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FIRE, DRY DIPTEROCARP FOREST, AND THE CARNIVORE COMMUNITY IN HUAI KHA KHAENG WILDLIFE SANCTUARY, THAILAND.

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ABSTRACT

Widespread annual burning in parts of Thailand has degraded natural forest formations and encouraged the spread of the fire resilient dry dipterocarp forest. The influence of fire and dry dipterocarp forest on the carnivore community was examined during a two year study in Huai Kha Khaeng Wildife Sanctuary, Thailand. Seasonal fires influenced mortality and movements of carnivore species. All carnivores showed a disproportionately low use of dry dipterocarp forest compared to other habitat types, and all took refuge in evergreen forest during the driest times of the year. Some carnivore species were restricted to evergreen forest alone. The evergreen forest was a crucial component of carnivore home ranges. The dry dipterocarp forest was a resource poor habitat characterized by seasonal water scarcity and a relatively low abundance of prey species and fruiting trees. Small carnivores were more affected by fires and by resource scarcity in dry dipterocarp forest than were larger, wider-ranging carnivores. However the distribution of the tiger in the study area was also limited by dry dipterocarp forest. Despite a diverse carnivore community in the study area, seasonal fires and the presence of dry dipterocarp forest threatens the health and stability of many carnivore populations. Dry dipterocarp forest should not be allowed to spread at the expense of evergreen forest formations. Total exclusion of fire is not feasible in Thailand's remaining forest areas, but an alternative policy of prescribed burning combined with fire exclusion in high priority habitats appears sensible.

INTRODUCTION

Although fire is a naturally occurring phenomenon, most of the fires that have influenced present day tropical forest formations have been anthropogenic (BUDOWSKI, 1966; BATCHELDER, 1967). Through a long history of uncontrolled human use, fire has become an endemic ecological force in the seasonally dry forests and grasslands of the tropics (BARTLETT, 1956; STOTT, 1988b). This is clearly evident over large areas of mainland south–east Asia. Widespread annual burning during the long dry seasons has gradually degraded natural forest formations and encouraged the spread of fire–resilient dry dipterocarp forest formations which today cover large areas of Burma, Thailand, Laos, Cambodia, and Vietnam (STOTT, 1984; WHARTON, 1966, 1968).

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Despite its destructive force, fire is rarely considered to be harmful to wildlife. Most vertebrates are capable of escaping harm (KOMAREK, 1969; SINGER et al., 1989) and do not often die in wildfires or prescribed burns (BENDELL, 1974; HOWARD et al., 1959; LEEGE. 1968). In areas with seasonal fires, animals are presumed to be fire-adapted through natural selection (KOMAREK, 1969), with avoidance being the most prevalent adaptation (STOTT, 1988b). Some species of wildlife, particularly ungulates, benefit from the protein-rich shoots which sprout after a burn (KOMAREK, 1969; MOE et al., 1990) and are attracted to habitats that fire helps sustain (STOTT, 1988a; WHARTON, 1966, 1968).

There is little information published on the effects of uncontrolled seasonal fires and fire-associated habitats on wildlife communities. In south-east Asia, despite the apparent benefits of fire and dry dipterocarp forest to large species of ungulates such as gaur *(Bos gaurus)* and banteng *(B. javanicus)*, the dry dipterocarp forest is relatively impoverished in wildlife such as small terrestrial mammals (WALKER & RABINOWITZ, in press; WILES, 1981), birds (WILES, 1980; ROUND, 1988), herpetofauna (HEYER, 1970) and invertebrates (WHARTON, 1966). In the combined areas of Thung Yai and Huai Kha Khaeng Wildlife Sanctuaries on the western border of central Thailand, only eight vertebrates are listed as primarily associated with bamboo and dry dipterocarp forest areas, while 325 species are associated with mixed deciduous and evergreen forest formations (NAKHASATHIEN & STEWART-COX, 1990).

In the dry tropical forests of Huai Kha Khaeng Wildlife Sanctuary, fires are started by both local people and sanctuary staff every year. During years of heavy rainfall, fire is primarily confined to the more open dry dipterocarp forest formations. During drier years, particularly when leaf litter and ground cover from previous years has not been burned, hotter and more extensive fires penetrate into the evergreen and mixed deciduous forest areas and do more damage to the dry dipterocarp forest itself (STOTT, 1986). Fire in the less fire-resilient mixed deciduous and evergreen forest, allows the further spread of dry dipterocarp formations (STOTT, 1986, 1988).

Research on the carnivore community was carried out in Huai Kha Khaeng Wildlife Sanctuary between 1987 and 1989 (RABINOWITZ, 1989, 1990, 1991 ; RABINOWITZ & WALKER, 1991). I present data on how fire and the dry dipterocarp forest affects some of these carnivores, and what the current fire regimes mean for the future of the sanctuary's wildlife communities. Possible fire management strategies for Thailand are also discussed.

STUDY AREA

Huai Kha Khaeng Wildlife Sanctuary (2,575 km^2) encompasses the Huai (= stream or small river) Kha Khaeng and part of the Huai Thap Salao watersheds. The core study area encompassed 50 km^2 around Khao Nang Rum Research Station, in the eastern portion of the sanctuary, and included part of two stream systems, the Huai Chang Tai and Huai Ai Yo. Only the Huai Ai Yo is a permanent source of water throughout the year.

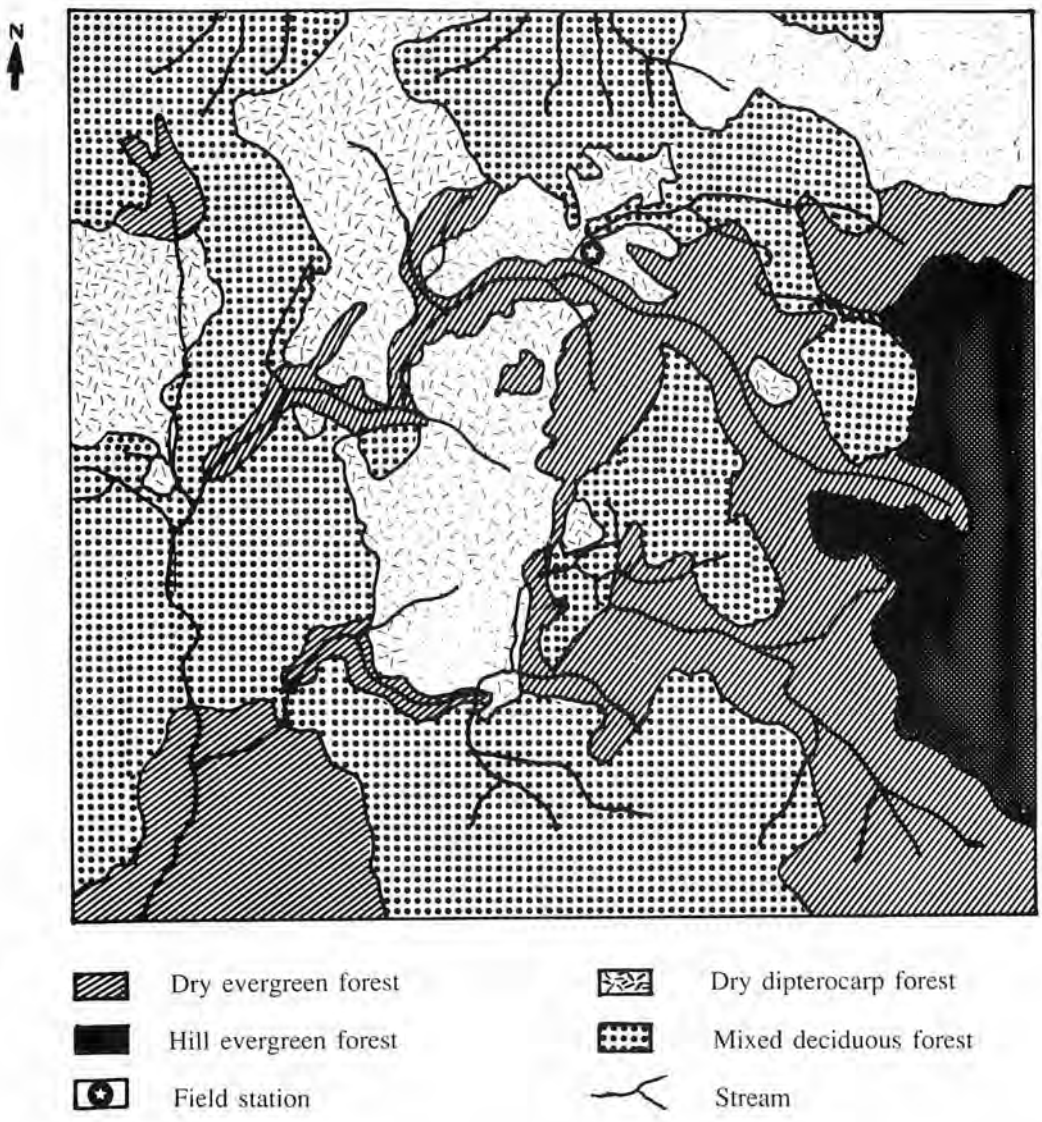

Figure 1. Map showing distribution of habitats at study site, Illustration represents a 10 km x 10 km area.

Most of the study area ranges in elevation from 400–600 m, but includes part of Khao Khieo mountain at 1350 m.

Vegetation in the area is a mosaic of four forest types (Fig. 1), described in greater detail by BHUMPAKKAPUN *et al.*, (1985), STOTT (1984), and THITATHAMAKUL

(1985). These include the following: *Mixed deciduous forest,* comprising 35% of the study area and found primarily on moderately sloping and flat areas near streams. The tallest trees are 20–30 m high and average ground cover is 70%; *Dry deciduous dipterocarp forest,* comprising 23% of the study area, with a more open canopy, and a floral composition indicative of an artificial climax maintained by annual fires (STOTT, 1986). The tallest trees are 20–30 m high and average ground cover is 80% in the rainy season. After dry season fires, the ground is mostly bare; *Dry evergreen forest,* comprising 35% of the study area, a relatively dense formation found mostly along the waterways. Ground cover averages 47%, and is dense only in gap areas; *Hill evergreen forest,* comprising 7% of the study area, is found only above 1000 m around the summit of Khao Khieo Mtn.

Temperature and rainfall records from 1983–1987 (Table 1) show clear seasonal patterns. During the 1988 study season, rainfall was greater than in previous years. The fire season, generally from December through March–April (STOTT, 1986), was shortened to March through mid-April by unusually heavy rains. Consequently, there was less fire damage in the study area, and the dry deciduous dipterocarp forest was burned more severely than the mixed deciduous and dry evergreen forest.

RESULTS

Twenty-one carnivore species of five families occur in the study area (RABINOWITZ & WALKER, 1991). A total of 27 carnivore species are listed for the entire sanctuary (NAKHASATHIEN & STEWART-COX, 1990).

Felidae —One resident tiger *(Panthera tigris)* and four resident leopards *(P. pardus)* were tracked for more than a year (RABINOWITZ, 1989). Despite minimum home ranges of these large cats between 11–37 km^2, their core activity areas (where an animal was located >75% of the time) were much more restricted and were based around waterways in the evergreen forest formations. During the dry season, the cats clearly avoided forest that was burning and were found in dry dipterocarp forest much less frequently than during other times of the year.

Four species of small to medium-sized cats also occur in the study area (RABINOWITZ & WALKER, 1991), but all except the leopard cat *(Felis bengalensis)* were uncommon. The clouded leopard *(Neofelis nebulosa)* and the jungle cat *(F. chaus)* were both seen on a single occasion in mixed deciduous forest. The Asian golden cat *(F. temminicki)* was seen scavenging a dead banteng carcass in the dry dipterocarp forest.

Five leopard cats were captured and four were tracked for periods ranging from one to 13 months (RABINOWITZ, 1990). All captures and all core activity areas were in dry evergreen or mixed deciduous forest close to a waterway.

One male leopard cat shifted ranges during the fire season. For unknown reasons, he moved from an unburned evergreen forest area into dry dipterocarp forest that was burning extensively. He took refuge in a ravine along a small waterway but was later

Figure 2. Fire-influenced dry dipterocarp forest in Huai Kha Khaeng Wildlife Sanctuary (photo by Seub Nakhasathien).

Figure 3. Dry evergreen forest around Khao Nang Rum Research Station in Huai Kha Khaeng Wildlife Sanctuary (photo by Alan Rabinowitz).

Figure 4. Dry season fires burning dry dipterocarp forest in Huai Kha Khaeng Sanctuary (photo by Sompoad Srikosamatara).

Figure 5. An advancing ground fire in dry dipterocarp forest in Huai Kha Khaeng Sanctuary (photo by Belinda Stewart–Cox).

Figure 6. The result of several fire seasons eating away at the "yang oil" holes at the base of a large, healthy dipterocarp (photo by Susan Walker).

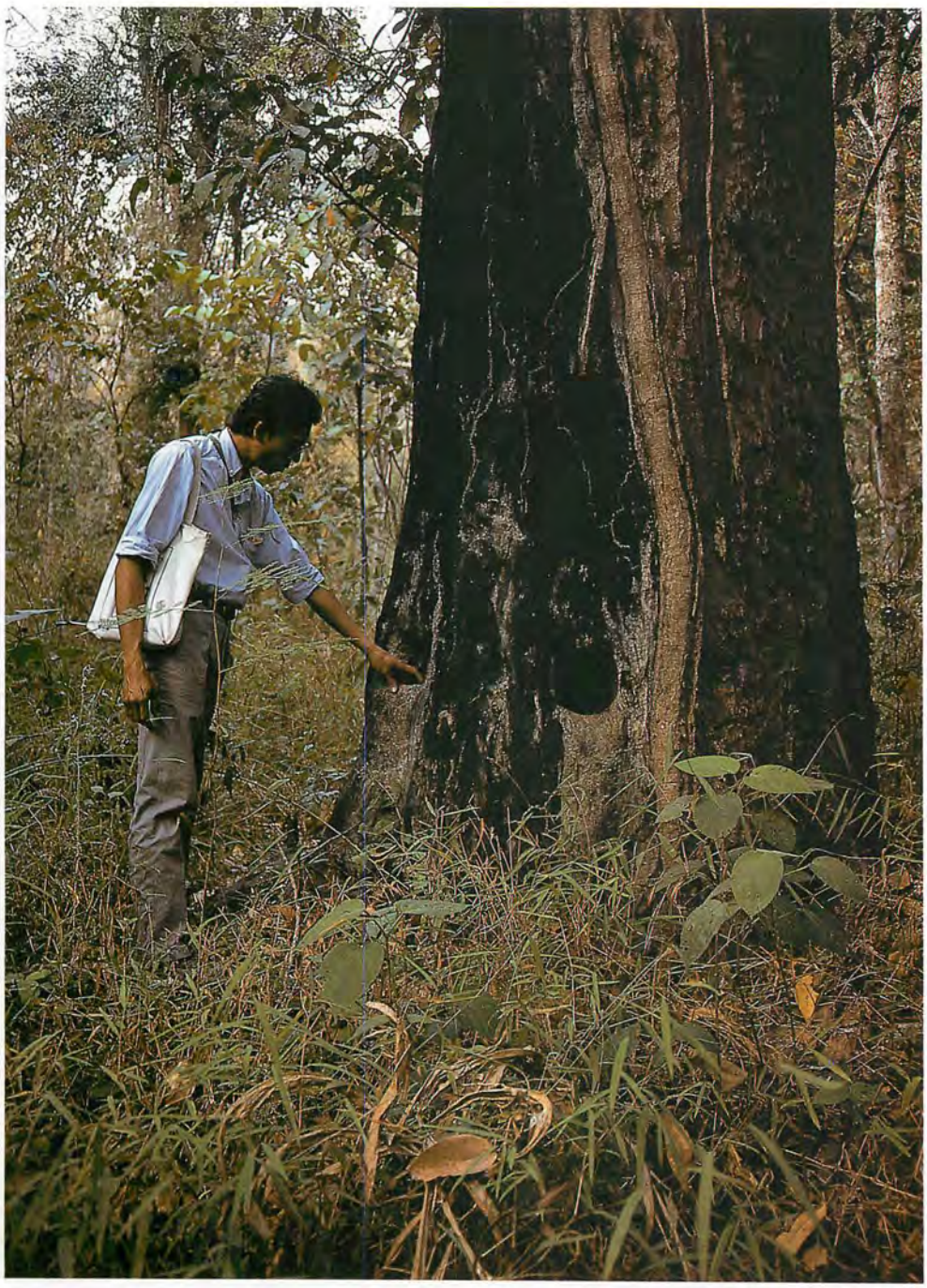

Figure 7. Chief of Huai Kha Khaeng Sanctuary, Mr. Seub Nakhasathien, examining fire damage and "yang oil" holes at the base of a lage, healthy dipterocarp (photo by Belinda Stewart–Cox).

Table 1. Monthly temperature and rainfall at Khao Nang Rum Research Station, Huai Kha Khaeng Wildlife Sanctuary, Thailand, from 1983–1987, and for the study period 1988.

Month	Temperature (°C)		Rainfall (mm)	
	1983–87	1988	1983–87	1988
January	20.3	20.7	2.6	0.0
February	23.8	25.3	25.2	112.0
March[1]	25.7	26.8	45.2	36.8
April[1]	27.5	27.8	105.1	104.1
May	26.6	27.1	229.9	294.6
June	27.1	26.7	133.1	93.2
July	25.9	26.7	109.3	330.0
August	25.7	26.0	114.9	227.0
September[2]	25.2	25.4	302.3	603.5
October[2]	24.2	24.6	335.0	402.0
November	22.2	21.2	91.6	10.7
December	19.2	19.2	13.5	0.0
Average	24.4	24.8	125.7	184.5

[1] Fire in study area in 1988 season.

[2] Intermittent flooding in lowlands in 1988 season.

found dead inside a stand of burned bamboo. The cause of death was not apparent but his skeletal remains showed the loss of the upper left canine, an injury not present at capture.

A female leopard cat, followed for 13 months, used a total area of 6.5 km^2 consisting of 32% dry dipterocarp forest. Despite seasonal shifts in her ranging pattern, all core activity areas were in dry evergreen forest with good water sources. All but one of the cat's located resting sites (N=18) were on the ground with an average ground cover of 90%; all but three resting sites were in mixed deciduous or dry evergreen forest.

A third male leopard cat was followed for only four weeks during December and January, the driest time of year (Table 1), before being killed by camp dogs. During this time, the cat's range of 1.5 km^2 contained 47% dry dipterocarp forest with patchy water sources. This leopard cat was found to be catching free-ranging domestic chickens close to camp. Three other radio-collared leopard cats, in areas with better water sources and more evergreen forest close to camp, were never found taking chickens.

Two cat species, the fishing cat *(F. viverrina)* and the marbled cat *(F. marmorata)*, were not recorded in the study area. But they were known to occur in adjacent areas of evergreen and deciduous forest with larger, more permanent waterways.

Viverridae – Five individuals of four civet species were radio-collared and followed for periods ranging from six to 12 months. Observations were made on two additional species (RABINOWITZ, 1991b). Home ranges varied between 3.1 km^2 for the small Indian civet *(Viverricula malaccensis)* to 12.3 km^2 for the large Indian civet *(Viverra zibetha)*, but seasonal activity centers were nearly all based around waterways in the dry evergreen forest.

Although the civets had a wide range of food preferences, including both animal prey and at least 18 species of fruiting trees (RABINOWITZ, 1991), the dry dipterocarp forest was used proportionately much less than all other forest types. Eighty percent of civet day beds located were in mixed deciduous forest less than 150 m from a waterway. During the peak of fire season, March through mid–April, civets had slightly lower than average levels of activity with larger monthly home ranges and movements. The extent of an individual's movements during this time depended on the proportion of dry dipterocarp forest in his range.

A male small Indian civet whose range consisted of 62% dry dipterocarp forest showed his largest monthly home range shift when fires came through the area in March. His movements, which were previously centered in dry dipterocarp forest, now shifted into the dry evergreen forest along the Huai Chang Tai. A male common palm civet *(Paradoxurus hermaphroditus)*, whose original range consisted of 60% dry dipterocarp forest and was centered around Huai Chang Tai, also shifted his movements when fires came through. He established a new range consisting of 44% dry dipterocarp forest which was based near the larger, more permanent waterway, Huai Ai Yo.

A masked palm civet (*Paguma larvata*) with only 3% dry dipterocarp forest within his range showed larger than average daily movements during the fire season, but did not shift away from his pre-fire season area. His range, with 67% dry evergreen forest, was virtually untouched by the fires.

The semi-arboreal binturong *(Arctictis binturong)* and the arboreal small-toothed palm civet *(Arctogalidia trivirgata)* were sighted only in the dry evergreen forest component of the study area. The banded linsang *(Prionodon linsang)*, know from evergreen areas further west in the sanctuary (NAKHASATHIEN & STEWART–COX, 1990), was never reported in the study area.

Ursidae – The two Asian bear species, the Malayan sun bear *(Helarctos malayanus)* and the Asiatic black bear *(Selenarctos thibetanus)*, occur in the study area, but both are uncommon (RABINOWITZ & WALKER, 1991). Occasional bear feces were found along trails in the evergreen forest during the rainy season.

Mustelidae – Evidence of small-clawed otter *(Aonyx cinerea)* was found in the evergreen forest along a seasonal tributary of Huai Chang Tai. No evidence of the smooth-coated otter *(Lutra perspicilla)* was found, although it occurs in adjacent areas of mixed

deciduous and evergreen forest containing larger, more permanent waterways (RABINOWITZ & WALKER, 1991).

DISCUSSION

Dry Dipterocarp Forests

The dry dipterocarp forests of south-east Asia are distinctive formations, characterized by xerophytic dipterocarps which are clearly adapted to and often ecologically dependent on dry season fires. In the absence of fire, the dry dipterocarp forests would be confined like "island refuges" to their edaphic cores, surrounded by more extensive formations of dry evergreen and mixed deciduous forest (STOTT, 1988b; WHARTON, 1966). In Thailand, dry dipterocarp forest occupies nearly half of the forest area (STOTT, 1988a).

STOTT (1986) classified fires in the dry dipterocarp forest into two types: litter burns and ground cover burns. These burns could be either "typical" or "extreme" depending on the depth of litter or the abundance of highly flammable pygmy bamboo. The main fuel for fires is provided by leaves shed during the early part of the dry season (up to 90% of the leaf cover by the end of January) and, later in the season, by the ground cover of dry grasses. Although frequent burnings may restrict seedling, sapling and tree growth in the dry dipterocarp forest (SUTTIVANITCH, 1989), STOTT (1986) concluded that most types of fire do little direct damage to the dry dipterocarp forest ecosystem. Only extreme ground cover burns, which occur when an area has not been burned in a long time, pose a serious threat to dry dipterocarp forests.

Dry deciduous dipterocarp forest comprised nearly one-quarter of the habitat mosaic of the study area and was defined primarily by topographical features such as stream beds and sharp ridges (Fig. 1). Seasonal fires help maintain this dry dipterocarp forest in a sub-climax state. But even when fires do minimal damage to the floral components of the dry dipterocarp forest, they contribute to a cycle in which the forests become drier, more open, and their understory more flammable (NAKHASATHIEN & STEWART-COX, 1990). Fires also promote the intrusion of the dry dipterocarp forest into the fire–sensitive dry evergreen and mixed deciduous formations. Although dry dipterocarp forest is "clearly adapted to the ancient force of fire" (STOTT, 1988b), the continued spread of this forest type outside of its edaphic core areas threatens the integrity of natural forest systems.

The Carnivore Community

In the extreme, seasonal fires can affect individual mortality, particularly when other stresses are present. This may have been the case for the dispersing male leopard cat that was found dead in a newly burned bamboo patch, and was missing one of his canines. Fire can also stress healthy individuals when dry dipterocarp forest makes up a large proportion of an animal's home range. Since this dry, open forest formation is

burned more frequently than other forest types, carnivores must be able to move to escape the fire, and must cope with an immediate decrease in food availability. Post-fire trapping in the dry dipterocarp forest showed that the biomass of three major small mammal prey species dropped 56% compared with pre-fire trapping at the same site (WALKER & RABINOWITZ, in press).

Over the long term, smaller carnivores must cope with the impoverishment of the dry dipterocarp forest, namely seasonal water scarcity and a relatively low abundance and biomass of small terrestrial mammals (WILES, 1980; WALKER & RABINOWITZ, in press) and fruiting trees (RABINOWITZ, 1991). Wider ranging movements are expected when critical resources are seasonally affected by fire (CHRISTIAN, 1977). This is particularly important with small, solitary, flesh-eating carnivores such as leopard cats, whose dietary needs already force these species to use larger areas than other species of similar size (GITTLEMAN & HARVEY, 1982). A large proportion of dry dipterocarp forest in the home range of one of the male leopard cats, may have prompted his chicken depredations during the dry season.

Larger, wider-ranging carnivores are less affected by the immediate consequences of fire, but must also deal with seasonal food and water scarcity in the dry dipterocarp forest. Leopards were not uncommon in the study area but tigers were scarce. Species that are most successful in surviving and adapting to degraded habitats are those which combine dietary breath and ranging flexibility (BERENSTAIN, 1986). Leopards generally hunt smaller prey, can use secondary growth and burned areas, and can survive with less water than the tiger (JOHNSINGH, 1983). Tigers prefer riverine forest with shade and dense vegetation, and areas where larger prey species (50–100 kg) are available (SCHALLER, 1967 : SUNQUIST, 1981). In the more extensive evergreen and deciduous forests of the Huai Kha Khaeng river valley, tigers were at least three times as abundant as they were in the study area (RABINOWITZ, unpublished data).

In the study area, prey within the tiger's preferred size range is limited primarily to sambar deer *(Cervus unicolor)* and wild boar *(Sus scrofa)*. Sambar deer are seasonally abundant, becoming sparse and patchy in the dry dipterocarp forest during the dry season (SRIKOSAMATARA, unpublished data), while wild boar are uncommon in the area because they prefer wetter forest and more permanent waterways (LEKAGUL & MCNEELY, 1977). Barking deer *(Muntiacus muntjak)*, the major prey for leopards, are relatively abundant in the dry dipterocarp forests and helped contribute to a healthy leopard population. Important secondary prey items for the leopard however, such as monkeys *(Macaca* sp. *& Presbytis* sp.*)* and hog badgers *(Arctonyx collaris)*, are found primarily in mixed deciduous and evergreen forest (LEKAGUL & MCNEELY, 1977).

The forest mosaic of the study area supports a relatively diverse carnivore community. Open woodland species, such as the common palm civet, are found alongside dense forest species such as the binturong. Yet, some carnivore species, such as tiger, medium-sized cats, bears, and the small-clawed otter, were uncommon; evidence of their presence was often restricted to the evergreen and deciduous forest. Other species such

as the small-toothed palm civet and the binturong did not appear to use the dry dipterocarp forest at all. Species that needed extensive year-round water sources, such as the fishing cat and the smooth-coated otter, were absent from the study area.

All the carnivores studied showed a disproportionately low use of dry dipterocarp forest compared with other forest types within their home range, and all found refuge in wetter areas of evergreen forest during the driest times of the year. Clearly, the dry dipterocarp forest plays a role in restricting the distribution and population sizes of many carnivore species. Continued uncontrolled burning and the spread of dry dipterocarp forest at the expense of mixed deciduous and evergreen forest threatens the long term health and stability of the carnivore community.

Current Fire Practices and Management Recommendations

Some of the most common reasons for the deliberate setting of fires in south–east Asia include: the control of insect pests and diseases, clearing of undergrowth for traveling through the forest,extracting wood-oil from *Dipterocarpus* species, shifting cultivation, producing new grass for attracting wild ungulates, carelessness with cigarette butts, matches and campfires, and simple mischief. At the present time, the official policy of the Royal Forest Department (RFD) of Thailand is to prevent and stop fires, particularly in protected areas such as national parks and wildlife sanctuaries. In reality, this policy is often blatantly ignored and, in areas such as Huai Kha Khaeng Wildlife Sanctuary, fires are set deliberately.

Many government officials and RFD workers believe that seasonal fires are mostly beneficial. Their experience has shown that the forest will become lush and green again with the onset of rains, that wild ungulates will be more frequently seen around newly burned areas, and that the area around their station will be easier to patrol. Thus, every dry season in Huai Kha Khaeng Sanctuary, fires are randomly set by the sanctuary staff, adding to those set by the local people.

Research from this study and others suggests that uncontrolled fires and the continued spread of dry dipterocarp forest is not beneficial to numerous carnivore species. The author agrees with STOTT (1988 a&b) that attempting to totally exclude fire from the forest is neither feasible nor sensible. If fires cannot be continually prevented over the long term, then the ground cover and litter build-up resulting from several years of fire exclusion could devastate the entire forest when a fire eventually comes through.

An alternative policy would be low-level, prescribed burning, preferably early in the dry season when fuel accumulation is limited. However, although this option would prevent the hotter, more extensive fires that could damage the dry dipterocarp forest, it would still not prevent damage to the more fire-sensitive forest formations. Such a policy does not fully address the spread of dry dipterocarp forest at the expense of the evergreen and mixed deciduous forest components that are so essential to carnivores and other more canopy dependent species such as primates.

In a dry tropical forest mosaic such as the study area at Huai Kha Khaeng Sanctuary, it is felt that a realistic policy might be one of limited fire exclusion combined with prescribed burning. Prescribed burning could be done in a grid-like pattern so that most areas are burned in two to three year cycles instead of annually. Areas to be managed for large ungulates could have patches burned at different times of the dry season to allow nutritious fodder to be continuously available (MOE et al., 1990).

Fire should be excluded in some of the fire-sensitive evergreen and mixed deciduous forest areas. Certain key wildlife habitats, such as lowland riparian sites, should be given special protection and management priority. The size of the area where fire exclusion is practiced must depend upon the management capability of forest officials. If possible, fire exclusion should extend into ecotones and boundary areas so that the fire-sensitive forest formations can spread outward. Fire exclusion zones MUST be policed effectively, otherwise the area to be protected is put at an even greater risk from an intense fire. In situations where a potential fire exclusion zone cannot be properly patrolled and maintained, it is better to limit fire management to prescribed burning alone.

Any fire management policy must be geared to the local situation. Factors to be considered include: the protected status and management priority of the forest in question, funds and manpower available, regional climatic patterns, and the forest configuration. The current priority in Thailand, where remaining forest areas are becoming smaller and more isolated, should be two-fold: (1) to prevent large-scale, intense and potentially devastating fires in remaining forest areas; (2) to stem the encroachment of the dry dipterocarp forest into the more fire-sensitive yet biologically diverse evergreen forest areas that still exist.

Some initial steps that can be immediately implemented in Thailand include the following: the establishment of clear forestry department directives regarding fire policy, a country-wide assessment of the current status of fires in protected forest areas, prohibiting the haphazard setting of fires by forestry staff, the appointment of "fire officers" in each of the parks and sanctuaries, and the education of forestry staff and local villagers about the potential long term effects of fire to wildlife and forest communities.

SUMMARY

1. Seasonal fires are mostly anthropogenic and, in many areas, help to spread the fire-resilient dry dipterocarp forest at the expense of evergreen and mixed deciduous forest.
2. Seasonal fires can affect carnivore mortality and stress healthy individuals whose home range contains dry dipterocarp forest.
3. Carnivore species show a disproportionately low use of dry dipterocarp forest compared to other forest types; most carnivores took refuge in wetter areas of evergreen forest during the driest times of year.

4. Seasonal water scarcity and a relatively low abundance of many prey species and fruiting trees in dry dipterocarp forest limits the distribution of many carnivore species and results in lower species densities than might exist in other forest types.
5. Small carnivores are more affected by seasonal fires and the resource poor dry dipterocarp forest than larger wider-ranging carnivores.
6. The long term health and stability of the carnivore community is threatened by uncontrolled burning and by the spread of dry dipterocarp forest at the expense of the evergreen formations.
7. A policy of total exclusion of forest fires is not feasible in Thailand. An alternative policy is that of prescribed burning combined with fire exclusion in high priority habitats.
8. Fire management policy must be geared to local situations and consider the management priority of the forest, funds and manpower available, regional climatic patterns, and the forest configuration.
9. If fire exclusion zones cannot be properly policed and maintained, then it is better to limit fire management in that particular area to prescribed burning alone.

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