

The Human-Elephant Conflict: A Review of Current Status and Mitigation Methods

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Globally, wild elephants are present in 50 countries, 13 of which are in Asia and 37 in Africa. At present the number of wild Asian elephants (*Elephas maximus*) is between 35,000 and 50,000 (www.elephantcare.org), while the number in captivity is around 16,000. The trend in almost all Asian range states has been a drastic decline in wild elephant numbers, due to a range of anthropogenic factors related to increasing human population, loss and degradation of forest habitat, fragmentation of breeding populations and increasing human-elephant conflict (HEC). The Asian elephant is categorized as an 'endangered' species in the Red List of the World Conservation Union (IUCN, 2008: www.iucnredlist.org) and is classified with the Convention for International Trade of Endangered Species (CITES, www.cites.org) under Appendix I.

The number of wild African elephants (*Loxodonta africana*) at present is between 470,000 and 630,000 (Blanc *et al.* 2007). They have declined from over 5 million animals located throughout the continent 100 years ago, to the current number confined to fragmented habitats in sub-Saharan regions. Whereas poaching for ivory and meat was a major reason for the decline in the past, loss of habitat is the biggest threat to their continued survival at present. Paradoxically, though, elephant numbers are increasing in some countries and may need to be controlled in order to prevent degradation of their habitats. The African elephant is categorized as 'near threatened' in the IUCN Red List and populations of most range states are classified under Appendix I with CITES, except those of Botswana, Namibia, South Africa and Zimbabwe, which are included in Appendix II.

Elephants play an important role as 'keystone' and 'umbrella' species, maintaining biodiversity

of the ecosystems they inhabit. Due to their requirement for large areas of forest habitat, conservation of elephants will automatically ensure the conservation of other species that co-exist in the same habitat. However, they can also modify the environment in positive as well as negative ways by their actions. The elephant is also a 'flagship' species, especially in Asian countries, being closely associated with the social and cultural aspects of people, and this factor can be harnessed to promote its conservation.

Many studies have been carried out on HEC both in Asia (Sukumar 2003; Jayawardena 2004; de Silva & de Silva 2007) and Africa (Hoare 1999; Walpole & Linkie 2007), but despite the lessons learnt and the wide range of measures and management strategies that have been employed to mitigate HEC (Nelson *et al.* 2003; Osborn & Anstey 2007; Fernando *et al.* 2008), the intensity of the problem is clearly increasing.

The objective of this paper is to: (a) review the current status of HEC and methods used for its mitigation in the Asian range states; (b) highlight some differences in the African context; (c) summarize the current and potential new technologies for mitigation of HEC; and (d) identify further studies and actions needed.

Elephant range, population and human-elephant conflict

The population of wild Asian elephants in most range countries is a matter of debate. The minimum and maximum numbers in each country as estimated by the Asian Elephant Specialist Group (AsESG: www.asesg.org) of the IUCN and World Wide Fund for Nature (WWF: www.panda.org/) 2000 are given in Table 1, together with more recent estimates. The distribution of

elephant populations, intensity of HEC and the mitigation methods used in the Asian range states are summarized below.

Bangladesh

The resident population of wild elephants is between 151 and 344 (Feeroz *et al.* 2004). They are restricted to the southeastern forested areas, which are shrinking due to pressure from human activities, leading to increasing incidents of HEC. There is also trans-border movement of elephants in to Bangladesh, from Meghalaya and Assam in India and from Myanmar. These non-resident herds cause serious damage to crops and houses (Anwarul Islam, pers. comm.). Feeroz *et al.* (2004) report that during a period of one year from June 2001 to May 2002, HEC occurred in 28% of the elephant range and resulted in 38 deaths and 94 injuries to humans, as well as 3 elephant deaths and damage to crops and households amounting to US\$ 86,000.

Bhutan

The current population is believed to be between 400 and 600 (Murdoch 2008) and are located along the border with India. With a land area of 38,000 km² and a very low density of human population, the occurrence and intensity of HEC is low.

Cambodia

The number of wild elephants is uncertain, but possibly 250-600 (Murdoch 2008). There are

two main populations with over 100 elephants in each (Hefferman 2004). Studies are underway using camera trapping and faecal DNA based capture-recapture methodology to establish more accurate figures (Pollard 2007). Most incidents of HEC have occurred in the south and southwestern regions, and have been increasing with crop raiding and damage to cottages reaching a frequency of two per month in some areas (Hefferman 2004). The recently established Seima Biodiversity Conservation Area (SBCA) in eastern Cambodia is an important habitat for elephants, together with the Phnom Prich Wildlife Sanctuary lying to the north. Although there are many indigenous villages within the SBCA as well as large recent settlements around it, at present there are few problems with HEC. The mitigation measures include land-use planning and law enforcement, undertaken by the Forest Administration with the support of local communities (Pollard 2007).

China

Elephants exist only in the Upper Mekong Basin, in the southwestern part of Yunnan and the current number is between 165 and 213, distributed in 6 counties (Zhang 2007). The number of incidents of losses to household crops increased from 612 in 1991 to 16,380 in 2004, with 132 people being injured by elephants and 24 of them dying during this period (Luo 2007). The mitigation methods used include electric fences, anti-elephant ditches and walls, and improving elephant habitats to increase their natural feed availability and keep them away from farm lands. In some instances village settlements have been relocated, but

Table 1. The estimated population of wild Asian elephants in the range states in 2000 (source: www.elephantcare.org/asiandem.htm) and recent available estimates.

Country	2000 estimate		Current	
	Min.	Max.	Estimate	Reference
Bangladesh	195	239	151 – 344	Feeroz <i>et al.</i> 2004
Bhutan	60	100	400 – 600	Murdoch 2008
Borneo	1000	2500	1100 – 1600	Murdoch 2008
Cambodia	200	500	250 – 600	Murdoch 2008
China	250	300	165 – 213	Zhang 2007
India	19,090	29,450	27,669 – 27,719	http://envfor.nic.in/pe/pe.html
Indonesia (Sumatra)	2800	4800	2000 – 2500	Hammatt <i>et al.</i> 2004
Lao PDR	950	1300	800 – 1000	Khounboline 2007
Malaysia (Peninsular)	800	1200	1220 – 1466	www.wildlife.gov.my
Myanmar	4639	5000	4000 – 6000	Kyaw & Cho 2004
Népal	41	60	70 – 100	Yadav 2004
Sri Lanka	3160	4405	3500 – 4000	www.dwlc.lk
Thailand	1300	2000	3000 – 3500	Stewart-Cox & Ritthirat 2007
Vietnam	109	144	57 – 81	Hefferman 2004
Total	34,594	50,998		

elephants seem to find their way to these new locations as well. Currently local government and management agencies are helping villagers to plant cash crops that elephants dislike and are providing more compensation for losses, but the success of many of these measures has been limited (Roger Luo, pers. comm.).

India

Project Elephant of the Government of India (<http://envfor.nic.in/pe/pe.html>) estimates the present number of wild elephants to be 27,669-27,719. This project has declared 26 elephant reserves with an area of 60,000 km² to protect elephants, their habitats and corridors. The 5 elephant reserves in Assam have around 3,780 animals and, although poaching is not a serious issue in the state, there have been about 152 deaths of elephants during 2001-2007 that can be related to unnatural causes (Amit Sharma, pers. comm.). Each year, HEC results in about 300 human deaths and damage to 10,000-15,000 houses and 8-10 million hectares of crops, while over 200 elephants die due to human-related activities, which include poaching for ivory or meat, poisoning, cattle-borne diseases, electrocution and collision with trains (Bist 2002).

The full range of traditional and modern measures for mitigation of HEC is used by the state institutions and villagers, with varying degrees of success (Fernando *et al.* 2008). The Government of Assam has formed an Elephant Task Force, and several NGOs are actively assisting in HEC management. WWF-India (www.wwfindia.org) is implementing the AREAS (Asian Rhino and Elephant Action Strategy) programme, and has evolved a model for HEC management (the Sonitpur Model) that uses high tech tools like GIS and remote sensing along with traditional methods like elephant monitoring, guarding key depredation tracks employing kunkies (trained tame elephants) and chasing off wild herds. Longer term measures include maintaining contiguity of habitats and elephant populations in the critical areas by working with and supporting the state departments and communities (Amit Sharma, pers. comm.). Other NGOs that are active include Aaranyak (www.aaranyak.org), which is working

with the support of the US Fish and Wildlife Service to minimize HEC by encouraging villagers to adopt alternative cropping and livelihood options, and Ecosystems India and Green Guard, which work mainly on developing early warning systems and experimenting with chilies and other biotic deterrents.

Indonesia

The number of elephants in Sumatra had been estimated to be 2000-2500 (Hammatt *et al.* 2004), but more recent estimates indicate this to be 2400-2800 (M. Wahyu & Donny Gunaryadi, pers. comm.). The important elephant habitats are in the provinces of South Sumatra and Lampung in the south, Aceh in the north and Riau in the east. In the early 1980s Lampung was reported to have 12 areas with elephant populations, but Hedges *et al.* (2005) have found that only three areas, Bukit Barisan Selatan National Park (BBSNP), Way Kambas National Park (WKNP) and the Gunung Rindingan-Way Waya complex (GRWW) still had resident populations in 2002. Their estimates of elephant populations for the BBSNP and WKNP were 498 and 180, respectively. A study on modelling of the population trend in the WKNP (Sitompul *et al.* 2008) has shown that the population would continue to increase over the next 50 years, even with a moderate degree of anthropogenic removal of elephants.

The high human population density of Lampung province and the close proximity of settlements to the remaining elephant habitats have resulted in a high degree of HEC. Between June 2000 and September 2002 Hedges *et al.* (2005) investigated 717 crop damage incidents around BBSNP and WKNP, and found that elephants destroyed 21 houses, killed three people and disabled another three persons. The direct financial loss due to crop raiding in villages around WKNP during this period was US\$ 12,000. A range of strategies are used for mitigating HEC, including habitat management, barriers, early warning systems, deterrents, driving away using “flying squads” of men and mahouts with captive elephants, and capture of problem animals followed by translocation or taming. Taming of captured animals is done in Elephant Training Centres,

but the survival rate of such animals appears to be very low, raising major concerns regarding its success (Hammatt *et al.* 2004).

Lao PDR

Known historically as *Lane Xang* (land of a million elephants), the current number of wild elephants in Lao PDR is not known, but is thought to be 800-1000 (Khounboline 2007). Many of the elephant populations are thought to be relatively small and dispersed within national and provincial Protected Areas (PAs), corridors and adjoining areas, located in the north, central and southern parts of Lao (Alex McWilliam, pers. comm.).

Nearly two thirds of the human population in Lao live in rural areas and practice shifting cultivation, many doing so within or near the network of PAs. Levels of HEC are increasing and it is now a social and economic issue. In addition, many development projects are planned or underway in areas where elephants occur and this will further reduce habitats available to elephants. The Wildlife Conservation Society (WCS: www.wcs.org) states that deaths of elephants due to HEC are increasing, but a major threat is also poaching for ivory, involving both local and transboundary hunters. An ongoing study in the Nakai Plateau, where a hydroelectric project has inundated a large area of elephant habitat in and adjacent to the Nakai-Nam Theun PA, showed an increase in HEC incidents from 7 to 11.2 per month over a four year period (McWilliam 2008). The main mitigation methods include community based crop defence involving early warning systems and active as well as passive deterrents (Khounboline 2007). The WCS has obtained positive results with rope lines erected around cropping areas from which bells and rattles are hung to provide early warning to crop guards at night and passive deterrents such as bottles filled with vinegar hung on fences (McWilliam 2008).

Malaysia

The Department of Wildlife and National Parks of Malaysia (www.wildlife.gov.my) estimates the number of elephants in peninsular Malaysia to be

1,220-1,466. A recent study using dung counts in the Taman Negara NP has shown the presence of around 630 animals, which is much higher than previously believed (www.elephant-news.com). The Malaysian state of Sabah on the island of Borneo and the adjacent areas of Indonesian Kalimantan have a combined population estimated at 1100-1600 (Murdoch 2008). HEC occurs in most areas around elephant habitats, and the mitigation measures used include erection of electric fences and translocation of problem animals to NPs.

Myanmar

Myanmar has a land area of 676,000 km² and 50% of this is under forest cover, with 4% declared as PAs, and the number of wild elephants is estimated at 4000-6000 (Kyaw & Cho 2004). A study by Leimgruber *et al.* (2008) has found that the capturing of about 100 elephants each year, which has been practiced for many years to maintain the captive population at around 6,000, could result in extinction of the wild population in 31 years. The number of incidents of crop raiding, damage to houses and human deaths is increasing, and the main methods of mitigation are driving elephants back to forest habitats and capture followed by translocation or taming (Kyaw & Cho 2004).

Nepal

Nepal has a land area of 147,000 km² and 18% of this is designated as PAs. The number of resident wild elephants is between 70 and 100, with an additional transboundary population of 50-75 shared with India (Yadav 2004). HEC is present at a moderate level in the areas around elephant habitats, with crop damage being the main consequence. The number of deaths attributed to HEC during the past 20 years was 66 humans and 18 elephants. The main strategies for mitigation of HEC include establishment of more PAs and corridors, development of infrastructure for guarding and protecting crops (training of villagers, erecting watch towers and electric fencing), deterrent measures (sirens, search lights and shotguns) and planting alternate crops such as tea (Yadav 2004).

The data available with the Department of Wildlife Conservation of Sri Lanka (www.dwlc.lk) indicates a population of 3500–4000 wild elephants. The forest cover is 20% of the total land area of 65,000 km², and 14% of this is designated as PAs. Sri Lanka has 10% of the wild Asian elephant population, but only 2% of the range available for elephants in the region.

The intensity of HEC in many rural areas adjacent to elephant habitats has been increasing rapidly. The data from the DWLC shows that 1369 elephants were killed during the past 10 years, with gunshot injuries accounting for 56% of them and 68% being adult bulls (Fig. 1). Other causes of mortality were electrocution and poisoning (due to illegal actions taken by farmers to protect their crops), landmines, accidental falling into agricultural wells and abandoned gem pits and collision with trains. Between 1992 and 2001, 536 people were killed by wild elephants (75% men, 13% women and 12% children). On average, HEC results in deaths of 150 elephants and 50–70 humans each year. However, in spite of the severe hardships and economic losses suffered by rural people, many still have a positive attitude towards elephant conservation (Bandara & Tisdell 2003).

The mitigation measures used have been comprehensively reviewed by Fernando *et al.* (2008). The main activities of the DWLC include: establishment of new NPs, elephant corridors and conservation areas; habitat enrichment; capture and translocation of problem animals;



Figure 1. An adult male tusker found dead in the south-east of Sri Lanka with gunshot injuries.

collective drives of herds to PAs; electrical and biological fencing; and provision of assistance and thunder flashes to villagers to drive away invading elephants. Two further initiatives for elephant conservation are *ex situ* conservation at the Pinnawela Elephant Orphanage (PEO) and re-introduction of orphans in to the wild from the Elephant Transit Home (ETH) at Uda Walawe. Many NGOs are engaged in community level activities and educational programmes for conservation of elephants and mitigation of HEC, including the Wildlife and Nature Protection Society (www.wnpssl.org), the Sri Lanka Wildlife Conservation Society (www.slwcs.org) and the Biodiversity and Elephant Conservation Trust.

A recent study on HEC in three districts of the north-western wildlife region of Sri Lanka (Perera 2007; Perera *et al.* 2007), covering a land area of 11,000 km² and comprising around 1200 villages, showed that there were over 1,000 elephants in the area. During 2006, HEC resulted in the deaths of 24 humans and 66 elephants, while there were 452 incidents of crop damages and 119 incidents of property damages (Fig. 2). A major consequence of HEC was a very significant deterioration in the quality of life of rural people. The main mitigation measures used by villagers were: making sounds using voice, fire-crackers and thunder flashes; lighting lamps or fires around homesteads and fields; keeping watch at night in huts built on trees; hanging metal or glass objects on perimeter fences; planting live fences of thorny scrub; and use of shot-guns to scare or injure elephants. However, elephants often became habituated to these measures and even became more aggressive with time.

This study identified an urgent need to: (a) organize proper awareness programmes and establish good communication channels with villagers; (b) recruit and train villagers to handle village level management activities for preventing elephant intrusion; (c) introduce crop diversification using species that are not favoured by elephants; (d) promote alternative economic activities (e.g. inland fishery, livestock industries); and (e) consider relocation of elephants or humans in areas where no other alternative exists. As emphasized by previous authors (Corea 2004;



Figure 2. House damaged by an elephant that attempted to consume the rice stored inside.

de Silva & de Silva 2007; Fernando *et al.* 2008), rational and scientific management strategies need to be coupled with community participation and careful selection of the mitigation methods for each location.

Thailand

The current number of elephants is estimated to be 3000–3500, scattered over 60 PAs (Stewart-Cox & Ritthirat 2007). The Western Forest Conservation Complex (WEFCOM) has the largest population of around 1,000, and includes the Salakpra Wildlife Sanctuary and adjoining Chalerm Rattanakosin NP, where 130–150 elephants reside. Studies conducted by the Elephant Conservation Network (www.ecn-thailand.org) show that human activities inside the forest cause considerable disturbance to elephants, and that most crop-raiding in any one area is done by 1–3 bull elephants targeting sugarcane, papaya and mango.

Another important elephant habitat is Kaengkrachan-Kuiburi Complex in southwestern Thailand, which contains 4 PAs with around 150 elephants. The complex has over 450 agricultural areas around it, and HEC is a common occurrence. In 2005 the value of crops damaged was over 4 million Baht. A programme initiated by HM the King has allocated land that was previously used for pineapple cultivation around the Kuiburi NP for reforestation and habitat improvement, together with measures to improve the income

and quality of life of the rural people, resulting in a marked reduction in HEC (Srikrachang & Srikosamatara 2005).

Vietnam

The wild elephant population was estimated at between 57 and 81 in 2002, located in 11 different areas (Hefferman 2004). HEC has reached crisis levels in some areas, with 26 people killed over a two year period at one site. The drastic population crash from the numbers that were present in the 1980s, coupled with the fragmented nature of the present population and the continuing pressure on limited habitats, indicate the need for urgent action to prevent the extinction of Vietnam's elephants.

Africa

The African Elephant Database (<http://data.iucn.org/themes/ssc/sgs/afesg/aed/pdfs/aesr2007.pdf>) of the African Elephant Specialist Group provides the most reliable information on the population of elephants in African range states. It lists three statistics for each region and country, in terms of the “Definite”, “Probable” and “Possible” numbers. The estimates for the four regions containing elephants are given in Table 2 (Blanc *et al.* 2007).

The elephant populations of some African countries such as Botswana, South Africa, Tanzania and Zimbabwe are increasing. Zimbabwe has an elephant population of around 90,000 (Blanc *et al.* 2007), whereas the carrying capacity of the country is considered to be less than 40,000. Increases in both human and elephant populations have had severe negative impact on the environment and biodiversity, resulting in a growing HEC. An analysis by Foggin (2003) indicates that, if unresolved, this crisis will probably result in a massive die-off of elephants in some areas, and it appears unlikely that any method other than lethal control can be applied either efficiently or soon enough to overcome the crisis. In other countries such as Kenya, attempting to confine elephants to PAs has resulted in habitat damage, making it necessary to find humane methods for population control.

Table 2. The estimated population of wild African elephants and their proportion of the elephant range (=ER) (Source: Blanc *et al.* 2007)

Region	Number of elephants			% ER
	Definite	Probable	Possible	
Central	10,000	59,000	102,000	29
East	137,000	166,000	201,000	26
South	298,000	321,000	346,000	39
West	7,500	8,200	9,300	5
Total	472,000	554,000	637,000	100

Reports on HEC in many African countries (Hoare 1999; Smith 2007; Walpole & Linkie 2007) show a marked increase in incidence during recent years. However, in the African context, elephants are not the most frequent crop raiding species. Other taxa such as primates, suids, rodents, birds or insects often cause greater crop losses, but complaints about elephant damage tend to be disproportionately higher than its relative contribution (Hoare 1999).

The results from HEC mitigation methods adopted in several countries (Nelson *et al.* 2003; Sitati & Walpole 2006; Osborne & Anstey 2007) indicate that a ‘bundle of methods’ need to be developed for each situation, based on a combination of low-cost farm-based vigilance and deterrent measures, with active participation of the affected communities.

Current management strategies and methods to mitigate HEC

HEC is increasing in both Asia and Africa. It is now a major focus of international attention, as reflected in the work of the AsESG and the AfESG of the IUCN’s Species Survival Commission. The AsESG has established several Task Forces and Working Groups, one of which is on HEC. The AfESG has also established a Human-Elephant Conflict Working Group (HECWG), which has identified five issues that need urgent attention (Hoare 1999).

The methods of mitigation ranging from simple, traditional methods used by villagers to modern, expensive technologies implemented by state agencies have been described and classified by many previous authors (Nelson *et al.* 2003; Osborn & Anstey 2007; de Silva & de Silva

2007; Fernando *et al.* 2008). A brief overview of the various methods is given below.

1. Physical barriers (to keep elephants within PAs or prevent their entry to villages)

Electric fences - expensive and difficult to maintain, some elephants become ‘fence-breakers’. Small community type fences enclosing villages and croplands with maintenance by the community can be effective (Fig. 3);

Non-electric fences - need strong material, usually ineffective;

Live fences - thorny plants (e.g. cactus, agave) and trees planted in a close (sometimes triangular) pattern. Other measures (e.g. electric fence) are needed to prevent damage to the plants until they mature;

Trenches - problems in maintenance due to erosion during rains and elephants filling them by kicking in the sides.

2. Vigilance methods (to alert farmers to approaching elephants and increase the chance of driving them away)

Buffer zones - clearing of a five metre wide strip around fields or villages;

Watch-towers - at strategic points or at half-kilometre intervals along intrusion borders, with communication to alert other farmers (e.g. whistles) (Fig. 4);

String fences - with metal or glass objects (cans, bottles, bells, etc.) that make a sound (Fig. 5);

Detection and alarm systems using tripwire fences, seismic, optical, laser or infrasound technologies;

Lights or fires - at strategic entry points.

3. Deterrent methods (to impede or discourage the passage of elephants in to fields and villages)

Buffer zones of unpalatable crops - e.g. chilli, sesame, tea, tobacco, citrus;

Making noise (acoustic) - banging on metal, fire-crackers, thunder-flashes, fire-arms, cracking whips, trip-wire alarms, recorded sounds (e.g. African honey-bees, elephant distress calls, infrasound);

Fires and lights - burning chilli or chilli seeds



Figure 3. Electric fence and solar power unit.

and dung, strong flashing lights, light shining on compact disks hung on string;

String fences - with application of grease and chilli, hot pepper oil, vinegar or other irritants; musth secretions or 'fear' pheromones;

Nails and spikes - sometimes with poison.

4. Repulsion methods (to drive away elephants that enter fields or villages)

Use of noise (as above) and irritants - pepper spray (oleo-resin capsicum) and pepper-crackers;

Elephant Response Units or "Flying Squads" - teams of people with or without captive elephants;

Causing pain and injury - fire-arms, spears.

5. Elephant drives

To drive herds or individual problem animals to PAs or other forest habitats that will hopefully become their new home range; using people, sometimes with trained elephants, vehicles or aircraft. Low success rate, due to some elephants breaking back from the driven herd, or to those driven returning to their former habitat.

6. Capture, followed by translocation or taming

Usually done for problem animal control (PAC) involving adult males, which take more risks than breeding herds and therefore become habitual crop raiders. Translocation requires a high degree of expertise and logistics, and the animals may return to the original site or create problems in

the new location. Success with taming depends on the age of the captured animal and expertise of the tamers, and has not been very promising in some situations.

7. Culling (killing or lethal control)

A highly controversial and emotive issue, ethically and culturally unacceptable in most Asian countries. Has been used in Africa to control overpopulation and prevent damage to habitats. When employed for PAC, the culled animal may be replaced by another problem animal.

8. Compensation schemes

Can make people more tolerant to damages caused by elephants, but most are often inadequate, highly bureaucratic and open to problems such as fraudulent claims and corruption.

9. Land-use planning

Lack of proper planning has resulted in a marked increase in competition between humans and wildlife for land, feed and water resources and is the root cause of increasing HEC in most countries (Nelson *et al.* 2003). The main factors that bring humans and elephant into situations of increasing confrontation are: (a) expansion of human settlements and agriculture into forest areas; (b) loss of elephant habitats and blocking of traditional migration routes; (c) human activities that attract elephants, such as planting crops in previous elephant habitats, logging in forests resulting in secondary vegetation, and creating water reservoirs for irrigation or power generation. These confrontations invariably lead to aggressive behaviour in both humans and elephants, thus escalating HEC. Traditional land-use patterns such as the slash-and-burn (chena) cultivation practiced in some Asian countries have proven to be elephant-friendly, and could be suitably adapted for mitigating HEC in some locations.

New biological technologies to mitigate HEC

Biological methods that hold promise for mitigating HEC include physiological,

pharmacological and immunological methods for modifying the reproduction and/or behaviour of elephants. These could have applications in situations where elephant populations need to be reduced or maintained without further increase, or for controlling aggressive behaviour and musth in adult males.

Manipulating female reproduction

Induction of temporary infertility (i.e. reversible contraception) in cycling females can be achieved by immuno-contraception, involving immunization against cellular components or hormones that are essential for reproduction. A vaccine prepared using glycoproteins of the Zona Pellucida (ZP) of pig oocytes, when injected in to many species including horses and elephants, results in the production of antibodies that disrupt the normal functions of the ZP, preventing conception (Fayrer-Hosken 2008). Trials in Africa have shown that three doses administered at intervals of three weeks using drop-out darts prevented pregnancies in elephant cows for up to one year (Delsink *et al.* 2003).

An alternative method is immunization against Gonadotrophin-Releasing Hormone (GnRH), which is produced in the hypothalamus and is a key regulator of reproductive functions in both males and females. When GnRH is conjugated to a suitable hapten and administered with an adjuvant, it causes the production of antibodies that bind with endogenous GnRH,

thus suppressing reproductive cycles in females. Studies in many domestic species and a few wild species (e.g. deer, bison) have shown that 2-3 doses of the vaccine are effective in achieving contraception for 1-2 years with no adverse side-effects (Fayrer-Hosken 2008). Studies are currently underway in South Africa (Henk Bertschinger, Pers. Comm.) and Sri Lanka to test the efficacy of this procedure in elephants.

Another approach is treatment with long acting preparations of oestradiol 17- β , which causes negative feedback on the hypothalamus and pituitary, resulting in inhibition of ovulation. Trials in African elephants using sub-cutaneous implants that are commercially available for livestock have shown that pregnancies can be prevented for over 12 months (Hildebrandt *et al.* 2006).

Manipulating male reproduction and aggression

Immunization against GnRH in male domestic animals causes two reversible effects in the testes: reduction in testosterone production from the Leydig cells (resulting in reduced libido); and disruption of spermatogenesis in the seminiferous tubules (resulting in infertility). African bull elephants vaccinated with three doses had lower faecal epiandrosterone concentrations, indicating a reduction in testosterone production from the testes, and showed a marked reduction in aggression for periods of 6-9 months (Stout *et al.* 2007). Further, re-vaccination of bulls that were in musth resulted in cessation of aggressive behavior within 7-10 days of the first booster vaccination.

Conclusions

This review shows that much information is available on the causes and effects of HEC, the methods used for its mitigation and their effectiveness in many of the range states in Asia and Africa. However, gaps in knowledge do exist, and require studies to document the quantitative effects of HEC and to determine the most appropriate combination of methods that can mitigate HEC under the specific conditions of each location. As discussed by Hoare (1999)



Figure 5. Typical watch-hut built on a tree.



Figure 6. Metal and glass objects hung on perimeter fences

and Barnes (2008), future studies should use standardized designs and data collection protocols, as well as modern information systems to report, record, manage and respond to incidents of elephant damage.

Studies are also needed on new pharmacological methods such as immuno-contraception to reversibly inhibit female and male fertility, and to control musth and aggression in problem bulls. These will have important applications in the future as adjuncts to the array of methods that are currently in use.

It is important that all studies are undertaken in an inter-disciplinary manner, using a fully participatory approach with all stakeholders from the design stage through to implementation. This requires active collaboration between scientists, wildlife managers, policy makers, wildlife enthusiasts and the local communities in order to find successful and sustainable solutions to HEC. An essential consideration in obtaining the support of local communities is providing them with the necessary information, motivation and training activities that are targeted to their needs in keeping with socio-cultural backgrounds.

Finally, land-use must be addressed in a forthright manner and hard decisions made on alternatives such as crop diversification using species that are not favoured by elephants, promoting economic activities that are not prone to elephant damage, and relocation of elephants or humans in areas where no other alternative exists.

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References

- Bandara, R. & Tisdell, C. (2003) Comparison of rural and urban attitudes to the conservation of Asian elephants in Sri Lanka: empirical evidence. *Biological Conservation* **110**: 327–342
- Barnes, R.F.W. (2008) The design of crop raiding studies. *Gajah* **28**: 4-7.
- Bist, S.S. (2002) An overview of elephant conservation in India, *The Indian Forester* **128**: 121-136.
- Blanc, J.J., Barnes, R.F.W., Craig, G.C., Dublin, H.T., Thouless, C.R., Douglas-Hamilton, I. & Hart, J.A. (2007) *African Elephant Status Report 2007: An Update from the African Elephant Database*. IUCN Species Survival Commission, African Elephant Specialist Group. IUCN, Gland, Switzerland. <http://data.iucn.org/themes/ssc/sgs/afesg/aed/pdfs/aesr2007.pdf>
- Corea, C. (2004) Saving elephants by helping people – lessons in community integrated elephant conservation. In: *Endangered Elephants: Past, Present and Future*. Jayawardena, J. (ed.) Biodiversity & Elephant Conservation Trust, Colombo, Sri Lanka. pp 136–139.
- Delsink, A., Bertschinger, H.J., Kirkpatrick, J.F., DeNys, H., Grobler, D., van Altena, J.J. & Turkstra, J. (2003) Contraception of African

- elephant cows in two private conservancies using porcine zona pellucida vaccine and the control of aggressive behaviour in elephant bulls with GnRH vaccine. In: *Control of Wild Elephant Populations*. Utrecht University, The Netherlands. pp 43-45.
- De Silva, M. & De Silva, P.K. (2007) *The Sri Lankan Elephant: Its Evolution, Ecology and Conservation*. WHT Publications, Colombo, Sri Lanka.
- Fayrer-Hosken, R. (2008) Controlling animal populations using anti-fertility vaccines. *Reproduction in Domestic Animals* **43** (Suppl. 2): 179-185.
- Feeroz, M.M., Aziz, M.A., Islam, M.T. & Islam, M.A. (2004) Human-elephant conflict in southeastern hilly areas of Bangladesh. In: *Endangered Elephants: Past, Present and Future*. Jayewardene, J. (ed.) Biodiversity & Elephant Conserv Trust, Colombo, Sri Lanka. pp 98-102.
- Fernando, P., Kumar, M.A., Williams, A.C., Wikramanayake, E., Aziz, T. & Singh, S.M. (2008) *Review of Human-Elephant Conflict Mitigation Measures Practiced in South Asia*. AREAS Technical Support Document Submitted to World Bank, World Wide Fund for Nature.
- Foggin, C.M. (2003) The elephant problem in Zimbabwe: can there be any alternative to lethal population control? In: *Control of Wild Elephant Populations*. Utrecht University, The Netherlands. p 11.
- Hammatt, H., Fahrimal, D.Y. & Mikota, S. (2004) Implications of new data for Sumatran elephants in captivity – time for change. In: *Endangered Elephants: Past, Present and Future*. Jayewardene, J. (ed.) Biodiversity & Elephant Conserv. Trust, Colombo, Sri Lanka. pp 61-64.
- Hedges, S., Tyson, M.J., Sitompul, A.F., Kinnaird, M.F., Gunaryadi, D. & Aslan (2005) Distribution, status, and conservation needs of Asian elephants (*Elephas maximus*) in Lampung Province, Sumatra, Indonesia. *Biological Conservation* **124**: 35–48.
- Hefferman, J. (2004) An overview of human-elephant conflict in Cambodia and Vietnam. In: *Endangered Elephants: Past, Present and Future*. Jayewardene, J. (ed.) Biodiversity & Elephant Conservation Trust, Colombo. pp 114-117.
- Hildebrandt, T.B., Göritz, F., Hermes, R., Reid, C., Dehnhard, M. and Brown, J.L. (2006) Aspects of the reproductive biology and breeding management of Asian and African elephants *Elephas maximus* and *Loxodonta Africana*. *International Zoo Yearbook* **40**: 20-40.
- Hoare, R.E. (1999) *A Standardized Data Collection and Analysis Protocol for Human-Elephant Conflict Situation in Africa*. IUCN/SSC African Elephant Specialist Group, Nairobi, Kenya.
- Jayewardene, J. (ed.) (2004) *Endangered Elephants: Past, Present and Future*. Proceedings of the symposium on human elephant relationships and conflicts, Sri Lanka, September 2003. Biodiversity & Elephant Conservation Trust, Colombo, Sri Lanka.
- Khounboline, K. (2007) Human-elephant conflict (HEC) pilot study in southern Lao PDR. *Gajah* **26**: 18-20.
- Kyaw, U.A. & Cho, U.K.M. (2004) Human-elephant relationships and conflicts in Myanmar. In: *Endangered Elephants: Past, Present and Future*. Jayewardene, J. (ed.) Biodiversity and Elephant Conservation Trust, Colombo, Sri Lanka. pp 103-105.
- Leimgruber, P., Senior, B., Uga, M.A., Songer, M.A., Mueller, T., Wemmer, C. & Ballou, J.D. (2008) Modeling population viability of captive elephants in Myanmar (Burma): implications for wild populations. *Animal Conserv.* **11**: 198-205.
- Luo, A. (2007) Brief introduction to the human-elephant conflicts in Upper Mekong region. *Gajah* **26**: 34-36.
- McWilliam, A. (2008) Monitoring and mitigation of human-elephant conflict at a hydropower project site in Lao PDR. In: *2008 International*

- Elephant Conservation and Research Symposium*. Pattaya, Thailand. p 35.
- Murdoch, G. (2008) Factbox - *Threats Facing Asia's Endangered Wild Elephants*. www.reuters.com/article/latestCrisis/idUSSP266929
- Nelson, A. Bidwell, P. & Sillero-Zubiri, C. (2003) *A Review of Human Elephant Conflict Management Strategies*. People and Wildlife Initiative, Wildlife Conservation Research Unit, Oxford University, United Kingdom.
- Osborn, F.V. & Anstey, S. (2007) *Elephant/Human Conflict and Community Development around the Niassa Reserve, Mozambique*. WWF Southern African Regional Programme. www.elephantpepper.org/downloads/Niassa%20ele%20report.pdf
- Perera, B.M.A.O. (2007) Status of elephants in Sri Lanka and the human-elephant conflict. In: *EU-Asia Link Project Symposium "Managing the Health and Reproduction of Elephant Populations in Asia"*. Kasetsart University, Bangkok, Thailand. pp 14-22.
- Perera, B.M.A.O., Abeygunawardena, H., Abeygunawardena, I.S., Wanigasundera, W.A.D.P., Gunatilake, J. & Jayasooriya, A.P. (2007) The human-elephant conflict (HEC): background and current situation in the north-western wildlife region of Sri Lanka. *Loris* **24**: 10-20.
- Pollard, E. (2007) Asian elephants in the Seima Biodiversity Conservation Area, Mendulkiri, Cambodia. *Gajah* **27**: 52-55.
- Sitati, N.W. & Walpole, M.J. (2006) Assessing farm-based measures for mitigating human-elephant conflict in Transmara District, Kenya. *Oryx* **40**: 279-286.
- Sitompul, A.F., Carroll, J.P., Peterson, J. & Hedges, S. (2008) Modeling impacts of poaching on the Sumatran elephant population in Way Kambas National Park, Sumatra, Indonesia. *Gajah* **28**: 31-40.
- Smith, D.M. (2007) *Botswana Human-Elephant Conflict: Growing Elephant Population Damages Crops and Frustrates Locals*. http://wildlife-conservation.suite101.com/article.cfm/humananimal_conflict_in_botswana
- Srikrachang, M. & Srikosamatara, S. (2005) Elephant crop raiding problems and their solutions at Kuiburi National Park. *Natural History Bulletin of Siam Society* **53**: 87-109.
- Stewart-Cox, B. & Ritthirat, J. (2007) Mitigating human-elephant conflict in Asia: a new initiative in Thailand. In: *Mitigating Human-Elephant Conflict: Case Studies from Africa and Asia*. Walpole, M. & Linkie, M. (eds.) Fauna & Flora International, Cambridge, UK. pp 13-22.
- Stout, T.A.E., Bertschinger, H. J. & Colenbrander, B. (2007) The use of GnRH vaccines for reproductive suppression in horses and elephants. In: *EU-Asia Link Project Symposium "Managing the Health and Reproduction of Elephant Populations in Asia"*. Kasetsart University, Bangkok, Thailand. pp 114-116.
- Sukumar, R. (2003) *The living Elephants: Evolutionary Ecology, Behavior, and Conservation*. Oxford Univ. Press, Oxford, UK.
- Walpole, M. & Linkie, M. (eds.) (2007) *Mitigating Human-Elephant Conflict: Case Studies from Africa and Asia*. Fauna & Flora International (FFI), Cambridge, UK.
- Yadav, B.R. (2004) Human-elephant relationships and conflicts in eastern Nepal. In: *Endangered Elephants: Past, Present and Future*. Jayewardene, J. (ed.) Biodiversity & Elephant Conservation Trust, Colombo, Sri Lanka. pp 90-92.
- Zhang, L. (2007) Current conservation status and research progress on Asian elephants in China. *Gajah* **27**: 35-41.
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