysis (Primer program) of 162 species occurred in 12 quadrats in Ba Be National Park included Similarity Percentages - species contributions, *Worksheet*: Sample selection: All Variable Selection: All, *Parameters*: Standardise data: No, Transform: None, Cut off for low contributions: 90.00%. Factor name: Sites. *Factor groups*: MS, DT1, DT2, RU

PRIMER SIMPER – scale 1

Group MS

Average similarity: 21.33

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
S. ilicifolius	24.33	4.05	4.67	18.99	18.99
G. fagraeoides	11.00	2.47	4.74	11.58	30.58
C. sinensis	10.00	2.13	4.83	9.96	40.54
M. puya	12.00	1.85	4.74	8.69	49.23
S. lanceolata	9.67	1.68	0.58	7.85	57.08
A. villosum	14.00	1.33	0.58	6.23	63.31
C. petelotii	17.33	1.25	0.58	5.88	69.19
B. hsienmu	15.00	1.24	4.74	5.79	74.98
T. planicaule	14.00	1.11	0.58	5.19	80.18
T. strumarum	7.67	0.86	0.58	4.04	84.22
M. suanvis	6.00	0.84	0.58	3.93	88.15
A. nidus	6.33	0.59	0.58	2.77	90.92

Group DT1

Average similarity: 43.12

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
S. ilicifolius	38.00	13.75	5.36	31.89	31.89
B. hsienmu	21.33	5.58	3.05	12.94	44.83
D. sylvatica	11.00	3.43	6.87	7.96	52.78
P. cerasoides	9.33	2.77	12.67	6.44	59.22
C. petelotii	9.67	2.57	3.33	5.97	65.18
G. fagraeoides	11.00	2.07	1.26	4.79	69.97
T. planicaule	7.00	1.19	1.88	2.76	72.73
M. suanvis	6.67	1.07	0.58	2.47	75.21
S. sinica	3.00	0.91	2.68	2.10	77.30
T. nudiflora	7.67	0.89	3.25	2.07	79.38
D. bonii	8.33	0.85	0.58	1.98	81.36
A. capitata	7.33	0.85	0.58	1.98	83.34
D. duperreanum	6.00	0.75	0.58	1.73	85.07
H. hainania	7.33	0.71	0.58	1.66	86.72
V. quinata	10.33	0.53	0.58	1.24	87.96
S. diver	4.33	0.53	0.58	1.24	89.20
M. puya	3.67	0.53	0.58	1.24	90.43

Group DT2

Average similarity: 9.79

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
M. montanum	15.50	4.15	#######	42.42	42.42
E. odoratum	14.00	3.86	#######	39.39	81.82
A. mycrocalyx	8.50	1.78	#######	18.18	100.00

Group RU

Average similarity: 36.58

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
S. ilicifolius	38.50	16.25	6.98	44.44	44.44

B. hsienmu	14.50	5.08	2.69	13.89	58.33
G. fagraeoides	12.00	3.11	0.88	8.49	66.82
H. ilicifolia	12.50	1.80	0.84	4.93	71.75
C. petelotii	9.00	1.54	0.63	4.22	75.97
C. parasiticus	6.75	1.51	0.84	4.14	80.11
P. subcordata	5.50	0.89	0.41	2.44	82.55
C. sinensis	3.50	0.82	0.82	2.25	84.80
P. truncatolobatum	8.00	0.79	0.41	2.15	86.95
D. fumatus	6.00	0.57	0.41	1.55	88.50
C. duniana	8.00	0.57	0.41	1.55	90.05

Groups MS & DT1

Average dissimilarity = 67.45

Species	Group MS Av.Abund	Group DT1 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
B. hsienmu	15.00	21.33	2.47	1.85	3.66	3.66
S. ilicifolius	24.33	38.00	2.46	1.15	3.65	7.31
S. macrophyllus	11.33	4.67	2.37	0.80	3.52	10.83
A. villosum	14.00	0.00	2.12	1.13	3.14	13.97
C. petelotii	17.33	9.67	2.01	1.88	2.98	16.95
V. quinata	8.33	10.33	2.01	0.92	2.98	19.93
T. planicaule	14.00	7.00	1.71	1.72	2.54	22.47
S. lanceolata	9.67	2.33	1.63	1.33	2.41	24.88
S. mucclure	12.33	0.00	1.44	0.66	2.13	27.01
D. sylvatica	7.00	11.00	1.38	1.50	2.05	29.06
P. cerasoides	1.67	9.33	1.31	1.79	1.94	31.00
P. subcordata	10.67	0.00	1.24	0.66	1.84	32.84
C. parasiticus	8.00	4.67	1.22	1.30	1.81	34.64
T. strumarum	7.67	0.00	1.21	1.16	1.80	36.44
H. hainania	4.67	7.33	1.20	1.28	1.78	38.22
D. bonii	2.00	8.33	1.20	1.18	1.77	39.99
M. puya	12.00	3.67	1.19	1.31	1.77	41.76
T. nudiflora	0.00	7.67	1.17	1.02	1.73	43.49
A. capitata	4.33	7.33	1.12	1.06	1.67	45.16
D. variegata	7.67	3.33	1.09	1.18	1.62	46.78
D. bulbifera	9.00	0.00	1.05	0.66	1.55	48.33
E. scandens	5.67	0.00	1.01	0.66	1.49	49.82
S. diver	4.33	4.33	0.99	1.08	1.47	51.29
G. fagraeoides	11.00	11.00	0.99	1.76	1.46	52.75
A. nidus	6.33	0.00	0.96	1.12	1.43	54.18
C. sinensis	10.00	4.00	0.96	1.37	1.42	55.60
I. angustifolia	5.00	0.00	0.89	0.66	1.32	56.92
O. reptans	3.00	5.33	0.87	1.15	1.29	58.21
D. duperreanum	1.00	6.00	0.85	1.46	1.26	59.47
A. chinensie	4.00	3.67	0.85	0.80	1.26	60.73
M. sauvious	6.00	6.67	0.84	1.09	1.24	61.97
A. lurida	6.33	0.67	0.81	0.80	1.20	63.17
E. phseoloides	5.00	3.00	0.80	1.02	1.18	64.35
T. sureni	2.33	4.00	0.77	0.94	1.14	65.50
A. pinata	4.33	0.00	0.77	0.66	1.14	66.64
H. anthelminthica	2.00	5.33	0.75	1.21	1.11	67.75
D. fumatus	3.33	2.67	0.73	0.90	1.08	68.83
P. truncatolobatum	2.33	3.67	0.72	0.97	1.07	69.91
A. acuta	2.33	3.67	0.72	0.97	1.07	70.98
P. petelotii	4.00	0.00	0.71	0.66	1.05	72.04
H. ilicifolia	4.33	2.67	0.70	0.96	1.04	73.07
A. balansa	4.00	4.33	0.70	1.48	1.03	74.11
C. mitis	3.67	0.00	0.65	0.66	0.97	75.07
P. chinensis	3.33	0.00	0.63	0.72	0.93	76.00
S. glabra	5.33	0.00	0.62	0.66	0.92	76.92
V. agnus-castus	3.33	0.00	0.59	0.66	0.88	77.80
P. cattheartt (1)	0.00	4.00	0.58	0.65	0.86	78.66
M. glabriusculus	2.33	2.67	0.58	0.77	0.86	79.52
M. oreophyla	4.67	0.00	0.54	0.66	0.81	80.33
A. cernuum	4.67	0.00	0.54	0.66	0.81	81.13
E. dubius	1.67	3.67	0.52	1.19	0.77	81.90
D. tonkinensis	0.00	2.67	0.51	0.64	0.76	82.66

I. cymosa	4.33	0.00	0.50	0.66	0.75	83.41
E. stricta	0.00	3.33	0.50	1.22	0.74	84.14
M. Cauda-felina	2.67	0.00	0.47	0.66	0.70	84.84
G. grossefibrosa	2.67	0.00	0.47	0.66	0.70	85.55
D. heynei	2.67	0.00	0.47	0.66	0.70	86.25
B. ovata	2.67	0.00	0.47	0.66	0.70	86.95
A. citroides	0.33	2.33	0.46	0.68	0.68	87.63
E. odoratum	3.67	0.00	0.43	0.66	0.63	88.26
C. myrianthus	3.33	0.00	0.41	0.85	0.61	88.87
A. rivieri	2.33	0.00	0.41	0.66	0.61	89.49
Turpinia sp	0.00	2.67	0.41	0.65	0.61	90.10

Groups MS & DT2

Average dissimilarity = 90.69

Species	Group MS Av.Abund	Group DT2 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
S. ilicifolius	24.33	3.50	3.03	1.40	3.34	3.34
A. villosum	14.00	20.00	2.86	1.29	3.16	6.50
M. montanum	0.00	15.50	2.23	4.51	2.46	8.96
C. petelotii	17.33	0.00	2.19	1.24	2.41	11.37
S. macrophyllus	11.33	5.50	2.09	0.90	2.31	13.68
D. lineari	0.00	12.50	1.84	0.88	2.03	15.71
A. tonkinensis	0.00	12.50	1.77	0.88	1.95	17.66
T. planicaule	14.00	0.00	1.74	1.27	1.92	19.58
M. acuminata	0.00	11.50	1.69	0.88	1.86	21.44
E. odoratum	3.67	14.00	1.63	1.57	1.80	23.24
S. lanceolata	9.67	0.00	1.58	1.28	1.74	24.98
M. puya	12.00	0.00	1.56	2.77	1.72	26.70
A. setaceus	0.00	11.00	1.56	0.88	1.72	28.41
G. fagraeoides	11.00	0.00	1.54	5.96	1.70	30.11
B. hsienmu	15.00	2.00	1.50	0.93	1.66	31.77
V. quinata	8.33	0.00	1.42	0.65	1.56	33.33
A. kurzii	0.00	10.00	1.41	0.88	1.56	34.89
S. mucclure	12.33	0.00	1.32	0.65	1.45	36.34
C. sinensis	10.00	9.00	1.30	2.93	1.43	37.77
A. trewioides	0.00	8.50	1.25	0.88	1.38	39.15
A. mycrocalyx	0.00	8.50	1.23	2.47	1.36	40.51
M. glauca	0.00	8.50	1.20	0.88	1.33	41.84
A. sagxttifolius	0.00	8.50	1.20	0.88	1.33	43.16
O. compositus	0.00	8.00	1.18	0.88	1.30	44.46
C. parasiticus	8.00	6.50	1.16	1.42	1.28	45.73
P. subcordata	10.67	0.00	1.14	0.65	1.26	46.99
L. flexuosum	0.00	7.50	1.10	0.88	1.22	48.21
S. Doederleinii	0.00	7.00	1.03	0.88	1.13	49.34
C. chinensis	0.00	7.00	1.03	0.88	1.13	50.48
M. suanvis	6.00	0.00	0.97	1.23	1.07	51.54
D. bulbifera	9.00	0.00	0.96	0.65	1.06	52.61
E. chinense	0.00	6.50	0.96	0.88	1.05	53.66
T. sureni	2.33	6.50	0.93	1.11	1.02	54.68
T. strumarum	7.67	4.00	0.91	1.22	1.01	55.69
E. scandens	5.67	0.00	0.88	0.65	0.97	56.66
W. tomentosa	0.00	6.00	0.88	0.88	0.97	57.64
B. fruticosa	0.00	6.00	0.88	0.88	0.97	58.61
B. papyrifera	0.00	6.00	0.88	0.88	0.97	59.58
A. nidus	6.33	0.00	0.86	1.12	0.94	60.52
S. octophylla	0.00	6.00	0.85	0.88	0.94	61.46
B. javanica	0.00	6.00	0.85	0.88	0.94	62.40
D. variegata	7.67	0.00	0.84	0.72	0.93	63.32
D. sylvatica	7.00	0.00	0.83	1.01	0.92	64.24
S. diver	4.33	3.00	0.83	0.98	0.91	65.16
D. angustifolia	0.00	5.50	0.81	0.88	0.89	66.05
I. angustifolia	5.00	0.00	0.78	0.65	0.86	66.91
C. philippinensis	0.00	5.50	0.78	0.88	0.86	67.76
H. hainania	4.67	0.00	0.75	0.75	0.83	68.59
A. capitata	4.33	0.00	0.74	0.65	0.81	69.40
F. semicordata	0.00	5.00	0.74	0.88	0.81	70.21
E. phseoloides	5.00	0.00	0.70	0.98	0.77	70.98

A. lurida	6.33	0.00	0.68	0.65	0.75	71.73
A. pinata	4.33	0.00	0.68	0.65	0.74	72.47
M. denticulata	0.00	4.50	0.66	0.88	0.73	73.20
F. lacor	0.00	4.50	0.66	0.88	0.73	73.93
A. acuta	2.33	4.50	0.65	1.05	0.72	74.65
P. petelotii	4.00	0.00	0.62	0.65	0.69	75.34
D. esculentum	0.00	4.00	0.59	0.88	0.65	75.99
C. mitis	3.67	0.00	0.57	0.65	0.63	76.62
S. glabra	5.33	0.00	0.57	0.65	0.63	77.25
C. wampi	0.33	4.00	0.57	0.92	0.62	77.87
C. harmandiana	0.00	4.00	0.57	0.88	0.62	78.50
A. vespertilio	0.00	4.00	0.57	0.88	0.62	79.12
P. chinensis	3.33	0.00	0.55	0.71	0.60	79.72
V. agnus-castus	3.33	0.00	0.52	0.65	0.57	80.29
D. fumatus	3.33	0.00	0.52	0.65	0.57	80.87
V. arborea	0.00	3.50	0.51	0.88	0.57	81.43
O. reptans	3.00	0.00	0.51	0.65	0.56	82.00
A. macrorrhiza	1.67	3.50	0.51	1.05	0.56	82.56
M. oreophyla	4.67	0.00	0.50	0.65	0.55	83.11
A. cernuum	4.67	0.00	0.50	0.65	0.55	83.66
B. americana	0.67	3.50	0.50	1.11	0.55	84.21
A. chinense	0.00	3.50	0.49	0.88	0.55	84.75
A. balansa	4.00	0.00	0.47	0.96	0.52	85.27
H. ilicifolia	4.33	0.00	0.46	0.65	0.51	85.78
I. cymosa	4.33	0.00	0.46	0.65	0.51	86.29
D. duperreanum	1.00	3.00	0.43	1.18	0.47	86.77
A. chinensie	4.00	0.00	0.43	0.65	0.47	87.24
C. polyanthum	0.00	3.00	0.42	0.88	0.47	87.70
B. sapida	0.00	3.00	0.42	0.88	0.47	88.17
M. Cauda-felina	2.67	0.00	0.42	0.65	0.46	88.63
G. grossefibrosa	2.67	0.00	0.42	0.65	0.46	89.09
D. heynei	2.67	0.00	0.42	0.65	0.46	89.55
B. ovata	2.67	0.00	0.42	0.65	0.46	90.01

Groups DT1 & DT2

Average dissimilarity = 93.75

Species	Group DT1 Av.Abund	Group DT2 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
S. ilicifolius	38.00	3.50	5.83	4.37	6.22	6.22
A. villosum	0.00	20.00	3.29	0.90	3.51	9.72
B. hsienmu	21.33	2.00	3.11	2.70	3.31	13.04
M. montanum	0.00	15.50	2.60	6.50	2.77	15.81
E. odoratum	0.00	14.00	2.36	6.00	2.51	18.32
D. lineari	0.00	12.50	2.15	0.90	2.29	20.61
A. tonkinensis	0.00	12.50	2.05	0.90	2.19	22.80
M. acuminata	0.00	11.50	1.98	0.90	2.11	24.91
D. sylvatica	11.00	0.00	1.90	2.37	2.03	26.94
G. fagraeoides	11.00	0.00	1.81	1.60	1.93	28.87
A. setaceus	0.00	11.00	1.81	0.90	1.93	30.80
A. kurzii	0.00	10.00	1.64	0.90	1.75	32.55
V. quinata	10.33	0.00	1.63	0.83	1.73	34.28
C. petelotii	9.67	0.00	1.62	2.42	1.72	36.01
P. cerasoides	9.33	0.00	1.54	3.74	1.65	37.65
C. sinensis	4.00	9.00	1.49	1.27	1.59	39.25
A. trewioides	0.00	8.50	1.46	0.90	1.56	40.80
A. mycrocalyx	0.00	8.50	1.44	2.70	1.53	42.34
M. glauca	0.00	8.50	1.40	0.90	1.49	43.83
A. sagxttifolius	0.00	8.50	1.40	0.90	1.49	45.32
O. compositus	0.00	8.00	1.37	0.90	1.47	46.78
D. bonii	8.33	0.00	1.30	1.07	1.39	48.17
L. flexuosum	0.00	7.50	1.29	0.90	1.37	49.54
H. hainania	7.33	0.00	1.23	1.00	1.31	50.85
S. Doederleinii	0.00	7.00	1.20	0.90	1.28	52.13
C. chinensis	0.00	7.00	1.20	0.90	1.28	53.41
T. nudiflora	7.67	0.00	1.20	1.03	1.28	54.69
C. parasiticus	4.67	6.50	1.15	0.94	1.23	55.92
A. capitata	7.33	0.00	1.14	1.14	1.22	57.14

E. chinense	0.00	6.50	1.12	0.90	1.19	58.33
T. planicaule	7.00	0.00	1.10	1.56	1.17	59.50
T. sureni	4.00	6.50	1.08	0.94	1.15	60.65
S. macrophyllus	4.67	5.50	1.06	1.03	1.13	61.79
W. tomentosa	0.00	6.00	1.03	0.90	1.10	62.89
B. fruticosa	0.00	6.00	1.03	0.90	1.10	63.99
B. papyrifera	0.00	6.00	1.03	0.90	1.10	65.09
M. suanvis	6.67	0.00	1.03	1.29	1.10	66.18
S. octophylla	0.00	6.00	0.99	0.90	1.05	67.23
B. javanica	0.00	6.00	0.99	0.90	1.05	68.29
D. angustifolia	0.00	5.50	0.94	0.90	1.01	69.29
C. philippinensis	0.00	5.50	0.90	0.90	0.96	70.26
A. acuta	3.67	4.50	0.86	1.02	0.92	71.18
F. semicordata	0.00	5.00	0.86	0.90	0.92	72.09
H. anthelminthica	5.33	0.00	0.81	1.10	0.87	72.96
O. reptans	5.33	0.00	0.81	0.99	0.86	73.83
D. duperreanum	6.00	3.00	0.81	1.26	0.86	74.69
M. denticulata	0.00	4.50	0.77	0.90	0.82	75.51
F. lacor	0.00	4.50	0.77	0.90	0.82	76.34
A. chinensie	3.67	0.00	0.72	0.65	0.77	77.10
D. esculentum	0.00	4.00	0.69	0.90	0.73	77.83
A. balansa	4.33	0.00	0.67	1.18	0.72	78.55
T. strumarum	0.00	4.00	0.66	0.90	0.70	79.25
C. harmandiana	0.00	4.00	0.66	0.90	0.70	79.95
C. wampi	0.00	4.00	0.66	0.90	0.70	80.66
A. vespertilio	0.00	4.00	0.66	0.90	0.70	81.36
S. diver	4.33	3.00	0.61	1.13	0.65	82.01
V. arborea	0.00	3.50	0.60	0.90	0.64	82.65
A. macrorrhiza	0.00	3.50	0.60	0.90	0.64	83.29
P. cattheartt (1)	4.00	0.00	0.60	0.65	0.64	83.93
E. phseoloides	3.00	0.00	0.59	0.65	0.63	84.55
B. americana	2.67	3.50	0.58	1.34	0.62	85.18
A. chinense	0.00	3.50	0.58	0.90	0.61	85.79
M. puya	3.67	0.00	0.56	1.28	0.60	86.39
E. dubius	3.67	0.00	0.56	1.19	0.60	86.99
P. truncatolobatum	3.67	0.00	0.55	0.65	0.58	87.57
M. glabriusculus	2.67	0.00	0.52	0.65	0.56	88.13
D. tonkinensis	2.67	0.00	0.52	0.65	0.56	88.69
D. fumatus	2.67	0.00	0.52	0.65	0.56	89.25
S. sinica	3.00	0.00	0.52	2.37	0.55	89.80
D. variegata	3.33	0.00	0.51	1.24	0.54	90.34

Groups MS & RU

Average dissimilarity = 72.68

	Group MS	Group RU				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
S. ilicifolius	24.33	38.50	2.62	1.16	3.60	3.60
S. macrophyllus	11.33	3.00	2.47	0.77	3.39	6.99
A. villosum	14.00	0.00	2.23	1.15	3.07	10.06
C. petelotii	17.33	9.00	2.21	1.44	3.04	13.11
B. hsienmu	15.00	14.50	2.09	2.46	2.87	15.98
H. ilicifolia	4.33	12.50	2.02	0.96	2.77	18.75
T. planicaule	14.00	3.25	1.92	1.57	2.64	21.40
P. subcordata	10.67	5.50	1.83	1.26	2.51	23.91
V. quinata	8.33	1.75	1.80	0.75	2.47	26.39
S. lanceolata	9.67	3.00	1.65	1.43	2.27	28.66
M. puya	12.00	2.25	1.50	1.88	2.06	30.72
S. mucclure	12.33	0.00	1.49	0.68	2.05	32.77
C. duniana	0.00	8.00	1.39	0.75	1.91	34.68
C. myrianthus	3.33	7.00	1.34	0.74	1.84	36.52
P. truncatolobatum	2.33	8.00	1.33	1.15	1.83	38.35
T. strumarum	7.67	0.00	1.28	1.19	1.76	40.11
C. parasiticus	8.00	6.75	1.20	1.65	1.64	41.76
G. fagraeoides	11.00	12.00	1.18	1.44	1.62	43.38
D. variegata	7.67	3.25	1.17	1.18	1.61	44.99
D. fumatus	3.33	6.00	1.13	1.05	1.55	46.54
D. bulbifera	9.00	0.00	1.09	0.68	1.50	48.04

E. scandens	5.67	0.00	1.07	0.67	1.47	49.51
D. sylvatica	7.00	4.00	1.05	1.35	1.44	50.95
C. sinensis	10.00	3.50	1.02	2.20	1.40	52.36
A. nidus	6.33	2.50	0.97	1.07	1.33	53.69
S. diver	4.33	1.25	0.95	0.78	1.30	54.99
I. angustifolia	5.00	0.00	0.94	0.67	1.29	56.28
A. capitata	4.33	1.00	0.94	0.76	1.29	57.58
E. stricta	0.00	5.75	0.92	0.70	1.27	58.84
H. hainania	4.67	0.00	0.92	0.77	1.26	60.10
M. suanvis	6.00	2.75	0.90	1.34	1.24	61.35
V. diospyroides	0.00	5.25	0.87	0.65	1.20	62.55
P. heterophyllum1	0.00	5.00	0.86	0.54	1.18	63.73
A. pinata	4.33	0.00	0.81	0.67	1.12	64.85
E. phseoloides	5.00	1.50	0.80	1.05	1.10	65.94
M. glabriusculus	2.33	3.75	0.78	0.72	1.08	67.02
A. lurida	6.33	0.00	0.77	0.68	1.05	68.08
P. petelotii	4.00	0.00	0.75	0.67	1.03	69.11
C. mitis	3.67	0.00	0.69	0.67	0.95	70.06
C. balansae	0.00	4.00	0.67	0.54	0.92	70.98
P. chinensis	3.33	0.25	0.66	0.74	0.90	71.89
S. glabra	5.33	0.00	0.65	0.68	0.89	72.77
A. chinensie	4.00	1.75	0.64	0.90	0.88	73.65
O. reptans	3.00	0.25	0.64	0.71	0.87	74.53
V. agnus-castus	3.33	0.00	0.63	0.67	0.86	75.39
C. tonkinense	0.00	3.50	0.60	0.67	0.82	76.21
H. anthelminthica	2.00	3.50	0.60	1.00	0.82	77.03
S cuminii	0.33	3.25	0.59	0.94	0.81	77.84
M. oreophyla	4.67	0.00	0.56	0.68	0.78	78.62
A. cernuum	4.67	0.00	0.56	0.68	0.78	79.40
A. balansa	4.00	0.25	0.53	1.04	0.73	80.13
I. cymosa	4.33	0.00	0.52	0.68	0.72	80.85
A. rivieri	2.33	1.75	0.52	0.79	0.72	81.57
B. americana	0.67	2.75	0.51	0.73	0.70	82.27
M. Cauda-felina	2.67	0.00	0.50	0.67	0.69	82.96
G. grossefibrosa	2.67	0.00	0.50	0.67	0.69	83.65
D. heynei	2.67	0.00	0.50	0.67	0.69	84.34
B. ovata	2.67	0.00	0.50	0.67	0.69	85.03
T. sureni	2.33	1.25	0.49	0.91	0.68	85.71
A. acuta	2.33	0.00	0.49	0.67	0.67	86.38
A. citroides	0.33	2.75	0.46	0.81	0.64	87.02
E. odoratum	3.67	0.00	0.44	0.68	0.61	87.63
T. strumarum	0.00	2.00	0.39	0.53	0.53	88.17
G. arborea	0.00	2.25	0.38	0.54	0.52	88.68
E. dubius	1.67	0.50	0.36	0.78	0.50	89.19
D. bonii	2.00	1.25	0.36	1.32	0.49	89.68
D. Sylvatica	0.33	1.75	0.36	0.58	0.49	90.17

Groups DT1 & RU

Average dissimilarity = 59.96

Species	Group DT1 Av.Abund	Group RU Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
H. ilicifolia	2.67	12.50	2.37	0.99	3.96	3.96
V. quinata	10.33	1.75	1.95	0.91	3.25	7.21
B. hsienmu	21.33	14.50	1.89	2.00	3.15	10.36
G. fagraeoides	11.00	12.00	1.75	1.53	2.92	13.28
D. sylvatica	1.00	4.00	1.70	1.34	2.84	16.11
C. duniana	0.00	8.00	1.66	0.77	2.77	18.89
P. cerasoides	9.33	1.50	1.61	2.04	2.69	21.58
P. truncatolobatum	3.67	8.00	1.58	1.01	2.63	24.21
C. petelotii	9.67	9.00	1.54	1.79	2.57	26.78
D. bonii	8.33	1.25	1.52	1.16	2.53	29.31
H. hainania	7.33	0.00	1.51	1.06	2.51	31.83
C. parasiticus	4.67	6.75	1.42	1.46	2.36	34.19
T. nudiflora	7.67	0.25	1.40	1.05	2.34	36.53
A. capitata	7.33	1.00	1.34	1.25	2.23	38.76
C. myrianthus	0.00	7.00	1.31	0.55	2.18	40.94
D. fumatus	2.67	6.00	1.27	1.07	2.12	43.06

P. subcordata	0.00	5.50	1.20	0.93	2.00	45.06
E. stricta	3.33	5.75	1.18	0.96	1.97	47.03
T. planicaule	7.00	3.25	1.14	1.51	1.89	48.93
M. suanvis	6.67	2.75	1.12	1.71	1.88	50.80
V. diospyroides	2.00	5.25	1.11	0.87	1.85	52.65
M. glabriusculus	2.67	3.75	1.11	0.92	1.85	54.50
D. duperreanum	6.00	0.25	1.09	1.32	1.83	56.33
S. macrophyllus	4.67	3.00	1.07	0.84	1.78	58.11
P. heterophyllum1	0.00	5.00	1.02	0.55	1.71	59.81
A. chinensie	3.67	1.75	0.99	0.82	1.65	61.46
O. reptans	5.33	0.25	0.96	1.06	1.60	63.07
H. anthelminthica	5.33	3.50	0.96	1.27	1.60	64.66
T. sureni	4.00	1.25	0.86	0.87	1.43	66.09
E. phseoloides	3.00	1.50	0.81	0.82	1.35	67.45
A. balansa	4.33	0.25	0.80	1.27	1.34	68.78
C. balansae	0.00	4.00	0.80	0.55	1.33	70.11
B. americana	2.67	2.75	0.78	1.17	1.31	71.42
S. diver	4.33	1.25	0.76	1.17	1.27	72.69
A. citroides	2.33	2.75	0.73	1.00	1.22	73.92
C. tonkinense	0.00	3.50	0.72	0.68	1.20	75.11
P. cattheartt (1)	4.00	0.00	0.72	0.67	1.19	76.31
S. cuminii	0.00	3.25	0.71	0.93	1.19	77.50
D. tonkinensis	2.67	1.00	0.71	0.86	1.18	78.68
D. variegata	3.33	3.25	0.69	1.22	1.15	79.83
M. puya	3.67	2.25	0.68	1.35	1.13	80.95
S. lanceolata	2.33	3.00	0.67	1.17	1.13	82.08
A. acuta	3.67	0.00	0.66	0.67	1.09	83.17
E. dubius	3.67	0.50	0.65	1.31	1.09	84.26
C. sinensis	4.00	3.50	0.63	1.14	1.05	85.32
S. sinica	3.00	0.50	0.55	1.60	0.92	86.24
Turpinia sp	2.67	0.00	0.51	0.67	0.86	87.09
A. nidus	0.00	2.50	0.51	0.55	0.85	87.95
S. ilicifolius	38.00	38.50	0.50	0.80	0.84	88.78
A. dulcis	2.00	0.00	0.50	0.67	0.83	89.62
T. strumarum	0.00	2.00	0.47	0.54	0.79	90.41

Groups DT2 & RU

Average dissimilarity = 94.49

Species	Group DT2 Av.Abund	Group RU Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
S. ilicifolius	3.50	38.50	6.23	5.66	6.59	6.59
A. villosum	20.00	0.00	3.47	0.93	3.67	10.26
E. odoratum	14.00	0.00	2.49	7.78	2.63	12.89
M. montanum	15.50	1.50	2.48	4.07	2.63	15.52
D. lineari	12.50	0.00	2.27	0.93	2.40	17.92
B. hsienmu	2.00	14.50	2.22	2.52	2.35	20.26
H. ilicifolia	0.00	12.50	2.19	1.01	2.32	22.58
A. tonkinensis	12.50	0.00	2.17	0.93	2.29	24.87
G. fagraeoides	0.00	12.00	2.16	1.46	2.29	27.16
M. acuminata	11.50	0.00	2.09	0.93	2.21	29.37
A. setaceus	11.00	0.00	1.91	0.93	2.02	31.39
A. kurzii	10.00	0.00	1.73	0.93	1.83	33.22
C. petelotii	0.00	9.00	1.59	1.12	1.68	34.90
C. sinensis	9.00	3.50	1.57	1.46	1.67	36.57
A. trewioides	8.50	0.00	1.54	0.93	1.63	38.20
A. mycrocalyx	8.50	0.00	1.52	2.88	1.61	39.81
M. glauca	8.50	0.00	1.47	0.93	1.56	41.36
A. sagxttifolius	8.50	0.00	1.47	0.93	1.56	42.92
O. compositus	8.00	0.00	1.45	0.93	1.54	44.46
C. duniana	0.00	8.00	1.42	0.76	1.51	45.97
L. flexuosum	7.50	0.00	1.36	0.93	1.44	47.41
P. truncatolobatum	0.00	8.00	1.34	0.89	1.42	48.83
S. Doederleinii	7.00	0.00	1.27	0.93	1.34	50.17
C. chinensis	7.00	0.00	1.27	0.93	1.34	51.52
E. chinense	6.50	0.00	1.18	0.93	1.25	52.77
C. parasiticus	6.50	6.75	1.15	1.35	1.22	53.99
C. myrianthus	0.00	7.00	1.14	0.54	1.21	55.19

T. sureni	6.50	1.25	1.13	1.08	1.20	56.39
W. tomentosa	6.00	0.00	1.09	0.93	1.15	57.54
B. fruticosa	6.00	0.00	1.09	0.93	1.15	58.69
B. papyrifera	6.00	0.00	1.09	0.93	1.15	59.85
D. fumatus	0.00	6.00	1.08	0.84	1.14	60.99
S. octophylla	6.00	0.00	1.04	0.93	1.10	62.09
B. javanica	6.00	0.00	1.04	0.93	1.10	63.19
P. subcordata	0.00	5.50	1.02	0.93	1.08	64.27
S. macrophyllus	5.50	3.00	1.00	0.97	1.06	65.33
D. angustifolia	5.50	0.00	1.00	0.93	1.06	66.39
C. philippinensis	5.50	0.00	0.95	0.93	1.01	67.39
E. stricta	0.00	5.75	0.95	0.71	1.00	68.40
F. semicordata	5.00	0.00	0.91	0.93	0.96	69.36
V. diospyroides	0.00	5.25	0.90	0.65	0.95	70.31
P. heterophyllum1	0.00	5.00	0.88	0.54	0.93	71.24
M. denticulata	4.50	0.00	0.82	0.93	0.86	72.10
F. lacor	4.50	0.00	0.82	0.93	0.86	72.97
A. acuta	4.50	0.00	0.82	0.93	0.86	73.83
B. americana	3.50	2.75	0.78	1.08	0.82	74.65
D. esculentum	4.00	0.00	0.73	0.93	0.77	75.42
T. strumarum	4.00	0.00	0.69	0.93	0.73	76.15
C. harmandiana	4.00	0.00	0.69	0.93	0.73	76.89
C. wampi	4.00	0.00	0.69	0.93	0.73	77.62
A. vespertilio	4.00	0.00	0.69	0.93	0.73	78.35
C. balansae	0.00	4.00	0.69	0.54	0.73	79.08
D. sylvatica	0.00	4.00	0.68	0.81	0.72	79.80
M. glabriusculus	0.00	3.75	0.66	0.54	0.70	80.50
V. arborea	3.50	0.00	0.64	0.93	0.67	81.17
A. macrorrhiza	3.50	0.00	0.64	0.93	0.67	81.84
C. tonkinense	0.00	3.50	0.62	0.68	0.65	82.49
A. chinense	3.50	0.00	0.61	0.93	0.64	83.13
S cuminii	0.00	3.25	0.61	0.93	0.64	83.78
H. anthelminthica	0.00	3.50	0.59	0.92	0.62	84.40
T. planicaule	0.00	3.25	0.56	0.81	0.59	84.99
D. variegata	0.00	3.25	0.55	0.90	0.58	85.57
S. lanceolata	0.00	3.00	0.52	0.88	0.56	86.12
S. diver	3.00	1.25	0.52	0.99	0.55	86.68
D. duperreanum	3.00	0.25	0.52	0.99	0.55	87.23
C. polyanthum	3.00	0.00	0.52	0.93	0.55	87.78
B. sapida	3.00	0.00	0.52	0.93	0.55	88.33
M. suanvis	0.00	2.75	0.52	0.92	0.55	88.88
A. citroides	0.00	2.75	0.48	0.79	0.50	89.38
C. cristata	2.50	0.00	0.45	0.93	0.48	89.86
B. megellanica	2.50	0.00	0.45	0.93	0.48	90.34

PRIMER SIMPER - scale 2

Group MS

Average similarity: 33.15

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
S. ilicifolius	12.17	4.60	1.82	13.87	13.87
G. fagraeoides	5.50	2.51	4.70	7.56	21.43
C. sinensis	5.00	2.18	4.17	6.59	28.02
M. puya	6.00	1.99	4.50	6.01	34.02
S. lanceolata	4.83	1.74	0.75	5.25	39.27
A. villosum	7.00	1.74	0.73	5.25	44.52
C. petelotii	8.67	1.59	0.69	4.80	49.32
B. hsienmu	7.50	1.45	1.15	4.38	53.69
T. planicaule	7.00	1.41	0.77	4.25	57.94
T. strumarum1	3.83	0.98	0.71	2.96	60.90
S. macrophyllus	5.67	0.90	0.26	2.71	63.61
M. suanvis	3.00	0.89	0.59	2.69	66.30
A. nidus	3.17	0.68	0.73	2.05	68.36
Vitex quinata	4.17	0.63	0.26	1.92	70.27
C. parasiticus	4.00	0.55	0.75	1.66	71.93
E. phseoloides	2.50	0.51	0.66	1.55	73.48

D. sylvatica	3.50	0.48	0.61	1.45	74.93
S. mucclure	6.17	0.40	0.26	1.20	76.13
H. hainania	2.33	0.39	0.37	1.17	77.30
P. subcordata	5.33	0.35	0.26	1.07	78.37
E. scandens	2.83	0.35	0.26	1.06	79.42
A. capitata	2.17	0.32	0.26	0.96	80.38
I. angustifolia	2.50	0.31	0.26	0.92	81.30
D. variegata	3.83	0.28	0.33	0.86	82.16
D. bulbifera	4.50	0.27	0.26	0.80	82.96
S. diver	2.17	0.26	0.26	0.80	83.76
A. pinata	2.17	0.26	0.26	0.79	84.55
A. balansa	2.00	0.24	0.72	0.74	85.29
P. chinensis	1.67	0.22	0.36	0.67	85.96
P. petelotii	2.00	0.22	0.26	0.66	86.62
D. fumatus	1.67	0.22	0.26	0.66	87.28
C. mitis	1.83	0.22	0.26	0.66	87.94
S. glabra	2.67	0.18	0.26	0.53	88.47
M. Cauda-felina	1.33	0.17	0.26	0.53	89.00
D. heynei	1.33	0.17	0.26	0.53	89.53
B. americana	1.00	0.17	0.48	0.51	90.04

Group DT1

Average similarity: 49.09

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
S. ilicifolius	19.00	14.14	4.30	28.81	28.81
B. hsienmu	10.67	5.95	3.51	12.13	40.94
D. sylvatica	5.50	3.24	5.31	6.60	47.54
C. petelotii	4.83	2.58	1.82	5.27	52.80
P. cerasoides	4.67	2.44	1.66	4.96	57.76
G. fagraeoides	5.50	2.19	1.13	4.46	62.22
T. planicaule	3.50	1.26	1.13	2.57	64.80
T. nudiflora	3.83	1.20	0.99	2.43	67.23
M. suanvis	3.33	1.16	0.78	2.35	69.59
Vitex quinata	5.17	1.05	0.50	2.15	71.73
A. capitata	3.67	1.03	0.66	2.10	73.84
D. bonii	4.17	1.03	0.79	2.09	75.93
H. hainania	3.67	0.90	0.63	1.84	77.77
D.-perreanum	3.00	0.88	0.70	1.80	79.57
A. balansa	2.17	0.64	0.76	1.31	80.88
S. diver	2.17	0.64	0.76	1.31	82.19
C. sinensis	2.00	0.64	0.76	1.30	83.50
O. reptans	2.67	0.63	0.70	1.29	84.79
M. puya	1.83	0.56	0.77	1.13	85.92
E. dubius	1.83	0.55	0.78	1.13	87.05
S. sinica	1.50	0.55	1.09	1.13	88.17
H. anthelminthica	2.67	0.55	0.65	1.11	89.28
E. stricta	1.67	0.51	0.79	1.04	90.33

Group DT2

Average similarity: 34.28

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
M. montanum	7.75	4.25	23.31	12.41	12.41
E. odoratum	7.00	3.47	4.59	10.13	22.54
A. villosum	10.00	1.90	0.41	5.56	28.10
A. mycrocalyx	4.25	1.89	2.27	5.52	33.62
A. tonkinensis	6.25	1.14	0.41	3.33	36.95
M. acuminata	5.75	1.13	0.41	3.30	40.26
D. lineari	6.25	1.13	0.41	3.30	43.56
A. kurzii	5.00	0.86	0.41	2.50	46.06
A. trewioides	4.25	0.82	0.41	2.40	48.46
M. glauca	4.25	0.76	0.41	2.22	50.68
A. setaceus	5.50	0.76	0.41	2.22	52.90
A. sagxttifolius	4.25	0.67	0.41	1.94	54.85
S. Doederleinii	3.50	0.62	0.41	1.80	56.65
L. flexuosum	3.75	0.62	0.41	1.80	58.45

O. compositus	4.00	0.62	0.41	1.80	60.25
E. chinense	3.25	0.62	0.41	1.80	62.05
C. chinensis	3.50	0.62	0.41	1.80	63.85
C. sinensis	4.50	0.57	0.41	1.67	65.52
B. javanica	3.00	0.57	0.41	1.67	67.19
W. tomentosa	3.00	0.51	0.41	1.50	68.69
B. fruticosa	3.00	0.51	0.41	1.50	70.19
B. papyrifera	3.00	0.51	0.41	1.50	71.69
S. macrophyllus	2.75	0.48	0.41	1.39	73.08
T. sureni	3.25	0.48	0.41	1.39	74.47
S. octophylla	3.00	0.48	0.41	1.39	75.86
M. denticulata	2.25	0.41	0.41	1.20	77.06
D. esculentum	2.00	0.41	0.41	1.20	78.26
D. angustifolia	2.75	0.41	0.41	1.20	79.46
C. philippinensis	2.75	0.38	0.41	1.11	80.57
C. harmandiana	2.00	0.38	0.41	1.11	81.68
C. wampi	2.00	0.38	0.41	1.11	82.79
A. vespertilio	2.00	0.38	0.41	1.11	83.91
V. arborea	1.75	0.31	0.41	0.90	84.81
F. semicordata	2.50	0.31	0.41	0.90	85.71
C. parasiticus	3.25	0.31	0.41	0.90	86.61
A. acuta	2.25	0.31	0.41	0.90	87.51
A. macrorrhiza	1.75	0.31	0.41	0.90	88.41
T. strumarum1	2.00	0.29	0.41	0.83	89.24
S. diver	1.50	0.29	0.41	0.83	90.07

Group RU

Average similarity: 42.04

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
S. ilicifolius	19.25	16.28	6.46	38.72	38.72
B. hsienmu	7.00	4.86	3.38	11.55	50.27
G. fagraeoides	6.00	3.01	0.97	7.16	57.43
H. ilicifolia	6.25	2.20	0.84	5.24	62.68
C. petelotii	4.50	1.75	0.72	4.16	66.83
C. parasiticus	3.38	1.46	0.95	3.46	70.30
P. truncatolobatum	4.00	1.11	0.50	2.64	72.94
P. subcordata	2.63	0.98	0.50	2.32	75.26
C. sinensis	1.75	0.84	0.91	1.99	77.25
C. duniana	4.00	0.83	0.44	1.98	79.23
D. fumatus	3.00	0.77	0.46	1.83	81.06
S. macrophyllus	2.38	0.73	0.50	1.73	82.79
E. stricta	2.88	0.49	0.49	1.18	83.96
H. anthelminthica	1.75	0.49	0.49	1.17	85.14
D. sylvatica	2.00	0.47	0.46	1.12	86.26
D. variegata	1.63	0.45	0.49	1.06	87.32
M. suanvis	1.38	0.40	0.51	0.95	88.28
S. lanceolata	1.50	0.40	0.45	0.95	89.22
T. planicaule	1.63	0.37	0.50	0.87	90.09

Groups MS & DT1

Average dissimilarity = 68.60

	Group MS	Group DT1				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
B. hsienmu	7.50	10.67	2.47	1.85	3.60	3.60
S. ilicifolius	12.17	19.00	2.46	1.18	3.59	7.20
S. macrophyllus	5.67	2.33	2.38	0.83	3.46	10.66
C. petelotii	8.67	4.83	2.21	1.95	3.22	13.88
A. villosum	7.00	0.00	2.12	1.17	3.09	16.97
Vitex quinata	4.17	5.17	2.03	0.97	2.96	19.92
T. planicaule	7.00	3.50	1.72	1.65	2.51	22.44
S. lanceolata	4.83	1.17	1.64	1.24	2.39	24.82
D. sylvatica	3.50	5.50	1.43	1.35	2.09	26.91
S. mucclure	6.17	0.00	1.43	0.69	2.09	29.00
P. cerasoides	0.83	4.67	1.35	1.61	1.97	30.96
C. parasiticus	4.00	2.33	1.25	1.24	1.82	32.78

P. subcordata	5.33	0.00	1.24	0.69	1.80	34.58
H. hainania	2.33	3.67	1.23	1.16	1.79	36.38
M. puya	6.00	1.83	1.23	1.37	1.79	38.17
G. fagraeoides	5.50	5.50	1.23	2.26	1.79	39.95
T. strumarum1	3.83	0.00	1.22	1.15	1.77	41.73
D. bonii	1.00	4.17	1.18	0.91	1.73	43.45
T. nudiflora	0.00	3.83	1.16	1.06	1.69	45.15
A. capitata	2.17	3.67	1.15	1.06	1.67	46.82
D. variegata	3.83	1.67	1.10	1.17	1.60	48.41
D. bulbifera	4.50	0.00	1.04	0.69	1.52	49.93
E. scandens	2.83	0.00	1.01	0.69	1.47	51.40
S. diver	2.17	2.17	0.99	1.02	1.44	52.84
C. sinensis	5.00	2.00	0.98	1.40	1.43	54.27
A. nidus	3.17	0.00	0.96	1.09	1.39	55.66
A. chinensie	2.00	1.83	0.94	0.71	1.37	57.03
M. suanvis	3.00	3.33	0.93	1.08	1.36	58.40
I. angustifolia	2.50	0.00	0.89	0.69	1.30	59.69
O. reptans	1.50	2.67	0.89	1.11	1.30	60.99
D. perreanum	0.50	3.00	0.85	1.33	1.24	62.22
E. phseoloides	2.50	1.50	0.83	1.06	1.20	63.43
H. anthelminthica	1.00	2.67	0.81	1.07	1.18	64.61
A. lurida	3.17	0.33	0.80	0.80	1.17	65.78
D. fumatus	1.67	1.33	0.78	0.88	1.14	66.92
T. sureni	1.17	2.00	0.77	0.98	1.12	68.05
A. pinata	2.17	0.00	0.77	0.69	1.12	69.17
P. truncatolobatum	1.17	1.83	0.73	0.94	1.06	70.23
A. balansa	2.00	2.17	0.73	1.34	1.06	71.29
A. acuta	1.17	1.83	0.73	0.99	1.06	72.34
P. petelotii	2.00	0.00	0.71	0.67	1.04	73.38
H. ilicifolia	2.17	1.33	0.70	0.91	1.01	74.40
C. mitis	1.83	0.00	0.65	0.69	0.95	75.35
P. chinensis	1.67	0.00	0.63	0.70	0.92	76.26
S. glabra	2.67	0.00	0.62	0.69	0.90	77.17
M. glabriusculus	1.17	1.33	0.60	0.78	0.88	78.04
V. agnus-castus	1.67	0.00	0.59	0.62	0.86	78.90
P. cattheartt (1)	0.00	2.00	0.58	0.68	0.85	79.75
M. oreophyla	2.33	0.00	0.54	0.68	0.79	80.54
A. cernuum	2.33	0.00	0.54	0.68	0.79	81.33
E. dubius	0.83	1.83	0.52	1.17	0.76	82.09
D. tonkinenses	0.00	1.33	0.51	0.67	0.74	82.83
I. cymosa	2.17	0.00	0.51	0.57	0.74	83.57
E. stricta	0.00	1.67	0.50	1.17	0.72	84.29
G. grossefibrosa	1.33	0.00	0.48	0.65	0.70	84.99
M. Cauda-felina	1.33	0.00	0.47	0.69	0.69	85.68
D. heynei	1.33	0.00	0.47	0.69	0.69	86.37
B. ovata	1.33	0.00	0.47	0.66	0.69	87.06
A. citroides	0.17	1.17	0.44	0.54	0.64	87.70
S. sinica	0.67	1.50	0.43	0.85	0.62	88.32
E. odoratum	1.83	0.00	0.42	0.66	0.62	88.94
A. rivieri	1.17	0.00	0.41	0.68	0.60	89.54
C. myrianthus	1.67	0.00	0.41	0.86	0.60	90.14

Groups MS & DT2

Average dissimilarity = 90.82

Species	Group MS Av.Abund	Group DT2 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
S. ilicifolius	12.17	1.75	3.03	1.48	3.33	3.33
A. villosum	7.00	10.00	2.86	1.37	3.15	6.48
M. montanum	0.00	7.75	2.23	4.68	2.45	8.94
C. petelotii	8.67	0.00	2.19	1.19	2.41	11.35
S. macrophyllus	5.67	2.75	2.09	0.96	2.31	13.65
D. lineari	0.00	6.25	1.83	0.94	2.02	15.67
A. tonkinensis	0.00	6.25	1.77	0.95	1.94	17.62
T. planicaule	7.00	0.00	1.73	1.33	1.91	19.53
M. acuminata	0.00	5.75	1.69	0.94	1.86	21.39
E. odoratum	1.83	7.00	1.69	1.67	1.86	23.25
S. lanceolata	4.83	0.00	1.58	1.26	1.74	24.99

A. setaceus	0.00	5.50	1.55	0.89	1.71	26.70
B. hsienmu	7.50	1.00	1.55	1.06	1.71	28.41
M. puya	6.00	0.00	1.55	2.58	1.71	30.12
G. fagraeoides	5.50	0.00	1.54	5.13	1.69	31.81
Vitex quinata	4.17	0.00	1.42	0.69	1.56	33.37
A. kurzii	0.00	5.00	1.41	0.94	1.56	34.92
C. sinensis	5.00	4.50	1.33	1.86	1.47	36.39
S. mucclure	6.17	0.00	1.31	0.69	1.45	37.84
A. trewioides	0.00	4.25	1.25	0.94	1.37	39.21
C. parasiticus	4.00	3.25	1.24	1.12	1.36	40.58
A. mycrocalyx	0.00	4.25	1.23	2.38	1.36	41.93
M. glauca	0.00	4.25	1.20	0.94	1.32	43.25
A. sagxttifolius	0.00	4.25	1.20	0.92	1.32	44.58
O. compositus	0.00	4.00	1.17	0.90	1.29	45.86
P. subcordata	5.33	0.00	1.14	0.69	1.25	47.12
L. flexuosum	0.00	3.75	1.10	0.92	1.21	48.33
C. chinensis	0.00	3.50	1.03	0.92	1.14	49.46
S. Doederleinii	0.00	3.50	1.03	0.93	1.13	50.59
M. suanvis	3.00	0.00	0.97	1.08	1.07	51.66
D. bulbifera	4.50	0.00	0.96	0.69	1.05	52.71
E. chinense	0.00	3.25	0.96	0.94	1.05	53.76
T. strumarum1	3.83	2.00	0.93	1.23	1.03	54.79
T. sureni	1.17	3.25	0.93	1.10	1.02	55.81
W. tomentosa	0.00	3.00	0.88	0.91	0.97	56.78
E. scandens	2.83	0.00	0.88	0.69	0.97	57.75
B. fruticosa	0.00	3.00	0.88	0.93	0.97	58.72
B. papyrifera	0.00	3.00	0.88	0.93	0.97	59.69
A. nidus	3.17	0.00	0.85	1.11	0.94	60.63
B. javanica	0.00	3.00	0.85	0.95	0.93	61.56
S. octophylla	0.00	3.00	0.85	0.92	0.93	62.49
D. variegata	3.83	0.00	0.84	0.76	0.92	63.42
D. sylvatica	3.50	0.00	0.83	1.05	0.92	64.33
S. diver	2.17	1.50	0.83	0.98	0.91	65.24
D. angustifolia	0.00	2.75	0.80	0.89	0.89	66.13
I. angustifolia	2.50	0.00	0.78	0.69	0.86	66.99
C. philippinensis	0.00	2.75	0.78	0.89	0.86	67.84
H. hainania	2.33	0.00	0.75	0.77	0.83	68.67
F. semicordata	0.00	2.50	0.74	0.82	0.81	69.48
A. capitata	2.17	0.00	0.74	0.69	0.81	70.29
E. phseoloides	2.50	0.00	0.70	1.00	0.77	71.06
A. acuta	1.17	2.25	0.68	1.07	0.75	71.81
A. pinata	2.17	0.00	0.67	0.69	0.74	72.55
A. lurida	3.17	0.00	0.67	0.66	0.74	73.29
M. denticulata	0.00	2.25	0.66	0.94	0.73	74.02
F. lacor	0.00	2.25	0.65	0.75	0.72	74.74
P. petelotii	2.00	0.00	0.63	0.67	0.69	75.43
D. esculentum	0.00	2.00	0.59	0.94	0.65	76.08
C. mitis	1.83	0.00	0.57	0.69	0.63	76.70
S. glabra	2.67	0.00	0.57	0.69	0.63	77.33
C. wampi	0.17	2.00	0.57	0.98	0.62	77.95
C. harmandiana	0.00	2.00	0.57	0.95	0.62	78.57
A. vespertilio	0.00	2.00	0.57	0.95	0.62	79.20
P. chinensis	1.67	0.00	0.54	0.71	0.60	79.80
D. fumatus	1.67	0.00	0.52	0.69	0.57	80.37
V. agnus-castus	1.67	0.00	0.52	0.63	0.57	80.94
V. arborea	0.00	1.75	0.51	0.93	0.56	81.50
O. reptans	1.50	0.00	0.51	0.64	0.56	82.06
A. macrorrhiza	0.83	1.75	0.51	1.08	0.56	82.62
B. americana	1.00	1.75	0.50	1.18	0.55	83.17
M. oreophyla	2.33	0.00	0.50	0.68	0.55	83.72
A. cernuum	2.33	0.00	0.50	0.68	0.55	84.27
A. chinense	0.00	1.75	0.49	0.93	0.54	84.81
A. balansa	2.00	0.00	0.47	0.89	0.52	85.33
I. cymosa	2.17	0.00	0.47	0.57	0.51	85.85
H. ilicifolia	2.17	0.00	0.46	0.63	0.50	86.35
A. chinensie	2.00	0.00	0.43	0.64	0.47	86.82
D. perreanum	0.50	1.50	0.43	1.21	0.47	87.29
C. polyanthum	0.00	1.50	0.42	0.95	0.47	87.76
B. sapida	0.00	1.50	0.42	0.95	0.47	88.23

G. grossefibrosa	1.33	0.00	0.42	0.66	0.46	88.69
M. Cauda-felina	1.33	0.00	0.42	0.69	0.46	89.15
D. heynei	1.33	0.00	0.42	0.69	0.46	89.60
B. ovata	1.33	0.00	0.41	0.67	0.46	90.06

Groups DT1 & DT2

Average dissimilarity = 94.02

Species	Group DT1 Av.Abund	Group DT2 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
S. ilicifolius	19.00	1.75	5.84	4.54	6.21	6.21
A. villosum	0.00	10.00	3.29	0.96	3.50	9.71
B. hsienmu	10.67	1.00	3.10	2.88	3.30	13.01
M. montanum	0.00	7.75	2.60	6.38	2.77	15.78
E. odoratum	0.00	7.00	2.37	3.51	2.52	18.30
D. lineari	0.00	6.25	2.15	0.95	2.28	20.58
A. tonkinensis	0.00	6.25	2.06	0.96	2.19	22.77
M. acuminata	0.00	5.75	1.98	0.96	2.11	24.87
D. sylvatica	5.50	0.00	1.88	1.84	2.00	26.87
A. setaceus	0.00	5.50	1.81	0.90	1.92	28.80
G. fagraeoides	5.50	0.00	1.79	1.44	1.90	30.70
A. kurzii	0.00	5.00	1.64	0.96	1.75	32.45
C. petelotii	4.83	0.00	1.63	2.02	1.73	34.18
Vitex quinata	5.17	0.00	1.62	0.88	1.73	35.91
P. cerasoides	4.67	0.00	1.53	2.21	1.62	37.54
C. sinensis	2.00	4.50	1.49	1.13	1.59	39.13
A. trewioides	0.00	4.25	1.46	0.96	1.55	40.68
A. mycrocalyx	0.00	4.25	1.44	2.55	1.53	42.21
M. glauca	0.00	4.25	1.40	0.96	1.49	43.70
A. sagxttifolius	0.00	4.25	1.40	0.94	1.49	45.19
O. compositus	0.00	4.00	1.37	0.92	1.46	46.64
C. parasiticus	2.33	3.25	1.32	0.99	1.40	48.04
D. bonii	4.17	0.00	1.29	0.94	1.37	49.41
L. flexuosum	0.00	3.75	1.29	0.93	1.37	50.78
H. hainania	3.67	0.00	1.21	0.97	1.29	52.07
C. chinensis	0.00	3.50	1.21	0.94	1.29	53.35
S. Doederleinii	0.00	3.50	1.20	0.95	1.28	54.63
T. nudiflora	3.83	0.00	1.20	1.10	1.27	55.90
A. capitata	3.67	0.00	1.14	1.12	1.21	57.12
T. sureni	2.00	3.25	1.14	1.05	1.21	58.32
E. chinense	0.00	3.25	1.12	0.95	1.19	59.52
T. planicaule	3.50	0.00	1.09	1.49	1.16	60.68
S. macrophyllus	2.33	2.75	1.06	1.08	1.13	61.81
W. tomentosa	0.00	3.00	1.04	0.93	1.10	62.91
B. fruticosa	0.00	3.00	1.03	0.94	1.09	64.01
B. papyrifera	0.00	3.00	1.03	0.94	1.09	65.10
M. suanvis	3.33	0.00	1.03	1.35	1.09	66.19
B. javanica	0.00	3.00	0.99	0.96	1.05	67.24
S. octophylla	0.00	3.00	0.99	0.94	1.05	68.29
D. angustifolia	0.00	2.75	0.94	0.91	1.00	69.29
C. philippinensis	0.00	2.75	0.90	0.90	0.96	70.26
A. acuta	1.83	2.25	0.89	1.05	0.94	71.20
F. semicordata	0.00	2.50	0.87	0.83	0.92	72.12
D. perreanum	3.00	1.50	0.86	1.45	0.91	73.04
H. anthelminthica	2.67	0.00	0.81	0.94	0.86	73.90
O. reptans	2.67	0.00	0.81	1.04	0.86	74.76
M. denticulata	0.00	2.25	0.77	0.96	0.82	75.58
F. lacor	0.00	2.25	0.77	0.77	0.81	76.40
D. esculentum	0.00	2.00	0.69	0.96	0.73	77.13
A. chinensie	1.83	0.00	0.69	0.49	0.73	77.86
A. balansa	2.17	0.00	0.68	1.16	0.72	78.58
C. harmandiana	0.00	2.00	0.66	0.96	0.70	79.28
C. wampi	0.00	2.00	0.66	0.96	0.70	79.98
A. vespertilio	0.00	2.00	0.66	0.96	0.70	80.68
T. strumarum1	0.00	2.00	0.66	0.91	0.70	81.38
S. diver	2.17	1.50	0.61	1.13	0.65	82.02
V. arborea	0.00	1.75	0.60	0.95	0.64	82.66
A. macrorrhiza	0.00	1.75	0.60	0.95	0.64	83.30

P. cattheartt (1)	2.00	0.00	0.60	0.69	0.64	83.94
E. phseoloides	1.50	0.00	0.59	0.68	0.63	84.57
B. americana	1.33	1.75	0.58	1.25	0.62	85.19
A. chinense	0.00	1.75	0.58	0.94	0.61	85.80
M. puya	1.83	0.00	0.56	1.24	0.60	86.40
E. dubius	1.83	0.00	0.56	1.25	0.60	87.00
P. truncatolobatum	1.83	0.00	0.55	0.65	0.58	87.58
D. fumatus	1.33	0.00	0.54	0.58	0.57	88.16
S. sinica	1.50	0.00	0.54	0.98	0.57	88.73
M. glabriusculus	1.33	0.00	0.53	0.65	0.56	89.29
D. tonkinenses	1.33	0.00	0.52	0.69	0.56	89.85
D. variegata	1.67	0.00	0.51	1.09	0.55	90.40

Groups MS & RU

Average dissimilarity = 73.37

	Group MS	Group RU				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
S. ilicifolius	12.17	19.25	2.61	1.19	3.56	3.56
S. macrophyllus	5.67	2.38	2.52	0.92	3.43	6.99
C. petelotii	8.67	4.50	2.43	1.62	3.31	10.29
A. villosum	7.00	0.00	2.22	1.18	3.02	13.32
H. ilicifolia	2.17	6.25	2.04	1.02	2.79	16.10
B. hsienmu	7.50	7.00	2.02	2.20	2.76	18.86
T. planicaule	7.00	1.63	1.91	1.53	2.60	21.46
P. subcordata	5.33	2.63	1.79	1.27	2.44	23.90
Vitex quinata	4.17	0.88	1.79	0.78	2.44	26.34
S. lanceolata	4.83	1.50	1.65	1.28	2.25	28.60
S. mucclure	6.17	0.00	1.48	0.70	2.02	30.62
M. puya	6.00	1.13	1.48	1.74	2.02	32.64
C. duniana	0.00	4.00	1.38	0.73	1.88	34.52
C. myrianthus	1.67	3.50	1.34	0.75	1.82	36.34
P. truncatolobatum	1.17	4.00	1.33	1.18	1.81	38.15
T. strumarum1	3.83	0.00	1.28	1.17	1.74	39.89
G. fagraeoides	5.50	6.00	1.25	1.27	1.71	41.60
C. parasiticus	4.00	3.38	1.24	1.30	1.69	43.30
D. variegata	3.83	1.63	1.17	1.19	1.59	44.89
D. fumatus	1.67	3.00	1.13	1.00	1.54	46.42
D. bulbifera	4.50	0.00	1.08	0.69	1.47	47.89
D. sylvatica	3.50	2.00	1.06	1.36	1.45	49.34
E. scandens	2.83	0.00	1.06	0.70	1.45	50.79
C. sinensis	5.00	1.75	1.04	1.97	1.41	52.20
M. suanvis	3.00	1.38	1.03	1.23	1.41	53.61
A. nidus	3.17	1.25	1.02	1.12	1.39	55.00
S. diver	2.17	0.63	0.94	0.77	1.28	56.28
I. angustifolia	2.50	0.00	0.94	0.70	1.28	57.56
A. capitata	2.17	0.50	0.93	0.75	1.27	58.83
E. stricta	0.00	2.88	0.92	0.69	1.25	60.08
H. hainania	2.33	0.00	0.91	0.77	1.24	61.33
E. phseoloides	2.50	1.00	0.91	1.06	1.24	62.56
V. diospyroides	0.00	2.63	0.86	0.62	1.18	63.74
P. heterophyllum	0.00	2.50	0.86	0.53	1.17	64.91
A. pinata	2.17	0.00	0.81	0.70	1.11	66.01
M. glabriusculus	1.17	1.88	0.78	0.73	1.06	67.08
A. lurida	3.17	0.00	0.76	0.67	1.03	68.11
P. petelotii	2.00	0.00	0.75	0.68	1.03	69.14
C. mitis	1.83	0.00	0.69	0.69	0.93	70.07
C. balansae	0.00	2.00	0.68	0.53	0.92	70.99
P. chinensis	1.67	0.13	0.66	0.72	0.90	71.89
S. glabra	2.67	0.00	0.64	0.70	0.87	72.77
A. chinensie	2.00	0.88	0.64	0.85	0.87	73.64
O. reptans	1.50	0.13	0.63	0.67	0.86	74.50
H. anthelminthica	1.00	1.75	0.63	1.03	0.85	75.35
V. agnus-castus	1.67	0.00	0.62	0.63	0.84	76.20
B. americana	1.00	1.38	0.60	0.92	0.81	77.01
C. tonkinense	0.00	1.75	0.60	0.63	0.81	77.82
A. rivieri	1.17	0.88	0.59	0.84	0.80	78.62
S. cuminii	0.17	1.63	0.57	0.70	0.78	79.41

M. oreophyla	2.33	0.00	0.56	0.68	0.77	80.17
A. cernuum	2.33	0.00	0.56	0.68	0.77	80.94
A. balansa	2.00	0.13	0.53	0.91	0.73	81.67
I. cymosa	2.17	0.00	0.53	0.58	0.72	82.38
G. grossefibrosa	1.33	0.00	0.50	0.66	0.69	83.07
M. Cauda-felina	1.33	0.00	0.50	0.70	0.68	83.75
D. heynei	1.33	0.00	0.50	0.70	0.68	84.43
B. ovata	1.33	0.00	0.50	0.67	0.68	85.11
T. sureni	1.17	0.63	0.49	0.92	0.67	85.78
A. acuta	1.17	0.00	0.49	0.68	0.66	86.44
A. citroides	0.17	1.38	0.47	0.82	0.63	87.08
E. odoratum	1.83	0.00	0.44	0.67	0.60	87.67
D. bonii	1.00	0.88	0.41	1.08	0.56	88.24
T. strumarum	0.00	1.00	0.38	0.53	0.52	88.76
G. arborea	0.00	1.13	0.38	0.55	0.51	89.28
E. dubius	0.83	0.25	0.36	0.73	0.50	89.77
P. cerasoides	0.83	0.75	0.36	0.80	0.49	90.26

Groups DT1 & RU

Average dissimilarity = 61.03

Species	Group DT1 Av.Abund	Group RU Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
H. ilicifolia	1.33	6.25	2.35	1.01	3.86	3.86
G. fagraeoides	5.50	6.00	1.99	1.42	3.26	7.11
Vitex quinata	5.17	0.88	1.94	0.94	3.18	10.30
B. hsienmu	10.67	7.00	1.91	1.79	3.12	13.42
D. sylvatica	5.50	2.00	1.72	1.20	2.81	16.23
P. cerasoides	4.67	0.75	1.66	1.82	2.72	18.95
C. duniana	0.00	4.00	1.66	0.75	2.71	21.66
P. truncatolobatum	1.83	4.00	1.61	1.06	2.64	24.30
C. petelotii	4.83	4.50	1.58	1.56	2.59	26.89
H. hainania	3.67	0.00	1.48	0.98	2.42	29.31
D. bonii	4.17	0.88	1.48	0.98	2.42	31.73
C. parasiticus	2.33	3.38	1.45	1.33	2.38	34.11
T. nudiflora	3.83	0.13	1.40	1.07	2.29	36.40
A. capitata	3.67	0.50	1.36	1.15	2.23	38.63
D. fumatus	1.33	3.00	1.35	1.02	2.22	40.84
C. myrianthus	0.00	3.50	1.32	0.56	2.16	43.00
S. macrophyllus	2.33	2.38	1.24	1.13	2.04	45.04
E. stricta	1.67	2.88	1.18	0.91	1.93	46.97
V. diospyroides	1.00	2.63	1.16	0.84	1.91	48.87
T. planicaule	3.50	1.63	1.15	1.33	1.88	50.75
P. subcordata	0.00	2.63	1.14	0.93	1.87	52.62
M. suanvis	3.33	1.38	1.14	1.44	1.86	54.49
M. glabriusculus	1.33	1.88	1.11	0.91	1.82	56.31
D.-perreanum	3.00	0.13	1.09	1.24	1.78	58.09
A. chinensie	1.83	0.88	1.04	0.66	1.71	59.80
P. heterophyllum	0.00	2.50	1.03	0.54	1.69	61.49
H. anthelminthica	2.67	1.75	1.03	1.14	1.68	63.17
O. reptans	2.67	0.13	0.96	1.07	1.57	64.74
E. phseoloides	1.50	1.00	0.93	0.84	1.53	66.27
T. sureni	2.00	0.63	0.86	0.90	1.41	67.67
A. citroides	1.17	1.38	0.82	0.92	1.34	69.01
C. balansae	0.00	2.00	0.81	0.54	1.33	70.33
A. balansa	2.17	0.13	0.80	1.18	1.32	71.65
B. americana	1.33	1.38	0.79	1.12	1.29	72.94
S. diver	2.17	0.63	0.77	1.18	1.26	74.20
D. variegata	1.67	1.63	0.72	1.18	1.18	75.38
C. tonkinense	0.00	1.75	0.71	0.65	1.17	76.55
P. cattheartt (1)	2.00	0.00	0.71	0.70	1.17	77.72
D. tonkinenses	1.33	0.50	0.71	0.85	1.16	78.88
S. cuminii	0.00	1.63	0.69	0.70	1.14	80.02
M. puya	1.83	1.13	0.69	1.21	1.13	81.14
C. sinensis	2.00	1.75	0.68	1.20	1.12	82.26
S. lanceolata	1.17	1.50	0.67	1.09	1.10	83.36
A. acuta	1.83	0.00	0.65	0.69	1.07	84.43
S. sinica	1.50	0.25	0.65	0.94	1.07	85.50

E. dubius	1.83	0.25	0.65	1.24	1.07	86.57
Turpinia sp	1.33	0.00	0.51	0.67	0.83	87.40
S. ilicifolius	19.00	19.25	0.50	0.82	0.82	88.22
A. nidus	0.00	1.25	0.50	0.52	0.82	89.04
A. dulcis	1.00	0.00	0.49	0.66	0.80	89.84
T. strumarum	0.00	1.00	0.47	0.54	0.77	90.61

Groups DT2 & RU

Average dissimilarity = 94.40

Species	Group DT2 Av.Abund	Group RU Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
S. ilicifolius	1.75	19.25	6.21	5.87	6.57	6.57
A. villosum	10.00	0.00	3.45	0.98	3.66	10.23
E. odoratum	7.00	0.00	2.49	3.80	2.63	12.87
M. montanum	7.75	0.75	2.48	4.03	2.62	15.49
D. lineari	6.25	0.00	2.26	0.97	2.39	17.88
H. ilicifolia	0.00	6.25	2.17	1.05	2.30	20.18
A. tonkinensis	6.25	0.00	2.16	0.98	2.29	22.47
G. fagraeoides	0.00	6.00	2.15	1.37	2.28	24.75
B. hsienmu	1.00	7.00	2.11	2.56	2.23	26.98
M acuminata	5.75	0.00	2.08	0.97	2.21	29.19
A. setaceus	5.50	0.00	1.90	0.92	2.01	31.20
A. kurzii	5.00	0.00	1.73	0.97	1.83	33.03
C. petelotii	0.00	4.50	1.58	1.15	1.68	34.70
C. sinensis	4.50	1.75	1.57	1.22	1.66	36.37
A. trewioides	4.25	0.00	1.54	0.98	1.63	37.99
A. mycrocalyx	4.25	0.00	1.51	2.67	1.60	39.60
M. glauca	4.25	0.00	1.47	0.98	1.56	41.15
A. sagxttifolius	4.25	0.00	1.47	0.95	1.55	42.70
O. compositus	4.00	0.00	1.44	0.93	1.53	44.23
C. duniana	0.00	4.00	1.42	0.75	1.50	45.73
C. parasiticus	3.25	3.38	1.38	1.26	1.46	47.19
L. flexuosum	3.75	0.00	1.35	0.95	1.43	48.62
P. truncatolobatum	0.00	4.00	1.34	0.94	1.42	50.04
C. chinensis	3.50	0.00	1.27	0.95	1.35	51.39
S. Doederleinii	3.50	0.00	1.26	0.96	1.34	52.73
E. chinense	3.25	0.00	1.18	0.97	1.25	53.97
C. myrianthus	0.00	3.50	1.14	0.56	1.21	55.19
T. sureni	3.25	0.63	1.13	1.06	1.19	56.38
W. tomentosa	3.00	0.00	1.09	0.95	1.15	57.53
B. fruticosa	3.00	0.00	1.08	0.96	1.15	58.68
B. papyrifera	3.00	0.00	1.08	0.96	1.15	59.83
D. fumatus	0.00	3.00	1.08	0.83	1.14	60.97
B. javanica	3.00	0.00	1.04	0.98	1.10	62.07
S. octophylla	3.00	0.00	1.04	0.95	1.10	63.17
S. macrophyllus	2.75	2.38	1.01	1.18	1.07	64.24
D. angustifolia	2.75	0.00	0.99	0.92	1.05	65.28
P. subcordata	0.00	2.63	0.97	0.96	1.03	66.31
C. philippinensis	2.75	0.00	0.95	0.92	1.01	67.32
E. stricta	0.00	2.88	0.94	0.71	1.00	68.32
F. semicordata	2.50	0.00	0.91	0.84	0.97	69.28
V. diospyroides	0.00	2.63	0.89	0.63	0.94	70.23
P. heterophyllum	0.00	2.50	0.88	0.55	0.93	71.16
M. denticulata	2.25	0.00	0.81	0.97	0.86	72.02
A. acuta	2.25	0.00	0.81	0.90	0.86	72.88
F. lacor	2.25	0.00	0.80	0.78	0.85	73.73
B. americana	1.75	1.38	0.77	1.10	0.82	74.55
D. esculentum	2.00	0.00	0.72	0.98	0.77	75.32
C. balansae	0.00	2.00	0.70	0.54	0.74	76.05
C. harmandiana	2.00	0.00	0.69	0.98	0.73	76.78
C. wampi	2.00	0.00	0.69	0.98	0.73	77.52
A. vespertilio	2.00	0.00	0.69	0.98	0.73	78.25
T. strumarum1	2.00	0.00	0.69	0.92	0.73	78.98
D. sylvatica	0.00	2.00	0.68	0.85	0.72	79.70
M. glabriusculus	0.00	1.88	0.66	0.56	0.70	80.39
V. arborea	1.75	0.00	0.63	0.96	0.67	81.06
A. macrorrhiza	1.75	0.00	0.63	0.96	0.67	81.73

C. tonkinense	0.00	1.75	0.61	0.65	0.65	82.38
A. chinense	1.75	0.00	0.60	0.96	0.64	83.02
S. cuminii	0.00	1.63	0.59	0.71	0.63	83.65
H. anthelminthica	0.00	1.75	0.58	0.94	0.62	84.27
T. planicaule	0.00	1.63	0.55	0.80	0.58	84.85
D. variegata	0.00	1.63	0.55	0.93	0.58	85.43
S. diver	1.50	0.63	0.52	1.03	0.55	85.98
S. lanceolata	0.00	1.50	0.52	0.88	0.55	86.54
D.-perreanum	1.50	0.13	0.52	1.03	0.55	87.08
C. polyanthum	1.50	0.00	0.52	0.98	0.55	87.63
B. sapida	1.50	0.00	0.52	0.98	0.55	88.18
M. suanvis	0.00	1.38	0.51	0.79	0.54	88.72
A. citroides	0.00	1.38	0.48	0.82	0.51	89.23
C. cristata	1.25	0.00	0.45	0.93	0.48	89.71
B. megellanica	1.25	0.00	0.45	0.75	0.47	90.18

PRIMER SIMPER – scale 3

Group MS

Average similarity: 34.17

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
S. ilicifolius	4.87	4.80	1.63	14.06	14.06
G. fagraeoides	2.20	2.36	2.52	6.91	20.96
C. sinensis	2.00	1.86	1.75	5.44	26.40
C. petelotii	3.47	1.80	0.70	5.26	31.66
S. lanceolata	1.93	1.78	0.80	5.22	36.89
M. puya	2.40	1.69	1.13	4.95	41.84
A. villosum	2.80	1.68	0.72	4.93	46.77
T. planicaule	2.80	1.56	0.83	4.58	51.35
B. hsienmu	3.00	1.32	0.69	3.87	55.22
S. macrophyllus	2.27	1.25	0.32	3.66	58.87
T. strumarum	1.53	1.02	0.69	2.98	61.86
M. suanvis	1.20	0.83	0.63	2.43	64.29
A. nidus	1.27	0.63	0.60	1.83	66.12
V. quinata	1.67	0.62	0.28	1.80	67.93
C. parasiticus	1.60	0.60	0.60	1.75	69.67
S. mucclure	2.47	0.56	0.32	1.64	71.32
D. sylvatica	1.40	0.52	0.67	1.53	72.85
E. scandens	1.13	0.49	0.32	1.42	74.27
E. phseoloides	1.00	0.45	0.44	1.30	75.58
H. hainania	0.93	0.44	0.40	1.29	76.87
P. subcordata	2.13	0.44	0.32	1.27	78.14
D. bulbifera	1.80	0.36	0.32	1.06	79.21
S. diver	0.87	0.36	0.29	1.06	80.27
A. capitata	0.87	0.36	0.29	1.06	81.33
I. angustifolia	1.00	0.36	0.29	1.05	82.38
D. variegata	1.53	0.33	0.36	0.97	83.35
P. petelotii	0.80	0.33	0.32	0.96	84.32
A. pinata	0.87	0.30	0.30	0.86	85.18
C. mitis	0.73	0.26	0.30	0.77	85.95
A. balansa	0.80	0.23	0.48	0.68	86.63
A. lurida	1.27	0.22	0.31	0.64	87.27
D. fumatus	0.67	0.22	0.29	0.64	87.91
V. agnus-castus	0.67	0.22	0.29	0.63	88.54
T. tuberculatum	0.67	0.22	0.28	0.63	89.17
O. reptans	0.60	0.21	0.31	0.61	89.78
M. Cauda-felina	0.53	0.20	0.31	0.59	90.37

Group DT1

Average similarity: 47.61

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
S. ilicifolius	7.60	14.29	3.51	30.02	30.02
B. hsienmu	4.20	5.45	1.78	11.44	41.46

D. sylvatica	2.20	2.76	1.83	5.79	47.26
P. cerasoides	1.87	2.65	1.85	5.57	52.83
C. petelotii	1.93	2.47	1.24	5.19	58.01
G. fagraeoides	2.20	2.07	0.95	4.36	62.37
T. planicaule	1.40	1.15	0.78	2.41	64.78
D. bonii	1.67	1.11	0.71	2.33	67.11
V. quinata	1.93	1.10	0.51	2.30	69.42
M. suanvis	1.33	1.03	0.78	2.15	71.57
T. nudiflora	1.53	0.99	0.63	2.07	73.64
D. duperreanum	1.20	0.97	0.69	2.03	75.67
A. capitata	1.47	0.93	0.65	1.94	77.61
H. hainania	1.47	0.91	0.46	1.92	79.53
A. balansa	0.87	0.74	0.81	1.56	81.09
S. diver	0.87	0.65	0.67	1.37	82.46
H. anthelminthica	1.07	0.62	0.54	1.31	83.77
C. sinensis	0.80	0.51	0.56	1.07	84.84
O. reptans	1.07	0.51	0.45	1.07	85.91
M. puya	0.73	0.47	0.57	0.99	86.91
E. phseoloides	0.60	0.44	0.31	0.93	87.84
B. americana	0.53	0.44	0.60	0.91	88.75
E. dubius	0.73	0.37	0.47	0.77	89.52
D. tonkinensis	0.53	0.36	0.30	0.75	90.27

Group DT2

Average similarity: 34.10

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
E. odoratum	2.80	3.59	4.43	10.52	10.52
A. villosum	4.00	2.56	0.53	7.49	18.01
M. acuminata	2.30	1.55	0.52	4.53	22.55
D. lineari	2.50	1.54	0.51	4.51	27.05
A. mycrocalyx	1.70	1.37	1.01	4.02	31.07
A. tonkinensis	2.50	1.34	0.52	3.92	34.99
A. kurzii	2.00	1.03	0.50	3.02	38.01
A. setaceus	2.20	0.95	0.50	2.78	40.78
A. sagxttifolius	1.70	0.85	0.51	2.51	43.29
M. glauca	1.70	0.83	0.49	2.44	45.73
O. compositus	1.60	0.82	0.52	2.41	48.14
L.flexuosum	1.50	0.82	0.47	2.39	50.53
C. chinensis	1.40	0.80	0.47	2.35	52.88
M. montanum	1.60	0.77	0.50	2.26	55.14
C. sinensis	1.80	0.77	0.46	2.25	57.38
E. chinense	1.30	0.75	0.52	2.21	59.60
A. trewioides	1.70	0.73	0.46	2.14	61.74
S. Doederleinii	1.40	0.68	0.47	1.99	63.72
T. sureni	1.30	0.67	0.52	1.97	65.69
C. philippinensis	1.10	0.64	0.53	1.87	67.57
B. javanica	1.20	0.64	0.53	1.87	69.44
W. tomentosa	1.20	0.61	0.48	1.80	71.24
B. papyrifera	1.20	0.61	0.49	1.79	73.02
B. fruticosa	1.20	0.61	0.49	1.78	74.80
S. octophylla	1.20	0.60	0.48	1.75	76.55
F. semicordata	1.00	0.58	0.49	1.71	78.25
C. parasiticus	1.30	0.55	0.42	1.61	79.86
S. macrophyllus	1.10	0.44	0.48	1.29	81.15
D. angustifolia	1.10	0.43	0.46	1.26	82.41
C. harmandiana	0.80	0.41	0.49	1.21	83.62
A. vespertilio	0.80	0.41	0.50	1.20	84.82
V. arborea	0.70	0.39	0.51	1.16	85.98
D. esculentum	0.80	0.39	0.51	1.16	87.13
S. ilicifolius	0.70	0.35	0.51	1.03	88.16
T. strumarum	0.80	0.35	0.51	1.02	89.19
A. macrorrhiza	0.70	0.33	0.37	0.97	90.16

Group RU

Average similarity: 41.97

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
S. ilicifolius	7.70	16.21	5.11	38.63	38.63
B. hsienmu	2.90	4.37	1.82	10.41	49.04
G. fagraeoides	2.40	3.02	0.88	7.19	56.22
H. ilicifolia	2.50	2.41	0.80	5.73	61.96
C. petelotii	1.80	1.66	0.66	3.96	65.91
C. parasiticus	1.35	1.35	0.83	3.21	69.12
P. truncatolobatum	1.60	1.07	0.50	2.55	71.67
P. subcordata	1.10	1.05	0.53	2.51	74.18
C. duniana	1.60	1.01	0.42	2.40	76.58
C. sinensis	0.70	0.78	0.70	1.86	78.44
D. fumatus	1.20	0.76	0.43	1.82	80.26
S. macrophyllus	0.95	0.68	0.45	1.61	81.87
E. stricta	1.15	0.55	0.40	1.32	83.19
D. sylvatica	0.80	0.53	0.50	1.27	84.46
S. cuminii	0.65	0.43	0.39	1.02	85.48
C. myrianthus	1.40	0.43	0.23	1.02	86.50
V. diospyroides	1.05	0.41	0.29	0.99	87.49
M. suanvis	0.55	0.35	0.34	0.84	88.33
D. variegata	0.65	0.35	0.39	0.83	89.15
A. citroides	0.55	0.32	0.41	0.77	89.92
T. planicaule	0.65	0.32	0.38	0.77	90.69

Groups MS & DT1

Average dissimilarity = 71.12

	Group MS	Group DT1				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
B. hsienmu	3.00	4.20	2.62	1.57	3.68	3.68
S. ilicifolius	4.87	7.60	2.47	1.13	3.48	7.16
S. macrophyllus	2.27	0.93	2.39	0.82	3.35	10.52
C. petelotii	3.47	1.93	2.29	1.84	3.22	13.74
V. quinata	1.67	1.93	2.18	0.91	3.07	16.81
A. villosum	2.80	0.00	2.11	1.09	2.96	19.77
T. planicaule	2.80	1.40	1.74	1.45	2.45	22.22
S. lanceolata	1.93	0.47	1.65	1.08	2.33	24.55
D. sylvatica	1.40	2.20	1.51	1.02	2.12	26.67
M. puya	2.40	0.73	1.48	1.39	2.08	28.75
S. mucclure	2.47	0.00	1.43	0.70	2.02	30.77
H. hainania	0.93	1.47	1.35	1.04	1.89	32.66
P. cerasoides	0.40	1.87	1.33	1.56	1.87	34.53
G. fagraeoides	2.20	2.20	1.31	1.45	1.84	36.37
A. capitata	0.87	1.47	1.31	0.98	1.84	38.21
C. parasiticus	1.60	0.93	1.28	1.07	1.80	40.01
D. bonii	0.40	1.67	1.26	0.96	1.77	41.78
P. subcordata	2.13	0.00	1.24	0.67	1.75	43.53
T. strumarum	1.53	0.00	1.22	1.08	1.71	45.24
T. nudiflora	0.00	1.53	1.16	0.94	1.62	46.87
C. sinensis	2.00	0.80	1.15	1.23	1.61	48.48
D. variegata	1.53	0.67	1.13	1.00	1.59	50.07
M. suanvis	1.20	1.33	1.12	1.12	1.58	51.65
D. bulbifera	1.80	0.00	1.04	0.67	1.47	53.11
S. diver	0.87	0.87	1.03	0.94	1.45	54.56
E. scandens	1.13	0.00	1.02	0.68	1.43	55.99
O. reptans	0.60	1.07	1.00	0.91	1.40	57.39
A. nidus	1.27	0.00	0.95	0.95	1.34	58.73
A. chinensis	0.80	0.73	0.94	0.67	1.32	60.06
H. anthelminthica	0.40	1.07	0.94	0.89	1.32	61.38
E. phseoloides	1.00	0.60	0.90	0.96	1.27	62.64
I. angustifolia	1.00	0.00	0.89	0.64	1.25	63.90
D. duperreanum	0.20	1.20	0.88	1.23	1.23	65.13
D. fumatus	0.67	0.53	0.85	0.75	1.20	66.33
A. lurida	1.27	0.13	0.80	0.73	1.13	67.45
T. sureni	0.47	0.80	0.77	0.85	1.09	68.54
A. acuta	0.47	0.73	0.77	0.79	1.08	69.62
A. pinata	0.87	0.00	0.77	0.63	1.08	70.70
P. truncatolobatum	0.47	0.73	0.76	0.82	1.07	71.77
H. ilicifolia	0.87	0.53	0.73	0.84	1.03	72.80

A. balansa	0.80	0.87	0.73	1.12	1.02	73.82
P. petelotii	0.80	0.00	0.72	0.67	1.01	74.84
C. mitis	0.73	0.00	0.65	0.65	0.91	75.75
T. tuberculatum	0.67	0.00	0.63	0.56	0.89	76.63
E. dubius	0.33	0.73	0.63	0.91	0.88	77.52
M. glabriusculus	0.47	0.53	0.62	0.72	0.87	78.39
S. glabra	1.07	0.00	0.62	0.63	0.87	79.26
V. agnus-castus	0.67	0.00	0.59	0.62	0.83	80.09
P. cattheartt (1)	0.00	0.80	0.58	0.55	0.81	80.91
S. sinica	0.27	0.60	0.56	0.71	0.78	81.69
A. cernuum	0.93	0.00	0.55	0.61	0.77	82.46
M. oreophyla	0.93	0.00	0.54	0.62	0.76	83.22
D. tonkinensis	0.00	0.53	0.51	0.64	0.72	83.94
I. cymosa	0.87	0.00	0.51	0.55	0.71	84.66
E. stricta	0.00	0.67	0.50	0.76	0.70	85.36
D. heynei	0.53	0.00	0.49	0.48	0.69	86.04
M. Cauda-felina	0.53	0.00	0.47	0.66	0.66	86.71
G. grossefibrosa	0.53	0.00	0.47	0.49	0.66	87.37
B. americana	0.40	0.53	0.47	0.94	0.66	88.02
B. ovata	0.53	0.00	0.46	0.55	0.65	88.68
A. citroides	0.07	0.47	0.45	0.48	0.63	89.31
E. odoratum	0.73	0.00	0.42	0.59	0.60	89.90
A. rivieri	0.47	0.00	0.41	0.57	0.57	90.48

Groups MS & DT2

Average dissimilarity = 91.56

Species	Group MS Av.Abund	Group DT2 Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
S. ilicifolius	4.87	0.70	3.08	1.46	3.36	3.36
A. villosum	2.80	4.00	2.89	1.32	3.16	6.52
C. petelotii	3.47	0.00	2.21	1.17	2.42	8.93
S. macrophyllus	2.27	1.10	2.12	0.92	2.32	11.25
D. lineari	0.00	2.50	1.87	0.92	2.05	13.30
B. hsienmu	3.00	0.40	1.77	1.18	1.94	15.24
E. odoratum	0.73	2.80	1.77	1.80	1.93	17.16
A. tonkinensis	0.00	2.50	1.76	0.92	1.92	19.09
T. planicaule	2.80	0.00	1.76	1.32	1.92	21.00
M. acuminata	0.00	2.30	1.73	0.95	1.89	22.90
S. lanceolata	1.93	0.00	1.62	1.15	1.77	24.66
M. puya	2.40	0.00	1.58	1.59	1.73	26.39
G. fagraeoides	2.20	0.00	1.56	2.96	1.70	28.09
A. setaceus	0.00	2.20	1.56	0.80	1.70	29.79
C. sinensis	2.00	1.80	1.47	1.53	1.61	31.40
V. quinata	1.67	0.00	1.43	0.60	1.56	32.96
A. kurzii	0.00	2.00	1.42	0.89	1.55	34.51
S. mucclure	2.47	0.00	1.33	0.70	1.45	35.96
C. parasiticus	1.60	1.30	1.29	1.03	1.41	37.37
A. trewioides	0.00	1.70	1.28	0.75	1.39	38.76
A. mycrocalyx	0.00	1.70	1.24	1.25	1.35	40.12
M. glauca	0.00	1.70	1.22	0.85	1.33	41.44
A. sagxttifolius	0.00	1.70	1.20	0.89	1.31	42.76
O. compositus	0.00	1.60	1.18	0.83	1.29	44.05
P. subcordata	2.13	0.00	1.15	0.68	1.26	45.31
M. montanum	0.00	1.60	1.14	0.85	1.24	46.55
L. flexuosum	0.00	1.50	1.12	0.86	1.22	47.77
C. chinensis	0.00	1.40	1.06	0.86	1.16	48.93
S. Doederleinii	0.00	1.40	1.05	0.79	1.15	50.08
T. strumarum	1.53	0.80	1.01	1.19	1.10	51.18
M. suanvis	1.20	0.00	0.98	0.95	1.07	52.25
E. chinense	0.00	1.30	0.97	0.89	1.06	53.32
D. bulbifera	1.80	0.00	0.97	0.67	1.06	54.37
T. sureni	0.47	1.30	0.94	0.96	1.03	55.40
W. tomentosa	0.00	1.20	0.91	0.81	1.00	56.40
E. scandens	1.13	0.00	0.90	0.69	0.98	57.38
B. papyrifera	0.00	1.20	0.90	0.83	0.98	58.36
B. fruticosa	0.00	1.20	0.90	0.83	0.98	59.34
S. diver	0.87	0.60	0.87	0.86	0.95	60.29

A. nidus	1.27	0.00	0.86	0.97	0.94	61.22
B. javanica	0.00	1.20	0.86	0.86	0.93	62.16
D. variegata	1.53	0.00	0.85	0.71	0.93	63.09
S. octophylla	0.00	1.20	0.84	0.88	0.92	64.01
D. sylvatica	1.40	0.00	0.83	0.94	0.91	64.92
D. angustifolia	0.00	1.10	0.82	0.69	0.89	65.81
A. acuta	0.47	0.90	0.80	0.85	0.87	66.68
I. angustifolia	1.00	0.00	0.79	0.64	0.86	67.54
C. philippinensis	0.00	1.10	0.78	0.94	0.85	68.39
H. hainania	0.93	0.00	0.76	0.71	0.83	69.22
F. semicordata	0.00	1.00	0.76	0.86	0.83	70.05
A. capitata	0.87	0.00	0.75	0.63	0.82	70.87
E. phseoloides	1.00	0.00	0.71	0.80	0.78	71.65
A. pinata	0.87	0.00	0.68	0.64	0.74	72.39
A. lurida	1.27	0.00	0.68	0.64	0.74	73.13
M. denticulata	0.00	0.90	0.67	0.69	0.73	73.87
F. lacor Buch.	0.00	0.90	0.66	0.59	0.72	74.58
P. petelotii	0.80	0.00	0.64	0.68	0.70	75.28
A. macrorrhiza	0.33	0.70	0.60	0.86	0.65	75.93
D. esculentum	0.00	0.80	0.59	0.81	0.65	76.58
C. mitis	0.73	0.00	0.58	0.65	0.63	77.21
S. glabra	1.07	0.00	0.57	0.63	0.63	77.84
C. wampi	0.07	0.80	0.57	0.75	0.63	78.46
C. harmandiana	0.00	0.80	0.57	0.89	0.62	79.08
A. vespertilio	0.00	0.80	0.56	0.90	0.61	79.69
B. americana	0.40	0.70	0.56	0.89	0.61	80.30
T. tuberculatum	0.67	0.00	0.55	0.57	0.60	80.90
V. arborea	0.00	0.70	0.53	0.86	0.57	81.48
V. agnus-castus	0.67	0.00	0.52	0.62	0.57	82.05
D. fumatus	0.67	0.00	0.52	0.62	0.57	82.62
O. reptans	0.60	0.00	0.52	0.55	0.57	83.19
A. cernuum	0.93	0.00	0.51	0.62	0.55	83.74
M. oreophyla	0.93	0.00	0.50	0.62	0.55	84.29
A. chinense	0.00	0.70	0.50	0.62	0.54	84.83
A. balansa	0.80	0.00	0.47	0.78	0.51	85.35
I. cymosa	0.87	0.00	0.47	0.55	0.51	85.86
H. ilicifolia	0.87	0.00	0.46	0.56	0.50	86.36
D. heynei	0.53	0.00	0.43	0.48	0.47	86.83
A. chinensis	0.80	0.00	0.43	0.63	0.47	87.30
D. duperreanum	0.20	0.60	0.43	0.94	0.47	87.77
C. polyanthum	0.00	0.60	0.43	0.73	0.47	88.24
M. Cauda-felina	0.53	0.00	0.42	0.66	0.46	88.70
G. grossefibrosa	0.53	0.00	0.42	0.49	0.46	89.15
B. ovata	0.53	0.00	0.41	0.56	0.45	89.60
B. sapida	0.00	0.60	0.41	0.57	0.45	90.05

Groups DT1 & DT2

Average dissimilarity = 94.54

	Group DT1	Group DT2				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
S. ilicifolius	7.60	0.70	5.96	3.98	6.30	6.30
A. villosum	0.00	4.00	3.32	0.98	3.51	9.81
B. hsienmu	4.20	0.40	3.16	2.12	3.35	13.15
E. odoratum	0.00	2.80	2.40	3.24	2.54	15.69
D. lineari	0.00	2.50	2.20	0.94	2.33	18.02
A. tonkinensis	0.00	2.50	2.05	0.94	2.17	20.19
M. acuminata	0.00	2.30	2.04	0.96	2.16	22.35
D. sylvatica	2.20	0.00	1.92	1.30	2.03	24.38
A. setaceus	0.00	2.20	1.82	0.81	1.92	26.30
G. fagraeoides	2.20	0.00	1.81	1.27	1.91	28.21
C. petelotii	1.93	0.00	1.67	1.60	1.76	29.97
A. kurzii	0.00	2.00	1.66	0.90	1.75	31.72
P. cerasoides	1.87	0.00	1.56	2.31	1.65	33.38
V. quinata	1.93	0.00	1.55	0.82	1.64	35.02
C. sinensis	0.80	1.80	1.53	1.03	1.62	36.65
A. trewioides	0.00	1.70	1.50	0.76	1.59	38.24
A. mycrocalyx	0.00	1.70	1.45	1.28	1.54	39.77

M. glauca	0.00	1.70	1.42	0.86	1.50	41.27
A. sagxttifolius	0.00	1.70	1.40	0.90	1.48	42.76
C. parasiticus	0.93	1.30	1.40	0.89	1.48	44.24
O. compositus	0.00	1.60	1.39	0.85	1.47	45.71
M. montanum	0.00	1.60	1.33	0.87	1.41	47.12
L. flexuosum	0.00	1.50	1.32	0.88	1.39	48.51
D. bonii	1.67	0.00	1.31	0.95	1.39	49.90
C. chinensis	0.00	1.40	1.25	0.87	1.33	51.22
S. Doederleinii	0.00	1.40	1.24	0.81	1.31	52.54
H. hainania	1.47	0.00	1.22	0.84	1.30	53.83
T. nudiflora	1.53	0.00	1.21	0.97	1.28	55.11
T. sureni	0.80	1.30	1.17	1.00	1.24	56.35
S. macrophyllus	0.93	1.10	1.17	0.98	1.24	57.59
A. capitata	1.47	0.00	1.16	0.88	1.23	58.81
E. chinense	0.00	1.30	1.15	0.91	1.21	60.03
T. planicaule	1.40	0.00	1.11	1.19	1.17	61.20
W. tomentosa	0.00	1.20	1.08	0.82	1.14	62.34
B. papyrifera	0.00	1.20	1.06	0.85	1.12	63.46
B. fruticosa	0.00	1.20	1.05	0.85	1.11	64.57
M. suanvis	1.33	0.00	1.04	1.12	1.10	65.67
B. javanica	0.00	1.20	1.00	0.88	1.06	66.73
A. acuta	0.73	0.90	0.98	0.92	1.04	67.77
S. octophylla	0.00	1.20	0.98	0.90	1.04	68.81
D. angustifolia	0.00	1.10	0.96	0.70	1.01	69.82
C. philippinensis	0.00	1.10	0.91	0.95	0.96	70.78
F. semicordata	0.00	1.00	0.90	0.88	0.95	71.73
D. duperreanum	1.20	0.60	0.89	1.32	0.94	72.68
H. anthelminthica	1.07	0.00	0.83	0.91	0.88	73.55
O. reptans	1.07	0.00	0.82	0.80	0.87	74.42
M. denticulata	0.00	0.90	0.79	0.70	0.84	75.26
F. lacor Buch.	0.00	0.90	0.77	0.60	0.81	76.07
S. diver	0.87	0.60	0.74	1.10	0.78	76.85
D. esculentum	0.00	0.80	0.70	0.82	0.74	77.59
A. chinensis	0.73	0.00	0.69	0.47	0.73	78.32
A. balansa	0.87	0.00	0.69	1.17	0.73	79.04
B. americana	0.53	0.70	0.67	1.15	0.71	79.75
C. wampi	0.00	0.80	0.66	0.74	0.70	80.45
C. harmandiana	0.00	0.80	0.66	0.91	0.70	81.14
A. vespertilio	0.00	0.80	0.65	0.92	0.69	81.83
T. strumarum	0.00	0.80	0.65	0.82	0.69	82.52
A. macrorrhiza	0.00	0.70	0.63	0.76	0.67	83.19
V. arborea	0.00	0.70	0.62	0.88	0.66	83.84
P. cattheartt (1)	0.80	0.00	0.60	0.56	0.64	84.48
E. phseoloides	0.60	0.00	0.60	0.67	0.64	85.12
A. chinense	0.00	0.70	0.58	0.63	0.62	85.73
M. puya	0.73	0.00	0.57	0.94	0.61	86.34
E. dubius	0.73	0.00	0.57	0.79	0.60	86.94
P. truncatolobatum	0.73	0.00	0.56	0.65	0.59	87.53
D. fumatus	0.53	0.00	0.55	0.48	0.58	88.11
S. sinica	0.60	0.00	0.54	0.63	0.57	88.69
M. glabriusculus	0.53	0.00	0.53	0.59	0.57	89.25
D. tonkinensis	0.53	0.00	0.53	0.66	0.56	89.81
D. variegata	0.67	0.00	0.52	0.77	0.55	90.37

Groups MS & RU

Average dissimilarity = 75.06

	Group MS	Group RU				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
S. ilicifolius	4.87	7.70	2.61	1.14	3.48	3.48
S. macrophyllus	2.27	0.95	2.52	0.91	3.35	6.83
C. petelotii	3.47	1.80	2.46	1.44	3.27	10.10
B. hsienmu	3.00	2.90	2.30	1.70	3.07	13.17
A. villosum	2.80	0.00	2.20	1.10	2.93	16.10
H. ilicifolia	0.87	2.50	2.09	1.02	2.79	18.89
T. planicaule	2.80	0.65	1.92	1.42	2.56	21.45
P. subcordata	2.13	1.10	1.82	1.17	2.42	23.87
V. quinata	1.67	0.35	1.78	0.66	2.38	26.25

S. lanceolata	1.93	0.60	1.70	1.11	2.26	28.51
M. puya	2.40	0.45	1.64	1.51	2.19	30.70
S. mucclure	2.47	0.00	1.48	0.70	1.98	32.68
G. fagraeoides	2.20	2.40	1.44	1.35	1.92	34.60
C. duniana	0.00	1.60	1.38	0.72	1.84	36.44
P. truncatolobatum	0.47	1.60	1.36	0.98	1.82	38.26
C. parasiticus	1.60	1.35	1.34	1.19	1.79	40.05
C. myrianthus	0.67	1.40	1.33	0.70	1.77	41.82
T. strumarum	1.53	0.00	1.27	1.10	1.70	43.52
D. fumatus	0.67	1.20	1.21	0.87	1.61	45.12
D. variegata	1.53	0.65	1.19	0.99	1.58	46.71
C. sinensis	2.00	0.70	1.16	1.37	1.55	48.26
M. suanvis	1.20	0.55	1.09	1.04	1.45	49.71
D. bulbifera	1.80	0.00	1.08	0.68	1.44	51.15
E. scandens	1.13	0.00	1.07	0.69	1.42	52.57
A. nidus	1.27	0.50	1.06	1.04	1.41	53.98
D. sylvatica	1.40	0.80	1.05	1.10	1.40	55.38
A. capitata	0.87	0.20	0.95	0.68	1.27	56.65
S. diver	0.87	0.25	0.95	0.71	1.27	57.92
I. angustifolia	1.00	0.00	0.93	0.64	1.24	59.16
E. phseoloides	1.00	0.40	0.93	0.88	1.24	60.40
E. stricta	0.00	1.15	0.92	0.67	1.22	61.63
H. hainania	0.93	0.00	0.91	0.70	1.21	62.84
V. diospyroides	0.00	1.05	0.86	0.58	1.15	63.99
P. heterophyllum	0.00	1.00	0.85	0.50	1.13	65.12
H. anthelminthica	0.40	0.70	0.81	0.67	1.07	66.20
A. pinata	0.87	0.00	0.80	0.64	1.07	67.27
M. glabriusculus	0.47	0.75	0.78	0.70	1.05	68.31
A. lurida	1.27	0.00	0.76	0.64	1.01	69.32
P. petelotii	0.80	0.00	0.75	0.67	1.01	70.33
C. mitis	0.73	0.00	0.68	0.65	0.91	71.23
T. tuberculatum	0.67	0.05	0.67	0.58	0.90	72.13
C. balansae	0.00	0.80	0.67	0.53	0.89	73.02
A. chinensis	0.80	0.35	0.65	0.77	0.87	73.89
S. glabra	1.07	0.00	0.64	0.63	0.85	74.74
O. reptans	0.60	0.05	0.63	0.57	0.84	75.59
V. agnus-castus	0.67	0.00	0.62	0.62	0.82	76.41
A. rivieri	0.47	0.35	0.61	0.69	0.81	77.22
B. americana	0.40	0.55	0.60	0.73	0.79	78.02
C. tonkinense	0.00	0.70	0.59	0.55	0.79	78.80
S. cuminii	0.07	0.65	0.58	0.72	0.77	79.58
A. cernuum	0.93	0.00	0.57	0.62	0.75	80.33
M. oreophyla	0.93	0.00	0.56	0.62	0.75	81.08
A. balansa	0.80	0.05	0.54	0.80	0.72	81.80
I. cymosa	0.87	0.00	0.52	0.55	0.70	82.50
T. sureni	0.47	0.25	0.51	0.75	0.68	83.19
D. heynei	0.53	0.00	0.51	0.48	0.68	83.87
A. acuta	0.47	0.00	0.50	0.51	0.66	84.53
M. Cauda-felina	0.53	0.00	0.50	0.66	0.66	85.19
G. grossefibrosa	0.53	0.00	0.49	0.49	0.66	85.85
B. ovata	0.53	0.00	0.49	0.56	0.65	86.50
D. bonii	0.40	0.35	0.48	0.73	0.64	87.14
A. citroides	0.07	0.55	0.48	0.68	0.63	87.77
E. odoratum	0.73	0.00	0.44	0.59	0.58	88.36
P. cerasoides	0.40	0.30	0.40	0.71	0.53	88.89
T. strumarum (1)	0.00	0.40	0.38	0.45	0.51	89.40
G. arborea	0.00	0.45	0.38	0.54	0.50	89.90
E. dubius	0.33	0.10	0.37	0.62	0.50	90.40

Groups DT1 & RU

Average dissimilarity = 63.80

	Group DT1	Group RU				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
H. ilicifolia	0.53	2.50	2.38	1.00	3.74	3.74
B. hsienmu	4.20	2.90	2.36	1.47	3.71	7.44
G. fagraeoides	2.20	2.40	2.16	1.30	3.38	10.82
V. quinata	1.93	0.35	1.88	0.87	2.94	13.77

D. sylvatica	2.20	0.80	1.85	1.00	2.90	16.67
C. petelotii	1.93	1.80	1.84	1.47	2.89	19.55
P. cerasoides	1.87	0.30	1.68	1.80	2.64	22.19
C. duniana	0.00	1.60	1.67	0.74	2.61	24.80
P. truncatolobatum	0.73	1.60	1.65	0.98	2.59	27.39
C. parasiticus	0.93	1.35	1.57	1.11	2.46	29.85
D. bonii	1.67	0.35	1.50	0.98	2.35	32.19
D. fumatus	0.53	1.20	1.47	0.84	2.30	34.50
H. hainania	1.47	0.00	1.47	0.83	2.30	36.79
T. nudiflora	1.53	0.05	1.42	0.98	2.23	39.02
A. capitata	1.47	0.20	1.40	0.91	2.19	41.21
S. macrophyllus	0.93	0.95	1.32	0.97	2.07	43.28
C. myrianthus	0.00	1.40	1.31	0.54	2.06	45.34
T. planicaule	1.40	0.65	1.29	1.22	2.03	47.37
E. stricta	0.67	1.15	1.26	0.88	1.97	49.34
V. diospyroides	0.40	1.05	1.20	0.77	1.88	51.22
P. subcordata	0.00	1.10	1.20	0.88	1.88	53.10
M. suanvis	1.33	0.55	1.19	1.17	1.87	54.97
H. anthelminthica	1.07	0.70	1.19	1.01	1.86	56.83
M. glabriusculus	0.53	0.75	1.12	0.83	1.75	58.58
D. duperreanum	1.20	0.05	1.09	1.17	1.71	60.29
A. chinensis	0.73	0.35	1.04	0.60	1.63	61.93
P. heterophyllum	0.00	1.00	1.02	0.51	1.60	63.53
O. reptans	1.07	0.05	0.98	0.82	1.53	65.06
E. phseoloides	0.60	0.40	0.92	0.82	1.45	66.51
D. variegata	0.67	0.65	0.88	0.96	1.38	67.89
A. citroides	0.47	0.55	0.87	0.78	1.36	69.25
T. sureni	0.80	0.25	0.86	0.84	1.35	70.60
C. sinensis	0.80	0.70	0.83	1.13	1.30	71.90
S. diver	0.87	0.25	0.81	1.09	1.28	73.18
A. balansa	0.87	0.05	0.80	1.15	1.26	74.44
C. balansae	0.00	0.80	0.80	0.54	1.25	75.69
S. lanceolata	0.47	0.60	0.79	0.87	1.23	76.92
B. americana	0.53	0.55	0.78	0.99	1.23	78.15
M. puya	0.73	0.45	0.75	1.04	1.18	79.33
D. tonkinensis	0.53	0.20	0.73	0.76	1.14	80.46
C. tonkinense	0.00	0.70	0.71	0.56	1.11	81.57
P. cattheartt (1)	0.80	0.00	0.71	0.57	1.11	82.68
S. sinica	0.60	0.10	0.70	0.66	1.10	83.78
S. cuminii	0.00	0.65	0.69	0.72	1.09	84.87
E. dubius	0.73	0.10	0.69	0.83	1.08	85.95
A. acuta	0.73	0.00	0.65	0.65	1.02	86.97
S. ilicifolius	7.60	7.70	0.60	0.62	0.94	87.91
Turpinia sp	0.53	0.00	0.50	0.56	0.79	88.70
A. nidus	0.00	0.50	0.50	0.51	0.79	89.48
A. dulcis	0.40	0.00	0.48	0.51	0.75	90.24

Groups DT2 & RU

Average dissimilarity = 95.03

	Group DT2	Group RU				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
S. ilicifolius	0.70	7.70	6.31	4.79	6.64	6.64
A. villosum	4.00	0.00	3.47	0.99	3.65	10.29
E. odoratum	2.80	0.00	2.51	3.50	2.64	12.93
B. hsienmu	0.40	2.90	2.32	1.65	2.44	15.37
D. lineari	2.50	0.00	2.31	0.95	2.43	17.81
H. ilicifolia	0.00	2.50	2.22	1.04	2.33	20.14
G. fagraeoides	0.00	2.40	2.20	1.27	2.31	22.45
A. tonkinensis	2.50	0.00	2.15	0.95	2.26	24.71
M. acuminata	2.30	0.00	2.14	0.98	2.25	26.96
A. setaceus	2.20	0.00	1.90	0.82	2.00	28.96
A. kurzii	2.00	0.00	1.73	0.91	1.82	30.78
C. petelotii	0.00	1.80	1.61	1.00	1.69	32.47
C. sinensis	1.80	0.70	1.58	1.09	1.67	34.14
A. trewioides	1.70	0.00	1.58	0.77	1.66	35.80
A. mycrocalyx	1.70	0.00	1.52	1.30	1.60	37.39
M. glauca	1.70	0.00	1.49	0.87	1.56	38.96

C. parasiticus	1.30	1.35	1.49	1.09	1.56	40.52
A. sagxttifolius	1.70	0.00	1.47	0.91	1.54	42.07
O. compositus	1.60	0.00	1.46	0.86	1.53	43.60
C. duniana	0.00	1.60	1.44	0.75	1.52	45.12
M. montanum	1.60	0.30	1.40	0.96	1.47	46.59
L.flexuosum	1.50	0.00	1.38	0.89	1.45	48.05
P. truncatolobatum	0.00	1.60	1.36	0.85	1.43	49.48
C. chinensis	1.40	0.00	1.31	0.88	1.38	50.86
S. Doederleinii	1.40	0.00	1.30	0.82	1.37	52.23
E. chinense	1.30	0.00	1.20	0.92	1.27	53.49
S. macrophyllus	1.10	0.95	1.16	1.10	1.22	54.72
C. myrianthus	0.00	1.40	1.15	0.55	1.22	55.93
T. sureni	1.30	0.25	1.15	0.97	1.21	57.14
W. tomentosa	1.20	0.00	1.13	0.83	1.19	58.33
B. papyrifera	1.20	0.00	1.11	0.86	1.17	59.49
B. fruticosa	1.20	0.00	1.10	0.86	1.16	60.65
D. fumatus	0.00	1.20	1.10	0.71	1.15	61.81
B. javanica	1.20	0.00	1.05	0.89	1.10	62.91
P. subcordata	0.00	1.10	1.03	0.90	1.08	63.99
S. octophylla	1.20	0.00	1.03	0.91	1.08	65.07
D. angustifolia	1.10	0.00	1.00	0.71	1.06	66.13
E. stricta	0.00	1.15	0.96	0.69	1.01	67.14
C. philippinensis	1.10	0.00	0.95	0.96	1.00	68.14
F. semicordata	1.00	0.00	0.94	0.89	0.99	69.13
V. diospyroides	0.00	1.05	0.90	0.60	0.95	70.08
P. heterophyllum	0.00	1.00	0.89	0.51	0.93	71.01
M. denticulata	0.90	0.00	0.83	0.71	0.87	71.89
A. acuta	0.90	0.00	0.81	0.70	0.85	72.74
F. lacor Buch.	0.90	0.00	0.80	0.60	0.85	73.59
B. americana	0.70	0.55	0.79	0.92	0.84	74.42
D. esculentum	0.80	0.00	0.73	0.83	0.77	75.19
C. balansae	0.00	0.80	0.70	0.54	0.73	75.93
C. wampi	0.80	0.00	0.69	0.75	0.73	76.65
D. sylvatica	0.00	0.80	0.69	0.80	0.73	77.38
C. harmandiana	0.80	0.00	0.69	0.92	0.73	78.10
A. vespertilio	0.80	0.00	0.68	0.93	0.72	78.82
T. strumarum	0.80	0.00	0.68	0.83	0.72	79.54
M. glabriusculus	0.00	0.75	0.67	0.55	0.70	80.24
A. macrorrhiza	0.70	0.00	0.66	0.77	0.69	80.94
V. arborea	0.70	0.00	0.65	0.89	0.68	81.62
C. tonkinense	0.00	0.70	0.62	0.57	0.65	82.27
A. chinense	0.70	0.00	0.61	0.64	0.64	82.91
S. cuminii	0.00	0.65	0.60	0.73	0.63	83.54
H. anthelminthica	0.00	0.70	0.60	0.60	0.63	84.17
S. diver	0.60	0.25	0.59	0.84	0.62	84.78
D. variegata	0.00	0.65	0.56	0.70	0.59	85.37
T. planicaule	0.00	0.65	0.56	0.67	0.58	85.96
S. lanceolata	0.00	0.60	0.53	0.66	0.56	86.51
C. polyanthum	0.60	0.00	0.52	0.75	0.55	87.07
D. duperreanum	0.60	0.05	0.52	0.92	0.55	87.61
M. suanvis	0.00	0.55	0.52	0.69	0.54	88.15
B. sapida	0.60	0.00	0.50	0.58	0.52	88.68
A. citroides	0.00	0.55	0.49	0.68	0.51	89.19
C. cristata	0.50	0.00	0.47	0.48	0.49	89.68
B. megellanica	0.50	0.00	0.45	0.62	0.47	90.18

Appendix 8: PRIMER analysis by SIMPER for general ecological data collected from 12 quadrats in Ba Be National Park; Similarity Percentages - species contributions

Standardise data: No
Transform: None
Cut off for low contributions: 90.00%
Factor name: Species

Factor groups
MS, DT1, DT2, RU

Group MS

Average similarity: 73.00

Factors	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Canopy Cover	5.33	7.08	4.52	9.70	9.70
Dominant Tree	5.00	5.02	1.50	6.88	16.58
Soil pH	3.33	4.07	2.26	5.58	22.16
Liana cover	3.33	4.03	2.46	5.53	27.68
Degree of showing stone's face	3.33	3.56	3.88	4.88	32.56
Soil Type	3.33	3.54	4.52	4.85	37.41
Soil Moisture	3.00	3.54	4.52	4.85	42.26
Water Availability	3.00	3.07	1.13	4.21	46.47
Degree of carved stone cover	3.00	3.05	41.37	4.17	50.64
Litter Cover	3.00	3.05	41.37	4.17	54.82
Bush Cover	2.00	3.05	41.37	4.17	58.99
Epiphyte cover	2.33	3.05	41.37	4.17	63.17
Endangered Species	3.33	3.05	41.37	4.17	67.34
Soil Depth layer	2.33	3.05	41.37	4.17	71.51
Position	2.00	2.04	2.22	2.79	74.31
Distance to Village	2.00	2.04	2.22	2.79	77.10
Deforestation Frequency	2.00	2.02	2.46	2.76	79.87
Aspect	2.33	2.02	2.46	2.76	82.63
Color of soil	2.00	2.02	2.46	2.76	85.39
Soil without stone	1.67	1.52	41.37	2.09	87.48
Green Cover	1.00	1.52	41.37	2.09	89.57
Bamboo Cover	1.67	1.52	41.37	2.09	91.65

Group DT1

Average similarity: 83.51

Factors	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Dominant Tree	5.67	7.56	8.08	9.05	9.05
Canopy Cover	5.67	7.55	8.97	9.04	18.09
Litter Cover	4.67	5.19	3.15	6.22	24.31
Aspect	3.67	4.73	5.29	5.66	29.96
Soil without stone	4.33	4.71	6.42	5.64	35.60
Color of soil	4.00	4.71	6.42	5.64	41.24
Soil pH	3.00	4.25	56.35	5.08	46.33
Distance to Village	3.33	3.78	2.30	4.52	50.85
Water Availability	3.33	3.30	4.00	3.96	54.81
Bush Cover	2.00	2.83	56.35	3.39	58.19
Epiphyte cover	2.00	2.83	56.35	3.39	61.58
Liana cover	2.67	2.83	56.35	3.39	64.97
Endangered Species	3.67	2.83	56.35	3.39	68.36
Deforestation Frequency	2.00	2.83	56.35	3.39	71.75
Slope	2.67	2.83	56.35	3.39	75.14
Position	2.00	2.83	56.35	3.39	78.53
Soil Depth layer	2.33	2.83	56.35	3.39	81.92
Degree of showing stone's face	2.67	2.37	1.41	2.84	84.77
Soil Moisture	2.33	2.34	1.48	2.80	87.57
Degree of carved stone cover	1.67	1.89	2.30	2.26	89.83
Green Cover	1.00	1.42	56.35	1.69	91.53

Group DT2

Average similarity: 80.30

Factors	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Soil without stone	6.00	9.09	#######	11.32	11.32
Litter Cover	5.00	6.06	#######	7.55	18.87
Canopy Cover	4.00	6.06	#######	7.55	26.42
Soil Type	4.50	6.06	#######	7.55	33.96
Dominant Tree	3.50	4.55	#######	5.66	39.62
Soil Depth layer	3.50	4.55	#######	5.66	45.28
Water Availability	3.00	4.55	#######	5.66	50.94
Degree of showing stone's face	2.00	3.03	#######	3.77	54.72

Bush Cover	2.00	3.03	#######	3.77	58.49
Deforestation Frequency	3.00	3.03	#######	3.77	62.26
Aspect	3.00	3.03	#######	3.77	66.04
Position	2.50	3.03	#######	3.77	69.81
Color of soil	3.00	3.03	#######	3.77	73.58
Soil Moisture	2.50	3.03	#######	3.77	77.36
Degree of carved stone cover	1.50	1.52	#######	1.89	79.25
Green Cover	1.00	1.52	#######	1.89	81.13
Bamboo Cover	1.00	1.52	#######	1.89	83.02
Grass Cover	1.50	1.52	#######	1.89	84.91
Epiphyte cover	1.50	1.52	#######	1.89	86.79
Liana cover	2.50	1.52	#######	1.89	88.68
Endangered Species	3.00	1.52	#######	1.89	90.57

Group RU

Average similarity: 85.19

Factors	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Water Availability	5.00	6.83	27.49	8.02	8.02
Canopy Cover	5.00	6.16	6.77	7.24	15.26
Litter Cover	4.75	6.15	8.27	7.22	22.47
Position	4.25	5.47	27.49	6.42	28.89
Dominant Tree	4.75	4.86	1.26	5.70	34.59
Altitude	3.75	4.32	9.72	5.07	39.66
Soil without stone	3.50	4.10	27.49	4.81	44.47
Soil pH	3.00	4.10	27.49	4.81	49.29
Aspect	3.25	3.62	3.49	4.25	53.54
Distance to Track	3.50	3.61	3.69	4.24	57.78
Degree of showing stone's face	2.75	3.43	4.11	4.03	61.81
Epiphyte cover	2.75	2.97	4.87	3.48	65.29
Slope	2.50	2.96	5.68	3.47	68.76
Degree of carved stone cover	2.00	2.73	27.49	3.21	71.97
Bush Cover	2.25	2.73	27.49	3.21	75.18
Endangered Species	2.25	2.73	27.49	3.21	78.39
Color of soil	3.25	2.69	1.91	3.16	81.55
Deforestation Frequency	2.00	2.06	2.58	2.42	83.97
Soil Type	1.75	2.06	2.58	2.42	86.40
Soil Depth layer	1.75	2.05	2.77	2.40	88.80
Distance to Village	2.00	2.03	2.96	2.38	91.18

Groups MS & DT1

Average dissimilarity = 21.49

		Group MS	Group DT1			
Factors	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Soil without stone	1.67	4.33	1.95	1.62	9.09	9.09
Endangered Species	3.33	3.67	1.56	0.92	7.25	16.33
Litter Cover	3.00	4.67	1.55	1.45	7.23	23.56
Color of soil	2.00	4.00	1.47	1.61	6.85	30.41
Soil Type	3.33	1.67	1.38	1.40	6.43	36.84
Dominant Tree	5.00	5.67	1.32	1.11	6.15	42.99
Water Availability	3.00	3.33	1.22	1.67	5.69	48.67
Aspect	2.33	3.67	1.15	1.34	5.37	54.04
D. Visible rock	3.33	2.67	1.15	1.37	5.33	59.37
Slope	2.00	2.67	1.14	1.54	5.30	64.67
Distance to Village	2.00	3.33	1.14	1.56	5.29	69.96
Eroded stone cover	3.00	1.67	0.97	0.85	4.52	74.48
Soil Moisture	3.00	2.33	0.82	1.20	3.82	78.29
Liana cover	3.33	2.67	0.81	1.05	3.79	82.08
Soil pH	3.33	3.00	0.73	38.18	3.42	85.50
Canopy Cover	5.33	5.67	0.58	0.92	2.70	88.19
Bamboo Cover	1.67	1.00	0.50	0.67	2.34	90.53

Groups MS & DT2

Average dissimilarity = 25.40

		Group MS	Group DT2			
Factors	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Soil without stone	1.67	6.00	3.30	4.00	13.00	13.00
Dominant Tree	5.00	3.50	1.89	2.44	7.44	20.44
Litter Cover	3.00	5.00	1.79	1.67	7.03	27.47
Endangered Species	3.33	3.00	1.78	1.39	7.01	34.48
Soil pH	3.33	2.00	1.27	1.62	4.98	39.46
Soil Type	3.33	4.50	1.15	1.39	4.54	44.00
Liana cover	3.33	2.50	1.14	1.10	4.47	48.47
Eroded stone cover	3.00	1.50	1.13	0.92	4.47	52.94
D.visible rock	3.33	2.00	1.03	0.96	4.06	56.99
Aspect	2.33	3.00	1.02	1.10	4.01	61.00
Color of soil	2.00	3.00	1.02	1.28	4.00	65.01
Deforestation F	2.00	3.00	1.02	1.28	4.00	69.01
Water Availability	3.00	3.00	1.01	2.69	3.97	72.98
Canopy Cover	5.33	4.00	1.00	1.29	3.93	76.91
Soil Depth layer	2.33	3.50	0.89	1.55	3.49	80.40
Slope	2.00	1.00	0.78	0.65	3.08	83.48
Distance to Village	2.00	1.00	0.77	1.10	3.04	86.52
Epiphyte cover	2.33	1.50	0.64	1.10	2.51	89.03
Position	2.00	2.50	0.63	1.11	2.48	91.51

Groups DT1 & DT2

Average dissimilarity = 21.27

		Group DT1	Group DT2			
Factors	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Soil Type	1.67	4.50	2.08	2.36	9.80	9.80
Endangered Species	3.67	3.00	1.95	1.43	9.17	18.97
Distance to Village	3.33	1.00	1.71	2.25	8.04	27.01
Dominant Tree	5.67	3.50	1.59	2.78	7.49	34.50
Soil without stone	4.33	6.00	1.23	1.21	5.80	40.29
Canopy Cover	5.67	4.00	1.22	3.20	5.74	46.03
Slope	2.67	1.00	1.22	1.62	5.73	51.76
Liana cover	2.67	2.50	1.10	1.45	5.16	56.92
D. visible rock	2.67	2.00	0.98	2.47	4.61	61.53
Color of soil	4.00	3.00	0.98	1.29	4.60	66.13
Litter Cover	4.67	5.00	0.98	1.29	4.59	70.72
Soil Depth layer	2.33	3.50	0.86	1.55	4.02	74.74
Water Availability	3.33	3.00	0.74	1.11	3.48	78.22
Aspect	3.67	3.00	0.74	1.11	3.46	81.68
Deforestation F	2.00	3.00	0.73	0.91	3.42	85.10
Soil pH	3.00	2.00	0.73	0.91	3.42	88.51
Soil Moisture	2.33	2.50	0.61	1.09	2.89	91.40

Groups MS & RU

Average dissimilarity = 25.08

		Group MS	Group RU			
Factors	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Altitude	1.00	3.75	1.97	3.48	7.84	7.84
Dominant Tree	5.00	4.75	1.62	1.04	6.45	14.29
Position	2.00	4.25	1.61	2.42	6.44	20.73
Distance to Track	1.33	3.50	1.54	1.75	6.15	26.87
Water Availability	3.00	5.00	1.43	1.38	5.70	32.57
Litter Cover	3.00	4.75	1.39	1.46	5.55	38.12
Soil without stone	1.67	3.50	1.32	1.39	5.25	43.37
Soil Moisture	3.00	1.25	1.25	1.84	4.98	48.36
Color of soil	2.00	3.25	1.25	1.11	4.97	53.33
Liana cover	3.33	2.25	1.14	1.40	4.53	57.86
Soil Type	3.33	1.75	1.12	1.16	4.47	62.33
Slope	2.00	2.50	1.08	2.88	4.31	66.64
Endangered Species	3.33	2.25	1.04	0.78	4.15	70.79
Aspect	2.33	3.25	1.03	1.29	4.09	74.88
D. visible rock	3.33	2.75	0.79	1.08	3.15	78.03
Soil pH	3.33	3.00	0.72	26.45	2.87	80.91
Canopy Cover	5.33	5.00	0.72	1.37	2.87	83.77

Eroded stone cover	3.00	2.00	0.71	0.68	2.85	86.62
Distance to Village	2.00	2.00	0.60	1.15	2.40	89.02
Deforestation F	2.00	2.00	0.60	1.16	2.39	91.42

Groups DT1 & RU

Average dissimilarity = 19.30

		Group DT1	Group RU			
Factors	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Distance to Track	1.00	3.50	1.72	2.25	8.89	8.89
Altitude	1.33	3.75	1.67	2.56	8.64	17.53
Position	2.00	4.25	1.56	5.57	8.08	25.61
Color of soil	4.00	3.25	1.22	1.40	6.34	31.95
Endangered Species	3.67	2.25	1.21	0.77	6.28	38.23
Water Availability	3.33	5.00	1.15	1.27	5.96	44.19
Distance to Village	3.33	2.00	1.05	1.46	5.46	49.65
Liana Frequency	2.67	2.25	0.98	1.62	5.08	54.73
Dominant Tree	5.67	4.75	0.96	0.70	4.97	59.70
Soil without stone	4.33	3.50	0.92	1.15	4.76	64.46
Soil Moisture	2.33	1.25	0.86	1.45	4.47	68.93
D. visible rock	2.67	2.75	0.75	1.37	3.89	72.82
Litter Cover	4.67	4.75	0.75	1.37	3.88	76.70
Soil Type	1.67	1.75	0.64	1.84	3.30	80.00
Slope	2.67	2.50	0.58	1.15	2.99	83.00
Canopy Cover	5.67	5.00	0.57	1.18	2.97	85.97
Aspect	3.67	3.25	0.53	0.97	2.75	88.72
Epiphyte cover	2.00	2.75	0.52	0.88	2.71	91.42

Groups DT2 & RU

Average dissimilarity = 25.62

		Group DT2	Group RU			
Factors	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Soil Type	4.50	1.75	1.97	4.01	7.70	7.70
Soil without stone	6.00	3.50	1.81	2.62	7.06	14.76
Dominant Tree	3.50	4.75	1.80	4.53	7.02	21.78
Distance to Track	1.00	3.50	1.77	2.20	6.92	28.70
Altitude	1.50	3.75	1.60	2.30	6.24	34.94
Water Availability	3.00	5.00	1.44	29.76	5.61	40.55
Endangered Species	3.00	2.25	1.43	2.16	5.60	46.15
Soil Depth layer	3.50	1.75	1.26	2.48	4.91	51.05
Color of soil	3.00	3.25	1.25	1.52	4.89	55.94
Position	2.50	4.25	1.25	2.60	4.88	60.82
Liana Frequency	2.50	2.25	1.08	1.07	4.21	65.03
Slope	1.00	2.50	1.07	2.90	4.19	69.22
Soil Moisture	2.50	1.25	0.90	1.75	3.51	72.73
Epiphyte cover	1.50	2.75	0.90	1.22	3.50	76.24
Deforestation F	3.00	2.00	0.89	1.22	3.47	79.70
Canopy Cover	4.00	5.00	0.73	1.33	2.83	82.54
Litter Cover	5.00	4.75	0.72	1.84	2.81	85.35
Aspect	3.00	3.25	0.72	1.07	2.81	88.16
Soil pH	2.00	3.00	0.71	0.93	2.79	90.94

APPENDIX 9: Primer Selection and Optimization of PCR

RAPD-PCR primers were selected at random within commercial kits where all decamer primers had a GC content of 50-70% (Williams *et al.,* 1990). From previous studies (De Filippis, 1996; Langton, 2000; Sommerville, 2001; Hoang, 2002), kits A and D from Operon technologies were good at producing multiple bands in plants, but other primers were also successful.

RAMP-PCR microsatellite primers were more carefully chosen. $(AT)_n$ primers are difficult to identify and can fail to produce amplification products (Wu *et al.,* 1994). $(AG)_n$ and $(AC)_n$ motifs were found to be abundant compared to $(AT)_n$ microsatellite DNA in plants (Echt and May-Marquardt, 1977). More specifically in forest and endangered species $(AC)_n$ and $(AG)_n$ motifs were moderately abundant, but not as abundant as $(GA)_n$ microsatellites (Colleviatti *et al.,* 2001). Finally, Sanchez de la Hoz et al. (1996) used anchored microsatellite primers in RAMP-PCR reactions and found that $(AC)_n$ motifs were best with either GT or GC anchors. From the available literature above, we chose both microsatellite primers to have $(AC)_n$ motifs with 2 different anchors: one containing a TG anchor and the other containing a CA anchor not tested by Sanchez de la Hoz *et al.,* (1996). RAPD and RAMP primers are given in Table 5.1 and Table 5.2.

PCR was carried out on each of the four DNA species of *E. scandens*, *M. stipulata*, *M. suaveolens* and *S. mucclure* using 11 RAPD primers (Table 5.1) and of the 11 RAPD primers tesed 2 were chosen for further use in RAMP. Two combinations of two microsatellite primers (Table 5.2) with the 2 chosen RAPD primers (at a ratio of 2:1 microsatellite to RAPD).

Each RAMP-PCR reaction was performed in a final volume of 25µl containing 1.5x *Taq* Polymerase Reaction Buffer [67mmol/L Tris-HCl - pH 8.8, 16.6mmol/L $[NH_4]_2SO_4$, 0.45% (w/v) Triton X-100, 0.2mg/ml gelatin] (Fisher Biotech), 1.0mol/L betaine, 2mmol/L of each of dATP, dTTP, dCTP, dGTP (mix dNTP- Fisher Biotech), varying amounts of genomic DNA, $MgCl_2$ (25mM/L and 3.0µl volume, and *Taq* DNA polymerase (Fisher Biotech), with 12nmol/L of each primer or combination of one anchored microsatellite and one decamer primer (12nmol MS to 6nmol RAPD primer). Reactions were carried out in a Biometra Personal Cycler.

Table 5.1: Oligonucleotide primer sequences used to detect polymorphisms in 4 rare and endangered forest tree species by RAPD analysis in Ba Be National Park of Vietnam

PRIMER	SEQUENCE	M.W.	% GC	Tm
A8	5' GTGACGTAGG 3'	3108	60	32^{0}C
A19	5' CAAACGTCGG 3'	3264	60	32^{0}C
B10	5' CTGCTGGGAC 3'	3273	70	34^{0}C
B12	5' CCTTGACGCA 3'	3216	60	32^{0}C
C13	5' AAGCCTCGTC 3'	3216	60	32^{0}C
C19	5' GTTGCCAGCC 3'	3233	60	32^{0}C
D2	5' GGACCCAACC 3'	2982	70	34^{0}C
D14	5' CTTCCCCAAG 3'	3176	60	32^{0}C
D17	5' TTTCCCACGG 3'	3208	60	32^{0}C
D18	5' CAGAGCCAAC 3'	3272	60	32^{0}C
F15	5' CCAGTACTCC 3'	3176	60	32^{0}C

Table 5.2: Anchored microsatellite primers used to detect polymorphisms in several species and. Bases underlined at the 5' end denote the anchors.

PRIMER	SEQUENCE	Molecular weight	%GC	Tm
MS1	5' CAACACACACACAC 3'	4155	50	40.1°C
MS2	5' TGACACACACACAC 3'	4186	50	40.2°C

Optimisation of PCR conditions

To obtain reproducible results from PCRs, it is necessary to determine the optimum reaction conditions for each primer/template combination (Yoon & Glawe, 1993). In the past, all reaction components were optimised. The number of possible combinations of these components is near endless, and it is now more common to include the majority of them in excess, optimising only the concentration of $MgCl_2$ required for each primer/ template combination (Magel *et al.,* 2000). In this project, however, different amounts of genomic DNA (10, 25, 40, 50, 70 and 100ng), and two different amounts of *Taq* DNA Polymerase (1.0 and 1.5 units) were tested. Betaine was also added to the reaction mix for the reasons noted.

(a) Optimising template DNA

Genomic DNA concentrations should generally be in the range of 10 to 500ng per reaction (Swanson, 1999), though amounts of 50ng or less appear to be more common. Too much template can decrease the specificity of samples on a gel (Swanson, 1999), while too little can result in no amplification at all. Sanchez de la Hoz *et al.,* (1996) successfully used 25ng of DNA in reaction conditions very similar to those used here, therefore in this experiment we tested amounts of 10, 20 and 40ng DNA per reaction.

(b) Optimising Taq DNA polymerase.

This enzyme, originally derived from the organism *Thermus aquaticus*, is stable at high temperatures and capable of catalysing highly accurate DNA synthesis (Eckert and Kunkel, 1990). It is generally used in PCR at a rate of 0.5 to 1.5 units per reaction. Two concentrations were tested here 1.0 and 1.5 units per reaction.

(c) Addition of betaine.

Betaine is a natural plant osmoprotectant that is now regularly used as an additive in PCR reactions. The compound has been shown to alter the melting temperature of DNA so that GC-rich regions melt at temperatures more similar to AT-rich regions (Rees *et al.,* 1992). This is useful in multiplex reactions, as used here, where care must be taken to ensure the primers used have approximately the same melting temperature (Sambrook and Russell, 2001). Betaine also performs several other useful functions:

1- It improves the yield and specificity of PCR amplifications (Swanson, 1999)

2- It increases the resistance of Taq DNA Polymerase to denaturation (Hengen, 1997);

3- It allows the application of PCR to DNA samples with low levels of contaminants; and

4- It may help to increase the reproducibility of low-stringency PCR conditions such as those used in this experiment (Weissensteiner and Lanchbury, 1996).