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Wildlife, human, and domestic animal use of buffer zone area

– Consequences for management strategies, Huai Kha Kaeng Wildlife Sanctuary (Thailand)

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Abstract

Protection of tropical forests and establishment of buffer zones adjacent to protected areas are key issues for the conservation of biodiversity in the world. Buffer zones are supposed to serve the dual purpose of 'extension buffering', or an extension of core habitat areas, and 'socio buffering' to provide goods and services to humans, but few studies have evaluated both human use of buffer zones and occurrence of wildlife.

The main goal of this study was to quantify human disturbance on wildlife by recording the use by humans and domestic animals in the 4 km wide buffer zone of Huai Kha Kaeng Wildlife Sanctuary (HKKWS), Thailand. Occurrence of large mammals were recorded along 37 transects and relationships between distance, human activities, occurrence of domestic animals, and different wildlife species were analyzed.

During this research 210 individuals from adjacent villages were interviewed. All interviewed respondents answered that they used the buffer zone, and the transect survey revealed that a large proportion of the plots (71 %) were used by humans and/or domestic animals. The buffer zone was also an important grazing area for domestic animals, mainly domestic cattle and buffalo; a large proportions of the plots (47 %) in the transect survey had signs of domestic animal occurrence.

In general, the HKKWS buffer zone was a suitable habitat for several wildlife species. Sambar deer and Banteng occurred in more then 25% of the plots. Thus, the results from this study suggest that the buffer zone in HKKWS reduces the impact of humans and domestic animals on the sanctuary, and fulfills the requirements of a well-designed buffer zone.

Size of human populations adjacent to buffer zones, type of habitat in the buffer zone, and in some cases restrictions for grazing, are suggested to be factors of importance for establishment of well-designed buffer zones in other areas.

Keywords: Buffer zone; domestic animals; management; protected area; Thailand; tropical forest; villages; wildlife

Contents

Introduction

Tropical forest loss and degradation are among the most important environmental issues now being faced on Earth (Foley et al. 2007; Lewis 2006; Pattanavibool & Dearden 2002; Singh 2002). Asia is of particularly high concern due to its higher relative rates of deforestation and less remaining forest. Deforestation rates are four times higher than those found elsewhere in the world (Laurance 1999). The current situation in Thailand is symptomatic of the region (Pattanavibool & Dearden 2002). In 1961 forests covered 53.3% of the land area; but by 1998 only 25.3% consisted of forest, and large areas were badly degraded (Rajani 1999).

There are examples from all over the world that demonstrate the immense strain protected areas receive from developed rural areas nearby (Shafer 1999; Timothy et al. 2003). For example, in Myanmar, high levels of deforestation, unrestricted burning, and destructive agricultural practices have resulted in significant wildlife decline and rapid loss of natural habitats. Extraction of non-timber forest products was reported in 85% of the protected areas; grazing, hunting, fuel-wood extraction, and permanent settlements occurred in more than 50% of the parks surveyed (Rao et al. 2002).

Farmers in close proximity to natural areas might be exposed to considerable disturbance from wildlife. Primates dominate lists of "pests" that damage crops around African parks and reserves (Naughton-Treves et al. 1998). Throughout Southeast Asia, rodents are commonly reported to be a serious pest of rice (Hill 1997). In addition to actual damages caused by crop raiding, the farmers' expressed fear may be influenced by the wild animals' perceived ability to harm or even kill humans (Hill 1997). In these conflicts, farmers often turn to hunting practices. For instance, traditional shifting cultivation farmers in tropical forest integrate farming with hunting of crop-raiding animals (Naughton-Treves et al. 1998).

Even though Southeast Asia is a mega-biodiversity region, and a global species "hotspot" (Myers et al. 2000), there is a paucity of published research from this area (Pattanavibool & Dearden 2002). From 1996 to 1998, Southeast Asian biota was the subject of less than 3% of research papers in conservation biology journals (Sodhi & Liow 2000). Prins and Wind (1993) compiled expert opinions on priorities for conservation research in Southeast Asia, and especially Indonesia. They suggested that emphasis should be given to studies of rainforest, especially research on keystone species, protection of conservation areas, buffer zones, and management of protected areas. However, few studies in Southeast Asia have examined human impacts on wildlife in protected areas. Pattanavibool and Dearden (2002), used aerial photographs and satellite images to examine fragmentation as a result of

traditional agricultural activities in the wildlife sanctuaries in northern Thailand. Fragmentation within protected areas and other disturbance factors were suggested to interact synergistically to reduce biodiversity. Karanth *et al.* (2006) showed that resource use and depletion by human inhabitants in Bhadra Wildlife Sanctuary, Western Ghats, in India influenced 8-10 % of the protected area. Village size and distance from village were significant predictors of the disturbance level.

Buffer zones are supposed to serve the dual purpose of 'extension buffering', or an extension of core habitat areas, and 'socio buffering' to provide goods and services to humans (MacKinnon et al. 1986). Thus, buffer zones are established to decrease human disturbance in protected areas. Buffer zones can increase the population of rare species because they provide additional usable habitat (UNESCO 1974), and also increase the population of more common species (Salwasser et al. 1987). In addition, buffer zones may facilitate wildlife movements by turning 'hard edges' into soft edges' (Stamps et al. 1987), and function as corridors (Vujakovic 1987). Large mammal populations theoretically are best conserved in landscapes where large protected areas are surrounded by buffer zones, connected by corridors, and integrated into a greater ecosystem (Nyhus & Tilson 2004).

In Thailand two main categories of protected areas forbid all extractive use: national parks and wildlife sanctuaries. However, despite the protection, many species in Thailand have already been extirpated and others reduced to such low abundance that they are considered "ecologically extinct" (Pattanavibool and Dearden 2002). Schombergk's deer (*Cervus schombergk*) is now extinct, as is probably the Kouprey (*Bos sauveli*). The Javan rhinoceros (*Rhinocerus sondaicus*) and Sumatran rhinoceros (*Dicerorhinus sumantrensis*) can no longer be found in the wild. Of the 282 species of mammals about 40 are classified as rare and endangered, 190 of 916 bird species, and 37 of 405 species of reptiles and amphibians are threatened with extinction (OEPP 1995). The main problem is the human impact on the protected area system, especially fragmentation as a result of agricultural activities and hunting (Pattanavibool & Dearden 2002). The main goal of this study was to quantify human disturbance on wildlife in the buffer zone of HKKWS in western Thailand. Different human activities and occurrence of domestic animals were recorded along 4 km transects from villages to the protected area. Occurrence of large mammals were recorded along the same transects and relationships between distance, human activities, occurrence of domestic animals and the different wildlife species were analyzed.

Methods

Study area characteristics

Protected areas in Thailand

Thailand has established more than 280 protected areas to safeguard the national biodiversity. There are 114 national parks, 75 being terrestrial parks with a total land area of 4.31 million ha (Pattanavibool & Dearden 2002). In addition there are 39 more parks proposed (2.03 million ha). There are also 47 wildlife sanctuaries with a total land area of 3.3 million ha. Another 12 proposed wildlife sanctuaries would add 501,828 ha (Rajani 1999). The government has a policy to maintain 25% of the landscape in protected areas (Pattanavibool & Dearden 2002).

Protected areas cover approximately 18% of the total country's land area, which exceeds the national target of 10% recommended by IUCN (Trisurat 2004). The Western Forest Complex (WEFCOM) is the largest conservation area in the country, and in mainland Southeast Asia, covering a total 622,200 ha. The WEFCOM is made up of 17 protected areas and it is considered to be the centre for terrestrial biodiversity in Thailand (Trisurat 2004). Six areas are wildlife sanctuaries: Salakpra, Huai Kha Kaeng, Thung Yai West, Thung Yai East, Khao Sanampriang, and Umphag. There are 11 national parks, including Erawan, Sai Yok, Chalerm Rattanakosin, Khlong Lan, Srinakarin, Mae Wong, Khao Laem, Khlong Wan Chao, Phutoey, Thong Pha Phoom and the proposed national park Lam Khlong Ngu (Fig. 1).

The high biodiversity in this complex results from it being situated at the crossroad of four biogeographic zones: the Indo-Chinese zone extending from China; the Sino-Malayan zone extending from the Himalayan region; the Indo-Burmese zone extending from nearby Myanmar and eastern India; and the Sundaic Realm of the Malaysian Peninsula (Nakasathien & Stewart 1990; Bhumpakphan 2001).

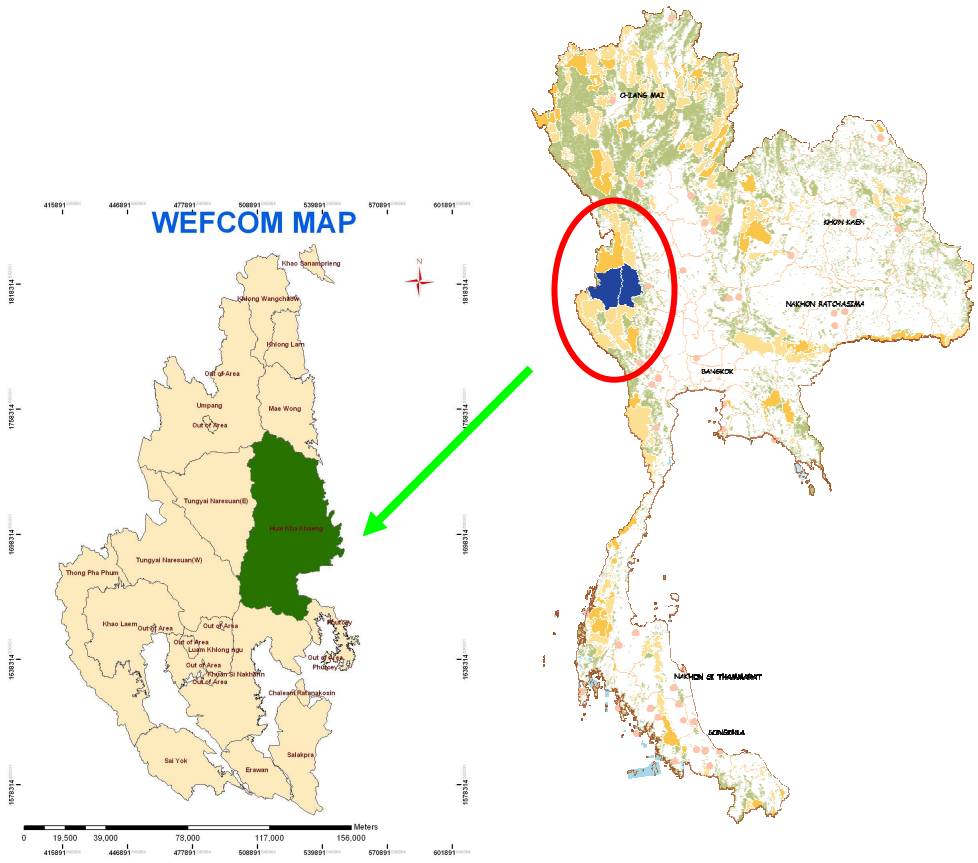


Fig. 1. Map of protected areas within the Western Forest Complex in Thailand. The study site Huai Kha Kaeng Wildlife Sanctuary is shown with green color (left).

Huai Kha Kaeng Wildlife Sanctuary

The study was performed at the eastern border of Huai Kha Kaeng Wildlife Sanctuary (HKKWS). In 1972 HKKWS was declared the fifth wildlife sanctuary in Thailand, and additional areas were included in 1986 and 1992. The area borders Mae Wong National Park and Umphang Wildlife Sanctuary in the north, Thung Yai Naresuan Wildlife Sanctuary to the west, and Sri Nakharin National Park in the south. To the east developed areas border HKKWS, with a sharp edge between protected forests and exploited land (Fig. 2). Before HKKWS was established, there were permanent human settlements present in the area. When the sanctuary was created, they were relocated to areas close by. Currently, developed areas adjacent to HKKWS consist of villages and farmland.

Fig. 2. Aerial photo (15° 33'44.81" N, 99° 24'12.83" E) of HKKWS and the exploited areas east of the protected area.

Amongst the seventeen protected areas within WEFCOM, HKKWS is the largest and the most well-known (Trisurat 2004). Covering 2,780 km² it is also ranked as the second largest sanctuary in Thailand, after Thung Yai. The conservation value of the area is the basis for the UNESCO World Heritage designation of Huai Kha Kaeng and Thung Yai Naresuan Wildlife Sanctuaries in 1991(ONEB, 1990).

The area is biogeographically unique, capable of sustaining flora and fauna, is of exceptional natural beauty and scientific value, and include very high biological diversity (United Nations Environmental Programme – World Conservation Monitoring Centre, 1991). Being located in a transition zone between the tropics and sub-tropics and, perhaps, because it was a Pleistocene refugee, a number of species of birds and mammals are sympatric here. HKKWS is considered a key site for the conservation of lowland and montane bird species (Round, 1988). Few other areas of dry tropical forest in the region are as large, as well protected or as pristine.

Elevation levels in HKKWS range from 100 m to 1660 m (Trisurat 2004). The research area is dominated by forested plains, with the study itself performed in areas below 300 m altitude. HKKWS is made up of dry evergreen, hill evergreen, dry dipterocarp, mixed deciduous, bamboo forest, and secondary growth (Fig. 3). The mosaic forest pattern continues into the buffer zone, the vegetation types being deciduous, mixed deciduous, dry dipterocarp, seasonal evergreen, bamboo forest, and secondary growth. A total of eighteen ranger stations are located within and near the wildlife sanctuary. Sanctuary officials

continually patrol the perimeter of HKKWS, and protection also extends to various parts of the buffer zone.

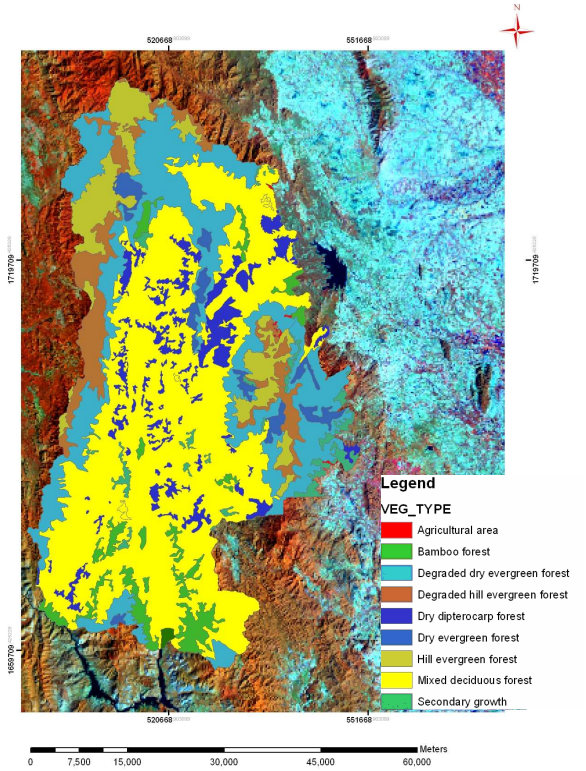


Fig. 3. Distribution of main vegetation types in HKKWS.

HKKWS Buffer Zone

The main study area is located within the designated buffer zone of HKKWS, which runs along the eastern border of the sanctuary, adjacent to developed areas. The buffer zone width varies between 0-5 km, depending on topographical conditions and the agreements between the surrounding villages and the Royal Forestry Department of Thailand. Mountains at the far north and south of HKKWS allow only a narrow buffer zone in those areas, but also provide natural protection for the sanctuary. This study focuses on the approximately 4 km wide buffer zone area at the northern half of the sanctuary, which is bordered by rural areas.

Two ranger stations**,** Khao Kiew and Thung Faek, are responsible for the research area. In addition, the HKKWS Headquarters is located in the center of study area. Close proximity of the ranger stations and effective patrolling of the buffer zone have disseminated major threats. Illegal timber logging and hunting of large animals are no longer considered as major threats in the study area. Nonetheless, HKKWS is under pressure from the nearby villages, although it is unclear how common human intrusion into HKKWS is.

Highway 3282 runs along the eastern boundary of the sanctuary, making HKKWS easily accessible for the local inhabitants. Illegal wood harvesting, hunting smaller game animals, gathering of firewood, bamboo harvesting, and collection of non-timber forest products (NTFP) are human activities occurring in HKKWS. NTFP include wild orchid species, mushrooms, fruits, vegetables, herbs, and young bamboo shoots which can be sold fresh for consumption or canned (Fig. 4).

Fig. 4. Non-timber forest products collected by local villager for consumption and sale; local fruit "sa-moor" (left) and young bamboo shoots (right).

Collection of NTFP is a lucrative business, providing additional income to the local inhabitants. One particularly sought after mushroom locally named "hed kone" has a market price of 200 – 400 THB, and up to 500 THB (≈17 USD) per kilogram if sold in Bangkok (Fig. 5).

Fig. 5. "Hed kone" mushrooms collected and cleaned by a villager, in preparation for sale.

Hunting and logging are illegal by the national law of Thailand, namely the National Reserve Forest Act of 1941, the National Park Act of 1961, and the Wildlife Preservation and Protection Act of 1960 (amended in 1992). HKKWS regulations regarding human intrusion and actions within the buffer zone are generally stated. Variations and adaptations can be implemented with

each new director of the wildlife sanctuary. Currently, the regulations permit humans to enter the buffer zone and collect only NTFP. Vehicles are not allowed access, or must be left at designated ranger stations for safe keeping. These new rules were implemented to limit the accessibility of HKKWS to local villagers. Without vehicles, people can not travel far into the buffer zone. The right to collect NTFP reflects the requirements and needs of local communities surrounding HKKWS, which can not be dismissed or prohibited. Consequently, due to the level elevation of the area, the land is also suitable for various farming practices. There is a constant encroachment by local farms and farmland slowly expands into the buffer zone. Rice, corn, and cassava are the dominating crops in the area. In addition, both local and transient villagers lead their domestic animals to graze within the buffer zone. Domestic animals, mainly cattle and buffalo, are lead daily from their stables to feed within the HKKWS buffer zone and possibly in the sanctuary itself.

Field surveys

Transects

Field surveys were conducted in August 2006 through February 2007, during the rainy season. This year the rainy season was unusually late, with an annual rainfall of 2,200 mm. Tropical storms usually occurred during the twilight, therefore field surveys were conducted in the morning and afternoon. Data on human activities, domestic animal activities, and occurrences of wildlife tracks were collected along transect lines within the designated HKKWS buffer zone. Global latitudinal lines were chosen as transect lines. Each transect was 1 km in length, running east to west. The longitudinal position of the start of each transect line was where the village/farm edges met HKKWS buffer zone. Transect lines were cleared of small trees and shrubs according to guidelines for estimating densities of large mammals outlined by Karanth and Nichols (2002). Shrubs and grasses were cleared so that the surveyor could pass, without creating a distinct trail, which may scare off animals. Each line was marked every 200 m with red rope. Transects were grouped into threes, interspaced by 500 meters, and each row placed 1 km apart (Fig. 6).

A total of 37 lines were surveyed: 15 next to the village/farms, 12 in the buffer zone, and 10 near HKKWS. All transects were surveyed once (approximately 5 hours per transect) with the help of two experienced field assistants. One assistant was a former hunter, and had lived inside the sanctuary area before it was declared as HKKWS. Both assistants were highly skilled at identification of animal tracks, markings, and plant taxonomy. They were familiar with the area and the local community because both were former officers of HKKWS. The survey of transect lines began in the north, ending with the southernmost transect.

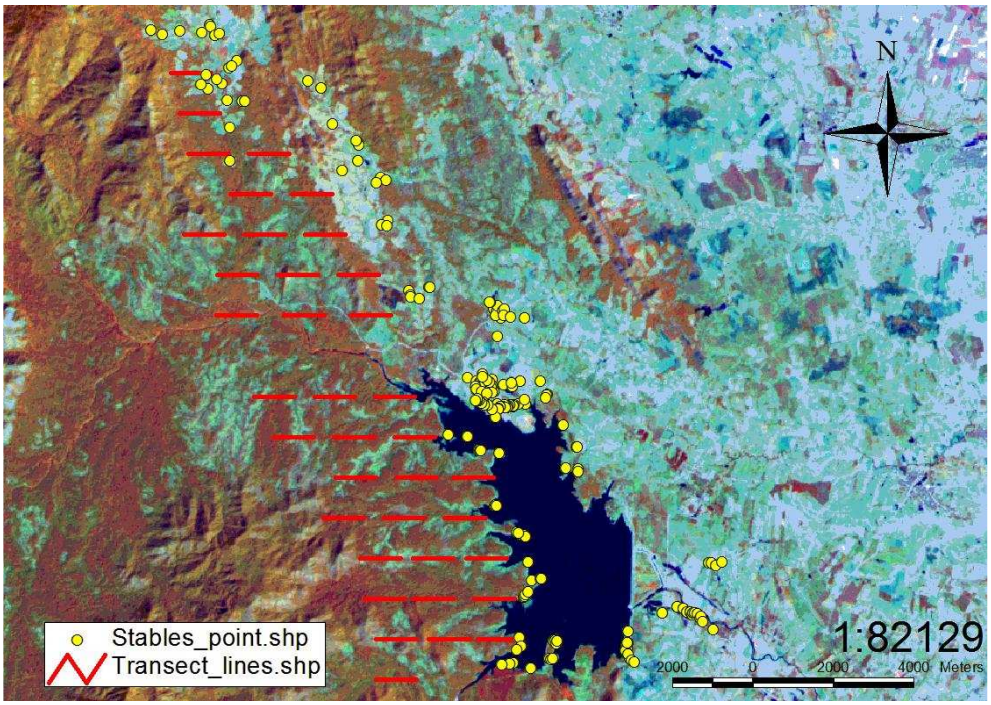


Fig. 6. Transect lines in the buffer zone of HKKWS (red lines), and GPS positions of all stables within approximately 1 km of buffer zone (yellow dots)

Human activities and occurrences of domestic animals

Signs of human activities and occurrence of domestic animals were recorded along the transect lines. Data was collected at 200 m intervals within circular plots with 15 m radius, resulting in six plots per 1 km transect (Fig. 7).

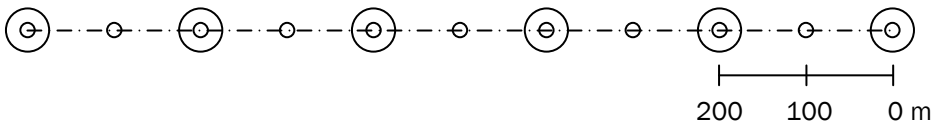


Fig. 7. (not drawn to scale) 1 km transect line, with six 15 m radius circular plots, and eleven 5 m radius circular plots

Plots were marked by pulling tape measures across the centre point and stopping at 15 m, marking the north, east, south, and west corners of the circular plot. If the terrain was dense, the procedure was repeated, to mark the north-east, south-east, south-west, and north-west corners also. An average of 15 to 30 minutes was spent in each plot to evaluate tracks and process the information. Data was always collected clockwise, moving from the centre outwards to avoid repetition. To detect signs of human disturbance, data was collected on: number of newly cut stems (< 5 years), number of cut bamboo

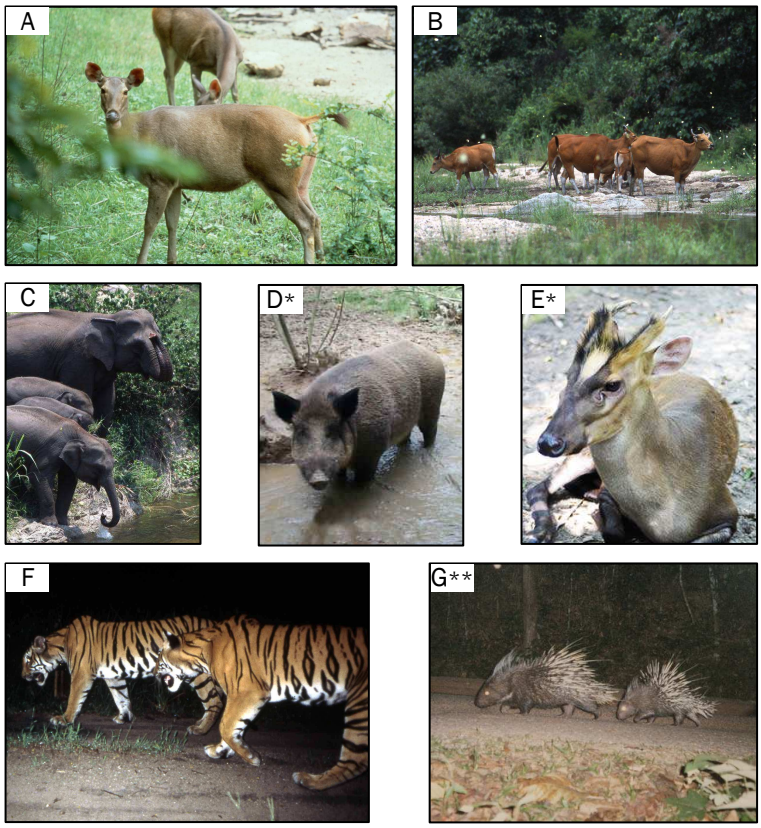
clusters, number of cut bamboo shoot clusters, signs of mushroom picking, trash, signs of hunting equipment, small branches cut, cut marks on trees, camp sites, campfires, and actual sightings of humans.

Domestic animal occurrences were also recorded at 200 m intervals in 15 m radius circular plots. Domestic animals investigated included cattle (*Bos primigenius indicus*), buffalo (*Bubalus bubalis)*, goat (*Capra aegagrus hircus*), sheep (*Ovis aries*), horse *(Equus caballus)*, pig (*Sus scrofa domestica*), and dog (*Canis lupus familiaris*) (Appendix 1). Tracks of domestic animals included footprint, walkway, scat, signs of grass/stems eaten, scavenging tracks, and actual animal sightings. Footprints of domestic cattle and buffalo may be similar to footprints of Banteng (*Bos javanicus*), however when other tracks were considered, identification was possible (Prayurasiddhi 1997; Steinmetz 2004). Additionally, the 15 m radius plot was large enough to include multiple tracks which aided the distinction of domestic cattle and buffalo evidence, from the wildlife evidence.

A percentage score was also given to the total amount of land use by humans, and land use by domestic animals. However, many of the variables were found to be correlated. Therefore two main variables, human activities (all variables combined) and domestic animals (all variables combined) were chosen for the final analysis. Each plot was categorized as disturbed by human activities, or domestic animals, or not.

Wildlife

Wildlife data was recorded every 100 m interval, within 5 m circular plots. The plot size was large enough for identification of wildlife footprints and other signs. Depending upon the density of the understory vegetation, which could obscure vision, 15 to 30 minutes was spent to search for wildlife tracks in each plot. Moving from the centre outwards, data was always gathered clockwise to avoid destroying animal footprints. Wildlife included sambar deer (*Cervus unicolor*), banteng (*Bos javanicus*), asiatic elephant (*Elephas maximus*), barking deer (*Muntiacus muntjak*), wild pig (Sus scrofa), tiger (*Panthera tigris*), and porcupine (*Hystrix brachyura*) (Fig.8). Signs of wildlife included footprints, walkways, signs of grass consumption, scat, and sleeping ditches (Appendix 2). Species specific tracks for identification also included: antler marks on trees, eaten bamboo shoots, eaten vegetation/roots, scavenging tracks, evidence of cassava plant consumption, and actual animal sightings. The occurrence of single species at the plot and transect level was later used for spatial analysis and relation to human activities.



* www.zoothailand.org, 2004
** www.worldwildlife.org, photographed by Sean Austin, 1991

Fig. 8. Wildlife species: A) Sambar deer (*Cervus unicolor*) in HKKWS; B) Banteng (*Bos javanicus*) herd in HKKWS; C) Asiatic elephant (*Elephas maximus*) next to a stream at HKKWS; D) Wild pig (*Sus scrofa*); E) Barking deer (*Muntiacus muntjak*); F) Camera trap picture of tiger (*Panthera tigris*) in HKKWS; G) Porcupine (*Hystrix brachyuran*)

Social surveys

Semi-structured interviews were conducted in households within 1 km the HKKWS buffer zone. At each residence, the exact GPS position of the domestic animal stables was taken using GARMIN® GPS 12. All interviews were conducted by the author. Any difficulties with understanding local dialects were avoided with the aid of two field assistants, who were fluent in both the local dialect and standard Thai. The interviews were conducted in an informal atmosphere. A casual dialog was initiated, followed by the main interview questions (Appendix 3). All stables were visited and their GPS locations recorded. The social survey was conducted to insure that domestic animal numbers and nearby stable locations could be accounted for. The data was not analysed in detail, but nonetheless demonstrates how humans and domestic animals use the HKKWS buffer zone.

Results

Human activities

Signs of human activities were common in the buffer zone (51.4% of all plots). The most common signs of human activity were newly cut tree stems (26.4% of the plots), cut bamboo clusters (13.9% of the plots) and hunting equipment or signs of hunting (4.6% of the plots). Less common signs (<4.1% of the plots) of human activity included mushroom picking, trash, cut bamboo shoots clusters, small cut branches, cut marks on trees, camp sites, campfires, and actual sightings of humans.

For spatial analysis all human activities were combined (i.e. plots were classified as having signs of human activities or not). The proportion of plots with signs of human activities decreased linearly with distance (Fig. 9). Close to the edge of the buffer zone most (>70%) of the plots showed signs of human activities, while <40% of the plots showed signs of human activities at distances over 3 km from the buffer zone edge (Fig. 9). Statistical analysis comparing the mean proportion of plots with signs of human activities on the transects close (0-1000 m), at intermediate distance (1500-2500 m) and far from the buffer zone edge (3000-4000 m) showed a negative relationship with distance (Linear regression, df=1,F=16.1, $p<0.001$, $R^2=0.31$). Statistical tests were not performed at the plot level, since adjacent plots were not considered as independent observations.

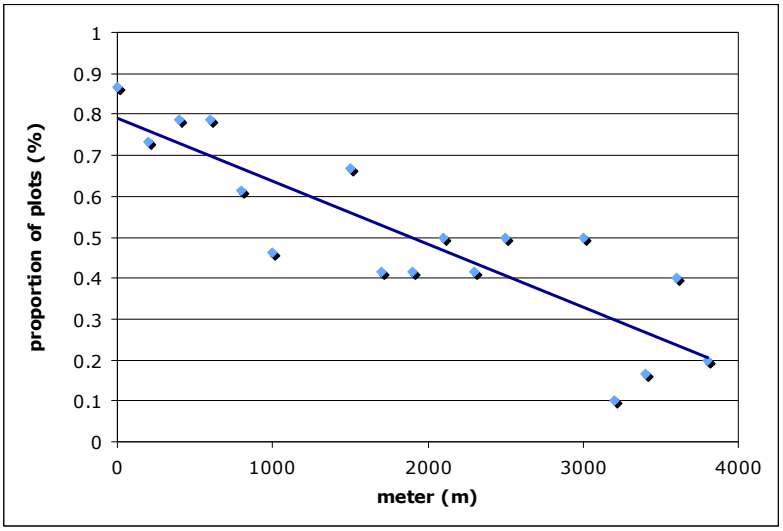


Fig. 9. Proportion of plots at different distances from the buffer zone edge with signs of human activities (i.e. occurrence or not of any sign of human activity)

Domestic animals

The proportion of plots with signs of occurrence of domestic animals was evaluated separately from other human activities. In general, domestic animals had visited a relatively large proportion of the sites (proportion 47.2%). From 0 to 2000 m, the mean proportion of plots with signs of domestic animals was quite high (approximately 60%). However, at distances larger than 2000 m the proportion of plots with signs of domestic animals dropped to approximately 30% (Fig. 10). Statistical analysis comparing the mean proportion of plots with signs of domestic animals on transects close (0-1000m), at intermediate distance (1500-2500m), and far from the buffer zone edge (3000-400m) showed a negative relationship with distance (Linear regression, df=1, F=4.2, $p<0,05$, $R^2=0.11$). Statistical tests were not performed at the plot level, since adjacent plots were not considered as independent observations.

The most common domestic animals were cattle (35.2% of the plots) and buffalo (25.5% of the plots). Other domestic animals (< 1.9% of the plots) were goat, sheep, horse, pig, and dog.

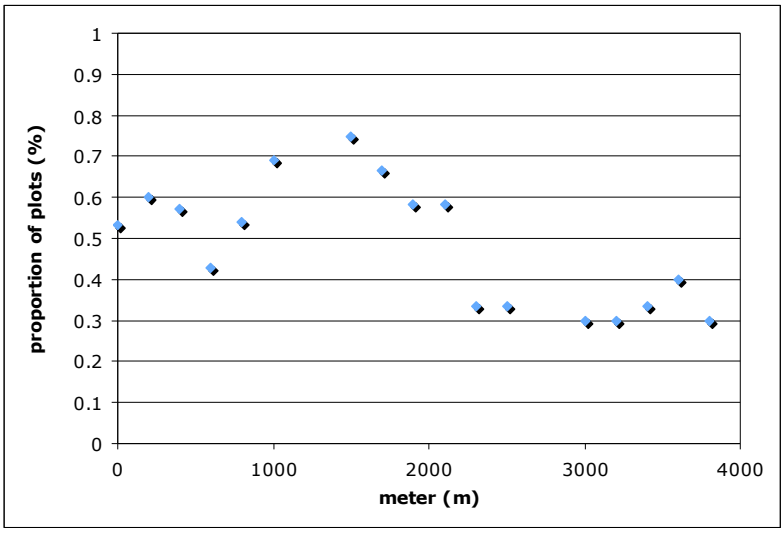


Fig. 10. Proportion of plots at different distances from the buffer zone edge with signs of domestic animals

Wildlife

The most common wildlife species were Sambar deer (29.3% of plots), Banteng (26.8%), Wild pig (11.4% of the plots), Barking deer (9.3%), and Elephant (2.6 %). Less common species, tiger (0.2%) and porcupine (0.2%), were not included in further analysis.

From 0 – 2500 m, signs of Sambar deer occurrence were uncommon or intermediate in abundance. Subsequently, the proportion of plots with signs of Sambar deer occurrence was intermediate to high from 2500 – 4000 m (Fig. 11). Statistical analysis on Sambar deer occurrence in relation to distance from buffer zone edge, occurrence of domestic animals and human activities, are presented in the section below.

Banteng and Sambar deer showed similar patterns of occurrence. There was a slow increase in the proportion of plots with signs of Banteng with distance (Fig 12). Statistical analysis on Banteng occurrence in relation to distance from buffer zone edge, occurrence of domestic animals and human activities, are presented in the section below.

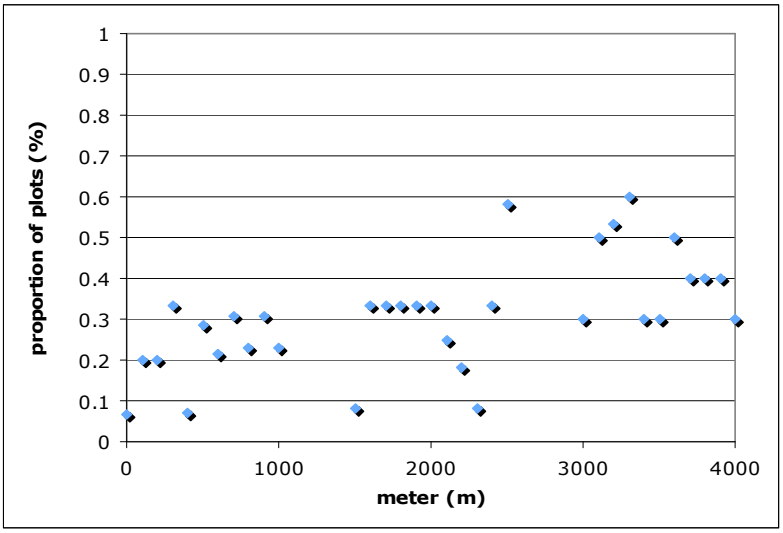


Fig. 11. Proportion of plots at different distances from the buffer zone edge with signs of Sambar deer

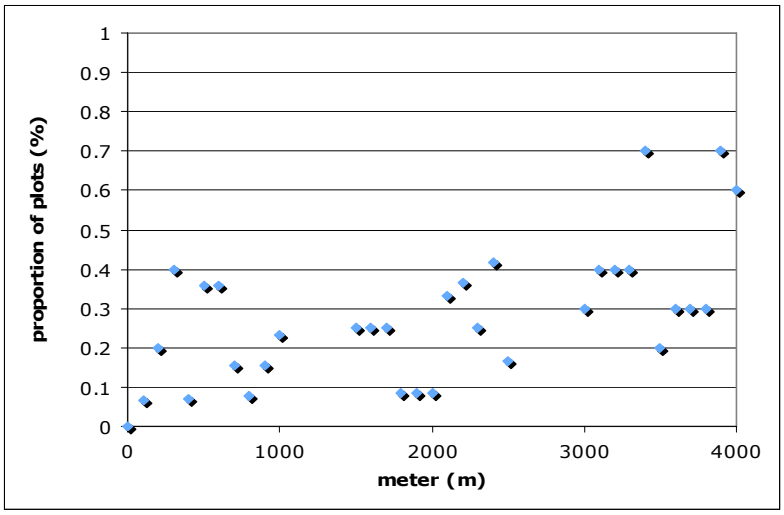


Fig. 12. Proportion of plots at different distances from the buffer zone edge with signs of Banteng

There were relatively few observations for Barking deer and wild pig. However, the spatial distribution of plots with occurrence of Barking deer (Fig. 13) and Wild pig (Fig. 14) suggested that their abundance increased with distance from the buffer zone edge, although there were large differences in abundance between plots with similar distance to the buffer zone edge. Statistical analysis on occurrence of Barking deer and Wild pig in relation to distance from buffer zone edge, occurrence of domestic animals and human activities, are presented in the section below.

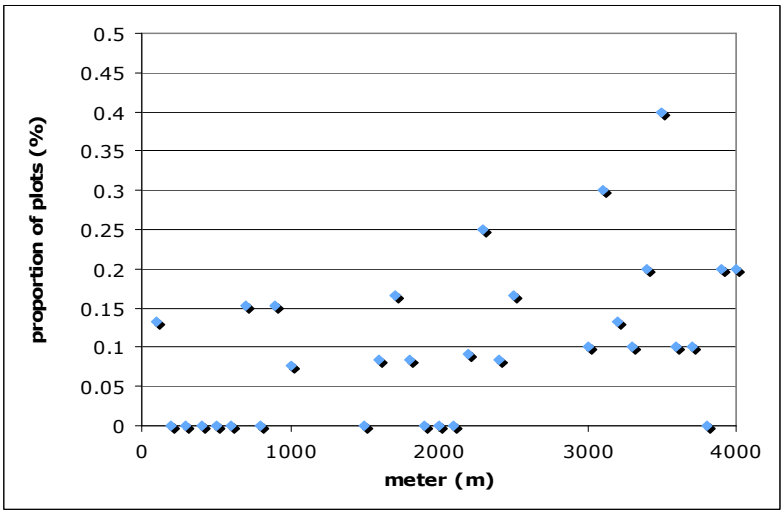


Fig. 13. Proportion of plots at different distances from the buffer zone edge with signs of Barking deer

Elephant occurred in fewer plots than other analyzed species. Most plots with signs of elephants were situated >2000 m from the buffer zone edge (Fig. 15). Statistical analysis on Elephant occurrence in relation to distance from buffer zone edge, occurrence of domestic animals and human activities, are presented in the section below.

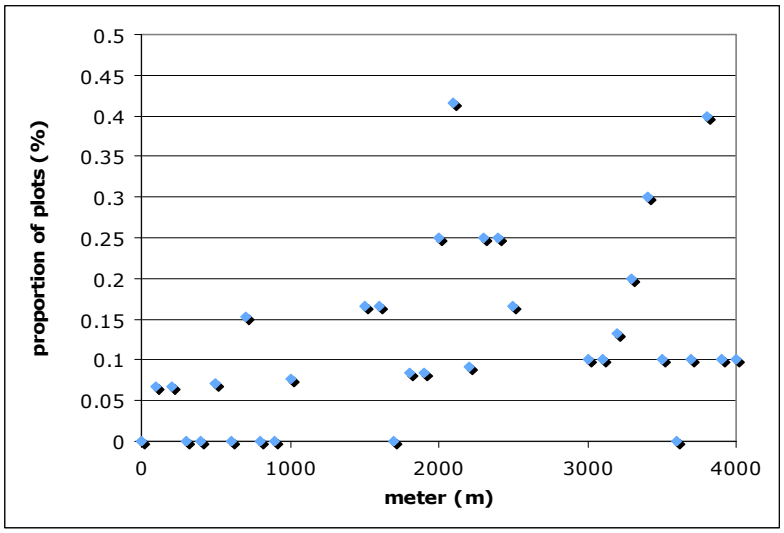


Fig. 14. Proportion of plots at different distances from the buffer zone edge with signs of Wild pig occurrence

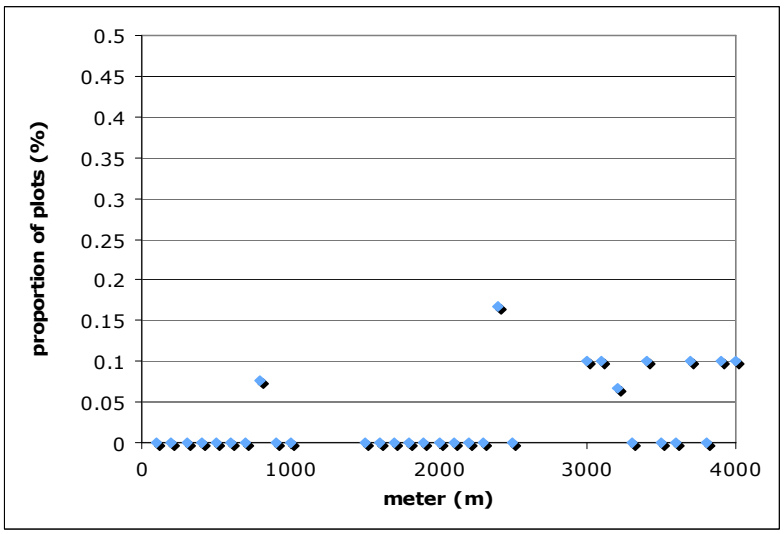


Fig. 15. Proportion of plots at different distances from the buffer zone edge with signs of Elephant

Wildlife, human activities and domestic animals

Data was collected from a total of 37 one kilometer transects. These transects were used as independent observations in the statistical analysis. For each transect the proportion of plots with occurrence of different wildlife species (dependent variables), signs of human activities and domestic animals (independent variables) were calculated. In the following linear regression analysis, maximum distance to the buffer zone edge (1000m, 2500m or 4000 m) was also included as an independent variable. Estimates of human activities and domestic animals were uncorrelated at the transect level ($r=0.17$, $p> 0.3$) and both variables were used as measures of disturbance rates in the buffer zone.

For each wildlife species, linear regression modeling by forward selection of variables was conducted. In each model distance to buffer zone edge, proportion of plots with human activities and proportion of plots with occurrence of domestic animals were included as independent variables. For the Sambar deer a significant negative relationship with proportion of plots with occurrence of domestic animals was found (Linear regression, $df=1$, $F=18.7$, $p<0.001$, $R^2=35\%$). There was no additional effect of distance to the buffer zone edge or the index of human disturbance.

The occurrence of Banteng also showed a significant negative relationship to proportion of plots with occurrence of domestic animals (Linear regression, $df=1$, $F=11.3$, $p<0.001$, $R^2=24\%$). There was no additional effect of distance to the buffer zone edge or the index of human disturbance. Also the occurrence of elephants was negatively associated with occurrence of domestic animals (Linear regression, $df=1$, $F=4.7$, $p<0.036$, $R^2=12\%$). Again, there was no additional effect of distance to the buffer zone edge or the index of human disturbance.

In contrast, Barking deer occurrence was negatively associated with proportion of plots with human activities (Linear regression, $df=1$, $F=6.2$, $p<0.018$, $R^2=15\%$). There was no additional effect of distance to the buffer zone edge or domestic animal occurrence. The occurrence of Wild pig was not significantly related to any of the three independent variables.

Discussion

The people from the adjacent villages used the buffer zone of HKKWS frequently. In interviews 100% of respondents (210 individuals) answered that they used the buffer zone, and the transect survey revealed that a large proportion of the plots (71%) were used by humans and/or domestic animals. Hunting and logging are deemed illegal by the national law of Thailand, National Reserve Forest Act of 1941, National Park Act of 1961, and the Wildlife Preservation and Protection Act of 1960 (amended in 1992). However specifics in HKKWS regulations, regarding human intrusion into the buffer zone, can be decided by the director of the wildlife sanctuary. The current regulations allow collection of NTFP in the buffer zone, and cutting of bamboo (14% of plots) was the most common activity for gathering of NTFP in the buffer zone. However, more subtle activities (e.g. mushroom picking and hunting smaller animals, see also methods) could have been more common that suggested by this study since such activities do not leave any persistent tracks. In addition, illegal wood harvesting (26% of plots) was common and signs of illegal hunting occurred in some plots (5%). It is not surprising to find low occurrences of activities such as hunting due to the secretive nature of these human activities. People involved in these actions try to leave as little evidence as possible, since the activities are violating the current regulations of HKKWS. To conclude, different materials needed or desired by the local villagers were collected in the HKKWS buffer zone and the buffer zone does indeed serve as 'socio buffering' (Straede & Treue 2006). Similarly several other studies have shown that buffer zones, community forests and similar areas might at least partly serve as substitutes for protected area when it comes to collection of NTFP (Nepal & Weber 1994). However, the lack of some products (Rawat 1997; Straede et al. 2002) and restrictions for cutting, hunting etc. might be seen as an obstacle by the local people (Straede & Treue 2006).

The buffer zone was also an important grazing area for domestic animals, mainly cattle and buffalo. The interviews located many stables adjacent to the buffer zone (Fig. 6) and a large proportions of the plots (47 %) in the transect survey had signs of domestic animal occurrence. Thus, a major function for buffer zones and other non-protected natural and semi-natural habitats is that they offer suitable grazing areas (Barve et al. 2005). In some areas there are problems with over-grazing, and the disturbance on wildlife from herds of grazing animals could be expected to be more extensive than from other human activities. However, the negative impact of grazing in the study area seemed to be restricted. Several factors might have contributed to this. First, grazing animals were taken back to the stables every night (outside the buffer zone), secondly the buffer zone was wide (up to 4 km), and thirdly the buffer zone consisted of intact mosaic forest vegetation.

Buffer zones are generally assumed to be beneficial for protected areas (Salwasser et al. 1987; Stamps et al. 1987; MacKinnon et al. 1986; UNESCO 1974; Vujakovic 1987), but few studies have evaluated their effect on disturbance (see however, Nyhus & Tilson 2004; O'Brien 2003), especially at longer distance from the buffer zone edge. In this study, the amount of human disturbance decreased proportionally with distance from the buffer zone edge, but continued throughout the HKKWS buffer zone (up to 4 km). Disturbance from domestic animals also decreased with distance, with a sharp decrease at 2 km distance from the buffer zone edge (Fig. 10). Considering that the altitude is level, and that a healthy mosaic forest occurs throughout the buffer zone, the most probable explanation for this pattern is distance from the buffer zone edge. Thus, the results from this study suggests that the buffer zone in HKKWS works as a real buffer and reduces the impact of humans and domestic animals on the sanctuary. A buffer zone of 4 km width seems to be sufficient for decreasing human disturbances, such as cutting of bamboo and illegal wood harvesting. Vehicles are not allowed access or must be left at designated ranger stations. These rules were implemented to limit the accessibility of HKKWS to local villagers, and this might have contributed to the pattern of decreasing disturbance with increasing distance from the buffer zone edge. Nevertheless, one limitation of this study is the lack of data concerning the total number of people and households in the villages next to HKKWS. Though the proportion of human and domestic animal activities were recorded, the population statistics would have influenced the intensity of the activities.

However, the effects of domestic animals seem to be more spatially extensive and also have stronger effects on the wildlife (see results and below). Thus, regulations for number of grazing animals in the buffer zone might be discussed, especially if the number of people and domestic animals that use the buffer zone increase in the future.

In general the HKKWS buffer zone was a suitable habitat for several wildlife species. Sambar deer and Banteng occurred in > 25% of the plots. The Sambar deer is the most widespread and common large deer in this region (Trisurat 2004). The Banteng is rare in most areas (Francis, 2001), and it is therefore a quality that this species occurred regularly in the HKKWS buffer zone. Also Wild pig and Barking deer occurred regularly (in 9-11 % of the plots). Thus the HKKWS buffer zone also increased the area of available habitat for these species, which is usually mentioned as a possible positive effect of buffer zones (MacKinnon et al. 1986; Salwasser et al. 1987; UNESCO 1974), although this rarely has been shown. However, the abundance of wildlife species seemed to increase with distance from the buffer zone edge, again suggesting that the buffer zone is affective and that the 4 km wide buffer zone decreased the disturbance on the studied wildlife species. The abundance of wildlife species

within HKKWS itself has also been studied (Srikosamatara 1993). However, the use of different methods does not allow for such comparisons, but overall the abundance of the studied species seems to be similar in the sanctuary and in the most distant parts of the buffer zone. Statistical analysis of factors related to the occurrence of the different wildlife species suggested that three of the species (Sambar deer, Banteng and Elephant) were negatively associated to the occurrence of domestic animals. One species, Barking deer, was negatively associated to the human disturbance, while the Wild pig not was associated to any of the three included variables (proportion of plots with occurrence of domestic animals, proportion of plots with signs of human activities and distance to the buffer zone edge).

The analysis suggested a stronger negative effect of grazing domestic animals (and accompanying persons) than of other human activities. Six months of daily observations during the field survey resulted in 296 encounters with domestic animals in the HKKWS buffer zone. In all cases, domestic cattle and buffalo were accompanied by 1 – 3 people and 1 – 3 domestic dogs. Domestic cattle and buffalo herds varied in number from 10 – 98 animals. These herds had a high impact on the buffer zone vegetation, since they moved in dense groups, consumed grass and stems down to the roots, and left walkways with trampled vegetation. Therefore, the footprints and various activities of the domestic cattle and buffalo basically erased any traces of human and domestic dog tracks. This is a possible reason why no correlation was found between proportion of plots with human activities and proportion of plots with occurrence of domestic animals. Possibly, some areas with good grazing conditions and within reasonable distances from the stable were preferred by herdsmen. Thus, the disturbance from grazing animals was more pronounced and probably also more predictable in time and space than movements of small groups of people that gathered NTFP in the buffer zone. Similarly, other studies have suggested strong negative effects of domestic animals on wildlife, although different mechanisms such as competition for grazing areas, habitat destruction, disturbance or direct persecution have been suggested as ultimate causes (Ndanyalasi et al. 2007). There is no obvious explanation for the negative association between barking deer occurrence and human activities. More detailed studies of the ecology and behaviour of this species is needed, although factors such as hunting also might contribute to this pattern. The elephant is greatly reduced in numbers by hunting and forest loss (Francis, 2001), and the number of plots with occurrence of Elephants in the buffer zone was low.

To conclude this study has shown that the HKKWS buffer zone is used by humans, domestic animals and wildlife. In general, the 4 km wide buffer zone fulfil several requirements of a buffer zone: I) humans use the buffer zone for collection of NTFP such as bamboo, II) wildlife species, also relatively rare

wildlife species such as the Banteng use the buffer zone frequently, and therefore the buffer zone increases the available area of suitable habitat for the studied species, III) the width of the buffer zone is sufficient since disturbance from humans and domestic animals decreased considerably at distances of 2-3 km from the buffer zone edge and in contrast IV) abundance of wildlife species increased with distance from the buffer zone edge, V) the effects of domestic animals on wildlife occurrence was stronger than effects of other human activities.

Many studies have shown the importance of buffer zones for people living adjacent to protected areas (Ndanyalasi et al. 2007; Rawat 1997; Straede & Treue 2006). However, few other studied have evaluated the importance of buffer zones for wildlife. Especially studies of both disturbance and occurrence of wildlife are scarce (Laidlaw 2000; Pattanavibool & Dearden 2002). In general, intensity and pattern of human disturbance should be expected to be influenced by the size of the human population adjacent to protected areas and buffer zones (Karanth et al. 2006; Pattanavibool & Dearden 2002). Furthermore, the habitat in the buffer zone is a factor of key-importance for human use and also for occurrence of wildlife outside protected areas. More degraded buffer zones have been shown to be of more restricted value for both humans and wildlife (Straede et al. 2002). Thus, size of buffer zones and restrictions to achieve the dual goal of managing buffer zones with high values both for people in surrounding areas and for wildlife might differ between habitats and regions. Use of local knowledge and participatory approaches (Nepal & Weber 1994) are suggested to have the largest potential for successful management of natural resources in general, and management and regulations for habitats used by humans (such as buffer zones) in particular.

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Appendix 1. List of tracks of different domestic animals recorded during the field survey

	footprint	walkway	scat	eat grass / stems	scavenge tracks
Cattle	X	X	X	X	
Buffalo	X	X	X	X	
Goat	X	X	X		
Sheep	X	X	X		
Horse	X	X	X		
Pig	X				X
Dog	X		X		

Appendix 2. List of wildlife variables recorded during the field survey

	footprints	walkways	scat	sleep ditch	eat grass	antler marks on trees	eat bamboo shoots	scavenge tracks	eat vegetation / roots	eat cassava plant
Sambar deer *(Cervus unicolor)*	X	X	X	X	X	X				
Banteng *(Bos javanicus)*	X	X	X	X	X		X			
Wild pig *(Sus scrofa)*	X	X		X				X		
Barking deer *(Muntiacus muntjak)*	X	X								
Asiatic elephant *(Elephas maximus)*	X	X	X						X	
Tiger *(Panthera tigris)*	X	X	X							
Porcupine *(Hystrix brachyura)*										X

Appendix 3. Interview questionnaire

Personal information:	1	Name and Title
	2	Address
Domestic animals:	3	Types of domestic animals kept
	4	Number of stables owned
	5	Location of stables
Use of HKKWS buffer zone:	6	Do you use the HKKWS buffer zone? (Yes/No)