PART IV
Exploitation and Conservation

Stephen Elliott

The Conservation Value of Doi Sutep–Pui National Park

The diversity of forest types and vascular plant species described in this monograph signifies the high conservation value of Doi Sutep–Pui National Park. The park's historical importance for development of botanical sciences in Thailand and its importance, as a type locality, to taxonomy has also already been detailed.

In addition to botanical interest, however, the park is home to a diverse fauna. Animal species include at least 326 birds (Round, 1984), 500 butterflies (Pinratana, 1977–85), 300 moths (Banziger, 1988), 61 mammals (Mahidol University Conservation Data Center, 2000; Elliott *et al.*, 1989), 28 amphibians and 50 reptiles (Nabhitabhata, 1987); all in a national park which covers just 261 km^2. Many of these animals play crucial ecological roles in the reproductive ecology of plant species on Doi Sutep–Pui by carrying out pollination and seed dispersal. Animals also influence plant community dynamics by modifying the habitat to favour certain plant species or exclude others.

Doi Sutep–Pui is also important as a site for ecological studies, which are discovering how seasonally dry forest ecosystems regenerate (Hardwick *et al.*, 1997). This knowledge is being used to improve forest management and to restore forest to degraded sites (Elliott *et al.*, 1995; Forest Restoration Research Unit, 1998). With more than 600 tree species, suited to a wide range of soil and climate conditions, Doi Sutep–Pui could provide a valuable seed source for forest restoration projects throughout northern Thailand. It could become especially important as a seed source for some of the rarer tree species (Kopachon *et al.*, 1996).

Situated so close to a major urban area, the national park is also important for environmental education. It provides ideal opportunities for field excursions and acts as an outdoor laboratory for Chiang Mai's many schools and three universities (Elliott & Beaver, 1991).

In addition to its biological value, the park also has high cultural and religious significance. Doi Sutep–Pui is most famous as the location of the Buddhist temple, Wat Prataht, which was constructed on an eastern sub-peak of the mountain, at about 1050 m above sea level, in 1372 or 1373 A.D. and is believed to house a relic of the Lord Buddha. Doi Sutep's cultural history, however, stretches back much further than the 14th century. Lawa tribal people were settled on the mountain by at least the 7th century and probably before. The guardian spirits of Chiang Mai city and Wat Prataht Doi Sutep–Pui are the ancient Lawa spirits, Pu Sae and Ya Sae. These spirits are still revered by the people of Chiang Mai and are worshipped in an annual ceremony, at the foot of Doi Sutep, near Mae Hia Nai Village, involving the sacrificial slaughter of a young buffalo. The Camadevivamsa, an early 15th century text, refers to Doi Sutep–Pui as "Sugar Cane Mountain", renowned as the home of the 7th–century Lawa sage, Vasudeva (also called Rishi Warsuthep), from whom the mọdern name of the mountain was subsequently derived (Swearer & Premchit,

1998; Higham & Thosarat, 1998). Vasudeva is a central character in local mythology. He is believed to be one of the architects of Haripunchai (today the city of Lamphun), the ancient capital of the Mon civilization in northern Thailand and to have invited Princess Chamadevi, from Lopburi, to rule over the city. With the establishment of Chiang Mai city in 1296 A.D., the mountain probably took on an even greater significance for local people, providing them with foods, medicines, bamboo, and timber to construct houses and boats.

Early citizens of Chiang Mai relied upon the mountain as a source of clean water. Until the early 20th century, the city was linked to Doi Sutep–Pui by aqueducts, which carried water from Huay Gayo (stream) to the city's northwestern corner. The mountain remains a grade B1 watershed and still supplies much of the western outskirts of Chiang Mai with water.

Today the mountain remains a sacred place of pilgrimage of the highest importance for most northern Thai people, a fact that has probably helped deter extensive forest clearance and urban development of the mountain's southern slopes. The mountain's main importance to the local economy is as an earner of foreign exchange. It is the principal tourist attraction of Chiang Mai Province, where tourism is one of the most important industries. On Doi Sutep–Pui, however, most tourists visit the temple, Puping Palace (a cool-season retreat of the Royal Family), and the Hmong hill tribe community, Ban Meo Doi Pui. Although there is a huge demand for nature-based, eco–tourism on the mountain (Elliott, 1992), it is not being met. Most tourists seeking nature walks or bird watching sites fail to obtain adequate information and leave the national park disappointed. This is a shame since, if tourism were based more on Doi Sutep–Pui's natural attractions, it would encourage conservation and could generate income to support conservation management.

With Doi Sutep–Pui serving so many different functions to different groups of people, often with conflicting interests, it is hardly surprising that the national park and its diverse botanical communities are continuously threatened with over–exploitation. Although such conflicting interests pose a considerable challenge to those responsible for managing the national park, their resolution is essential if the mountain's rich botanical heritage is to be conserved.

Threats to The Botanical Diversity of Doi Sutep–Pui National Park

Deforestation

Deforestation is the single most serious threat to botanical diversity in the national park. Being situated close to major centers of ancient civilizations, some chopping of trees for timber, firewood, and clearance of land for agricultural settlement would have occurred on Doi Sutep–Pui from the Iron Age onwards. However, major deforestation, resulting in a significant reduction of wildlife habitat and fragmentation of remaining forest, is a relatively recent occurrence (Photo 16). Reports about how much of the national park remains under forest cover are contradictory. National park officials have provided various estimates of forest cover for the national park, ranging from 40.2% to 73.5%. According to the first draft management plan for Doi Sutep–Pui National Park (Kasetsart University, 1988) between 1975 and 1985 forest cover fell from 225.34 km^2 (85.8%) to 148.98 km^2 (56.7%). Such comparisons, however, should be considered with caution, since differences in the figures can result from the different methods employed by different surveyors and different definitions of what constitutes forest. This is illustrated in the

latest study (Thailand Development Research Institute Foundation, 1997) which used computer analysis of satellite images to compare forest cover with a previous survey done in 1983. The report appears to show an increase in forest area from 173.4 km^2 (66.0%) in 1983 to 233.3 km^2 (83.1%) in 1993. The 1983 study classified degraded areas (49.4 km^2) and plantations (16.4 km^2) separately, whilst such areas were "not classified" in the later study, but must have been mistakenly classified as forest, to accumulate the total area surveyed. Areas occupied by agriculture and buildings were classified by both studies and increased from 39.7 km^2 (15.1%) in 1983 to 47.3 km^2 (16.8%) in 1993.

Several different activities have caused forest loss, but perhaps the most important have been logging in the lowlands, clearance of land for agriculture, and various tourism development projects. Although the 1997 report quoted above states that at least 16.8 % of the park has been converted to agriculture, national park officials have put this estimate as high as 43 % in recent years. Agricultural conversion usually affects large areas, often centered around hill tribe villages in the park's interior or adjacent to settlements along the boundary of the national park (Photo 1). The main reasons for this are increasing demand for agricultural products from the growing urban center of Chiang Mai and promotion of agricultural activities by several agricultural research centers based in the national park.

A huge increase in the number of people living in or around the national park has also promoted agricultural expansion at the expense of forest cover. In 1964 a survey recorded 369 people living inside what was to become Doi Sutep–Pui National Park. They were permitted to stay for the remainder of their lives, but were not allowed to sell their land. Only 148 people insisted on staying, but large numbers of immigrants soon joined them. By 1981 the number of people living in the park had increased to 1,956 and by 1988 the population had exploded to 13,694 (Kasetsart University, 1988). This last figure included people living along the boundaries of the national park, that were probably not included in earlier surveys, since the exact position of the national park boundary is uncertain and disputed. The latest report (Thailand Development Research Institute Foundation, 1997) compiles figures from the Land Department and Public Welfare Department to show a total population of 6,460 people or 1,135 families, living in 16 villages situated completely within the national park boundaries. The same report lists 76 settlements around the boundary of the national park with a total population of 51,109 people (growing at 2.4% per year) in 12,861 families (see Table 5 for 1999 hilltribe statistics). The pressure on forests near the boundaries of the national park is, therefore, clearly intense and likely to increase in the immediate future.

Many development projects that clear forest in the national park have been initiated to profit from the tourism boom. Stimulated by a phenomenal increase in land prices in the late 1980's and early 1990's, all kinds of methods were used to obtain land ownership documents for the development of resorts and other tourist attractions within the national park. Most are along the Mae Rim–Sameung road, which cuts through the northern part of the national park (Figure 1).

It is not only private tourism developers and agricultural communities who are to blame for deforestation on Doi Sutep–Pui. The establishment of government offices has also resulted in the loss of about 10 km^2 of forest. No fewer than 39 government agencies (TV transmitters, agricultural research stations, police and army posts *etc.*) lay claim to land in the park. Park officials consider that about 20 of these offices are technically illegal.The RFD themselves

recently greatly expanded tourist facilities at Montatahn Waterfalls. Many new buildings have been constructed at the expense of pristine **mxf**, thus degrading a previously beautiful area into another "resort"–like facility of not only dubious intent, but also questionable value.

Government officials advocate a pragmatic approach to the problem of encroachment by bringing encroachers to court on a case-by-case basis, rather than employing draconian measures to expel them all. However, such legal battles are lengthy and complicated due to ambiguous or forged land rights documents, often obtained with the connivance of corrupt officials. Several thousand such court cases would have to be fought to remove all encroachers from the park. Between 1987 and 1991, only 67 were successfully prosecuted and ordered to leave.

Fire

Fire is an annual hazard on Doi Sutep-Pui. It has probably always been a natural phenomenon in seasonally dry tropical forests, but human activities have greatly increased the extent and frequency of fires (Photos 4 & 17). Fires are started by local people to clear fields of weeds before planting crops and to release nutrients into the soil. Sometimes these fires escape into surrounding areas and burn out of control for many days. Local people also start fires to stimulate new growth of grass to attract game for hunting or to flush game out from dense forest. Some local people believe that fire stimulates the production of edible mushrooms, but research has shown fungal mycelia in burned areas is reduced after fire, compared with non-burnt areas (Juprachakorn, 1990; Kamsathorn, 1990). By clearing away the undergrowth, fire makes mushrooms easier to see, creating an illusion of increased production. Some fires are caused by careless behaviour, such as when cigarette butts are thrown away still alight, whilst others are started maliciously as part of local conflicts over control of the land.

The most significant effects of fire on the forest ecosystems in the national park are damage to mature vegetation, destruction of the ground flora, the soil seed bank, young tree seedlings and saplings. This destroys the ability of forest to regenerate. If fire occurs frequently enough to prevent establishment of young trees in the long term, the mature trees are not replaced when they die. This results in forest with a sparse, incomplete open canopy, a poorly developed or absent understorey, and a ground flora dominated by fire-resistant grasses. This situation already prevails in much of Doi Sutep–Pui's deciduous dipterocarp–oak forest. Eventually, this process leads to replacement of forest with degraded grassland. In degraded areas, frequent fires are one of the main factors preventing re–establishment of forest through the natural processes of succession, although lack of seed sources and seed dispersing animals are also constraints (Maxwell, 1993). Fire also has a significant impact on the forest ecosystems by causing losses of nutrients in smoke and killing ground-dwelling animals.

Studies that compared an area of deciduous dipterocarp–oak forest, protected from fire for 27–28 years with an adjacent frequently burnt area, on the lower slopes of Doi Sutep near Wat Palaht (520 m elevation), showed that frequent fires reduced both the density and species richness of the tree seedling community (Meng, 1997). Protection from fire increased the species richness of both the ground flora and tree communties (Kafle, 1997; Pokaew, 1993) and increased both the seed rain and the seed bank and soil moisture (Meng, 1997). Trees protected from fire retained their leaves for longer into the dry season and produced more fruit than trees in the burnt area (Kafle, 1997). These studies showed conclusively that protection from fire enhanced the biodiversity and conservation value of the forest.

Roads

One of the most effective methods to conserve biodiversity in any protected area is to control access, but in Doi Sutep–Pui National Park, access is neither controlled nor limited. In fact, construction of new roads and improvement of existing ones has made it easier than ever for loggers and hunters to penetrate previously inaccessible areas of the park. Road construction activities damage the vegetation and increase soil erosion, causing siltation of watercourses. Improved access facilitates activities which damage the forest *e.g.* collecting showy orchids and ferns for sale, rubbish dumping (Photo 18), tree felling *etc.*, and increases the risk of forest fires. Traffic disturbs wildlife and destroys the sense of wilderness, sought by many visitors to the park.

Extinct, Extirpated, or Endangered Plant Species

Proving that a plant species has definitely been extirpated from the national park is almost impossible, since there is always a faint chance that a species might still exist in inaccessible places, away from where we have worked. However, there are several species, which we have previously observed growing in single sites, which have disappeared in recent years and are highly likely to have become extirpated from the park. Such species include *Hoya engleriana* Hoss. (Asclepiadaceae) and *Dendrobium sutapense* Rol. *ex* Dow. (Orchidaceae).

Except for topotypes, plant species recorded on Doi Sutep–Pui by other authors, but not observed by us, have not been included in the enumeration. This is due to the difficulties of dealing with multiple taxonomic name changes and uncertainties about specimens collected and identified many years ago. Just considering the 512 species named from specimens collected on Doi Sutep–Pui, (*i.e.* type locality), we have not seen 55 of them and it is probable that they no longer grow on the mountain (see Table 7). Some may have been endemic to the mountain. For example, in 1958 K. Larsen discovered a curious violet, saprophytic plant *Sciaphilla thaidanica* (Triuridaceae) on Doi Sutep–Pui (Larsen, 1961). Since then, however, there have been no further records of this strange Doi Sutep–Pui endemic.

Disappearances of some plants are undoubtedly due to changes in habitat, especially increased frequency of fires and agricultural expansion. Almost complete loss of entire habitat types such as teak forest and pine forest and conversion of large areas of forest into cultivated fields and abandoned degraded areas must have resulted in losses of species with specific habitat requirements.

In addition, over-collection of plants with ornamental value, for the horticulture trade and by individual collectors has resulted in the extirpation of several species, especially orchids such as *Paphiopedilum callosum* (Rchb. f.) Pfitz. (Banziger, 1988), *Calanthe triplicata* (Willem) Ames, *Arundina graminifolia* (D. Don) Hochr., and *Phaius tankervilleae* (Banks *ex* L' Her.) Bl. (all Orchidaceae). *Psilotum nudum* (L.) Beauv. (Psilotaceae), is also a great loss to the mountain due to its scientific interest, being the most primitive of vascular plants found in Thailand. According to Maxwell, both *Cycas siamensis* Miq. (*Epicycas siamensis* (Miq.) de Laub.), from lowland **dof** and **bb/df** and *Cycas pectinata* B.–H. (Cycadaceae), found in upland **eg/pine** areas, have been extirpated from the national park because of their ornamental value, fire, and habitat destruction. Over–exploitation of many food plants and those with purported medicinal properties has also reduced the populations of several plant species to critically low levels. For example, *Melientha suavis* Pierre ssp. *suavis* (Opiliaceae) is collected for its edible leaves, whereas

Pueraria mirifica A. S. & Suvant. (Leguminosae, Papilionoideae), *Sapria himalayana* Griff. (Rafflesiaceae), and *Betula alnoides* Ham. *ex* D. Don (Betulaceae) are all exploited for their dubious medicinal properties. *Mahonia nepalensis* DC. (Berberidaceae), whose roots have purported medicinal value, and *Cephalostachyum pergracile* Munro (Gramineae, Bambusoideae), culms of which are used as a container for a condiment of sticky rice, have also become uncommon. *Aquilaria crassna* Pierre *ex* Lec. (Thymelaeaceae, sandalwood) has become so scarce that only a few trees from one remote location are known in the National Park—a secret which Maxwell refuses to divulge to those he does not trust.

Effects of Extirpation of Animal Species on Plant Communities

Even where the forest survives, there are few large animals due to hunting. Roads now enable hunters to reach previously inaccessible areas and hunting is growing as a recreational pastime for city dwellers. Hunting has eliminated all large mammal species from the national park (except barking deer, *Muntiacus muntjak*) in the past thirty years. Hunting has also exterminated at least ten bird species including all species of hornbills (formerly five hornbill species were present (Round, 1984). Even now, hunting continues unabated, especially during the cool season, when gunfire may be heard anywhere on the mountain. Hunters' platforms and the remains of wildlife barbecues are commonly found (Photo19). With the extermination of large animals from the park, hunters now turn their attention towards smaller species: squirrels and birds. There are two main groups of hunters in Doi Sutep–Pui National Park: local villagers, often using homemade guns and casual urban–based visitors, using more sophisticated weapons. Both groups hunt for sport. No residents of the national park rely on game as an essential food source.

Extirpation of large mammals and birds from the park has had serious consequences for the ecological functioning of the forest. In particular, seed dispersal is disrupted. The consequence is a reduction in animal-dispersed plant species, with wind-dispersed species filling the vacant niches. About 10% of deciduous dipterocarp–oak forest trees and 20% of evergreen forest trees relied on primates as seed dispersers. With the extirpation of most primates from the park, the reproductive ecology of these trees is adversely affected. In former times the main dispersers of large tree seeds from forest into degraded areas would have been rhinos, elephants, and wild cattle. The disappearance of these mammals from the mountain means that trees with very large seeds have no mechanism to re-colonize degraded areas. Trees establishing in such areas today tend to be restricted to those species with small, wind-dispersed seeds or those dispersed by extant smaller animals. Thus, even where forest is regenerating naturally, biodiversity is limited. For some plant species, passage of the seed through the gut of an animal is a prerequisite for germination (Traveset, 1998). Extirpation of large animals and the reduction of smaller animals to low populations will undoubtedly affect such plant species. Today the most important dispersers of tree seed are birds (especially bulbuls, barbets, starlings, mynahs, leaf birds and the common koel), fruit bats and civets, but none of these animals can disperse seeds larger than about 2 cm. For long term survival of the forest with its current high level of plant species richness, it is essential that regulations forbidding hunting in the park are vigorously enforced. It may be necessary to re-introduce some important seed-dispersing animals, such as hornbills and gibbons. Although sufficient habitat for viable populations of such animals still exists in the national park, attempts to re-introduce these species would be futile unless the hunting problem can be solved (Photo 19).

Table 14 lists 53 species that we consider to be in most need of conservation action.

Table 14. Vascular plant species in imminent danger of extirpation from Doi Sutep–Pui National Park

Species	Family	Habit	Abundance*	Known Elevation (m)
Clematis eichleri (M. Tam.) M. Tam.	Ranunculaceae	v	1	1075
Thalictrum foliolosum DC.	Ranunculaceae	v	1	1685
Polyalthia littoralis (Bl.) Boerl.	Annonaceae	t	1	325–350
Polyalthia sp.	Annonaceae	t	1	1000
Cocculus laurifolius DC.	Menispermaceae	l	1	1000–1125
Hibiscus mutabilis L.	Malvaceae	l	1	1275
Firmiana colorata (Roxb.) R. Br.	Sterculiaceae	t	1	1400–1500
Schoutenia glomerata King ssp. *peregrina* (Craib) Roekm. & Hart.	Tiliaceae	t	1	350
Tetrastigma yunnanense Gagnep.	Vitaceae	wc	1	1300–1500
Callerya atropurpurea (Wall.) Schot	Leguminosae, Papilionoideae	t	1	1000-1100
Sorbus verrucosa (Decne.) Rehd.var. *verrucosa*	Rosaceae	t	1	1550–1650
Crypteronia paniculata Bl. var. *paniculata*	Crypteroniaceae	t	1	620–1650
Haldina cordifolia (Roxb.) Rids.	Rubiaceae	t	1	500
Hymenopogon parasiticus Wall.	Rubiaceae	s	1	1275–1625
Monotropa hypopitys L.	Monotropaceae	h	1	1425–1650
Pouteria grandiflora (Wall.) Baeh.	Sapotaceae	t	1	1250–1340
Diospyros coaetanea Flet.	Ebenaceae	t	1	400–500
Schrebera swietenioides Roxb.	Oleaceae	t	1	450–550
Aganosma cymosa (Roxb.) G. Don var. *cymosa*	Apocynaceae	wc	1	350–400
Hoya engleriana Hoss.	Asclepiadaceae	h	0–1	1550–1685
Fagraea ceilanica Thunb.	Loganiaceae	s (t)	1	1500
Cordia mhaya Kerr	Boraginaceae	t	1	425
Utricularia exoleta R. Br.	Lentibulariaceae	h	1	550–1400
Strobilanthes rubro-glandulosus Craib	Acanthaceae	h, s	1	1000
Aristolochia versicolor Hwang	Aristolochiaceae	v	1	1250
Aquilaria crassna Pierre *ex* Lec.	Thymelaeaceae	t	1	1000–1100
Elytranthe albida (Bl.) Bl.	Loranthaceae	s	1	1500–1610
Euphorbia lacei Craib	Euphorbiaceae	t (l)	1	500–750
Sciaphila tuberosa K. Lar.	Triuridaceae	h	0–1	1000
Typhonium hirsutum (Hu) Mur. & Mayo	Araceae	h	1	1125–1150
Typhonium horsfieldii (Miq.) Steen.	Araceae	h	1	1100–1250
Stemona tuberosa Lour. var. *tuberosa*	Stemonaceae	v	1	1125-1525
Calamus arborescens Griff.	Palmae	s, wc	1	1050
Plectocomia kerrana Becc.	Palmae	wc	1	1375–1400
Anoectochilus siamensis Schltr.	Orchidaceae	h	1	1025–1050
Anoectochilus tortus (King & Pantl.) King & Pantl.	Orchidaceae	h	1	1425
Cymbidium tracyanum O' Brien	Orchidaceae	h	0–1	1650
Calanthe triplicata (Willem) Ames	Orchidaceae	h	0	1000–1400
Dendrobium sutepense Rol. *ex* Dow.	Orchidaceae	h	1	1650–1685
Nervilia calcicola Kerr	Orchidaceae	h	1	625
Paphiopedilum callosum (Rchb. f.) Pfitz.	Orchidaceae	h	0	?

Species	Family	Habit	Abundance*	Known Elevation (m)
Pecteilis susannae (L.) Raf.	Orchidaceae	h	1	375–525
Phaius tankervilleae (Banks *ex* L' Her.) Bl.	Orchidaceae	h	0–1	1500
Polystachya concreta (Jacq.) Garay & Sweet	Orchidaceae	h	1	850
Tainia viridifusca (Hk.) Bth. & Hk. f.	Orchidaceae	h	1	1450
Eleocharis congesta D. Don var. *congesta*	Cyperaceae	h	1	1000–1400
Podocarpus neriifolius D. Don	Podocarpaceae	t	1	1050–1400
Pinus merkusii Jungh. & De Vriese	Pinaceae	t	1	1200
Cephalotaxus griffithii Hk. f.	Cephalotaxaceae	t	1	1400–1550
Psilotum nudum (L.) Beauv.	Psilotaceae	h	0–1	350–500
Lycopodium squarrosum Forst.	Lycopodiaceae	h	1	1500–1525
Cyathea chinensis Copel.	Cyatheaceae	t	1	1350–1400

*0 = recently extirpated or 1 = in imminent danger of extirpation from Doi Sutep–Pui National Park

Current Conservation Management of Botanical Richness in the National Park

Reforestation

The first attempt to replant trees in the national park began in the late 1950's when the FAO (Food and Agricultural Organization of the United Nations) started providing assistance to the Royal Forest Department. Lowland areas were initially planted with selected strains of *Tectona grandis* L. f. (teak, Verbenaceae), while upland areas, especially upper water catchment valleys, were planted with *Pinus kesiya* Roy. *ex* Gord. (pine, Pinaceae), both native species, are suitable for the habitats they were planted in. The top 50 m of Doi Pui was clear-cut in the late 1950's and replanted with *Pinus kesiya* and *Cupressus torulosa* D. Don (Cupressaceae), from the Himalayas. Since that time the replanted forest there has thrived, but not spread, while none of the original forest there has been able to redevelop. Several species of *Eucalyptus*, especially *E. camadulensis* Dehn., *E. deglupta* Bl., and *E. maculata* Hk. (Myrtaceae), have also been introduced.

Recent years have seen a dramatic change in the reforestation policy of the national park, in line with national initiatives such as the "Plant a Big Forest for Our King" project to mark the Golden Jubilee of His Majesty King Bhumibol Adulyadej. The park policy is now to gradually replace plantations of exotic species with native forest trees. For example, in 1999 the *Cupressus* plantation on the summit of Doi Pui was under-planted with native trees, ready to replace the over-mature *Cupressus* trees as they die off. *Eucalyptus* plantations around the park have been earmarked for similar treatment. New plantings of eucalypts have ceased.

Many degraded areas in the park have been included in the Golden Jubilee tree-planting program. Most such areas were formerly cultivated by Hmong villagers and are clustered around Ban Meo Doi Pui, Bàn Chang Kian, Ban Mae Sa Mai, and Doi Pui checkpoint and summit. Since 1993, villagers from all the main villages in the park have joined events to replant these areas with indigenous tree species. Furthermore, agreements not to subsequently cultivate

the planted sites have mostly been adhered to. Other organizations such as Chiang Mai University, Payap University, and private-sector companies have participated in tree planting events by supplying sponsorship and labor.

Although, initial attempts at restoring forest on Doi Sutep–Pui generated a great deal of enthusiasm and public support, the results were variable, mostly due to lack of technical knowledge and poor implementation. Indiscriminate slashing of weeds often destroyed more naturally established tree seedlings than were replaced with planted ones. Rather few tree species were planted, on any particular site, reducing the value of the plantings for biodiversity. Low quality planting stock, poor planting methods, and inadequate aftercare often resulted in high mortality of the planted trees. Fire control measures failed to prevent several of the planted areas from being burnt (Photo 17).

With such a rapid change in policy, from monoculture plantations to mixed plantings with native forest tree species and with little technical information available, it was inevitable that initial attempts to restore Doi Sutep–Pui's forests would be problematical. Therefore, in November 1994 the Forest Restoration Research Unit (FORRU) was established at the headquarters of the national park to develop effective methods to complement and accelerate natural forest regeneration on deforested sites, for conservation of biodiversity and watersheds (Elliott *et al.*, 1995). FORRU is a joint initiative between Chiang Mai University (CMU) and Doi Sutep–Pui National Park headquarters. The unit has concentrated on three main areas of research: i) species selection to maximize biodiversity in planted areas; ii) improved nursery techniques to produce high quality planting stock, and iii) improved silvicultural treatments to maximize the performance of trees after planting.

FORRU is testing the suitability of the framework species method of forest restoration (Goosem & Tucker, 1995; Tucker and Murphy, 1997, Forest Restoration Research Unit, 1998), by selecting indigenous tree species capable of rapidly shading out weeds and attracting wildlife into planted plots. So far research has mostly concentrated on restoring evergreen forest in watershed areas above 1200 m elevation, but the work is now expanding to consider lowland areas.

In FORRU's research nursery, researchers have determined the best methods to clean seeds and treat them to accelerate germination and increase the final germination percentage (Kopachon, 1995). Optimal media and container types were identified to maximize seedling health and vigor (Zangkum, 1998) and production schedules have been formulated for more than 40 species (Forest Restoration Research Unit, 2000). A second tree nursery was established at the largest village in the park, the Hmong community of Ban Mae Sa Mai, in order to test the practicability, by local communities, of the new techniques developed and to act as an education and demonstration center.

Demonstration plots were planted near the village to: i) assess the relative performance of different tree species; ii) determine the most appropriate treatments to enhance tree performance after planting, and iii) monitor the return of biodiversity to planted areas (Photos 21 & 22).

The information generated by FORRU is made freely available to national park officers, villagers, NGO's, and educational groups and is disseminated through publications (*e.g.* Forest Restoration Research Unit, 1998 and 2000) and frequent workshops. This project has attracted interested from other provinces in Thailand as well as neighboring countries, thus confirming the critical role of Doi Sutep–Pui National Park as a natural laboratory and regional center for ecological research and education.

Fire Prevention

Considerable efforts have been directed towards prevention and suppression of forest fires on Doi Sutep–Pui in recent years. A fire control unit is situated inside the national park and fire control activities are co-ordinated by a larger fire control center just outside the southern boundary of the national park near Wat Umong. A helicopter and small fire engine are available to extinguish fires. Fire tools are placed at strategic locations throughout the park and a small army of seasonally employed fire fighters is on standby day and night, from January to April, to respond to fire outbreaks. Despite all these efforts, however, local people and careless tourists continue to start fires that ravage large parts of the park annually and the fire control unit is unable to extinguish them all.

The particularly disastrous fire season of 1998, when many reforestation plots were destroyed, prompted the Provincial Forest Office to increase the budget for fire control and implement measures to increase co-operation with local people (Photo 17). Park officials organized villagers to protect designated areas around their villagers, as well as to establish a network of fire breaks between the larger villages. This increased effort successfully reduced fires in 1999 and 2000 and the program is continuing.

Such enormous effort and expenditure directed at suppressing fires would not be necessary if fires were not started in the first place (Photo 17). Fires are often started due to ignorance, carelessness, and as a political weapon in land disputes. These problems can only be solved by better education, building better relationships between the park authorities and local people, and enforcement of the law.

Controlling Access

As one of the most heavily visited national parks in Thailand, it is difficult to limit access or to resist the constant demands from tour operators for better transportation facilities within the park. Currently, few areas of the park are subject to controlled access. The summit of Doi Pui is strictly off-limits to visitors when the Royal Family are in residence at Puping Palace. A manned checkpoint and barrier prevent access. Access to Mae Sa Waterfall is subject to an entrance fee, which might help to deter over-crowding of this beauty spot. In 1999, other checkpoints were established to levy entrance fees at the tracks to Ban Chiang Kian and Montatahn Waterfalls. Some of these checkpoints proved uneconomic and have since been abandoned. In recent years, the main road to Wat Prataht Doi Sutep–Pui has been widened to a three-lane highway (Photo 20); the track to Montatahn Waterfalls has been widened and the tracks to Ban Meo Doi Pui and Doi Pui summit have been upgraded to surfaced roads. The track from Pongyang to Ban Mae Sa Mai is currently being surfaced with concrete. An attempt to convert the track from Doi Pui checkpoint to Site B into a surfaced road in 1997 was thwarted by environmentalists. Therefore, at present, access to the more remote or fragile areas of the park seems to be actively encouraged by the park's policy on transportation, rather than controlled.

Conservation and Re-introduction of Endangered or Extirpated Species

Apart from the forest restoration activities, already described, there is little management to conserve individual plant species that have become endangered or to reintroduce plant species that have become extirpated from the park.

Most of the extirpated or endangered plant species listed in Table 15 could be conserved by better protection of the last remaining plants. This would involve continuous monitoring of remaining plant populations, preventing further habitat degradation, and stricter enforcement of the laws forbidding collection of plants within the national park.

Some species might benefit from attempts to establish new populations within the national park by transplanting plants from surviving populations to undisturbed areas where the species formerly grew. Reintroduction programs should be considered for those species listed in Table 15, involving collection of planting stock from nearby localities where such species still survive. Such conservation activities, focusing on the conservation of individual plant species, require intensive research to determine the habitat requirements and the reproductive ecology of the species concerned.

Management of Key Animal Species

At present there is no routine monitoring of animal populations that play a vital role in the reproductive ecology of plants *e.g.* seed-dispersers, pollinators, *etc.* There are no plans to reintroduce extirpated animals such as primates or hornbills, although sufficient habitat still exists in the national park. At present no security is available to guarantee the safety of reintroduced animals.

In the early 1990's Wildlife Fund Thailand mooted a plan to re-introduce gibbons and perhaps other extirpated wildlife in the national park. There was also a plan to have Hmong villagers there oversee and otherwise protect these animals with the idea that various ecotourism benefits would be gained. Aside from the inability of the RFD to accept or organize this pilot project, it was also considered, and perhaps quite realistically, impossible to prevent hunting—thus the plan never developed. Unless key pollinators and seed-dispersing animals can be introduced, the biodiversity in the national park will continue to decline—ultimately to the point of irrepairable degradation. The loss of another of the remaining few natural national treasures of Thailand is quite imminent.

Conservation Management Recommendations

1. Current forest restoration activities should continue and be improved in accordance with the latest research results and effective methods to restore lowland forests should be developed.

2. Existing plantations of exotic tree species should be gradually thinned and replaced with indigenous trees.

3. All stages of forest restoration projects should be planned in co-operation with local communities, from species selection to propagation, planting, aftercare, and protection of planted trees, and monitoring of the restored areas.

4. Recent improvements in the fire prevention and suppression program need to be maintained and strengthened.

5. Education and public information programs concerning fire prevention need to be increased and improved.

6. A sensible access policy for the national park needs to be formulated and implemented. Such a policy should include restricting access to the wilderness zone (as identified in the first

draft management plan for the national park (Kasetsart University, 1988)) and encouraging visitors to use areas that already have facilities catering for intensive visitor use.

7. No further expansion or improvement of the road system should be allowed in the national park.

8. A research program to routinely monitor populations of rare or endangered plant species in the national park should be devised and implemented.

9. Public awareness of the need to conserve endangered plant species should be increased and laws prohibiting collection of plants from the national park should be more strictly enforced.

10. Research to develop effective methods to propagate and plant or translocate endangered plant species needs to be carried out.

11. Laws prohibiting hunting in the national park should be more strictly enforced. Public awareness of the need to maintain animal populations within the national park needs to be increased.

12. Only after successful implementation of recommendation 11, experiments to re-establish populations of key animal species, particularly those responsible for dispersing large seeds, should be carried out.

13. Training of national park staff in conservation, nature education, ecotourism, basic ecology, and biodiversity surveying; and

14. Proper development of education centres, nature trails, existing guest facilities at the headquarters, and camping sites.

REFERENCES CITED

Ashton, P. 1990. Thailand: Biodiversity center for the tropics of Indo–Burma. J. Sci. Soc. Thailand 16, 107–116.

Bänziger, H. 1988. How wildlife is helping to save Doi Sutep: Buddhist sanctuary and national Park of Thailand. Symb. Bot. Ups. 28:3, 255–267.

Barnett, E. C. 1962. *Florae Siamensis Enumeratio* III:3. Siam Society, Bangkok; 181–240.

Baum, F., E. v. Braun, A. Hess, and K. E. Koch. 1982. Geological Map of Northern Thailand, l: 250,000; sheet 5. Federal Institute for Geosciences and Natural Resources; Hanover, Germany.

Blakesley, D., S. Elliott, and V. Anusarnsunthorn. 1998. Low technology tree propagation and the restoration of natural forest ecosystems. In: M. R. Davey, P. G. Anderson, K. C. Lowe, and J. B. Power eds., Tree Biotechnology: Towards the Millennium. Nottingham University Press.

Craib, W. G. 1911. Contributions to the flora of Siam, Dicotyledones. Bull. Misc. Info. (Kew Bull.); 7–60, 385–474. Reprinted: University of Aberdeen Studies 57 (1912) 210 pp.

_____ 1912. Contributions to the flora of Siam, Monocotyledones. Bull. Misc. Info. (Kew Bull.) 397–435. Reprinted: Aberdeen University Studies 61 (1913) 41 pp.

_____ 1914. Contributions to the Flora of Siam. *Additamenta* V, 4–11.

_____ ("Prof. B. Craib"). 1931. The flora and vegetation of Siam. The Mid-Pacific Mag. 41:4, 328–335.

Credner, W. 1935. Siam das land der Tai. reprint 1966: O. Zeller, Osnabruk; 105–135.

Downie, D. G. 1925. Contributions to the flora of Siam. *Additamentia* XVI, XVII.. Kew Bull. 367–394,404–426.

De'Ath, C. 1992. A history of timber exports from Thailand with emphasis on the 1870–1937 period. Nat. Hist. Bull. Siam Soc. 40:1, 49–66.

Edwards, M. V. 1950. Burma forest types. Indian Forest Record (Silviculture) 7:2, 133–173.

Elliott, S. 1992. Tourists' perceptions of wildlife and national parks in northern Thailand. *J. Wildlife in Thailand* 3:1, 43–50.

_____, J. F. Maxwell, and O. P. Beaver. 1989. A transect survey of monsoon forest in Doi Sutep–Pui National Park. Nat. Hist. Bull. Siam Soc. 37:2, 137–171.

_____, S. Ua–Apisitwong and O. Beaver, 1989. The small mammal communities of Doi Sutep–Pui National Park. Proc. 10th Ann. Wildlife Symp., Kasetsart University, Bangkok.

_____. and O. Beaver, 1991. The importance of Doi Sutep–Pui National Park for wildlife conservation, scientific research and education. In "The Future of Doi Sutep", proceedings of a seminar held at Chiang Mai University, 14–15 March 1991, The For Chiang Mai Group, Chiang Mai (in Thai). Reprinted in *Tigerpaper* (FAO), 14:3, 23–30 (in English).

_____, V. Anusarnsunthorn, N. Garwood, and D. Blakesley. 1995. Research Needs for restoring the forests of Thailand. Nat. Hist. Bull. Siam Soc. 43(2): 179–184.

_____, P. Navakitbumrung, S. Zangkum, C. Kuarak, J. Kerby, D. Blakesley, and V. Anusarnsunthorn. 2000. The performance and response to fertilizer of six native tree species, planted to accelerate the recovery of biodiversity in a degraded upland watershed. In Elliott, S., J. Kerby, K. Hardwick, D. Blakesley, K. Woods and V. Anusarnsunthorn

(Eds.). Forest Restoration for Wildlife Conservation. Biology Department, Faculty of Science, Chiang Mai University, Thailand, in press.

Forest Restoration Research Unit. 1998. Forests for the Future: Growing and Planting Native Trees for Restoring Forest Ecosystems. Biology Department, Faculty of Science, Chiang Mai University, Thailand; 60 pp.

Forest Restoration Research Unit. 2000. Tree Seeds and Seedlings for Restoring Forests in Northern Thailand. Biology Department, Faculty of Science, Chiang Mai University, Thailand;151 pp.

Fosberg, F. R. 1958. On the possibility of a rational, general classification of humid tropical vegetation. Proceedings of the Symposium on Humid Tropical Vegetation; Tjiawi, Indonesia; UNESCO; 46.

Garrett, H. B. G. and A. F. G. Kerr. 1925. Doi Angka —the highest mountain in Siam. J. Siam Soc. 19, 1–19.

Goosem, S. and N. Tucker, 1995. Repairing the Rainforest. Cassowary Publications, Cairns, Australia; 70 pp.

Hardwick, K., J. Healey, S. Elliott, N. C. Garwood, and V. Anusarnsunthorn. 1997. Understanding and assisting natural regeneration processes in degraded seasonal evergreen forests in Northern Thailand. Forest Ecology and Management 99: 203–214.

Hastings, P. J. and M. Liengsakul. 1984. Evidence for Holocene climatic change from Doi Intanon, Chiang Mai. Environmental Geology and Geologic Techniques Meeting, Chiang Mai, Thailand; February 1984; 10 pp. mimeograph.

Hennipman, E. and A. Touw. 1966. Report on the Thai-Dutch botanical expedition 1965/1966. Nat. Hist. Bull. Siam Soc. 21:3–4, 269–273.

Higham, C. and R. Thosarat. 1998. Prehistoric Thailand from Early Settlement to Sukothai. River Books, Bangkok; 234 pp.

Hjelmqvist, H. 1968. Fagaceae, Betulaceae, and Corylaceae. Studies in the flora of Thailand 44. Dansk Bot. Ark. 23:4, 475–516

Holdridge, L. R., W. C. Grenke, W. H. Hatheway, T. Liang, and J. A. Tosi. 1971. Forest Environments in Tropical Life Zones. Pergamon Press, Oxford; 4–14.

Hosseus, C.C. 1907. Die aus Siam bekannten Acanthaceen. Bot. Jahr. 41: 62–73

_____ 1907a. Zwei interessante neuheiten aus Siam im Kgl. Bot. Garten zu Dahlem. Notiz. Berl.–Dahl. 4 (Oct.), 314–318 and taf. 1 & 2.

_____ 1907b. Eine neue Rafflesiaceengattung aus Siam. Bot. Jahr. XLI, 55–61 and taf. 1, 2.

_____1908. Beitrage zur flora des Doi–Sutap, unter vergleichender berucksichtigung einiger anderer hohenzuge nord–Siams. Engl. Bot. Jahr. XL: 93, 92–99.

_____ 1910. Beitrage zur flora Siams. Bot. Centralbl. Beih. XXVII:2, 455–507 pp.

_____ 1911. Die botanisches ergebnisse meiner expedition Nach Siam. Bot. Centralbl. Beih. XXVIII:2, 357–457 pp.

_____ 1911a. Einige neue arten meiner Siam–expedition. Feddes repert. 10 (Oct.) 61–64.

IUCN. 1973. A working system for classification of world vegetation. IUCN Occasional Paper no. 5; Morges, Switzerland; 22 pp.

Jacobs, M. 1962. *Reliquae Kerrianae*. Blumea XI:2, 427–493.

Juprachakorn, P. 1990. Effects of forest fire on cellulolytic micro–organisms in the soil. B.Sc. thesis, Biology Department, Chiang Mai University; 44 pp.

Kafle, S. K. 1997. Effects of forest fire protection on plant diversity, tree phenology, and soil Nutrients in a deciduous dipterocarp–oak forest in Doi Sutep–Pui National Park. M.Sc. thesis, Graduate School, Chiang Mai University, Chiang Mai, Thailand; 91 pp.

Kamsathorn, S. 1990. Effects of forest fire on pectinolytic micro-organisms in soil. B.Sc. thesis, Biology Department, Chiang Mai University; 58 pp.

Kaosoot, B.; N. Nawnghanpitak, P. Saifahk, and G. Boonnagahn. 1996. Land use planning in the upper Ping River watershed. Department of Land Use Planning, Land Development Department, Ministry of Agriculture and Cooperatives; Bangkok, Thailand; 8.

Kasetsart University. 1988. A draft management plan for Doi Sutep–Pui National Park, Kasetsart University, Bangkok.

Kerr, A. F. G. 1911. Contributions to the flora of Siam: sketch of the vegetation of Chiang Mai. Bulletin of Miscellaneous Information (Kew Bull.) 1911:1, 1–6.

_____ 1933. William Grant Craib (obituary). Kew Bull. 409–412.

Kopachon, S., 1995. Seed germination and seedling development of dry tropical forest trees: a comparison between dry-season-fruiting and rainy-season-fruiting species. M. Sc. thesis, Graduate School, Chiang Mai University; 86 pp.

_____, K. Suriya, K. Hardwick, G. Pakaad, J. Maxwell, V. Anusarnsunthorn, D. Blakesley, N. Garwood, and S. Elliott. 1996. Forest restoration research in northern Thailand: 1. The fruits, seeds and seedlings of *Hovenia dulcis* Thunb. (Rhamnaceae). Nat. Hist. Bull. Siam Soc. 44: 41–52.

Küchler, A. 1966. The vegetation west of the Maenam Ping near Chiang Mai, Thailand; 1:30,000; a one sheet map inserted in Kuchler & Sawyer, 1967 (*q.v.*).

_____ and J. O. Sawyer. 1967. A study of the vegetation near Chiang Mai, Thailand. Trans. Kansas Acad. Sci. 70:30, 281–348.

Kurz, S. 1877. Forest Flora of British Burma I, Calcutta; XIII–XXX.

Larsen, K. 1961. Triuridaceae. Studies in the flora of Thailand. Dansk Botanisk Arkiv 20;1: 48–49.

Mahidol University. 1992. Rapid assessment of forest/wildlife/river ecology in area affected by Kaeng Sua Ten Dam. Center for Conservation Biology, Faculty of Science, Mahidol University; Bangkok, Thailand; 7–69.

_____ 1995. Survey of natural teak forests in Thailand. Center For Conservation Biology, Faculty of Science, Mahidol University; Bangkok, Thailand; 71 pp + map.

Maxwell, J. F. 1988. The Vegetation of Doi Sutep–Pui National Park, Chiang Mai Province, Thailand. Tigerpaper (FAO) 15:4, 6–14.

_____ 1989. Botanical notes on the vascular flora of Chiang Mai Province, Thailand. Nat. Hist. Bull. Siam Soc. 37:2, 177–185 pp.

_____ 1991. Botanical notes on the vascular flora of Chiang Mai, Thailand: 2. Nat. Hist. Bull. Siam Soc. 39:1, 71–83.

_____ 1992. Botanical notes on the flora of northern Thailand: 3. Nat. Hist. Bull. Siam Soc. 40:2, 185–189.

_____ 1992. Lowland vegetation (450–*c.* 800 m) of Doi Chiang Dao Wildlife Sanctuary, Chiang Mai Province, Thailand. Tigerpaper (FAO) 19:3, 21–25.

_____ 1993. More rot, less fire for Doi Sutep. Chiang Mai Newsletter 2:6 (June) 1, 3.

_____ 1994. Botanical notes on the flora of Thailand: 4. Nat. Hist. Bull. Siam. Soc. 42:2,

259–262.

——— 1995. Vegetation and vascular flora of the Ban Saneh Pawng area, Lai Wo Subdistrict, Sangklaburi District, Kanchanaburi Province, Thailand. Nat. Hist. Bull. Siam Soc. 43:1, 131–170.

——— 1996. Vegetation of the Mai Soi conservation area, Chom Tong District, Chiang Mai Province, Thailand. Tigerpaper (FAO) 23:1, 22–27.

——— 1998. Botanical notes on the flora of northern Thailand: 6. Nat. Hist. Bull. Siam Soc. 46:2, 149–154.

——— 1998. Upland vegetation of Doi Chiang Dao Wildlife Sanctuary, Chiang Mai Province, Thailand, Tigerpaper (FAO) 25:3, 5–11.

——— 1999. Mae Yom national park: A precious national botanical treasure. Nat. Hist. Bull. Siam Soc. 47:1, 7–11.

——— 1999a. Botanical note: *Hoya thomsonii* Hk. f. (Asclepiadaceae)—A new record for Thailand. Nat. Hist. Bull. Siam Soc. 47:2, 259 pp.

——— 2000. Vegetation in the Seephandon Wetland, Lao PRD. Nat. Hist. Bull. Siam Soc. 48, 47–93.

——— S. Elliott, P. Palee, and V. Anusarnsunthorn. 1995. The vegetation of Doi Kuhn Tan National Park, Lamphun–Lampun Provinces, Thailand. Nat. Hist. Bull. Siam Soc. 43:2, 185–206.

——— S. Elliott, P. Palee, and V. Anusarnsunthorn. 1997. The vegetation of Jae Sawn National Park, Lampang Province, Thailand. Nat. Hist. Bull. Siam Soc. 45:1, 71–97.

——— and V. Anusarnsunthorn. 1999. Distribution and conservation of bamboo species in northern Thailand. In A. N. Rao & V. R. Rao eds. Bamboo and Rattan Genetic Resources and Use Research Reports. IPGRI–APO; Serdang, Malaysia; 131–155.

Meng, M. 1997. Effects of forest fire protection on seed dispersal, seed bank, and tree seedling establishment in a deciduous dipterocarp–oak forest in Doi Sutep–Pui National Park. M.Sc. thesis, Graduate School, Chiang Mai University, Chiang Mai, Thailand; 89 pp.

Medway, Lord. 1972. Phenology of a tropical rain forest in Malaysia. Biol. J. Linn. Soc. 4, 117–125.

Nabhitabhata, J. 1987. Wildlife in Doi Sutep–Pui National Park. Kog–Ma Watershed Bull. (Kasetsart University, Bangkok) 48, 1–41.

Neal, D. G. 1967. Statistical description of the forests of Thailand. Military Research & Development Center; Bangkok, Thailand; 343 pp.

Ogawa, H.; K. Yoda, and T. Kira. 1961. A preliminary survey on the vegetation of Thailand. Nature and Life in SE. Asia I; Kyoto, Japan; 65–74, 149–150.

Pinratana, A. 1977–85. Butterflies of Thailand. Vols. 1–5. Viratham Press, Bangkok; 486 pp.

Pokaew, C. 1993. The diversity of trees and seedling in burnt and non-burnt forest. Independent study for Master of Science in Biology, Chiang Mai University. 49 pp.

Richards, P. W. 1952. The Tropical Rain Forest—An Ecological Study. University Press, Cambridge; 315–345.

——— 1996. *idem.* 2nd ed. Cambridge University Press, Cambridge; 389–405.

Robbins, R. G. and T. Smitinand. 1966. A botanical ascent of Doi Inthanond. Nat. Hist. Bull. Siam Soc. 21: 3 & 4, 205–227.

Rolfe, R. A. 1906. New orchids —decade 27. Bull. Misc. Info. (Kew Bull.) 84.

——— 1908. New orchids: decade 31. Bull. Misc. Info. (Kew Bull.) 70.

_____ 1908a. New orchids: decade 32. Bull. Misc. Info. (Kew Bull.) 412–414.
_____ 1909. New orchids: decade 38. Bull. Misc. Info. (Kew Bull.) 62.
Round, P. D. 1984. The status and conservation of the bird community in Doi Sutep–Pui National Park, north–west Thailand. Nat. Hist. Bull. Siam Soc. 32:1, 21–46.
Royal Forest Department. 1950. Types of forests in Thailand. Royal Forest Department; Bangkok, Thailand; 9 pp. + colour map (1952).
_____ 1962. Types of forests in Thailand. Royal Forest Department; Bangkok, Thailand; 12 pp. + colour map.
Samapuddhi, K. 1957. The forests of Thailand and forestry programmes. Royal Forest Department, no. R. 20; Bangkok, Thailand; 4–10.
Santisuk, T. 1985. Conservation of temperate and subalpine vegetation of the mountains and ridges of Doi Chiang Dao. In: Nature Conservation in Thailand. Siam Society, Bangkok; 237–242 (in Thai).
_____ 1988. An Account of the Vegetation of Northern Thailand. Franz Steiner, Stuttgart, Germany; 100 pp. + 75 plates.
_____ 1997. Geographical and ecological distribution of the two tropical pines, *Pinus kesiya* & *Pinus merkusii*, in southeast Asia. Thai Forest Bull. (Bot.) 25, 102–116.
_____ 1998. Doi Chiang Dao, A mountain of concern: rare and endangered plants. The Botanical Garden Organization Newsletter 6, 11–18.
Sawyer, J. O. and C. Chermsirivathana. 1969. The flora of Doi Sutep, Doi Pui, Chiang Mai, North Thailand. Nat. Hist. Bull. Siam Soc. 23: 1–2, 99–132.
Seidenfaden, G. 1979. Orchid genera in Thailand VIII, *Bulbophyllum* Thou. Dansk Bot. Ark. 33:3, 203.
Smitinand, T. 1966. The vegetation of Doi Chiang Dao—a limestone massive in Chiang Mai, north Thailand. Nat. Hist. Bull. Siam Soc. 21 (1&2), 93–100.
_____ 1977. Vegetation and ground cover of Thailand. Technical Paper no. 1, Faculty of Forestry, Kasetsart University; Bangkok, Thailand; mimeograph 15 pp.
_____ 1989. Floristic inventory of tropical countries: Thailand. D. G. Campbell and H.D. Hammond eds. New York Botanical Garden, New York; 64–81.
_____ S. Sabhasri, and P. Kunstadter. 1978. The environment of northern Thailand. In farmers in the forest. P. Kunstadter, E. C. Chapman, and S. Sabhasri eds. University Press of Hawaii, Honolulu; 24–40.
Statistical reports of Changwat Chiangmai. 1992–1997. Chiang Mai Statistical Office, National Statistical Office, Office of the Prime Minister; Bangkok, Thailand. 1992, p. 106; 1993, p. 114; 1994, p. 112; 1995, p. 110; 1996, p. 103; 1997, p.94.
Studies in the flora of Thailand, 1961–1968. Dansk Bot. Ark. 20:1–3, 275 pp; 23:1–4, 540 pp; 27:1, 107 pp.
Suwatcherunkul. P. and D. Srisawang. 1993. Land use planning of Chiang Mai Province. Department of Land Use Planning, Department of Land Development, Ministry of Agriculture and Cooperatives; Bangkok, Thailand; 134.
Swearer, D. K. and S. Premchit, 1998. The legend of Queen Cama. State University of New York, 195 pp.
Tagawa, M. amd K. Iwatsuki. 1979–1989. Pteridophytes. Flora of Thailand 3:1–4, 639 pp.
Tairapat, P. and P. Donsi. 1996. Natural resources study of soil, water, and forests in the uplands

of Mae Ping drainage. Department of Land Use, Ministry of Agriculture and Cooperatives, Bangkok; 8–9.

TDRI. 1996. The assessment of a master plan (1990–1994) and national park management plan, phase 2 in Doi Sutep–Pui National Park. Thailand Develoment and Research Institute; Bangkok, Thailand .

Thailand Development Research Institute Foundation. 1997. Management Plan of Doi Sutep–Pui National Park, B. E. 2541–2550 (3 volumes) Bangkok, Thailand.

Tosi, J. A. 1964. Climatic control of terrestrial ecosystems: a report on the holdridge model. Econ. Geogr. 40:2, 173–181.

Traveset, A., 1998. Effect of seed passage through vetebrate frugivores' guts on germination: a review. Perspectives in Plant Ecology, Evolution and Systematics, 1–2: 151–190.

Tucker, N. and T. Murphy, 1997. The effects of ecological rehabilitation on vegetation recruitment: some observations from the wet tropics of north Queensland. Forest Ecology and Management 99: 133 –152.

Walter, H. 1985. Vegetation of the Earth, third ed.; Springer–Verlag, Berlin; 45–112.

Werner, W. 1993. *Pinus* in Thailand. Franz Steiner Verlag, Stuttgart; 269-270.

_____ and T. Santisuk. 1993. Conservation and restoration of montane forest communities in Thailand. In H. Lieth and M. Lohmann eds. Restoration of Tropical Forest Ecosystems. Kluwer Academic Publishers, Netherlands; 193–202.

Whitmore, T. 1975. Tropical Rain Forests of the Far East. Clarendon Press, Oxford; 3–4, 43–51, 121–165.

_____ 1991. An Introduction to Tropical Rainforests. Clarendon Press, Oxford; 9–10.

Williams, L. 1967. Forests of Southeast Asia, Puerto Rico, and Texas. U. S. Department of Agriculture; Washington, D. C.; 58–249.

Zangkum, S. 1998. The effects of container type and media on growth and morphology of tree seedlings to restore forests. M.Sc. thesis, Graduate School, Chiang Mai University; 87 pp.

Zhu, H. 1997. Ecological and biogeographical studies on the tropical rain forest of south Yunnan, SW China, with a special reference to its relation with rain forests of tropical Asia. J. Biogeography 24, 647–662.

PHOTOGRAPHS

(Photos 1-22 were taken by Stephen Elliott)

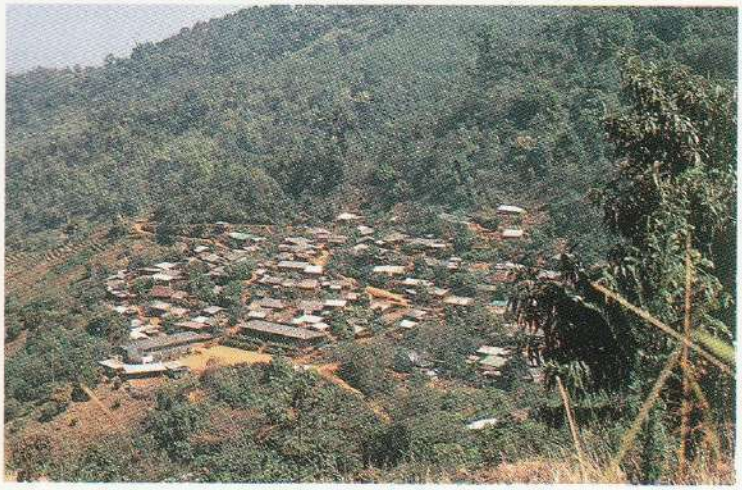

Photo 1

The Hmong community of Ban Mae Sa Mai in the northern part of Doi Sutep–Pui National Park at *c.* 1000 m is the largest village in the national park. Although, in the past, villagers have been responsible for clearing forest from large areas in the national park, they are now actively involved in forest restoration projects.

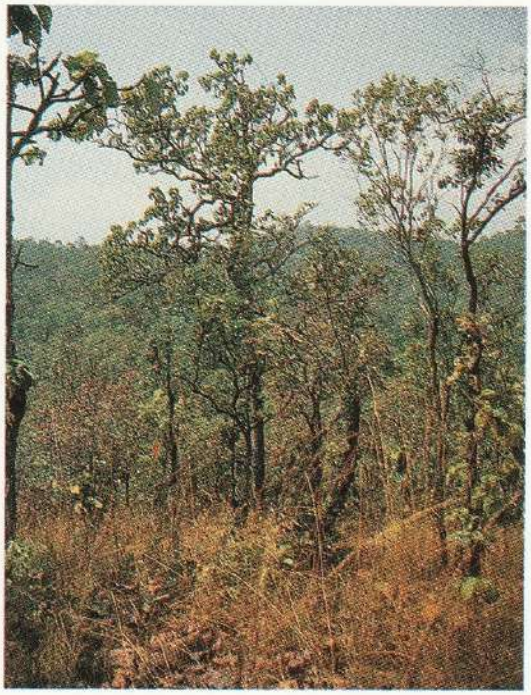

Photo 2

Deciduous dipterocarp–oak, seasonal forest prior to annual incineration, a kind of secondary forest which is maintained by fire, cutting, and soil erosion; is the dominant vegetation in the lowlands (350–*c.* 850 m) of the national park. It is dominated by several species of Dipterocarpaceae, *e.g. Dipterocarpus tuberculatus* Roxb. var. *tuberculatus*, as shown here, and Fageceae (oaks). 23 March 1990, *c.* 650 m.

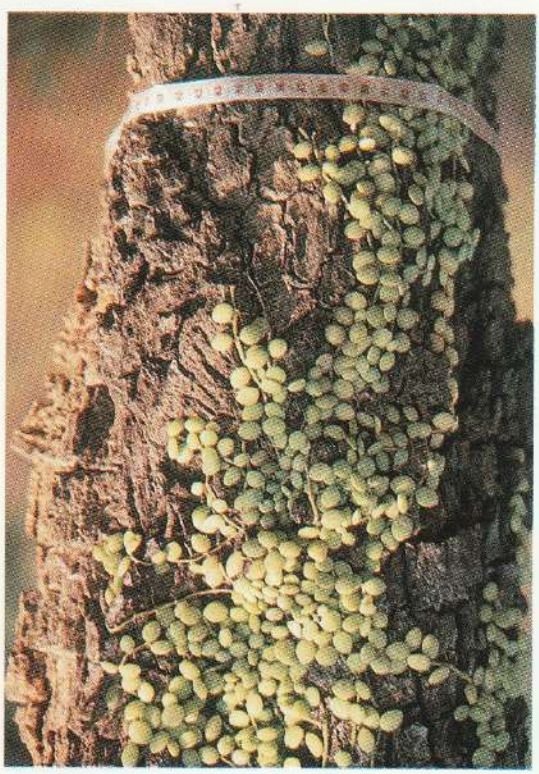

Photo 3

Dischidia nummularia R. Br. (Asclepiadaceae) is an evergreen, succulent, creeping, clustered, epiphytic herb found in deciduous dipterocarp–oak seasonal forest from 400 to 900 m. It is much less common now since it has been over-exploited for its horticultural value. Sirintorn Observatory, 3 March 1990, *c.* 850 m.

Photo 4

Annual fires continue to wreak havoc with the plant communities of Doi Sutep–Pui National Park. Research at the Biology Department, Chiang Mai University, has shown conclusively that protection from fire significantly increases biodiversity and conservation value of deciduous forests. 3 March 1996, *c.* 750 m.

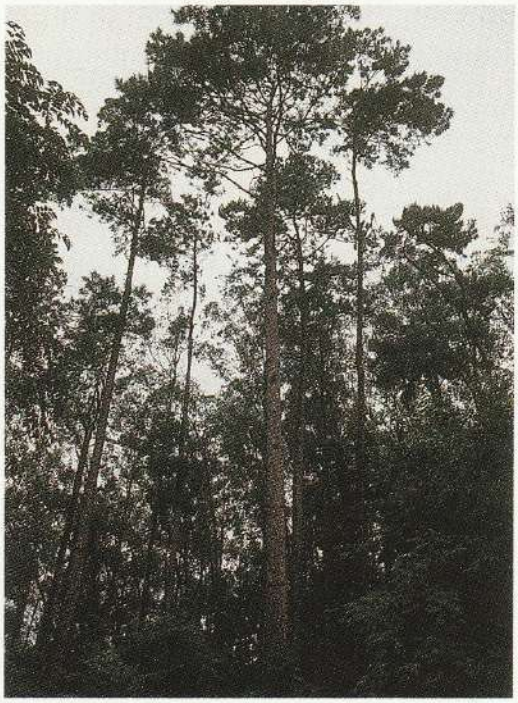

Photo 5

Deciduous dipterocarp–oak forest with pine is a rare forest type in the national park. Small patches can be seen on the eastern side of Doi Sutep at approximately 800–900 m elevation. 3 September 1994.

Photo 6

Villagers hack *Pinus kesiya* Roy. *ex* Gord. (Pinaceae, pine) trees to obtain slivers of resin-impregnated wood, which are used as fire-lighters. This destructive practice weakens trees so that they blow over during storms. Consequently very large pine trees are a rare sight in the park. Summit of Doi Sutep, 2 January 1996, *c.* 1620 m.

Photo 7

Symplocos racemosa Roxb. (Symplocaceae) in evergreen forest with pine on 2 April 1997 at *c.* 1100 m. This is a deciduous (in dof) or evergreen (in eg/pine) treelet or tree which is also found in deciduous dipterocarp–oak seasonal forest, often with pine, and has an overall elevation range of 350–1250 m.

Photo 8

Mixed evergreen + deciduous seasonal forest is typified by the presence of *Dipterocarpus costatus* Gaertn.f. (Dipterocarpaceae), an evergreen emergent tree, depicted here, which is restricted to this forest type. Montatahn Waterfalls, *c.* 750 m, 2 April 1997.

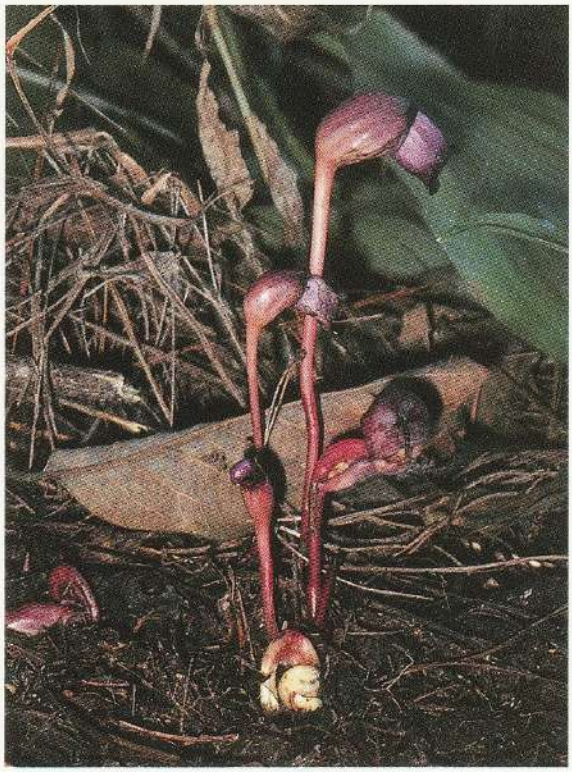

Photo 9

Aeginetia indica Roxb. (Orobanchaceae) is one of 23 species of parasitic plants that grow in Doi Sutep–Pui National Park. This species has no green pigmentation or leaves and is incapable of carrying out photosynthesis. This deciduous, perennial herb draws nutrients from the roots of nearby plants. It is found in all forest types, from 375 to 1650 m, in the national park. Flowers are produced from August to November and capsules during September to December. 26 November 1996, *c.* 1050 m.

Photo 10

Vaccinium sprengelii (D. Don) Sleum. (Ericaceae) is a common, evergreen, fire-resistant treelet or small tree found in most forest types at 600–1650 m in the national park. Flowers are produced from October to March and fruits from March to June. 3 February 1996, *c.* 850 m.

Photo 11

Aeschynanthus hosseusii Pell. (Gesneriaceae) is a common, evergreen epiphyte on trees in primary, evergreen, seasonal forest with pine from 1025 to 1525 m. This species produces flowers from July to October and capsules during September to December. It was named by the French botanist François Pellegrin in 1930 in honour of Carl Hosseus, a German who was the first botanist to collect on Doi Sutep–Pui late in 1904. The bright red corollas attract sunbirds which effect pollination. 2 November 1996, *c.* 1600 m.

Photo 12

Lithocarpus craibianus Barn. (Fagaceae) near the summit of Doi Pui, *c.* 1600 m on 2 September 1997. This species was first collected at 1500–1700 m on the summit areas of the national park by A. F. G. Kerr before 1910. It was described by Euphemia Barnett in 1938, based on this material, in honour of William Grant Craib. It is apparently endemic to northern Thailand.

Photo 13

A series of small dams along several streams on the east side of Doi Sutep were constructed in the early 1990s, in an attempt to keep more water on the mountain in the dry season. Most of these dams became clogged with silt within 6 months and by now many have cracked. The natural ecology of these streams has been severely disrupted. Near Puping Palace, 1400 m, 6 June 1992.

Photo 14

A scene typical of the agricultural encroachment that occurs over large areas of the national park. Slopes that are far too steep for cultivation are cleared, planted, and sprayed with toxic pesticides, resulting in soil erosion, water pollution, and siltation of waterways. This photograph was taken on 14 October 1990 at *c.* 1200 m near Erawan Resort in the northern part of the national park.

Photo 15

Ficus semicordata B.–H. *ex* J. E. Sm. var. semicordata (Moraceae) is a common deciduous tree found in disturbed areas from 350 to 1550 m in the national park. Figs are produced on branches from the trunk, some of which are underground, from February to May, and provide a food resource for rodents and ground-dwelling birds. In contrast to most other species of *Ficus* in the national park, humans can also eat these figs. 2 April 1997, *c.* 1250 m.

Photo 16

Large parts of the national park are deforested or have degraded land like this. Abandoned agricultural fields become dominated by herbaceous weeds, but scattered surviving trees can provide seeds to enable such areas to regenerate, provided they are protected from fire and other disturbances. 3 October 1996.

Photo 17

Serious fires during the dry season of 1998 wiped out many forest restoration plots. This plot, photographed on 10 April 1998 at 1350 m, has since been replanted and, so far, protected from destruction.

Photo 18

Disposal of garbage is a perpetual and increasingly dangerous problem in Doi Sutep–Pui National Park. Various garbage disposal schemes have been attempted over the years, but garbage dumps like this one are still a common sight. 5 May 1989, *c.* 1000 m.

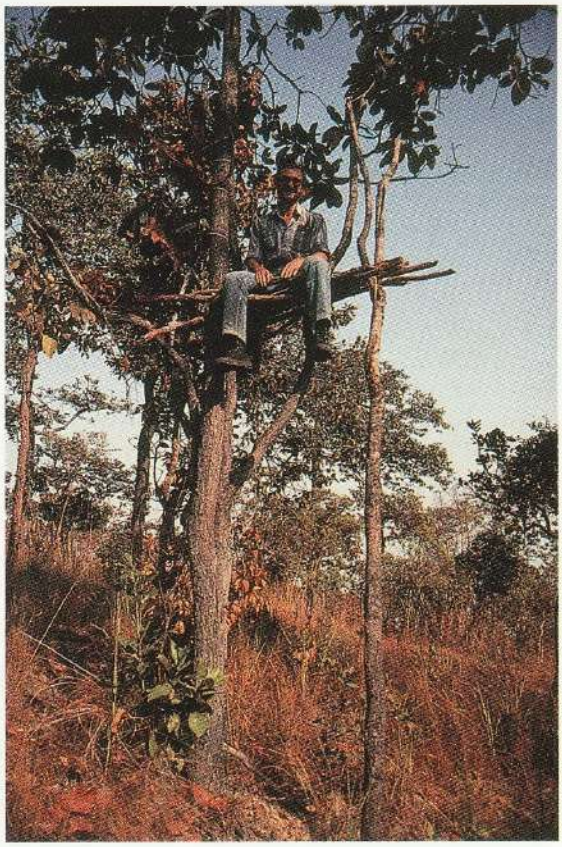

Photo 19

A hunter's platform in deciduous dipterocarp–oak, seasonal forest at *c.* 700 m. Hunting occurs commonly in the national park, especially during the cool-dry season. Extermination of all large mammal and bird species has seriously disrupted forest dynamics, especially seed dispersal. 12 February 1992.

Photo 20

Poor road construction and inadequate protection of the vegetation, combined with heavy rain, caused this landslide near Wat Prataht Doi Sutep at *c.* 1000 m in October 1994.

Photo 21

A Hmong hill tribe woman prepares to plant crops in between rows of native forest trees planted for forest restoration. Cultivation in upper watershed areas of the national park is gradually being replaced by forest restoration projects. 1 June 1996.

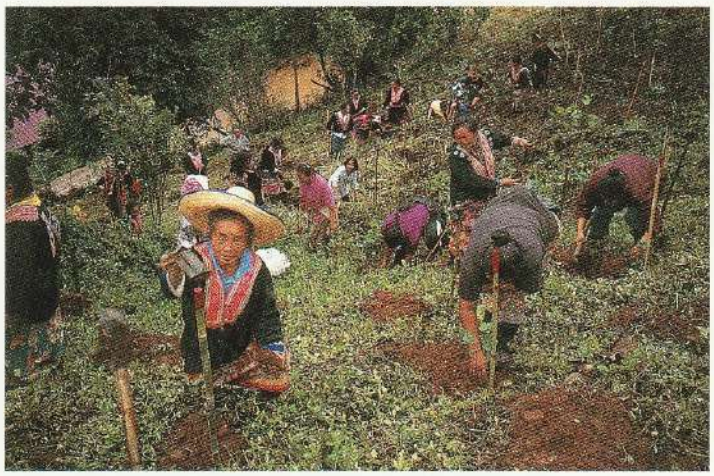

Photo 22

At the beginning of the rainy season, villagers living in the park join in forest restoration activities. Here the villagers of Ban Mae Sa Mai plant trees to celebrate the birthday of Queen Sirikit, 1 June 1997.

Photo 29

Mucuna macrocarpa Wall. (Leguminosae, Papilionoideae) is a common evergreen woody climber found in mxf, egf, and eg/pine forests from 450 to 1650 m. Inflorescences are cauliflorus and are produced during February–March and pendent infructescences with many-seeded pods from May to September.

Photo: Warren Brockelman, summit area of Doi Pui, *c.* 1650 m, early May 1997.

Photo 30

Mussaenda parva Wall. *ex* G. Don (Rubiaceae) includes two synonymous species described from Doi Sutep specimens, viz *Mussaenda sootepensis* Hoss. and *Mussaenda neosootepensis* Craib. It is a common deciduous (below 850 m) or evergreen vine, woody climber, or scandent plant found in all forest types, especially in open areas, from 500 to 1650 m. Flowers with orange corolla lobes are produced during July–March and berries from August to March. The white structures are an enlarged calyx lobe from one lobe on one flower in each cymule in the inflorescence.

Photo: Warren Brockelman, above Montatahn Falls, *c.* 850 m, early May 1997.

INDEX OF TAXA

Taxa printed in regular type are the names accepted in this monograph. *Italicized* entries represent basionyms and the more recent or common synonyms for the accepted names. The list of synonyms is far from complete.

ADDITIONS AND CORRECTIONS

Page 38 *Antidesma kerrii Craib* = *Antidesma montanum* Bl. var. *montanum*

38 *Sauropus siamensis* T. Chakrab. & Gang. = *Sauropus orbicularis* Craib var. *orbicularis*

71 *Euodia glomerata* Craib = *Melicope glomerata* (Craib) T. Hart.

71 *Euodia meliifolia* (Hance) Bth. = *Tetradium glabrifolium* (Champ. *ex* Bth.) T. Hart.

71 *Euodia triphylla* DC. = *Melicope pteleifolia* (Champ. *ex* Bth.) T.Hart.

72 *Euodia viticina* Wall. *ex* Kurz = *Melicope viticina* (Wall. *ex* Kurz) T. Hart.

92 *Lasianthus kurzii* Hk. f. var. *kurzii*

93 *Lasianthus kerrii* Craib 1 pe 3 gro egf 925-1250 my-jn sp-dc ja-dc topotype

104 *Cuscuta reflexa* Roxb. var. *reflexa*

110 *Vitex quinata* (Lour.) Will. var. *puberula* (Lam) Mold.

116 *Antidesma bunius* (L.) preng. var. *bunius*

116 *Antidesma montanum* Bl. var. *montanum*

116-117 material of *Aporusa villosa* (Wall. *ex* Lindl.) Baill. and *Aporusa wallichii* Hk. f. have been reexamined and now include *Aporusa octandra* (B.-H. *ex* D. Don) Vick. var. *octandra* and var. *yunnanensis* (Pax & K. Hoffm.) Schot, and *Aporusa villosa* (Wall. *ex* Lindl.) Baill.

117 *Croton robustus* Kurz. change to *Croton acutifolius* Ess., paratype Doi Sutep

JFM

30 August 2001

Published by
The Biodiversity Research and Training Program (BRT)

With support from
The Thailand Research Fund (TRF)
The National Center for Genetic Engineering and Biotechnology (BIOTEC)
The National Science and Technology Development Agency (NSTDA)