

## ELEPHANT CROP RAIDING PROBLEMS AND THEIR SOLUTIONS AT KUI BURI NATIONAL PARK, SOUTHWESTERN THAILAND

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### ABSTRACT

Measures to stop elephant crop raiding in an agro-industrial crop area are assessed, using the data from documentary research, field observation and reports from the park agency. Expansion of commercial pineapple growing in a lowland valley of favorable elephant habitat has pushed elephants into subordinate upland areas, which are now included in Kui Buri National Park. Due to the close proximity of croplands to the national park, elephants from the park come out and raid the croplands. When pineapple was expensive, 4 elephants were killed. Immediate actions to solve this problem were made under the HM the King's Initiated Project by allocating a part of croplands for elephant habitat improvement. The elephants have not been poached and killed since, but their herds have split into several smaller groups and dispersed, causing more frequent conflicts. Crop raiding occurs in both dry and wet seasons, and is related to the distribution, availability, and nutritional value of fodder in the forests and in the croplands, as well as water availability. Simple electric fences and chasing by park rangers and farmers are present measures to limit movement of elephants to cultivated areas. However, the effort is just a temporary one due to increasing of the elephant population and the very long park boundary in contact with croplands. Appropriate multiple countermeasures with participation of local stakeholders is the recommended longterm solution. They are carrying out land-use planning and establishing schemes to provide permanent benefits to the rural community by using the elephants in the conflict area.

Keywords: Asian elephant, crop raiding, Kui Buri National Park, Thailand

### INTRODUCTION

Crop raiding by elephants is currently the most important problem in the conservation and management of elephants in Thailand. However, elephants have special status due to their role in Thai national history (UMPHANWONG, 1994), so that they are under the patronage of the Thai Royal Family, which plays a very important role in solving this problem. The problem is difficult to solve due to complex factors associated with the interaction of people and elephant ecology (O'CONNELL *ET AL.*, 2000). Factors studied by previous researchers include competition for land and water sources (KANGWANA, 1995; KIIRU, 1995; THOULESS & SAKWA 1995; TCHAMBA, 1995), increases in the area of cultivation (DE SILVA, 1998; TCHAMBA, 1995), natural preference of crops by elephants (SUKUMAR, 1989), elephant optimal foraging strategy (SUKUMAR, 1990), the aggressiveness of male

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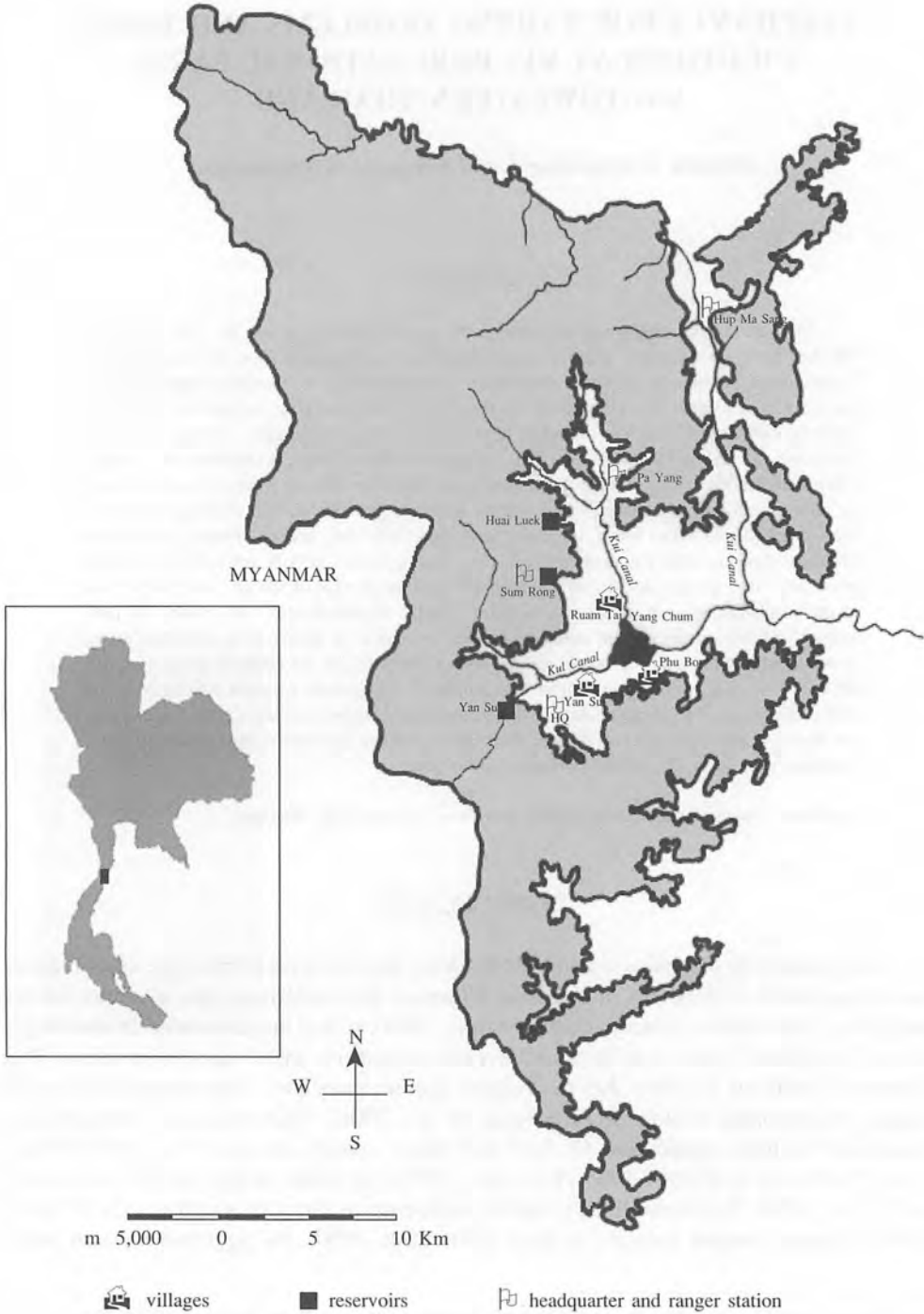


Figure 1. Map of Kui Buri National Park showing boundary and both Kui Canal Valleys that are excluded from the park and mainly grow pineapple as an agro-industrial crop for export.

elephants in finding mates (SUKUMAR, 1991), changes in rainfall (SAM *ET AL.*, 1998) and increase in numbers of wild elephant due to improved protection of habitats and poaching control, and loss of their fear of people (KANGWANA, 1995; TCHAMBA, 1995; NAUGHTON-TREVES, 1998; PRASAD & REDDY, 2002). Localized soil degradation forces people to plant crops in scattered patterns at greater distances from villages where they are more vulnerable to elephant raids (LAHM, 1996). In addition, the severity of this problem also depends on human densities (BARNES *ET AL.*, 1991; NEWMARK *ET AL.*, 1994), socio-economic improvement and raised expectations of the affected farmers and their attitude toward the elephants (BANDARA & TISDELL, 2003; MADDEN, 2004) etc. No single factor may completely explain the phenomenon of crop raiding by elephants, but several of the above factors may play significant roles under particular circumstances (NATH & SUKUMAR, 1998).

Crop raiding by elephants at Kui Buri National Park was studied to understand the phenomenon in an agro-industrial landscape. Other questions asked concerned the pattern of elephant crop raiding and the time of the serious incidents. And finally, what were the outcomes after “solutions” to the problem were implemented under the special project initiated by His Majesty the King.

## STUDY SITE AND METHODS

### Study Area

Kui Buri National Park (KBNP) lies within 11°40'–12°10'N and 99°20'–99°50'E in Prachuap Khiri Khan Province, southwestern Thailand. It has been protected as a National Park since 1990, but was gazetted in 1999 with a total area of 969 km<sup>2</sup>, or 79% of the present forest cover of the province (CHARUPPAT, 1998). This park is an important watershed area for the Kui canal system and its tributaries, which run through the valleys. The park was established by excluding the Kui canal valleys, which became croplands and villages. The present landscape of the park comprises three forest remnants and almost all boundaries in the north, east and south are adjacent to croplands (Fig. 1). The west side borders forest in Myanmar and a part of the northern boundary is adjacent to a Thai Military Security Area. Small villages of Karen people are settled in the northern part of the park. The mean annual rainfall of the Kui Buri district during 1990–2000 recorded by the Meteorological Department was 857 mm and mean annual temperature was 28°C (23.7°–32°C). The first wet season lasts from late April to September. Superabundant rain falls in September to October (Fig. 2). Vegetation of the park is roughly classified as 30% mixed deciduous forest and 70% evergreen forest (KUI BURI NATIONAL PARK, 1999).

Before the 1970s, the valleys were dense forest and elephants were abundant. Elephant captures in this area were legal, using the kraal or Kheddah method (capture of elephant herds by driving them into a large stockade) (SRIKRACHANG, 2004). It was also a refuge for communists (KANGWAN, 2000). After 1969, the Thai government encouraged settlement of remote areas to eliminate communism. The Provincial Administrative Organization rented 35 km<sup>2</sup> of this valley from the Royal Forest Department for 30 years (1979 to 2009) for settlement of 3 villages (Ban Ruam Thai, BanYan Su and Ban Phu Bon). On 31 July 2002, Kui Buri District recorded that there were 1,975, 841 and 151 people in those villages, respectively, and their populations were rather stable during the subsequent four

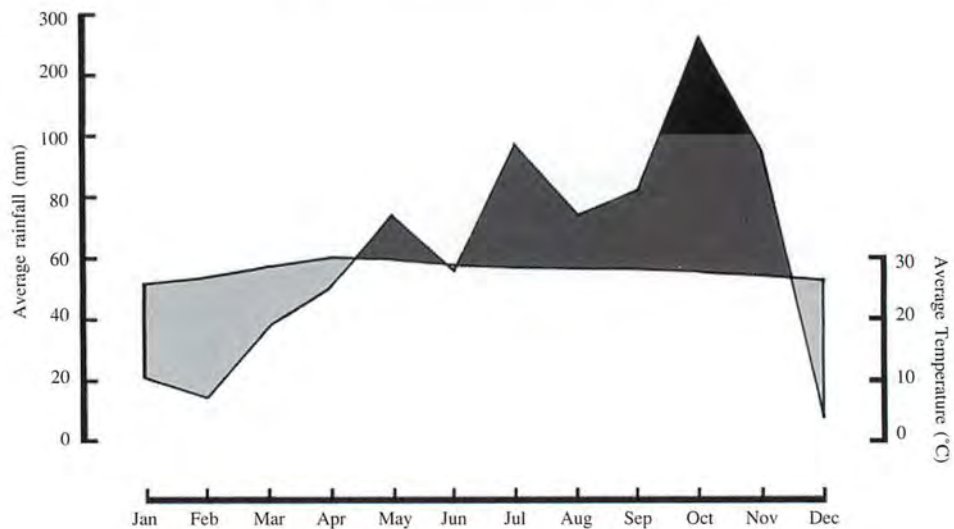


Figure 2. Climate diagram of Kui Buri National Park indicating period of drought (light gray) and period of rainfall superabundance (black). The mean annual rainfall of the Kui Buri district is 857 mm. Data obtained from Amphoe Kui Buri are monthly averages during 1990–2000. Source: Meteorological Department.



Figure 3. Pineapple fields, mango and jackfruit orchards in the Kui Canal valley.

years. People now grow mainly pineapples to supply 11 factories in the province. Other economic plants are mango, jackfruit, eucalyptus (*Eucalyptus camaldulensis* Dehnh.), casuarina (*Casuarina junghuhniana* Miq.), sugarcane, banana, para-rubber, etc (Fig. 3). Four reservoirs (Huai Luek, Som Rong, Yan Su and Yang Chum) were constructed to support the agricultural activities and household utilization (KUI BURI NATIONAL PARK, 1999). The efforts to eliminate communism and expansion of cultivated areas have also driven away the elephants from their preferred habitat. In addition, the elephants were poached heavily, and the population estimate for 1990 was very low (SRIKRACHANG, 1992).

## METHODS

Historical information associated with elephant crop raiding in this area comes from documentary research. The frequency of crop raiding by wild elephants was studied for three crop harvest periods during September 1999 to December 2000, which was soon after the start of the project "Conservation and Restoration of Kui Buri Forest" initiated by His Majesty the King. Under this project, a total of about 108 million baht (USD 2.9 million) was allocated through the Royal Development Project Board for the following activities: reforestation 52.7%, reservoir construction 30%, soil and water conservation 11.2%, park management 3.6%, land development 0.9%, check dam building 0.8%, life quality and agricultural practice improvement 0.7% and elephant food plant growth 0.1% (OFFICE OF THE ROYAL DEVELOPMENT PROJECT BOARD, 1999).

The monthly incidence and locations of crop raiding were collected from the farmers' complaints, reports of investigation of the park rangers, and observations of the first author.

It is very difficult to know the group sizes of elephants raiding the fields because the incidents usually occurred during the night. Therefore, elephant herd sizes and locations where they moved out from the forest edge to feed in the grassland in the evening were observed and noted. However, some clear numbers of elephant raiders in croplands during the night were also recorded. Some known locations of elephant resting areas and birth areas in the years 2000 and 2002 were recorded.

## RESULTS

### General Situation

#### ***Pineapple: An important agro-industrial product of Thailand***

Thailand is the world's largest pineapple producer and exporter (FALVEY, 2000). About 2.6 million tons of pineapple, or 22% of the world's production and 39% of Asia's production, are produced in Thailand (OFFICE OF AGRICULTURAL ECONOMICS, 1994). Canned pineapple and pineapple juices are major products (OFFICE OF AGRICULTURAL ECONOMICS, 2001). In 1994, canned pineapple export peaked at 0.7 million tons, representing 46% of the world's production with 0.1 million tons of pineapple juice in the same year. The export incomes from this crop during 1990–2000 were about 8,400–16,000 million baht per year (OFFICE OF AGRICULTURAL ECONOMICS, 2001).

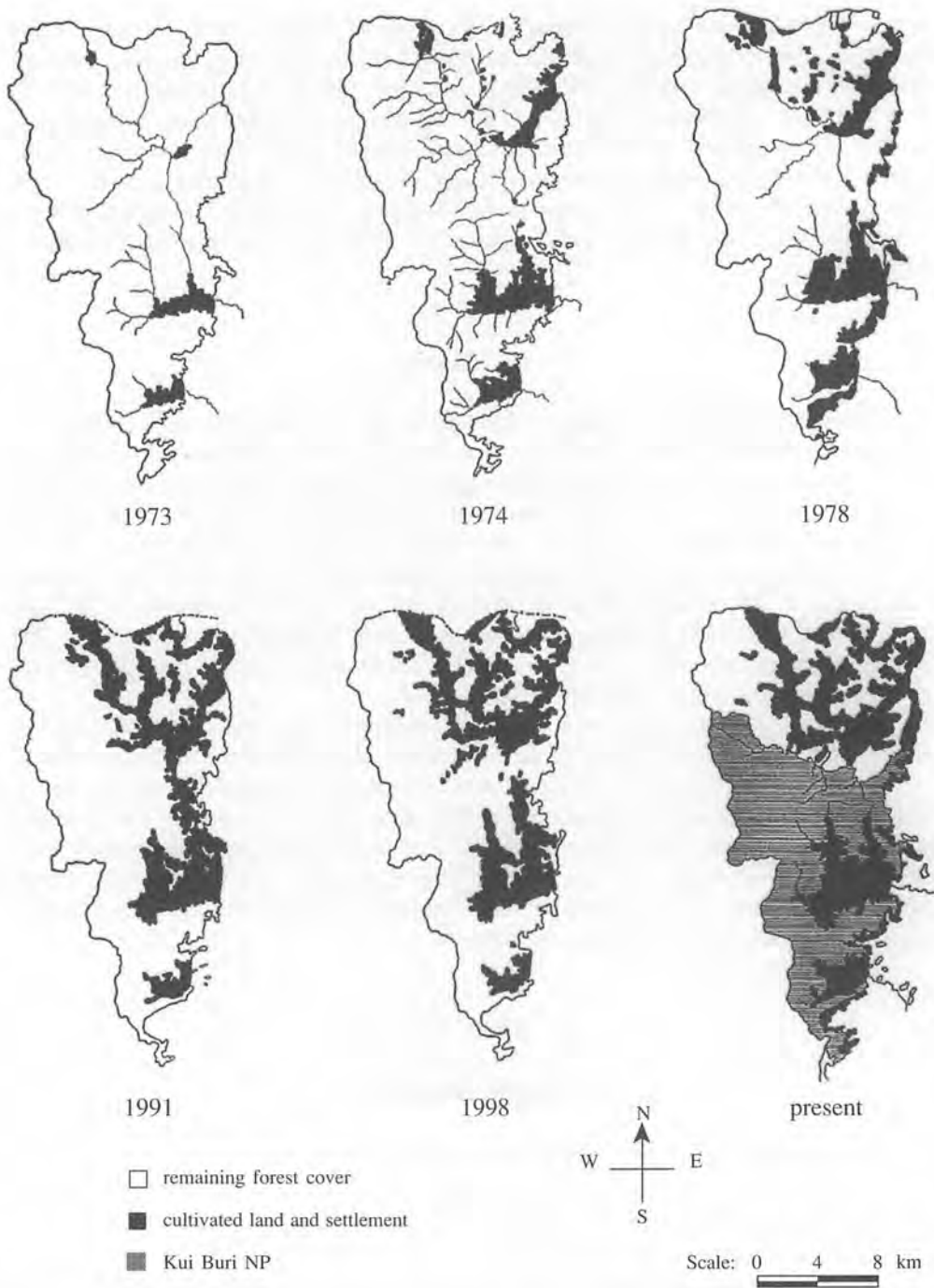


Figure 4. Changes of Kui Buri Reserved Forest in Prachuap Khiri Khan Province since 1973. Rapid conversion of the Kui Canal valleys occurred since 1978, when government promoted the expansion of pineapple plantations and settlement along the canals and their tributaries. Source: The Royal Forest Department.

Pineapple has developed as a major agro-industry since 1967 (THONG-PRASERT, 1983). At that time, the Thai government also had developed a policy to eliminate communism from many remote forests by encouraging settlement and providing the people with agricultural area. Prachuap Khiri Khan Province was one of the target areas for this policy (KANGWAN, 2000). This policy led to a decline of forest area in this province from 79% (5,038 km<sup>2</sup>) in 1961 to 28% in 1978 and 19% (1,228 km<sup>2</sup>) in 1998 (CHARUPPAT, 1998), as shown in Fig. 4. Prachuap Khiri Khan Province became the producer of about 40–60% of the country's pineapple (ALPHA RESEARCH, 2001). In addition, the Thai government had supported investments to establish 11 fruit-canning factories near growing areas in this province (OFFICE OF AGRICULTURAL ECONOMICS, 2001).

Therefore, the elephant habitat in the Kui canal valley became invaded more and more due to uncontrolled forest encroachment and illegal logging as well as lack of appropriate development for this agro-industrial crop. When pineapple prices increased, farmers expanded their growing areas. This caused price declines in the following years, and farmers abandoned the more remote plots close to the forest edges. Wild elephants could visit those croplands without conflict with people. When the crop prices became high again, the farmers came back to expand the pineapple growing area, causing more severe conflict with elephants.

### **Elephant Crop Raiding**

#### ***Before project implementation***

Kui Buri Forest was protected and managed as a national park after 1990 by the Royal Forest Department. Crop raiding by small groups of elephant (5–10 animals) occurred during the night in the dry and first wet season (February–June) of 1991 near the eastern and southern boundaries of the largest park remnant. The elephants visited croplands near the forest edge to drink water and take a bath in the reservoirs (Huai Luek and Yan Su) and man-made ponds and to eat grass, pineapples (ripe fruits and leaves), and visit mineral licks. The farmers tolerated the minor damage when the pineapple prices were dropping during that period (Fig. 6).

The situation has worsened since 1995, because crop raiding has been caused by large elephant herds and pineapple prices have risen (Fig. 6). Before a group of elephants comes out from the forest in the evening, an elephant groans very loudly 2–6 times. Then, they move out together in large compact herds (composed of several family units) to the reservoirs. The calves usually are in the center of the herds or close to their mothers (Fig. 5). About 70–80 elephants were often observed at Huai Luek reservoir, when they were drinking and taking a bath in the evenings of the dry months. However, the large herds usually split apart into smaller groups when they foraged in croplands during the night. Observations during 5–9 July 1997 (the first wet season) indicated that the elephants ate both grasses and pineapples in the croplands. The elephants moved back into the forest before dawn. CHUKAEW (1999) reported that, para skirmishes along the border between Myanmar military and minority Karen people during dry seasons of 1995 and 1996 caused the elephants to move to the Thai side. Many people also believe that shortage of fodder and water sources in the forest during dry periods was the major cause.

### ***Pineapple price: A critical factor***

The situation became severe in the large Kui canal valley when pineapples were expensive in 1997 and 1998 (Fig. 6). Four elephants were killed by farmers. One male and one female died on 22 and 23 May 1997. Post mortem examination indicated that the elephants ate poison, which might have been put inside pineapples. A carcass of one elephant of unknown sex was found on 26 January 1998 (dry season). It apparently consumed poisoned pineapples and died on the way back into the forest. On 20 March 1998 (dry season), an adult male elephant was shot and burnt in the southern valley. When pineapples became expensive, some farmers complained that the elephants damaged about 30 rai (5 hectares) or about 100 tons of pineapples in one night. This meant that the farmers might lose 400,000–600,000 baht (USD 10,500–16,000) at a single raid by the elephants. When pineapple prices were expensive again during 2002–2003 (Fig. 6), one tuskless male was shot on 9 March 2003 and one female died on 10 June 2003 in a cropland due to unknown causes because autopsy was not made.

### ***Solutions under HM the King's project***

After the deaths of the elephants, solutions to the elephant problem were formulated in May of 1997 in a meeting led by Princess Rangsinopdol Yugala, (His Majesty's cousin and an elephant lover) with the cooperation of the First Army and the Royal Forest Department, based on the belief that shortage of food and water inside the park had caused crop raiding by elephants in this area. Elephant habitat improvement has been undertaken in the northern cropland valley, especially enlargement of ponds and mineral licks. Elephant lovers bought fruits such as bananas, jackfruit, pineapples, guava and sugarcane, left them near the forest edges to feed the elephants. This measure has been carried out continuously to the present during the crop raiding season (dry to first wet season) (Figs. 7 and 8). Elephant food plants (banana, bamboo, sugarcane, etc) have been planted, with rows of dense, thorny thicket of Si Siad Nam (*Acacia* sp.) to prevent elephants from entering the plantations. When the trees grow up and have fewer thorns, the elephants eat them. Additional measures by park rangers, military personnel and farmers include guarding the crops and chasing the elephants from the croplands.

His Majesty's Project "Conservation and Restoration of Kui Buri Forest" has been implemented since May 1998 after a male elephant was shot and burnt on 20 March 1998. About 16 km<sup>2</sup> of the cropland in the northern valley was returned permanently to the project for reforestation, soil and water conservation, and elephant habitat improvement. Because the Kui canal and its tributaries have become dry or stopped flowing after being long-term crop growing areas, 9 small reservoirs, many ponds and hundreds of check dams were built to keep water all year round. Another 3 reservoirs were constructed in 2004. Some forage crops from the Department of Livestock Development have been sown from helicopters. About 30 artificial mineral licks were also created. Checkpoints were set up as stations for an "elephant driving team" to protect crops and elephant lives. Rangers and farmers are hired to guard crops and chase the elephants away from the plantations during the peak of the crop raiding season. Therefore, not only have wild elephants benefited from the project, but also local people have received income from the various activities of the project. In addition, two ranger stations, Pa Yang and Hup Ma Sang, were established in 1998 and 2004, respectively, in both Kui canal valleys to provide safety for the elephants.



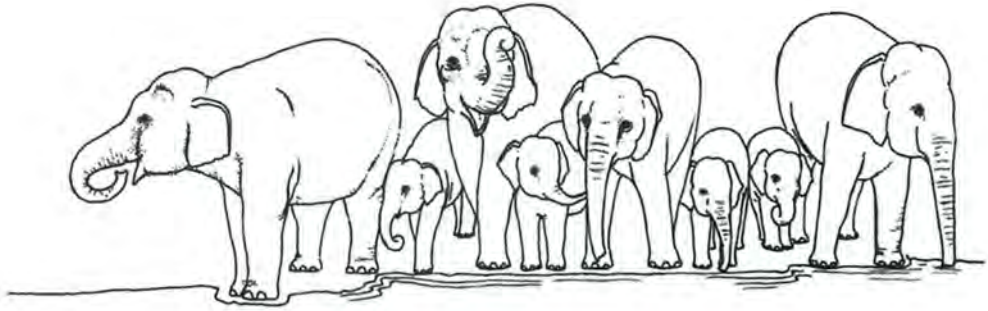


Figure 5. A group of a 22 elephants drinking water at Huai Luek reservoir on an evening in March 1998. The calves were close to their mothers. Picture drawn from a photo.

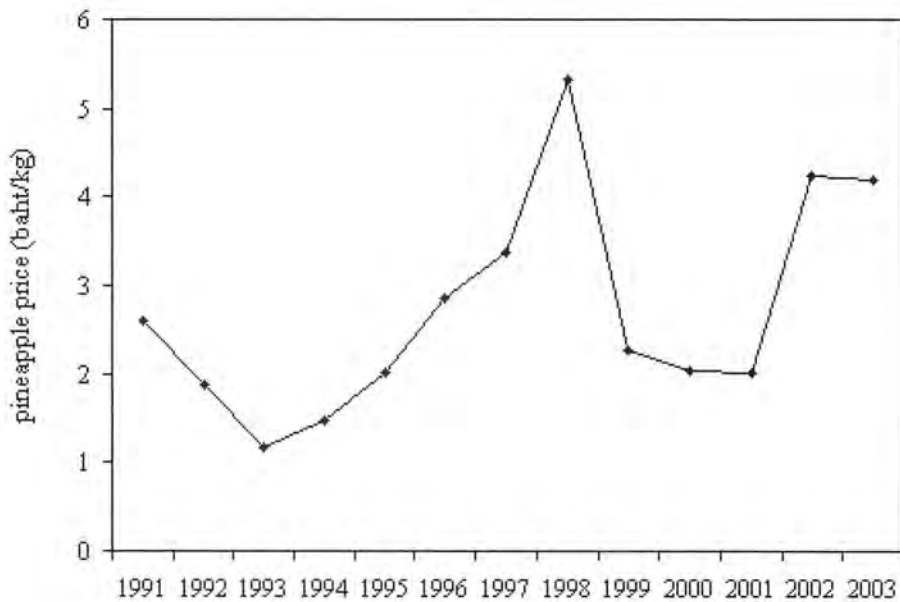


Figure 6. Pineapple prices in Thailand during 1991 and 2003, an important factor influencing the severity of man–elephant conflict at Kui Buri NP. Four wild elephants were killed by farmers when the pineapple prices were high in 1997 and 1998, and another two elephant deaths occurred in 2003. Source: Office of Agricultural Economics.



Figure 7. During dry season, Princess Rangsinopdol Yugala kindly provided a budget to buy food for wild elephants in Kui Buri NP.



Figure 8. An adult tusker came out soon after jackfruits were thrown on the ground near Pa Yang Ranger Station (24 December 2004).





Figure 9. Eleven small reservoirs and several ponds were constructed for the elephants.



Figure 10. The Project Area has become preferred habitat for wild elephants. It includes grassland and secondary forest, which attracts the elephants.

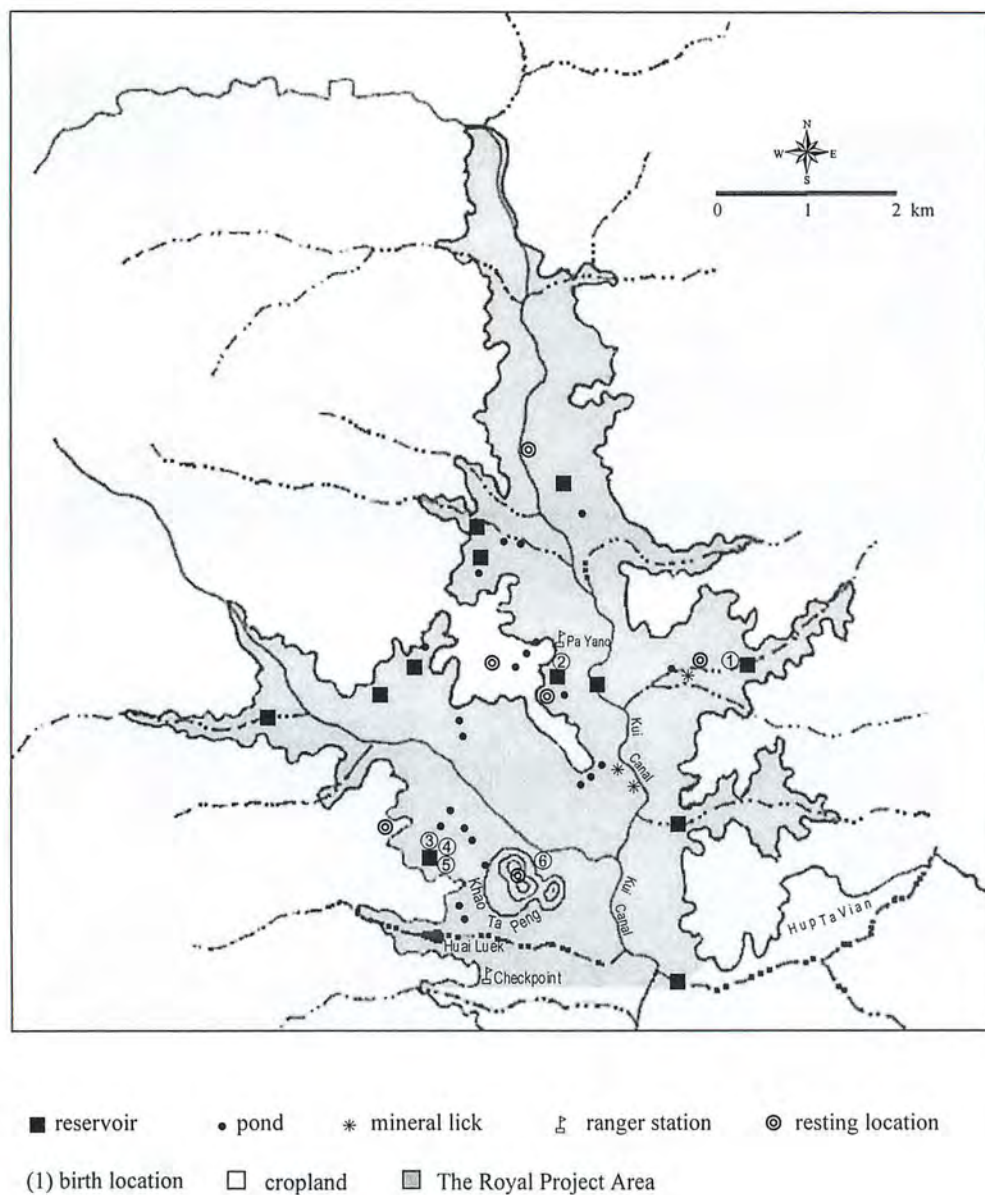


Figure 11. Locations of elephant birth and resting areas in the Project Area. The known birth locations observed in 2000 were: (1) 29 June at reservoir 7; (2) 18 July near Pa Yang Ranger Station; (3) 8 August at reservoir 6; (4) 11 September Hup Ta U near reservoir 6; (5) 14 October at reservoir 6; and, (6) 20 May 2002 near Khao Ta Peng.





Figure 12. Mother with young calf near Pa Yang Ranger Station in the wet season (22 September 2002).



Figure 13. Mother with two calves near Khao Ta Peng in the dry season (17 March 2003).

## After Solution Implementation

### *Return of preferred elephant habitat*

The King's project area has become the preferred habitat for the elephants again. It is composed of a mosaic of secondary forest, natural grassland, forest plantation, and large food patches for elephants as well as many water sources (Fig. 9). Weeding carried out in the reforestation plots in the dry season has increased elephant foods since many grasses sprouted new leaves abundantly during the first wet season (Fig. 10). Major elephant food plants include the grasses, *Pennisetum polystachyon* (L.) Schult, *Panicum* spp., *Brachiaria mutica* (Forssk.) Stapf, *Imperata cylindrica* Beauv., and *Panicum maximum* Jacq. It was observed that wild elephants consumed *Panicum* spp. all year round. The nutritional value of these grasses is shown in Appendix 1. *Eupatorium odoratum* Linn. (Asteraceae) is also abundant but the elephants did not eat this weed.

### *Crop raiding pattern*

Due to the project initiated by HM The King, poaching and forest encroachment can now be controlled. The elephants have been resident in the project area longer than before project implementation. Their resting areas and the locations where females gave birth were also found near the forest edges and in the project area. Six known elephants gave birth during the first wet and second wet season in 2000 and 2002. The amniotic sacs and blood were found in the following places: 1) 29 June at reservoir 7; 2) 18 July near Pa Yang ranger station; 3) 8 August at reservoir 6; 4) 11 September at Hup Ta U near reservoir 6; 5) 14 October at reservoir 6; and 6) 20 May 2002 near Khao Ta Peng (Fig.11). The project area is a preferred habitat for taking care their young (Fig. 12 and Fig. 13). There are probably 150 wild elephants in this park and population trend is increasing, as calves and juveniles are usually observed as the predominant age classes.

In addition, the mean herd sizes observed during 1998 and 2000 became smaller, from 31.1 individuals ( $N = 84$ ,  $SD = 13.91$ ) in 1998, 21.7 animals ( $N = 273$ ,  $SD = 14.29$ ) in 1999, and 14.1 animals ( $N = 389$ ,  $SD = 10.71$ ) in 2000 (Fig. 14). The elephants also have not been heard groaning before moving out from the forest to the grassland. They usually formed smaller groups and emerged silently from several points along the forest edge. They visited croplands more frequently and moved farther to the next Kui Canal Valley (Fig. 15) and seldom used the border habitat. Sometime large herds were still observed in the wet season. However, herds of 70–80 individuals have not been seen in recent years.

However, the elephants still maintain a pattern of crop-raiding during the dry season to early second wet season (April to August). Crop raiding data indicate that in 2000, 75% of incidents ( $N = 58$ ) occurred during April to August and 20% ( $N = 15$ ) occurred during the dry season (January–March and November–December) and only 5% ( $N = 4$ ) were during September–October (Fig. 16). During April and June, cropland areas damaged on 4 raids were estimated at 107, 155, 60 and 11 rai (or 17, 25, 10, 2 hectares), respectively. Efforts to drive the elephants away were made during this period (Fig. 17).

The peak of the crop raiding season is in the first wet season (April–July), when there are abundant new flushes of grasses which have high protein content. This season is in the pineapple harvest period. In addition, it is the season of mangos (April to May) and jackfruits (April to July).

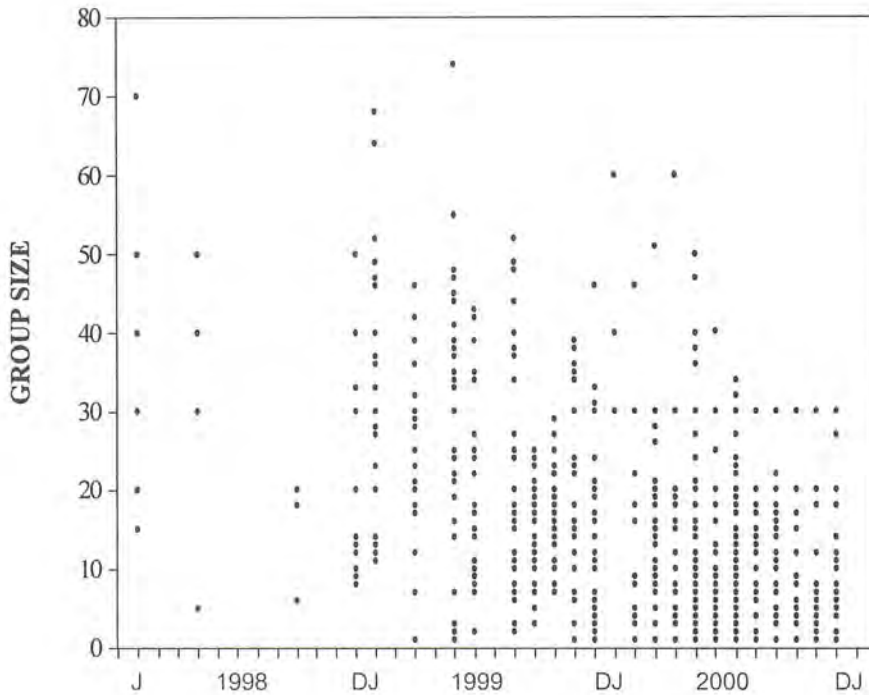


Figure 14. Group sizes of wild elephants when they came out from the forest observed during 1998–2000. D and J are December and January, respectively.

Elephants came out from the forest to forage in the grassland of the project area in the evening and on some nights they moved into the croplands. They moved back into the forest before dawn to take a rest or to feed in the shade of the forest inside the park to avoid the heat of the open areas during the day. However, in the wet season when the weather was cool and shady, the elephants foraged near the streams in the project area even at noon. When the second wet season arrived during September and October, which is “bamboo shoot season” in the forest, crop raiding occurred less frequently because the elephants fed mainly in the forest. When grasses dried out in the dry season from November and December to March, elephants mainly switched to browse in the forest. Crop raiding occurred due to the attraction of water in the croplands and elephant movements between forest patches which crossed croplands. Raiding frequency in dry months was less than in wet season.

#### *Other species that benefited*

Gaur is another species that is benefiting from the project following the return of the elephants. They were first observed in the north of the project area during May of 2000. The population at present is estimated at 50 individuals. Tigers can also be seen at the reservoirs and in the grassland.



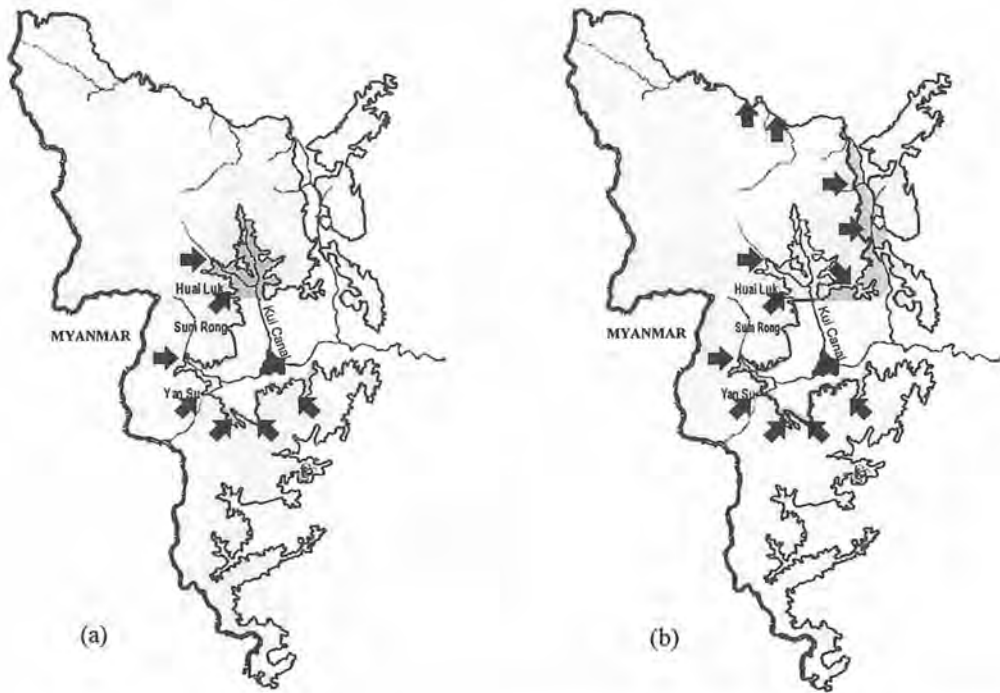


Figure 15. Maps of Kui Buri NP showing comparison of elephant crop raiding locations (gray) before and after project implementation. (a) During 1994–1997, crop raiding by wild elephants occurred in the northern large valley and along the forest edges in the southern part; (b) After the King's Project, by returning the conflict area in the northern valley for elephant habitat improvement in 1998, the elephants have dispersed their ranging to the next eastern Kui canal valley and the northern border (since 2003).

### *Lessons learned*

In the wet season during 1999 and 2001, 9 male calves drowned in some deep reservoirs and man-made ponds with steep banks. After the deaths of the elephant calves, the steep-sided banks were adjusted to be more gradual. One juvenile died in June 2002. It was speculated that it ate jackfruits in which had been put some substance to stimulate ripening.

Even the affected people received special income from activities of the King's Project. They have learned that killing elephants to solve the problems may cause them greater difficulties, such as having their lands returned to the park for habitat improvement. When two more elephant deaths occurred in the crop raiding season in 2003, the people claimed that they were not responsible for them.

After some croplands in the Kui canal valley were returned for elephant habitat improvement, the elephants came to use the area, which was adjacent to other croplands. This may have induced the elephants to disperse further, increasing conflict and crop raiding frequency.



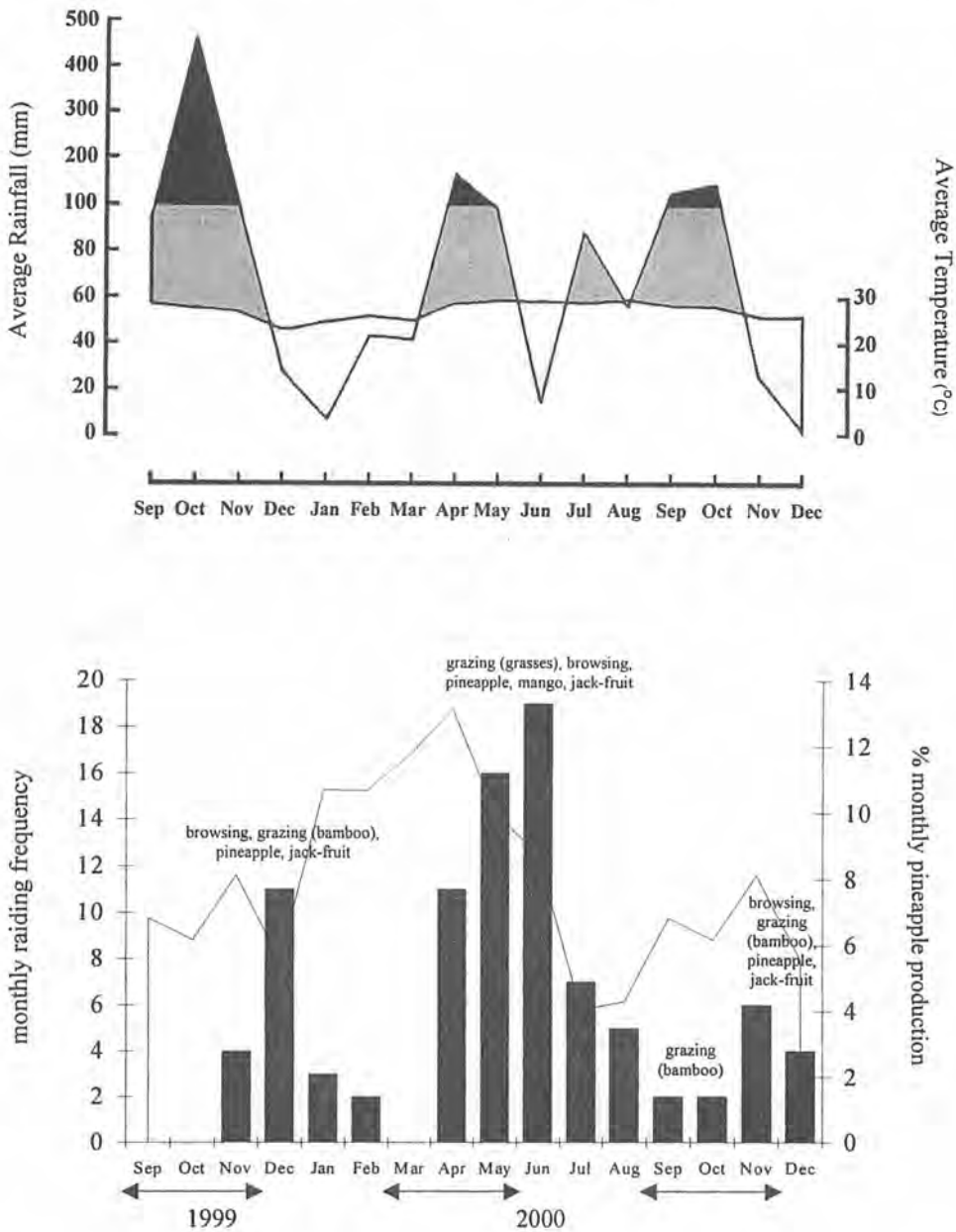


Figure 16. (Upper) Climatic diagram during September 1999 to December 2000 in the grassland of the Project Area, indicating period of drought (light gray) and period of rainfall superabundance (black). (Lower) Percentage average of monthly pineapple production (background), the arrow ranges were crop-harvesting periods of pineapple. Black columns represent monthly incidence of crop raiding by wild elephants.

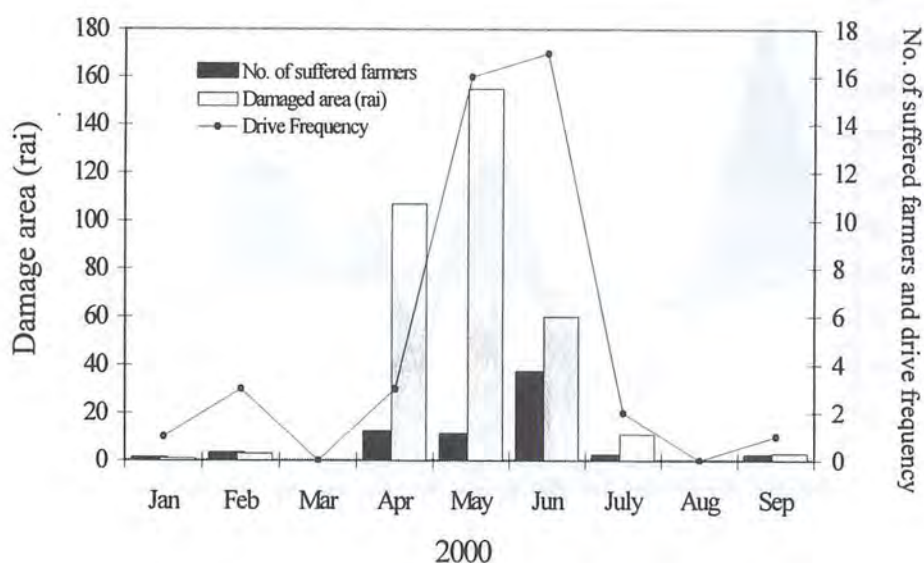


Figure 17. Areas of pineapple plantations damaged by wild elephants at Kui Buri NP during the peak period in 2000, and numbers of affected farmers and frequency of elephant driving. Data obtained from Kui Buri NP official. Note: 1 rai = 0.16 hectare.

## Current Measures

### *Methods of local people*

In the past, some people placed pieces of wood fixed with long nails on elephant trails to frighten the animals. This method has been prohibited as the result of the Royal Project. Elephant raiders usually were chased away from the plantations by cropland owners. Before the harvest period, guarding and using spotlights or making loud noises (such as beating on metallic plates, shouting, dogs barking, shooting into the air, firecrackers, fireballs, etc) are common methods used to chase elephants back into the forest. In addition, simple electric fences were installed around the pineapple plantation to limit elephant movement and reduce crop damage. Currently, this method is less effective because when some elephants break through the fence at any point, it is hard to drive them back because the fence is a barrier. However, the elephants have never tried to enter the peoples' villages.

### *Methods of park managers*

Since 2003, the expenses for elephant repulsion (about 400,000 baht or USD 9,640 a year) have been allocated from the income of the Department of National Parks, Wildlife and Plant Conservation. This income comes mostly from tourist services in the national parks.

## DISCUSSION

### Causes and Season of Crop Raiding

The proximate cause of elephant crop raiding at KBNP is large-scale expansion of the commercial pineapple growing area in the prime elephant habitat in the Kui canal valleys. The result of this factor has led to fragmentation and degradation of elephant habitat in close contact with pineapple plantations. Crop raiding generally occurs in both Kui Canal valleys from the north, east and south. This is also the root cause of crop raiding found in other areas (SUKUMAR, 1990; KIIRU, 1995; DE SILVA, 1998; TCHAMBA, 1995; WILLIAMS *ET AL.*, 2001).

Elephant movements and home ranges are usually governed by available food, water (both natural sources and man-made ponds) and mineral licks (SEIDENSTICKER & MCNEELY, 1975; LEKAGUL & MCNEELY, 1977), which the elephants can find in the croplands. Ultimately, crop raiding can be considered as an extension of the elephants' optimal foraging strategy, which relates to social organization and the "high-risk-high-gain strategy" adopted by male elephants to increase their fitness (SUKUMAR & GADGIL, 1988; SUKUMAR, 1990). However, in the low risk areas female herds or family groups also raid crops and sometimes they cause more damage than males (WILLIAMS *ET AL.*, 2001).

As found in many previous studies, elephants preferred to eat grasses during the wet season and mainly woody browse in the dry season (BARNES, 1982; SUKUMAR, 1990; SUKMASUANG, 1993). OSBORN (1996) found that movements of elephants out of the forest were associated with the onset of rain or the appearance of grass. SUKUMAR *ET AL.*, (1987) studied the different feeding patterns using the carbon isotope ratio ( $^{13}\text{C}/^{12}\text{C}$ ) of bones, and found that younger elephants preferentially grazed while adults primarily browsed. These may explain why crop raiding in KBNP by large female herds peaks in the early wet season. In abundance of grasses with high protein content has induced elephant foraging both in the Royal Project area and in adjacent croplands, which is the season of pineapple, jackfruit and mangos as well. Another important ultimate cause of crop raiding at KBNP is the pineapple price. When pineapple is expensive, the problem becomes more serious and the elephants are often killed.

### Group Sizes

In general, average group sizes of forest elephants are smaller than those of savanna populations (TURKALO & FAY, 1995), (about 4–6 animals) (OLIVIER, 1978; SUKMASUANG, 1993). DOBIAS (1985) found average group-size in Khao Yai NP of 9; these data came mainly from sightings at salt licks along the road where the elephants also tended to gather in the open.

Ecological factors may have influenced the formation of large elephant herds (70–80 animals) often observed in KBNP during the early period of crop raiding (during 1995–1997) before solutions were implemented under HM the King's Project. This may have been due to limitation of water sources in the dry season. The elephants aggregated mainly at Huai Luek reservoir, the only large water hole close to the forest edge. Stressful condition from human pressure is another reason. In Sri Lanka, the largest groups were often observed in habitats with poaching and encroachment (DISSANAYAKE & SANTIAPILLAI, 2001). In KBNP,

water sources were increased and better distributed after measures were taken to solve the problem. In addition, the measures were taken to protect the elephants. Large herds were not observed after that. However, herds of 20–30 elephants are still sometimes observed in the grassland. Factors cited as being important in causing aggregation include anti-predator strategy (EISENBERG *ET AL.*, 1990), distribution and abundance of food, and social interactions (TURKALO & FAY, 1995; DUBLIN, 1996). These phenomena are also observed in African elephants in the wet season when preferred forage plants are abundant, when family groups or cow–calf groups are accompanied by males (DUBLIN, 1996). In addition, this period is the season of mating in KBNP.

### Appropriate Long-term Solutions

Elephant crop raiding at KBNP has been reduced by HM the King's Project, which has been implemented by responsible government organizations with participation of the local community. The project has promoted benefits to the elephants, especially habitat improvement and increased security. The improved condition of the habitat may result in higher conception rates, shorter mean calving intervals, lower age of puberty, and higher juvenile survival (BARNES & DOUGLAS-HAMILTON, 1982). The elephant population in Kui Buri NP is increasing. Several smaller raiding herds have split off and dispersed. The severity and frequency of crop raids has also increased. At present, measures to reduce raiding are carried out by the park rangers, including guarding and chasing the raiding elephants from the plantations. The annual budget supporting this work is derived from the Department of National Park, Wildlife and Plant Conservation. Many studies have indicated that man–elephant conflict cannot be eliminated as long as elephant habitat and agricultural land co-exist side by side (THOULESS & SAKWA, 1995; BANDARA & TISDELL, 2003). In addition, Kui Buri NP has a very long boundary in contact with croplands. Therefore, long-term conflict cannot be avoided. The present Thai constitution, adopted in 1997, encourages decentralized management of natural resources with the participation of local communities. There is a particularly strong need for local stakeholders to participate in land use management, especially buffer zone management along park borders, eco-tourism, and even establishing schemes to provide permanent benefits to local people by using elephants and other wildlife. This process should be implemented through adaptive management, through learning by doing, and supported by research. Post-mortem examinations after elephant deaths should be carried out to establish the causes.

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**Appendix 1.** Nutritional value of some plant species (mainly grasses) and pineapple found in the HM King Initiated Project Area, Kui Buri National Park (PANICPHOL & CHIAM-CHETCHAROON, 1998)

Plant Species	% on dry basis											
	dry matter	crude protein	crude fat	crude fiber	ash	NFE	cellulose	ADF	NDF	Lignin	Ca	P
<i>Pennisetum sp.</i>	19.55	<b>10.11</b>	1.58	28.72	12.52	47.07	32.14	41.09	65.69	2.95	<b>0.33</b>	<b>0.24</b>
<i>Dichanthium annulatum</i>	-	<b>9.74</b>	1.29	30.21	12.07	46.69	32.12	42.66	69.32	4.89	<b>0.53</b>	<b>0.24</b>
<i>Brachiaria mutica</i>	21.55	<b>9.54</b>	2.24	33.63	12.60	41.99	32.30	41.87	64.63	3.74	<b>0.40</b>	<b>0.30</b>
<i>Panicum maximum</i>	24.10	<b>8.67</b>	1.37	29.51	11.89	48.56	37.19	44.51	69.57	5.07	<b>0.51</b>	<b>0.16</b>
<i>Cynodon dactylon</i>	27.10	<b>8.30</b>	2.09	29.49	8.83	51.29	-	-	-	-	<b>0.39</b>	<b>0.13</b>
<i>Panicum sp.</i>	23.80	<b>7.63</b>	2.23	33.68	9.01	47.45	37.30	46.38	74.05	4.82	<b>0.35</b>	<b>0.28</b>
(petal)	-	<b>8.58</b>	1.40	21.34	7.96	60.72	24.44	29.21	51.92	3.80	<b>0.65</b>	<b>0.18</b>
<i>Ananas comosus</i> * (peel)	10.02	<b>6.87</b>	1.13	20.60	6.62	64.78	-	23.40	43.90	2.60	<b>0.33</b>	<b>0.19</b>
(leaves)	-	<b>8.47</b>	2.17	17.89	5.89	65.58	21.39	25.87	42.28	3.61	<b>0.81</b>	<b>0.09</b>
<i>Dactyloctenium aegyptium</i>	-	<b>6.24</b>	1.19	26.29	10.25	56.03	29.63	38.75	70.05	5.24	<b>0.26</b>	<b>0.14</b>

\* pineapple

