

## Review: Status of wild elephant, conflict and conservation actions in Thailand

**RONGLARP SUKMASUANG<sup>1,\*</sup>, NARIS PHUMPAKPHAN<sup>1</sup>, PRATEEP DEUNGKAE<sup>1</sup>,  
RATTANAWAT CHAIYARAT<sup>2</sup>, MANANYA PLA-ARD<sup>1</sup>, NORASET KHIOWSREE<sup>3</sup>,  
KHWANRUTAI CHARASPET<sup>4</sup>, PAANWARIS PAANSRI<sup>5</sup>, JESADA NOOWONG<sup>1</sup>**

<sup>1</sup>Department of Forest Biology, Faculty of Forestry, Kasetsart University. 50 Phahonyothin Road, Chatuchak District, Bangkok 10900, Thailand.  
Tel.: +66-2-579-0176, Fax.: +66-2-942-8107, \*email: mronglar@gmail.com

<sup>2</sup>Wildlife and Plant Research Center, Faculty of Environment and Resource Studies, Mahidol University. Salaya, Nakhon Pathom Province 73170, Thailand

<sup>3</sup>Forest Research Center, Faculty of Forestry, Kasetsart University. 50 Phahonyothin Road, Chatuchak District, Bangkok 10900, Thailand

<sup>4</sup>Wildlife Research Division, Wildlife Conservation Office, Department of National Parks Wildlife and Plant Conservation. Bangkok 10900, Thailand

<sup>5</sup>Department of Fish and Wildlife Conservation, Virginia Polytechnic Institute and State University. Blacksburg, Virginia, 24061, USA

Manuscript received: 2 March 2024. Revision accepted: 11 April 2024

**Abstract.** *Sukmasuang R, Phumpakphan N, Deungkae P, Chaiyarat R, Pla-Ard M, Khiowsree N, Charaspert K, Paansri P, Noowong J. 2024. Review: Status of wild elephant, conflict and conservation actions in Thailand. Biodiversitas 25: 1479-1498.* This study comprehensively reviewed various aspects of population status, distribution, conflict situations, and conservation strategies for managing human-elephant conflicts (HECs). The primary goal is to foster a clear understanding of the current status, issues, and problem-solving approaches to benefit elephant conservation and management. The key element in elephant conservation is the acceptance of the coexistence between humans and elephants in their respective areas. Managing overlapping areas between humans and elephants is crucial for conservation efforts. A major concern is that elephants venture outside protected areas, increasing risk to both human and elephant populations. Therefore, enhancing the efficiency of conflict management is of the utmost importance to the long-term survival of elephants. This study revealed that vital approaches for managing elephant populations in Thailand include designating conservation areas as the foundation for long-term elephant conservation. In addition, habitat management at the population level, implementing compensation schemes, establishing community-based monitoring groups in conflict areas, improving conflict management practices, and decentralizing decision-making processes in conservation efforts are critical. Other essential elements of successful conservation and management in Thailand include setting population targets for elephants in each conservation area, with the goal of effective management. This was supported by research, community collaboration, decentralization, and performance evaluation to gauge the success of implemented measures in reducing HECs by assessing the number of conflict incidents and fatalities for both humans and elephants. This suggests the need for a fundamental reform of the elephant conservation policy.

**Keywords:** Conservation, habitat management, human-elephant conflict, mitigation strategies, population, Thailand

### INTRODUCTION

The alteration of land cover owing to the increasing demands of the human population, without proper planning and consideration of its impact on other living organisms, has led to habitat fragmentation and degradation. This is the primary cause of human-elephant conflicts (HECs) (Thouless et al. 2016; Calabrese et al. 2017; Liu et al. 2017; Kumar et al. 2018; van de Water and Matteson 2018; Krishnan et al. 2019; Menon and Tiwari 2019; Menon et al. 2022; Karanth and Vanamamalai 2020; Su et al. 2020; Montez and Leng 2021; Cabral de Mel et al. 2022; Thant et al. 2022; Belgrano et al. 2023; de Silva et al. 2023). These challenges have become significant management issues in wildlife and biodiversity conservation efforts (Neupane et al. 2017; Billah et al. 2021).

In the remaining areas of Asian elephants in the 13 countries, or within approximately 5% of the total distribution area in the past (Williams et al. 2020), the remaining habitat area for wild elephants was only approximately 22%, protected in the form of conservation

areas. The remaining 78% were areas with various human uses, including national reserve forests with human activities, agricultural areas, and settlements and housing areas (Naha et al. 2020). The demand for natural resources to meet the increasing needs of the human population has resulted in conflicts between people and wild elephants (Goswami et al. 2015). The lack of connectivity between forest patches, as observed in the past, prevents elephants from traveling between their original natural habitats (Sukumar et al. 2016; Menon et al. 2019), which could have implications for the health and genetic diversity of the elephant population (Chandranaiik et al. 2022).

The review of documents on the status, conflicts, and conservation of elephants in Thailand aimed to identify knowledge gaps and enhance our understanding of the current situation, management strategies, and conflict resolution between people and elephants (Ahmad Zafir and Magintan 2016; Shaffer et al. 2019; Kroutnoi et al. 2020; Montez and Leng 2021; Lim and Campos-Arceiz 2022; Sajla and Famees 2022). However, the implementation of these findings in Thailand has been limited. Despite the

availability of studies related to the ecology, population, land use, and conflict resolution between people and elephants, a gap remains in the application of this knowledge in addressing elephant-related challenges (Chen et al. 2016; Van de Water and Matteson 2018; Rukdee et al. 2020; Songmanee et al. 2017). The crucial question is how to utilize the existing research to address these challenges effectively. What knowledge is still lacking for effective elephant conservation, considering the context and avenues for problem-solving?

In this document review, the important objective was to understand HEC and provide directions for the coexistence of people and elephants as a suitable long-term conservation strategy in Thailand. It aims to create a framework for document examination to achieve the defined objectives. Five primary aspects are covered: (i) the population and distribution of elephants; (ii) the nature of HEC; (iii) strategies to reduce HEC, including protection and conflict mitigation; and (iv) problem prevention, community engagement, and community empowerment. It also explores the deep understanding of natural habitat use for management, leading to long-term conservation goals (v) for the coexistence of people and elephants.

## DATA COLLECTION

Review articles have become increasingly important in order to stay up-to-date with developments in specific research areas (Bahishti 2021). A well-crafted review article offers readers a comprehensive understanding of the field and highlights key gaps and challenges for future research (Dhillon 2021). A structured approach to understanding various aspects of human-wildlife conflict management, particularly regarding elephants, involves nine key dimensions: ecology and behavior of wild elephants; causes of HEC; habitat improvements such as foraging and saltlick areas; landscape modifications including the creation of elephant corridors; conditions leading to conflict and mitigation strategies; coexistence mechanisms between humans and elephants; conservation actions for resolving conflict; population management and

translocation of wild elephants; and the use of fencing as a mitigation measure. We utilized a comprehensive framework to categorize the documents, integrating data from a literature review and field observations. The literature review involved searching various databases, such as Scopus, Web of Science, Google Scholar, Google Books, and the Internet Archive, for references on human-elephant interactions. The documents were reviewed, and the study results were analyzed and synthesized based on thematic topics and various aspects outlined with the main objectives. The details are presented in Table 1.

## CURRENT ELEPHANT POPULATION AND DISTRIBUTION

Asian elephants inhabit a vast natural range covering approximately 9 million km<sup>2</sup> (Williams et al. 2020). Their distribution has historically extended from the Tigris-Euphrates River basin in Iraq through countries such as Turkey and Iran and regions near the Persian and Oman Gulfs to Southeast Asian countries (Cabral and de Mel et al. 2022). This range encompasses southern China, the Yangtze River basin, and various Southeast Asian countries (Lim et al. 2022), including Sumatra, Java, and Borneo. According to Williams et al. (2020), who stated that the current population of Asian elephants is estimated to be approximately 48,323-51,680 individuals (Menon and Tiwari 2019), which is similar to that report by Shaffer et al. (2019), who stated that approximately 41,410-52,345 individuals, which were within their habitat, which spans approximately 486,800 km<sup>2</sup> (Menon and Tiwari 2019). Currently, the distribution of wild elephants in their natural habitat begins in the western part of India, extends to the eastern part of Sri Lanka, gradually moving north through the northern region of India, encompassing countries along the Himalayan Mountain range, including Nepal, Bhutan, and eastern India. This distribution also includes Bangladesh, Myanmar, Thailand, and China in the southern region and Laos, Cambodia, Vietnam, Malaysia, Sumatra, and Borneo, totaling 13 countries.

**Table 1.** The number of publications on thematic topics on Asian elephants concerned

The study area of interest	International journal	National journal	Thai Language	Author team	Total
Ecology, population, and behavior of wild elephant	46	11	11	19	57
Causes of human-wild elephant conflict	7	1	1	2	9
Habitat improvement	16	0	0	0	16
Landscape improvement and wild elephant corridor	11	1	1	3	12
Human-wild elephant conflict conditions and mitigation method	16	1	1	1	17
Coexistence between humans and wild elephant	13	1	1	1	14
Conservation action for solving wild elephant conflict	25	3	3	3	28
Wild elephant population management, translocation, and fencing	12	0	0	0	12
People's opinions on wild elephant mitigation	6	4	4	4	10
Total	152	22	22	33	175

The estimated population of wild elephants ranges from 41,410-52,345 individuals (Menon and Tiwari 2019) within an approximate area of 486,800 km<sup>2</sup>. The population density of wild elephants is estimated to be approximately 0.10 individuals per km<sup>2</sup> or 10 individuals per 100 km<sup>2</sup> (Montez and Leng 2021). Most of the wild elephant population is found in India, with an estimated 26,000-29,964 individuals (Baskaran et al. 2011; Koshy 2021; Montez 2021), accounting for approximately 60% of the total wild elephant population. They inhabit an area of approximately 110,000 km<sup>2</sup> (Baskaran et al. 2018a; 2018b) across five regions of India.

In contrast, Sri Lanka houses approximately 10% of the total elephant population but covers only 2% of the overall distribution range (Williams et al. 2020). A survey conducted in 2011 found 5,879 elephants, with 60% of their habitat within the boundaries of Sri Lanka (Department of Wildlife Conservation: DWC, 2019). Shrestha and Shrestha (2021) reported that Nepal has an estimated wild elephant population of 200-250. This population is distributed in various areas, including Jhapa in eastern Nepal, the Koshi Tappu Wildlife Reserve, Sindhuli, Parsa National Park, Chitwan National Park, Bardiya National Park, and Suklaphanta National Park, along with adjacent forested areas.

In Bhutan, no established baseline exists for elephant populations because of the lack of nationwide surveys. Estimates range from 605 to 761 elephants, with increasing crop-raiding incidents possibly indicating a stable or increasing elephant population as uncultivated agricultural land is forested (Jigme and Williams 2011). Bangladesh houses an estimated 289-437 elephants, of which approximately 200 reside exclusively in the country, and approximately 100-150 have transboundary ranges into India (Islam et al. 2011). In 2003, the elephant population was estimated to be 178 based on dung counts, suggesting a population of 196-227 residents and 83-100 non-residents (IUCN Bangladesh 2016).

In China, Zhang et al. (2015) reported that the wild elephant population ranges from 221 to 245 individuals, whereas Menon and Tiwari (2019) estimated the number to be approximately 300. Historically, China had a substantial elephant population that was abundant and widely distributed along the eastern Yunnan border, particularly along the Lancang River (Mekong River) in the eastern part of China. Currently, the remaining elephant populations are found in the moist forests in the southernmost part of Yunnan Province, bordering Myanmar and Laos. These elephants are found in their native range in Xishuangbanna, northern Pu'er City, and Lincang City. In Xishuangbanna, the elephant population consists of approximately 18-23 individuals, primarily residing in the Nanganhe National Nature Reserve in Lincang City near the Burmese border. Pu'er City, located in the central part of Xishuangbanna, has approximately 34 elephants, including small family groups, three female subgroups, and two mature bulls. Furthermore, in the southern part of Xishuangbanna near the Laos border, elephants are dispersed into three subpopulations within three provinces: Mengyang, Mengla, and Shangyong

(Zhang et al. 2015; Liu et al. 2017; Wang et al. 2021). Wang et al. (2021) reported a remarkable elephant migration event that occurred from March 2020 to June 2021 when a group of elephants traveled approximately 500 km from Xishuangbanna northward to Kunming City. This migration is driven by complex changes in weather patterns, food availability, and the growth of human settlements along their routes. Historically, elephants in China have undergone significant migrations, with a notable migration during the Holocene that took them far north of the Hwang Ho (Yellow River) basin approximately 7000 years ago. During the early Holocene, the warm and wet climate led to abundant natural vegetation, prompting elephants to move southward toward Yunnan Province because of urban development, environmental changes, and ongoing human development in the region (Wang et al. 2021).

Myanmar has a significant population of Asian elephants (Songer et al. 2016). These elephants are widely distributed nationwide, mostly found in five regions. However, their habitat decreased by 5% (approximately 15,000 km<sup>2</sup>) between 1992 and 2006 (Songer et al. 2016). The elephant population in Myanmar, approximately 10,000 in 1935, decreased to less than 2,000 in the early 2000s (Leimgruber et al. 2011). Sampson et al. (2018; 2019) reported an increase in poaching intensity, especially in the Bago Yoma Mountain range, where they found at least 19 elephant carcasses, with an additional 40 found in the same area over two years. Additionally, they observed the movement of seven satellite-collared elephants over a continuous distance of approximately 500 km after their migration.

In Laos, the elephant population is estimated to range from 600-800 individuals. In the 1980s, approximately 2,000-3,000 elephants were present in the country. A 2008 report suggests approximately 800 elephants (Dubost et al. 2022). Laos's largest number of domesticated elephants is concentrated in Xayabouly, Khammoune, and Bolikhamxay provinces, although a declining trend has been observed (Chanthasene et al. 2022). Key elephant habitats in Laos include the Nakai Nam Theun National Biodiversity Conservation Area in Khammoune Province, which covers 4,270 km<sup>2</sup> (Khounboline 2011).

The wild elephant population in Cambodia was estimated to range from 250-600 individuals, and the southern Cardamom-protected forest is a significant elephant habitat (Maltby and Bourchier 2011), currently Menon and Tiwari (2019) reported the wild elephant population in Cambodia ranged 400-600 individuals. However, limited research has been conducted on elephant populations in Cambodia.

Nguyen et al. (2022, 2023) estimated the wild elephant population in Vietnam to be between 100 and 130 individuals, primarily distributed in the western regions bordering Cambodia and Laos. The Vietnamese government has identified four key regions critical for elephant conservation to protect the remaining elephant population from extinction. A study conducted between 1960 and 2008 revealed that the elephant populations in 11 noteworthy forest areas in Vietnam ranged between 1,223

and 1,677 individuals. However, the two areas have experienced elephant population decline and face extinction unless timely conservation actions are taken. Dong Nai Province has one of the only two populations that range entirely within the country, with other populations shared by either Cambodia or Lao PDR.

In Malaysia, specifically in the national parks of Selangor and Perlis, four national parks, namely Taman Negara, Kelantan, Perak, and Johor, saw a significant increase in elephant numbers. Conversely, elephant populations in Terengganu and N. Sembilan decreased, whereas those in Kedah exhibited stability (Saaban et al. 2011; Menon and Tiwari 2019).

The population of Sumatran elephants (*Elephas maximus sumatranus*) on the island of Sumatra has declined since 1931. In the 1980s, the total elephant population on the island was estimated to be between 2,800 and 5,000 individuals, spread across 44 different areas from the northern regions of Aceh to the southern areas of Lampung Province. However, by 2017, the number of elephants had decreased to 1,694-2,038 individuals, representing a loss of approximately 50% of the original population over the past 86 years. The main factors contributing to the decline of the elephant population include changes in forest conditions, poaching, wildlife diseases, environmental pollution, and HECs. The Indonesian government has classified the Sumatran elephant as a critically endangered species, highlighting its importance for conservation (Fadillah et al. 2014).

In Sumatra, the population of elephants was estimated to be approximately 1,724 individuals in 2014 (WWF Indonesia 2014) and has been rapidly decreasing due to habitat loss caused by the expansion of cultivated land. There are 25 subpopulations, with most elephants (approximately 85%) residing outside the protected areas (Sukmantoro et al. 2019). Severe HECs have also occurred (Desai and Riddle 2015; Mishra et al. 2015; Senthilkumar 2016). Sumatran elephants are considered critically endangered by the IUCN, similar to elephants in Borneo, which are also close to extinction (Wahed et al. 2016). Furthermore, the population of Bornean elephants (*Elephas maximus borneensis*) was bottlenecked and separated from the mainland population at the end of the Pleistocene epoch, approximately 11,000-18,000 years ago (Sharmar et al. 2018; 2020; 2021). The Bornean elephant population is estimated to reach approximately 2,040 (Asian Elephant Range States Meeting: AERSM 2017). The details are shown in Table 2.

## THE ELEPHANT POPULATION IN THAILAND

### Captive elephant

There was evidence of the adoption of wild elephants as domesticated elephants in human society approximately 4,000 years ago, found in the region of India (Clutton-Brock 2012). The trend showed that the number of captive elephants decreased accordingly. In 1997, Vanitha (2010) reported that the population of Asian elephants in captivity

in the world was approximately 19,500 elephants. Later, Sakamoto (2017) and CITES (2021) reported that the number of Asian elephants in captivity worldwide was approximately 14,000-15,000, or approximately 1/3 of the remaining Asian elephant population. Jerang et al. (2020) found that Burma had the largest population of captive elephants, between 6,000-7,000 elephants, including India with 3,600 elephants, Thailand with 3,500-4,000 elephants, Indonesia with 498 elephants, Lao People's Republic with 446 elephants, Sri Lanka with 253 elephants, etc. (CITES 2021).

Wild elephants have been used as pets in Thailand for hundreds of years. Before the 19<sup>th</sup> century, it was reported that the number of captive elephants in Thailand was more than 100,000 (Schliesinger 2015). Thitaram (2012) reported that the captive elephant population in Thailand was continuously decreasing. From a report that there was a population of 13,397 elephants in 1951, it decreased to 2,681 elephants in 2001, while Sukmasuang et al. (2013) reported the number of captive elephants registered with the Department of Livestock Development was 4,252 elephants. The main cause of the decline of the captive elephant population in Thailand was that the birth rate of captive elephants was lower than it should have been (optimum birth rate). It was also found that there was a large proportion of older captive elephants in the total captive elephant population. The number of adult female elephants that were not reproducing had also increased. Elephants raised in Thailand were found in 153 elephant camps in various parts of the country in 51 provinces. Most of the elephants were raised in places that provided tours for tourists. The number of captive elephants was found mainly in the northeastern region (n = 1,390), followed by the northern region (n = 1,278), the southern region (n = 1,060), and the central region (n = 5,97). Most of Thailand's captive elephants were old, aged 15-55 years, especially females. It was found that the age classes of captive elephants were not distributed evenly among the various age classes. The structural proportions in the captive elephant population were 1: 3.07: 10.96: 1.51 in elephants in the age groups 0-5 years, 5-10 years, 15-55 years, and over 55 years (Sukmasuang et al. 2013; Pla-ard et al. 2022).

### Wild elephant

Thailand has an estimated wild population of 4,013-4,422 wild elephants inhabiting 32 wildlife sanctuaries, one non-hunting area, and 38 national parks, totaling 71 protected areas and inhabiting some national forest reserves (Department of Wildlife National Parks and Plant Conservation: DNP 2023). Each area has many wild elephants ranging from fewer than 10 to more than 600 individuals, covering a habitat area of 56,270 km<sup>2</sup> (Sukmasuang 2009; 2014; 2015; 2016; 2018; 2019; DNP 2023). The number of wild elephant populations in Thailand is based on their primary habitat in the form of forest complexes consisting of conservation areas with connected territories. The details are as follows:

**Table 2.** A summary of the data on the elephant population, distribution, habitat, and levels of human-elephant conflict in various countries

Range country	Number of wild elephants (min-max) (individuals)	Habitat area (km <sup>2</sup> )	Suitable habitat area in 2015 (km <sup>2</sup> )	Country area (km <sup>2</sup> )	HEC level
India	29,964 <sup>1</sup> (26,000-28,000) <sup>10</sup>	110,000 <sup>1</sup> 239,056	82,793	2,973,190	High <sup>1</sup>
Nepal	127 <sup>1</sup> (109-145) <sup>1</sup> 200-250 <sup>16</sup>	3,227 <sup>3</sup> 10,982 <sup>12</sup> 42,456 <sup>16</sup>	4,750	143,350	High <sup>16</sup>
Bhutan	683 <sup>1</sup> (605-761) <sup>1</sup>	2,424 2,178	1,148 4,750	38,140	High <sup>16</sup>
Sri Lanka	5,879 <sup>1</sup>	36,196 <sup>12</sup>	22,603 <sup>12</sup>	61,864	High <sup>15</sup>
Bangladesh	363 <sup>1</sup> (289-437) <sup>1</sup>	6,770	1,770	130,170	High <sup>1</sup>
China	300 <sup>1</sup> (221-245) <sup>7</sup> (184-205) <sup>11</sup>	2,362	135	9,424,702	High <sup>14</sup>
Myanmar	3,000 <sup>1</sup> (2,000-4,000) <sup>1</sup>	71,281	36,591	652,790	Moderate <sup>1</sup>
Thai	(4,013-4,422) <sup>8</sup>	52,415	31,303	510,890	High <sup>8,13</sup>
Lao PDR	550 <sup>1</sup> (600-800) <sup>1</sup>	22,494	17,716	230,800	
Vietnam	114 <sup>9</sup> (104-130) <sup>9</sup>	527	515	310,070	
Cambodia	500 <sup>1</sup> (400-600) <sup>1</sup>	12,975	12,508	176,520	Moderate <sup>1</sup>
Indonesia				1,877,519	
Sumatra	1,724 <sup>1</sup>	56,033	27,507		Moderate <sup>1</sup>
Borneo	167	928	928		
Malaysia				328,550	
Peninsular	(1,220-1,460) <sup>1</sup> (1,223-1,677) <sup>6</sup>	28,649.02 13,413	10,682	131,598	Moderate <sup>1,6</sup>
Borneo (Sabah)	2,040 <sup>18</sup>	10,000	5,499		High <sup>18</sup>
Kalimantan	(60-80) <sup>1</sup>	12,589	12,007	539,237	Moderate <sup>1</sup>
Total	43,947	541,640	262,956		

Note: <sup>1</sup>Menon and Tiwari (2019); <sup>2</sup>de la Torre et al. (2022) <sup>3</sup>Pradhan et al. (2011); <sup>4</sup>Li et al. (2018); <sup>5</sup>Cheah and Yoganand 2022; <sup>6</sup>Mohd-Radz et al. 2022; <sup>7,8</sup>DNP (2023) <sup>9</sup>Nguyen et al (2022); <sup>10</sup>Baskaran et al. (2011; 2018a; 2018b); <sup>11</sup>Zhang et al. (2015); <sup>12</sup>Shrestha and Shrestha (2021); <sup>13</sup>van de Water and Matteson (2018); <sup>14</sup>Su et al. (2020); <sup>15</sup>Prakash et al. (2020); <sup>16</sup>Ram et al. (2021; 2022); <sup>17</sup>Jigme and Williams (2011); <sup>18</sup>Othman et al. (2013)

(i) The western forest complex (WFC) consisted of 17 conservation areas home to wild elephants, covering an area of 18,300.41 km<sup>2</sup> with a total population of 1022 wild elephants. The main wild elephant populations in the WFC were in the Huai Kha Khaeng Wildlife Sanctuary, Thap Salao-Huai Rabam Non-hunting Area, Salakpra Wildlife Sanctuary, Srinakarin Dam National Park, and Eastern Thungyai Naresuan Wildlife Sanctuary. The wild elephant population in the five main areas totaled 757 individuals, or 74% of the total population in the WFC (Sukmasuang 2017; DNP 2023). Wild elephants can travel between these areas because of their contiguous nature (Suksavet et al. 2023).

(ii) The Kaeng Krachan forest complex (KKFC) included four contiguous areas, with a combined area of 4089.4 km<sup>2</sup>, but wild elephants were found only in Kaeng Krachan and Kui Buri National Parks. The total population of wild elephants, including areas inhabited by wild elephants, amounts to 600 elephants, covering a total area of 3884 km<sup>2</sup> (Sukmasuang et al. 2013; DNP 2023).

(iii) The Dong Phrayayen Khao Yai Forest Complex consists of six protected forest areas, with a population of

560 wild elephants living over a total area of 6,193 km<sup>2</sup>. Most wild elephant populations reside in Khao Yai National Park, with approximately 300 individuals (Pla-ard 2019; 2021). These elephants occasionally move through the wildlife corridor between the Khao Yai and Thap Lan National Parks (Sukmasuang et al. 2020; Pla-ard 2019; 2021; DNP 2023).

(iv) The Phu Khiao Nam Nao Forest Complex (PKNNFC) comprised 12 conservation areas where wild elephants lived, covering an area of 1,471.53 km<sup>2</sup>, with a total population of 713 wild elephants. Most wild elephant populations were Phu Khieo, Phu Luang Wildlife Sanctuaries, and Phu Kradueng National Park. The three areas had a population of 365 elephants, accounting for 51.19% of the total population of the forest complex. These three areas are separated into highways, communities, and agricultural areas (Sukmasuang et al. 2013; DNP 2023).

(v) The Eastern Forest Complex included seven areas inhabited by wild elephants, such as Khao Ang Rue Nai, Khlong Krua Wai, Khao Soi Dao Wildlife Sanctuaries, Khao Sip Ha Chan, Khao Khitchakut, and Khao Chamao National Parks. Moreover, 534 wild elephants were living

in this area, with the main habitat in the Ang Rue Nai Wildlife Sanctuary and contiguous areas, including the Khao Sip Ha Chan National Park, Khao Soi Dao Wildlife Sanctuary, Khao Khitchakut National Park, and Khao Chamao National Park, covering an area of 2,857.2 km<sup>2</sup>. The elephant population in Khlong Kaew Waterfall National Park was a separate population of wild elephants in this forest complex, with approximately 58 individuals, covering a total area of 370.11 km<sup>2</sup> (Menkham et al. 2019; Sukmasuang et al. 2013; DNP 2023). According to the DNP (2023), there were 1779 recorded outings outside the conservation area in the eastern part of Thailand in 2019, of which 12 elephants were killed and 8 were injured. Additionally, 20 people died, and nine people were injured.

(vi) The Klongsaeng-Khaosok Forest Complex consists of nine conservation areas with 350 wild elephants, covering a combined area of 4,809.64 km<sup>2</sup>. The Khlong Saeng Wildlife Sanctuary has a total population of approximately 100 elephants, followed by the Khlong Yan Wildlife Sanctuary and Kaeng Krung National Park, which have 150 animals. The rest of the population was distributed in the Khlong Nakha Wildlife Sanctuary (approximately 64 animals), Khuan Mae Yai Mon Wildlife Sanctuary (60 animals), and other areas. This forest complex plays a crucial role in the conservation of wild elephants in the southern part of the country, considering the wild elephant population and the size of the contiguous area (Sukmasuang et al. 2013; DNP 2023), as detailed in Table 3 and Figure 1.

### CAUSES OF HUMAN-WILD ELEPHANT CONFLICT (HEC)

HEC is driven by geographical, socioeconomic, and ecological factors, reflecting the high complexity of causalities and contexts (Köpke et al. 2021; 2023). The

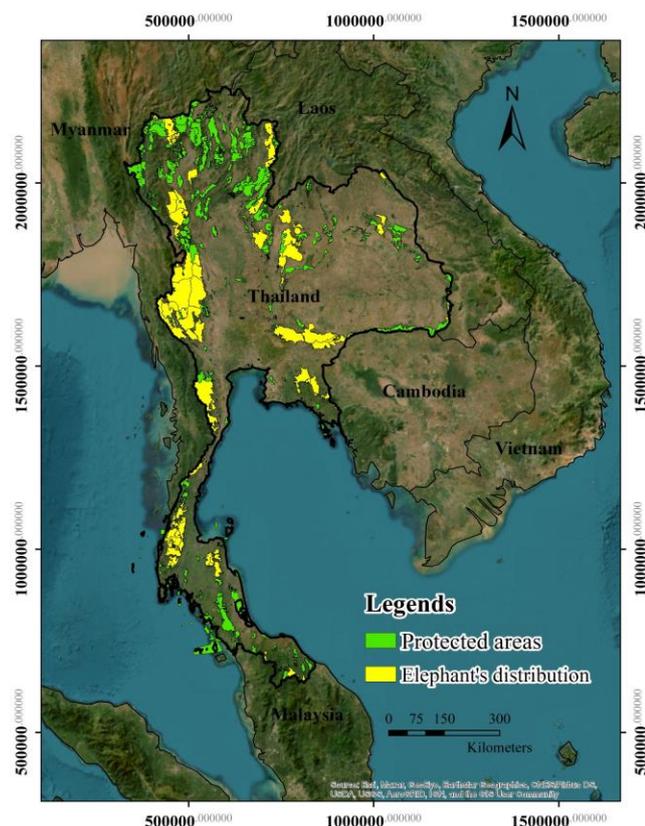
problem of wildlife-human conflict (WHC) is especially serious when people are killed by wildlife and slaughtered (Harich et al. 2013; Acharya et al. 2016; 2017; Ling et al. 2016). The consequences of HEC are not only key conservation concerns but also major socioeconomic and political issues. With approximately 575-650 human and 380-400 elephant deaths annually in Asia due to HEC, minimizing this conflict is crucial for effective elephant conservation (Montez and Leng 2021). Most of these conflicts were caused by human disturbances such as development and increased human population, land use changes from natural to agricultural areas, forest disturbances, hunting, and climate change. Human-wildlife conflict arises from an imbalance between economic development and wildlife conservation (Li et al. 2018; Jadhav and Barua 2012).

This has eventually led to frequent and violent conflicts between humans and wildlife. It has become a conservation focus for protected area management and indigenous communities in virtually every part of the world (Neupane et al. 2013; Cook et al. 2015; Goswami et al. 2015; Wilson et al. 2015; Mumby and Plotnik 2018; Xu et al. 2019). HEC has been extensively described (Plotnik 2018; Shaffer et al. 2019; Mekonen 2020) over the past 100 years (Shaffer et al. 2019). However, despite extensive research on HEC, mitigation strategies remain largely ad hoc and site-specific, merely shifting the problem from one area to another rather than addressing the root cause. Furthermore, the utilization of forest resources by the local population, both within the habitat area of wild elephants and in the surrounding regions, has contributed to conflicts between people and elephants (Ram et al. 2021). This conflict has arisen from the direct exploitation of the area (Mariki et al. 2014; Acharya et al. 2016; Lamichhane and Persoon et al. 2018; Mukeka et al. 2019; Naha et al. 2020), as seen in the past.

**Table 3.** The number of wild elephants in protected areas and the number of conservation areas where wild elephants live were assessed in Thailand while considering the forest groups and the level of severity of conflicts between humans and wild elephants by the DNP (2023)

Forest complex	Number of wild elephants (individuals)	Total area With wild elephants (km <sup>2</sup> )	Number of protected areas in forest clusters with wild elephants (areas)
Western	1,022	18,300.41	17
Phu Khieo Nam Nao	713	1,471.53	12
Kaeng Krachan	600	3,884	2
Eastern	592	2,193.11	7
Dong Phayayen-Khaoyai	560	6,193	6
Klongsaeng/Khaosok	350	4,809.64	9
Hala-Bala	145	1,637.18	4
Thung Salangluang	110	2,610	4
Khaoluang-Khaobuntud	100	1,674.90	6
Mae Ping	85	3798	5
Phu Phan-Phu Sa Dog Bua	57	851.50	2
Sri Lanna/Khun Tan/Sri Satchanalai	41	690.39	1
Phanom Dongrak-Phatam	35	350.64	1
Choomporn	31	1,986.64	4
Lumnampai Salawin	14	1,774	3
Total	4,455	52,224.94	83

Source: DNP (2023)



**Figure 1.** Conservation area where wild elephants habited according to the DNP (2023)

Consequently, Asian elephants have been classified as endangered since 1986 (Williams et al. 2020). Some elephant populations will be categorized as critically endangered by the IUCN in 2023, such as elephants in Bangladesh (Wahed et al. 2016) and Sumatran elephants (*Elephas maximus sumatranus*) (Ardiantiono et al. 2021). Extinct populations of elephants include those in Java and much of their range in Western Asia, along with most of the population residing in China (Williams et al. 2020).

Despite being an important keystone species in ecosystems (Amornitiyangkul et al. 2022) and an iconic symbol of conservation in large forested areas, Asian and African elephants have played a vital role as landscape engineers (Coverdale et al. 2016). Therefore, maintaining populations is essential for the health of the ecosystem. However, owing to changes in land cover, natural habitats being converted into agricultural areas (Abram et al. 2014, Goossens et al. 2016, Leimgruber et al. 2016) and habitat disturbance (Chaiyarat et al. 2023), and elephant mortality, especially due to poaching (Sukmasuang 2009; Sukmasuang et al. 2013; Thant et al. 2022), their conservation has faced significant challenges. Currently, approximately 60% of the Asian elephant population resides within the boundaries of India, covering an approximate area of 239,171 km<sup>2</sup>, particularly in the western and eastern regions of the country (De et al. 2021). In contrast, Sri Lanka hosts approximately 10% of the total Asian elephant population within an area of approximately

30,000 km<sup>2</sup>, of which approximately 21,193.4 km<sup>2</sup> are conservation areas (Montez and Leng 2021). However, it is worth noting that over 70% of the elephant population in Sri Lanka lives outside protected areas (Fernando et al. 2021). The remaining 30% of the Asian elephant population outside India and Sri Lanka is distributed across several countries, including Nepal, Bhutan, Bangladesh, Myanmar, China, Thailand, Laos, Cambodia, Vietnam, Malaysia, and Indonesia (Menon and Tiwari 2019; Naha et al. 2020; Williams et al. 2020). Most of these elephants also inhabit areas outside conservation zones, highlighting the conservation challenges faced by Asian elephant populations across their range (Williams et al. 2020).

The cause of the conflict could be summarized as follows: planting plants near the forest boundary where wild elephants lived (Thant et al. 2021). The depletion of crops by herbivores is largely due to scarcity in the nature and distribution of food and water and the absence of forest fragmentation (Mukeka et al. 2019). HEC occurs in all areas where wild elephants live (Tripathy et al. 2021). In India, there were 2,381 individuals, and 490 elephants died between 2015 and 2018 due to the HEC (Tripathy et al. 2021), and between 2000 and 2010, 0.5 million households suffered annual losses due to the encroachment of various crops by wild elephants (de la Torres et al. 2018). HEC in India was severe (Majumder 2022), with 400-450 people dying each year from conflict and 0.8-1.0 million hectares of agricultural land being damaged. Approximately 10,000-15,000 houses were destroyed by wild elephants, and 100 elephants were killed each year by the HEC (Chatterjee 2016).

The Government of India compensated approximately US\$19.2 million for crop loss and property damage and US\$5 million for human casualties due to HEC between 2014 and 2018 (Tripathy et al. 2021). Frequent HECs affect the livelihoods and economies of the local population (de la Torre et al. 2021), indirectly generating frustration and fear in the minds of residents and disturbing normal activities, which ultimately interfere with social life, economic security, and education (Chakraborty and Mondal 2013). People cultivate agricultural plant species to avoid encroachment on farmlands by wild elephants (Naha et al. 2020). Deliberate electrocution of wild elephants has been reported (Kalam et al. 2018), and poisons have been used in conflict areas (Radhakrishnan 2018). A study on the damage caused by wild elephants in India found damage from forage on more than 12,000 ha of agricultural land, with 800-1,000 homes destroyed between 2013 and 2014 (Agarwal 2015).

In addition to accidents, trains passing through wild elephant habitats pose serious threats to elephant conservation in India. Roy and Sukumar (2017) reported that trains in India cut through forests, resulting in collisions with many wild animals, including elephants. Between 1987 and 2015, more than 200 elephants were sacrificed. This was the case in Thailand, where a highway was built through a protected area inhabited by wild elephants (Pla-ard et al. 2021) and other wildlife species (Rattanawanawong et al. 2022). The conflict between humans and wild elephants in Sri Lanka has occurred with

increased human population, disturbance of natural areas, forest fragmentation, and drought (Gunawansa et al. 2023). Two hundred and fifty wild elephants and 50-70 people die from conflict every year, and it is likely to become the world's most severe HEC (Fernando 2015; Fernando et al. 2019; 2021; Gunawardana and Ranawana 2021; Köpke et al. 2021 Prakash et al. 2020; Warapitiya et al. 2021).

Prakash et al. (2020) reported that between 2010 and 2019, 14,516 HEC incidents were recorded in Sri Lanka, resulting in 807 deaths, 579 injuries, 10,532 property damages, and 2,631 deaths. In 2019 alone, 405 wild elephants died from HEC in Sri Lanka, and 407 deaths were reported. Additionally, more than 100 deaths from HEC are reported annually, with the highest number reported in the past 50 years. Injuries in humans and elephants have increased significantly over the past decade. Conflicts between humans and wild elephants in India and Sri Lanka have resulted in the deaths of approximately 450 wild elephants and 600 people per year, accounting for 80-85% of the losses between humans and wild elephants in Asia (Williams et al. 2020). Gunawansa et al. (2023) reported that human and elephant deaths due to HEC in Sri Lanka have increased over the past 30 years. Between 1991 and 2021, 5,954 elephant deaths and 2,111 human deaths occurred. The highest number of elephant deaths (407) was recorded in 2019. Regarding HEC mitigation efforts, Sri Lanka spent USD 2.47 million on electric fences in 2019 and 2020, totaling 4,756 km, as part of HEC mitigation measures.

In Thailand, HEC occurs in forest clusters with large populations of wild elephants (Sukmasuang et al. 2022). DNP (2023) reported wild elephant outings in 12 forest clusters across Thailand within 4 years of data between 2017 and 2020. There were 19,605 wild elephant outings nationwide, averaging 4,901 times per year. There were 3,793 reports of damage to crops and property, including 162 injured and dead people. Ninety-nine wild elephants died or were injured. The tendency to leave damaged areas increased accordingly. The Eastern Forest Complex is the main area of the HEC in Thailand. A total of 8,997 outings were found, with 111 injured and 46 wild elephants injured or dead, followed by the Kaeng Krachan Forest Complex. A total of 6,480 times they left the area, 2,317 times in the Dong Phrayayen Khao Yai Forest Complex, and 485 times in the Phu Khieo Nam Nao Forest Complex, as detailed in Table 4.

## MITIGATING CONFLICTS BETWEEN HUMANS AND WILD ELEPHANTS

The conservation of wild elephants increasingly depends on the management of HECs (Shaffer et al. 2019). This was due to the increasing tendency of wild elephants to roam outside protected agricultural and residential areas (Wettasin et al. 2022; 2023). The alleviation of human-wildlife conflicts, especially involving large wild animals that could be dangerous and damaging (Mekonen 2020), presents a significant challenge for global wildlife conservation (Karanth et al. 2013; Madden and McQuinn

2014; Goswami et al. 2017; Van de Water and Matteson 2018) Wahed et al. (2016) addressed the importance of continuous research and investigation into the causes of conflicts between humans and wild elephants. Therefore, solutions can be formulated to address conflicts by understanding their evolving nature. This understanding could help identify measures to reduce the negative impacts of conflict on humans and wildlife.

Technological innovation can play a crucial role in reducing conflicts between humans and elephants. The essential aspect is to conduct small-scale testing of innovations before scaling them up to assess their impacts and challenges. These results can be disseminated for broader benefits. While promoting innovation, it is important to remember that it is an ongoing process that requires adapting or improving systems, tools, or technologies to address new challenges and create them sequentially. Wahed et al. (2016) summarized the efforts to reduce conflicts between humans and wild elephants in Bangladesh, which included the following main strategies: non-preferred crop cultivation, bio-fencing, solar electric fencing, trip alarms, chili ropes, watchtowers, salt licks, plantations in elephant habitats, and elephant response teams.

The directions for ongoing conflict mitigation include recognizing and strengthening elephant response teams, monitoring, maintaining, replicating installed measures, scaling up nature-based solutions, and building public awareness and capacity. Nevertheless, the approach to mitigating human-wildlife conflict generally found that communities typically employed only a few methods, which they repeatedly used with minor variations. In summary, addressing human-wildlife conflict (Osei-Owusu 2018) can be categorized as follows:

1. Protection: Crop protection methods involve safeguarding crops from wild elephants. These methods have proven effective in deterring elephants (Gunaryadi et al. 2017). Crop protection methods can be summarized as follows:

- 1.1 The use of traditional methods (Traditional techniques) is divided into:

- 1.1.1. The use of acoustic deterrents, such as loud noises generated by firecrackers, is a common practice for startling and redirecting wild elephants in Thailand. The severity of the conflict began in 1998 at Khao Yai National Park, located within the Dong Phrayayen-Khao Yai Forest Complex. Rangers employ various methods to deter elephants, including burning car tires during late evenings, alternating with crop protection using firecrackers and guns, and deploying poison bait to instill fear in elephants (Sukmasuang 2015). Similar measures were taken at the Phu Khieo Wildlife Sanctuary in Bueng Kan Province, part of the Phu Phan Forest Reserve, where approximately 40 wild elephants were isolated from other forest areas. Some elephants venture into the territory of the Lao People's Democratic Republic, specifically into the Borikhamxay district, by crossing the Mekong River and foraging in riverbank areas. However, the construction of the Nong Khai-Nakhon Phanom Highway disrupted the traditional paths of elephants, leading to increased conflicts in the

area. In 1991, these conflicts resulted in significant injuries and casualties among the local population and wild elephants (Sukmasuang 2003; 2009; Chokchareon and Sukmasuang 2012).

1.1.2. Establishing physical barrier systems, such as elephant trenches, and using obstructive materials in wild elephants' paths played a crucial role in alleviating HECs. Physical barriers, including electric fences, deep trenches, stones, and rock walls, have been installed to mitigate conflicts in areas affected by the spread of elephants in HECs (Das et al. 2022). Efforts to prevent elephants from entering agricultural areas and damaging crops and human settlement areas have employed various barrier methods, such as electric fences, chili fences, beehive fences, or crop barrier systems placed on or near the border of rice fields or villages. The success of these barrier systems varies (Grange et al. 2022). For instance, elephant trenches were dug to keep elephants away from certain areas, with the trenches being approximately 3 m wide at the mouth, 1 m wide at the bottom, and 2 m deep (Rogers et al. 2023).

In Thailand, trenches spanning approximately 400 km were excavated in regions within the eastern forest complex, in the Khao Ang Rue Nai Wildlife Sanctuary, and the Dong Phrayayen-Khao Yai Forest Complex, with a total length of approximately 105 km (DNP, 2023). While trenching was conducted to prevent elephants from foraging in human communities, especially around district hospitals, electric fencing was used near the trenches. In areas where elephant trenching was carried out to prevent elephants from entering human settlements in the western forest complex, various large herbivores such as gaur, elephants, and muntjacs were found to forage (Menkham et al. 2018; 2019), indicating the proximity of human settlements to wildlife, although the trenches did not completely prevent elephants from venturing outside the designated areas (Sukmasuang et al. 2013; Songmanee et al. 2017; Rakdee et al. 2018).

1.1.3. Culturing certain plant species as vegetative barriers, characterized by dense and sharp foliage that acts as an obstacle to the movement of wild elephants, has proven effective. For instance, bamboo groves were planted to create barriers in Khao Yai National Park and Kaeng Krachan National Park (DNP 2023). Planting unpalatable species within the *Acacia* genus as a barrier, where elephants are discouraged from foraging (barrier of unpalatable crops), creating barrier vegetation, and establishing buffer zones for elephants were implemented by defining special management zones radiating from conservation areas to prevent elephants from venturing outside the designated areas (DNP 2023). In Khao Yai National Park, efforts have been made to establish buffer zones and protect elephants from foraging in human communities. Electric fencing was used with trenching to deter elephants, while efforts were also made to plant unpalatable crops in the buffer zones (Sukmasuang et al. 2013).

1.1.4. The construction of fences as barriers hindering the movement of wild elephants has been an effective strategy. Various fences, including electric, elephant-proof, and fences made from concrete posts combined with steel

or wires, were used. Electric fences are designed to deter animals based on shocks they do not recognize, leading to a psychological response. The source of the electric shock was not always clear to the animals, which caused them to exhibit avoidance behavior. Electric fences were primarily designed to deliver shocks that were not physically harmful because the electrical energy was similar to that used for aluminum, which is lightweight and not prone to corrosion. Therefore, an aluminum wire was chosen instead of steel or iron (Liefing et al. 2018). An overall assessment found that solar-powered electric fences effectively reduced HECs and protected human lives, crops, and property (Neupane et al. 2018). Fencing strategies for elephant deterrence can be divided into non-electric and electric fencing in protected areas such as the Phu Luang Wildlife Sanctuary (Sukmasuang et al. 2013), Phu Wua Wildlife Sanctuary (Chockchareon and Sukmasuang 2012), and Salak Phra Wildlife Sanctuary (Reongsomboon and Sukmasuang 2016; Ainoi et al. 2021) (DNP 2023). Single-strand fencing was performed at Kaeng Krachan National Park. Additionally, beehive fencing was deployed in several locations across Thailand, where most elephants (70.7%) exhibited behaviors indicative of alarms upon approaching the beehive fences (van de Water et al. 2020).

1.2. The use of chemical deterrents, substances capable of inhibiting elephants, odors that communicate pain, or targeted compounds such as hormones to induce fear may be an effective method for deterring elephants. Examples of chemical deterrents include using substances derived from fruits like chili peppers (*Capsicum* deterrent) and chili briquettes. It was observed that elephants altered their foraging behavior, shifting from nighttime foraging to daytime foraging primarily in areas where chili-briquettes were burned throughout the night (Poza et al. 2019). Additionally, substances released from male elephant musth secretions were tested and found to serve as deterrents for other elephants potentially. The use of pepper spray, which consists of tiny droplets of pepper extract, was also employed (DNP 2023).

2. HEC mitigation involves various approaches and strategies, as outlined below (Awasthi and Singh 2015):

2.1. Benefit-sharing aligns with the growing emphasis on community involvement in conservation efforts. Sharing the benefits of natural resource management is an effective way to garner greater community support for conservation activities. Communities may receive a portion of their income from ecotourism and wildlife conservation activities, which can be directed toward community development projects. The concept of benefit sharing is becoming increasingly important in community development.

2.2. Establish problem animal control units (PAC), which are created to redirect problem elephants back into conservation areas using loud noises. PAC units may also collaborate with local community members and provide local law enforcement or military personnel training to address HEC. Some PAC units are also tasked with law enforcement activities related to wildlife in their areas.

2.3. Wildlife tourism can serve as a mechanism to create incentives through wildlife tourism. This approach

has proven more effective than direct monetary compensation or incentives based on wildlife damage. This is considered an efficient form of generating financial support from service-oriented revenue within the ecotourism sector, as it aligns with the increasingly popular concept of financial support for effective conservation practices. This approach is gaining acceptance within local communities for its conservation efforts (Naeem et al. 2015). These strategies have been explored and employed to mitigate human and elephant conflicts (HEC) and are seen as effective conservation and community development approaches.

2.4. Compensation and insurance schemes have been extensively studied in the context of general wildlife-related compensation (Wang et al. 2024). An assessment of the efficiency of the compensation process is crucial. Vicitage victims of HEC must file complaints promptly with the relevant authorities. Proper documentation is essential to substantiate claims for damaged property. Claims related to official investigation reports, on-ground witnesses, and loss assessments by designated forestry officials are crucial (DNP 2023). Considering that the frequency and severity of HEC can vary significantly depending on various factors, it is essential to tailor mitigation and compensation strategies for regional HEC patterns, thereby addressing the benefits to both elephants and humans (Sengupta et al. 2020).

2.5. Translocation is a strategy to mitigate HEC and conserve important elephant populations. In Sri Lanka, translocations occur hundreds of times annually. Translocated elephants often return to their original areas (Fernando et al. 2012; Tiller et al. 2022). The translocated elephants exhibited different responses, including returning to their capture sites (homers), wandering in new areas (wanderers), and establishing themselves in new areas (settlers) shortly after release. Translating elephants from conflict areas can expand the range and increase HEC severity. Nonetheless, the translocation of elephants for conservation remains a necessary strategy (IUCN 2013). Additionally, translocating crop-raiding elephants away from agricultural or community conflict areas has been perceived positively by communities, even if the elephants return to their previous locations, often covering distances of up to 200 km within a few months (DNP 2023). The Department of National Parks (DNP 2023) has established an elephant-holding ground covering an area of approximately 0.64 km<sup>2</sup> within the Huai Kha Khaeng Wildlife Sanctuary since 2013.

2.6. Local land use planning, involving land use and land cover changes, is a primary driver of HEC (Nad et al. 2022). It is a major cause of biodiversity loss worldwide and underpins HEC (Neupane et al. 2017; Billah et al. 2021). These land use changes are linked to global environmental changes (Andualem et al. 2022). Nevertheless, conflict mitigation between humans and elephants can occur in small areas because of localized operational mechanisms, economic conditions, and the variability of conflict incidents (DNP 2023). Therefore, addressing the issue of HEC can be achieved within limited

regions based on operational mechanisms and socioeconomic variables.

### 3. Prevention Strategy

3.1. Land-use planning based on environmental systems is an effective way to prevent conflicts. Promlao et al. (2019) conducted a study using geospatial data and physical factors influencing elephant habitat selection within a 5-kilometer radius of the Salakpra Wildlife Sanctuary. They identified areas with varying degrees of risk for HECs. They categorized them as follows: low-risk areas covering 287.65 km<sup>2</sup>, moderate-risk areas covering 191.28 km<sup>2</sup>, and high-risk areas covering 404.07 km<sup>2</sup>, accounting for 32.58%, 21.66%, and 45.76%, respectively.

This study revealed that sugarcane is the most affected crop. However, sugarcane cultivation was prevalent due to its high market value, with the presence of sugar factories in the region. Farmers employed preventive measures, such as electric fences and trenches surrounding their fields, often combined with vigilant monitoring. Rice fields suffered moderate damage as they were less frequently monitored and lacked protective measures. In contrast, the cornfields experienced the least damage because they were often located near roads with electric fences. This information can help inform land use planning and conflict prevention efforts, allowing for a more targeted and effective approach to mitigating HECs.

3.2 Preventive elephant conflict (PEC) management through land-use planning consisted of (i) relocating agricultural activity out of the elephant range, (ii) zoning or changing the location of crop fields (e.g., to proximity to dwellings), and (iii) reducing human settlement encroachment into the elephant range; (iv) cultivating non-target crops (cultivating non-target crops), such as crops with a pungent smell, such as pepper, ginger, galangal, and chili; and (v) increasing productivity per farmer's area (intensification of agriculture).

3.3 PEC management through land-use planning includes the following strategies: (i) relocate agricultural activity out of the elephant range; (ii) implement zoning or relocate crop fields closer to dwellings; (iii) reduce human settlement encroachment in elephant ranges; (iv) cultivate non-target crops, such as crops with strong odors or spiciness, such as chili, ginger, and galangal; (v) intensify agricultural production within existing farming areas.

### 4. Community-based problem-elephant control strategy (CBPEC)

The CBPEC aims to address HECs with varying degrees of emphasis, depending on specific circumstances. The objectives of CBPEC range from reducing conflict occurrences, mitigating agricultural damage, and enhancing community acceptance of coexisting elephants to helping farmers improve their agricultural practices. This can be achieved by modifying cropping patterns, increasing crop yields, using improved cultivation techniques, harvesting efficiently, and reducing the risk of elephant raids. Several key principles guide the design of CBPEC operations: (i) cost-effectiveness: CBPEC interventions should be affordable and sustainable in the long term; (ii) effectiveness: they should be efficient in deterring elephants from agricultural areas; (iii) decentralized

management: CBPEC activities should be community-driven and managed at the local level; and (iv) availability of resources: local communities should have access to the necessary resources. Adaptability: CBPEC strategies should be flexible and adaptable to the local conditions. Utilization of multiple methods: Various techniques should be employed in the CBPEC approach. These strategies have been employed to address HECs and promote coexistence where these conflicts occur.

#### 5. Policy and institution

The Department of National Parks, Wildlife, and Plant Conservation (DNP) in Thailand has initiated comprehensive actions to address the issues of wild elephants within the country, as reported in 2023 (DNP 2023). The measures were based on resolutions set by the national committee appointed by the Deputy Prime Minister in October 2022. They were consistently implemented to urgently mitigate HECs, particularly in the eastern forest group areas, which faced severe challenges (see Table 1). The proposed action plan was approved and implemented to address these problems and achieve sustainable environmental conservation, community well-being, and natural resource preservation. Specific strategies and initiatives include the following:

**5.1. Habitat Management for Elephant Conservation:** This involved managing elephant habitats, establishing water and food sources, and ensuring they were adequate for maintaining elephants within conservation zones. Research efforts have expanded to understand the requirements for habitat management, maintaining ecological corridors within forest groups, reducing disturbances such as hunting, forest fires, and tourism, and addressing animal diseases.

**5.2. Elephant-Deterrent Measures:** Creating elephant-proof trenches, electric fences, and beehive fences were part of the efforts to restrict the movement of elephants outside their designated areas. These measures were consistently implemented, especially in the eastern forest group areas where HECs were prevalent.

**5.3. Monitoring and Encouraging the Elephant Movement:** In 2023, 172 monitoring teams comprising five staff members and the necessary equipment were established. Simultaneously, 342 community networks were formed to collaborate in monitoring and encouraging elephants to return to the conservation areas. These operations were conducted nationwide to address conflicts in forest group areas (DNP 2023).

**5.4. Assisting Affected Communities:** Compensation was considered for those affected by elephant crop damage, property loss, injuries, and fatalities. The actions included improving the legislation for compensation and increasing compensation amounts.

**5.5. Managing Large Elephant-Holding Areas:** These areas were designated as crucial elephant population centers containing more than 500 individuals for long-term conservation. Management efforts encompassed landscape-level planning, ecological corridor development, and determining suitable elephant populations within each forest group.

**5.6. Elephant Population Control:** As outlined by Lueders et al. (2017), birth control vaccines were integrated into the conservation framework. These measures provided guidelines for management and problem-solving and emphasized effective land management. The ultimate goals were to achieve elephant conservation, manage sustainable elephant populations, reduce HECs, and foster continued collaborative and sustainable elephant conservation efforts.

Saaban et al. (2020) recommended long-term management of elephant populations based on the results of a population viability analysis (PVA) in the Endau Rompin landscape of Malaysia. This approach focuses on comprehensive actions, including adequate habitat management, appropriate deterrence measures, rigorous law enforcement, and the establishment of ecological corridors to facilitate elephant movement between areas. These policies were crucial in accepting the coexistence of elephants in the region (Guru and Das 2021). Mumby et al. (2018) reported that research on behavior, ecology, and cognition has great promise for developing new strategies to prevent conflicts between humans and wildlife. When politicians, community leaders, and conservationists recognize our growing understanding of individuality within animal species and the need to take both human and wildlife perspectives in conservation practices, current approaches to mitigating conflict will evolve away from short-term stop-gap measures that temporarily avoid conflict and toward long-term solutions that effectively prevent it.

## HABITAT MANAGEMENT FOR WILD ELEPHANT

Sharma et al. (2020) stated that in suitable elephant habitat areas, the construction of roads had to be avoided because of their adverse impact on elephant habitation. Building roads forced elephants to leave the area. Furthermore, creating wildlife corridors to connect various forested areas for elephants, especially in transitional forested regions, is essential for effective habitat management (Chaiyarat et al. 2023). In their study, Yamamoto-Ebina et al. (2016) concluded that roads affected HEC. Elephants altered their diet near roads, favoring grasses, implying that roads functioned as large forest gaps, increasing the availability of grasses and early successional plants. Feeding elephants near roads has led to potential conservation conflicts in the form of road accidents and increased interactions with people. The identified plant species were associated with the nutritional needs of the elephants. Adults and subadults consume a more extensive range of plant species than juvenile elephants; however, there are no significant differences between age and sex groups (Abdullah-Fauzi et al. 2022). Analyzing the movements of 102 elephants equipped with satellite tracking devices showed that male and female elephants prefer habitat areas near the edges of protected forests, especially second-growth forests or forested areas, newly planted forests, and plantations (Thant et al., 2023). However, over half of the elephants remained outside the protected areas, indicating that most inhabited areas with

lower habitat preferences within these conservation zones (de la Torre et al. 2022). These findings underscore the importance of reducing human-induced disturbances in elephant habitats and highlight the need for effective management and conservation strategies that promote human-elephant coexistence. Such strategies should also address the specific habitat preferences of elephants and focus on preserving and restoring areas conducive to their long-term survival.

The study analysis revealed that elephant conservation strategies are needed to acknowledge that the long-term survival of elephants depends on promoting coexistence between humans and elephants in the buffer zones of protected areas. Elephant conservation should focus on the following key points: (i) Preserving large-scale conservation areas with substantial primary elephant habitats is crucial for long-term elephant survival. (ii) Promoting connectivity among conservation areas through wildlife corridors is essential. This can be accomplished by establishing wildlife pathways (Adams et al. 2017; Puyravaud et al. 2017; Huang et al. 2019; Ntuyey et al. 2022). (iii) Effectively managing HECs outside protected areas is imperative (de la Torre et al. 2022). Thant et al. (2023) reported from tracking 25 radio-collared elephants in Myanmar that factors such as elevation, distance from water sources, and average annual rainfall significantly influenced the distribution and suitability of elephant habitats. They found that elephants utilized disturbed and degraded forests more than prime elephant habitats. This leads to more aggressive behavior and increased HEC. This indicates that human intrusion into elephant habitats resulted in intensified HEC. Large-sized plantations, areas with lower conservation status, or those near degraded forests and water sources should receive prioritized attention to monitor and reduce HEC and promote habitat restoration and enrichment to attract elephants back into these areas. These findings are consistent with those of de la Torre et al. (2022), who found that elephants prefer foraging in second-growth forests, open areas, areas under regeneration, and agroforestry zones, which often act as transition zones between agricultural and forested regions. These aspects highlight the significance of addressing HECs, which severely threaten elephant populations. Managing salt licks to lure elephants into protected areas, especially to habitats distant from human settlements, is another effective approach (Sukmasuang 2009; Pla-ard et al. 2019; Pla-ard et al. 2021).

Regarding plant species in elephant habitats, local vegetation such as *Lantana camara* has been reported to influence elephant habitat use in the Mudumalai Tiger Reserve, India (Wilson et al. 2013). In contrast, Sampson et al. (2018) reported that natural elephants in Sri Lanka were most abundant in grasslands and were positively correlated with both herbivore and grass species richness, showing no significant impact from *Lantana camara*, a widespread invasive species. They concluded that natural habitats with suitable water resources are more critical than invasive

species. Evidence has shown that water sources in the wild are more frequent during dry periods (Sukmasuang 2009; Pastorini et al. 2010). These approaches collectively reinforce the necessity for effective elephant conservation and management strategies to preserve elephant habitats, mitigate HECs, and promote human-elephant coexistence in shared landscapes.

## COEXISTENCE BETWEEN HUMANS AND ELEPHANT

The 10-year Asian Elephant Action Plan (2020-2029) was developed collaboratively by all stakeholders, serving as a guideline for conservation efforts. The plan addressed four main objectives: (i) Reduce elephant mortality due to poaching, HECs, and habitat loss. (ii) Creating habitat connectivity for elephants. (iii) Strengthening the conservation of captive elephants and reducing conflicts between humans and wild elephants. (iv) Long-term monitoring of wild elephants. Key strategies to achieve these objectives are centered on the coexistence of humans and elephants in conflict areas. Successful implementation of these strategies requires mutual understanding, collaboration, and effective land management within these regions. Local communities must recognize the benefits of coexisting with elephants for community-based coexistence. Various methods have been employed, such as using beehive fences, to protect crops with the added advantage of honey production (van de Water and Matteson, 2018). However, the effectiveness of beehive fences in preventing elephants from entering farmland varies by region (Dror et al. 2020). Another method used for short-term deterrence is audio playback to discourage wild adult male Asian elephants from crop raiding, providing a cost-effective and humane way to mitigate HECs (Wijayagunawardane et al. 2016). Using sound cues to repel elephants in areas facing conflicts has shown positive results but requires further study (Plotnik and Jacobson 2022). The concept of coexistence between humans and elephants has been observed in different regions, including India, Indonesia (Ardiantiono et al. 2021; Kuswanda et al. 2022), and the Congo (Nsonsi et al. 2018). Therefore, to reduce conflicts between humans and elephants, the following actions are recommended:

The multi-faceted mitigation test on measurements and implementation of the most effective ones and enhancing local involvement through sustainable ecotourism and local culture conservation. Further research should be conducted to gain public support for the coexistence of humans and wildlife. The expansion of elephant habitats into agricultural areas is a common phenomenon. The distance from forest boundaries increased when there were more signs of elephant presence, indicating the need to relocate elephants from protected areas (Das et al. 2020).

**Table 4.** Records of wild elephants leaving the area, damage to life and property, injury and death of people, and wild elephants. Levels of human-elephant conflict in Thailand, 2017-2020

Forest complex	Number of events roaming out of the protected area					Number of event damages to crops and property					Number of people injured and killed					Number of injured and dead elephants					HEC level
	2017	2018	2019	2020	Σ	2017	2018	2019	2020	Σ	2017	2018	2019	2020	Σ	2017	2018	2019	2020	Σ	
EF	2,361	2,463	2,311	1,862	8,997	426	709	156	127	1,418	34	15	33	29	111	9	10	19	8	46	High
KK	871	779	2706	2124	6,480	62	207	133	95	497	5	0	2	3	10	0	0	3	4	7	Moderate
DPYK	348	1,102	517	350	2,317	177	80	413	178	848	17	0	3	0	20	1	1	13	2	17	High
PKNN	215	110	101	59	485	211	59	24	30	324	4	1	0	3	8	5	1	2	2	10	High
WF	60	224	116	84	484	32	78	26	60	196	1	3	3	3	10	1	2	2	0	5	Moderate
KLKB	6	84	95	99	284	9	2	67	49	127	0	0	1	0	1	0	0	0	2	2	Moderate
KSKS	10	35	23	96	164	8	1	11	74	94	0	0	0	0	0	0	1	1	1	3	Moderate
HLBL	25	59	46	22	152	29	0	24	10	63	1	0	1	0	2	1	0	2	1	4	Moderate
SLKTSS	64	41	13	21	139	80	10	19	23	132	0	0	0	0	0	0	0	1	0	1	Low
CP	0	0	49	5	54	0	0	46	5	51	0	0	0	0	0	0	0	0	0	0	Low
PDPT	6	4	15	13	38	0	23	2	18	43	0	0	0	0	0	0	0	0	0	0	Low
PPPSDB	0	9	2	0	11	0	0	0	0	0	0	0	0	0	0	3	1	0	0	4	Moderate
<b>Total</b>	<b>3,966</b>	<b>4,910</b>	<b>5,994</b>	<b>4,735</b>	<b>19,605</b>	<b>1,034</b>	<b>1,169</b>	<b>921</b>	<b>669</b>	<b>3,793</b>	<b>62</b>	<b>19</b>	<b>43</b>	<b>38</b>	<b>162</b>	<b>17</b>	<b>18</b>	<b>44</b>	<b>20</b>	<b>99</b>	

Note: DNP (2023); EF: Eastern Forest; KKCF: Kaeng Krachan; DPYK: Dong Phrayayen-Khaoyai; PKNN: Phu Khieo Nam Nao; WF: Western; KLKB: Khaoluang-Khaobuntud; KSKS: Klonsaeng/Khaosok; HLBL: Hala-Bala; SLKTSS: Sri Lanna/Khun Tan/Sri Satchanalai; CP: Choomporn; PDPT: Phanom Dongrak-Phatam; PPPSDB: Phu Phan-Phu Sa Dog Bua

However, the reasons for elephants venturing out of protected areas include natural behaviors, such as exploring open areas, searching for food, and learning. Additionally, factors such as human disturbances, droughts, forest fires, and the presence of non-native plant species (for example, *Mimosa diplotricha* var. *inermis*, *Rosa multiflora*, and *Lantana camara*) can affect the quality of elephant habitats and food sources within protected areas, leading them to forage outside (Kariyawasam et al. 2020; Sukumar et al. 2020). Chandran et al. (2023); Wang et al. (2023) reported that to promote human-elephant coexistence for the communities. The long-term goals were: (i) to bring about attitudinal and behavioral changes among the villagers to learn and appreciate the elephants and (ii) for the community to understand how to take responsibility for their lives through street play. (iii) Learning to coexist with elephants to make them understand human-elephant coexistence is the only solution for human-elephant conflicts. (iv) Sharing their learning experiences with other people.

#### GUIDELINES FOR MITIGATION OF WILD ELEPHANT PROBLEMS IN THAILAND

This study considered the issue of elephants moving outside their habitat areas in all forest groups where elephants reside in Thailand, which consists of 12 regions, as shown in Table 4. In 2018, the Department of National Parks (DNP) established a strategy to address HECs in Thailand from 2018 to 2038. This strategy included several components: (i) managing and resolving conflicts at the forest patch level and enhancing efficiency in monitoring and protection by establishing elephant watchtowers in critical areas. (ii) Use financial measures, such as compensation for damage and fair compensation, coupled with developing regulations and laws to improve elephant management. (iii) Promote livelihoods and community well-being by engaging communities in conflict resolution and applying innovative elephant prevention techniques. In the case of the Eastern Forest Group, the DNP framed its approach to managing elephant conflicts in forest-edge areas as follows: (i) restoration of elephant habitats in conservation areas; improving water sources, food availability, corridors, and other management aspects using geographic information systems (GIS) to determine appropriate intervention locations. (ii) Preventing elephants from leaving conservation areas by implementing electric fences, digging elephant-proof trenches, and maintaining damaged sections. (iii) Relocation or translocation of elephants that leave protected areas to bring them back into conservation zones.

The DNP (2023) implemented various measures to manage and conserve wild elephants, particularly by addressing HECs. Their actions are summarized: (i) Large-scale natural area management was conducted to sustain a substantial elephant population. (ii) Tracking and monitoring elephants at risk of conflict and causing harm to people outside protected areas were carried out using GPS collars for efficient monitoring. (iii) Dedicated

organizations such as the DNP and the National Elephant Institute were established to manage the well-being of elephants and reduce conflicts comprehensively. (iv) Surveys were conducted, and information was gathered to tackle potential impact areas from elephant conflicts. (v) Preventive and control measures were developed to enhance monitoring efficiency and create an observation network for crisis areas to minimize elephant threats. (vi) Local governance regulations were revised to allow the use of accumulated regional budget funds for the care, protection, and compensation of those affected by elephant conflicts without the need for disaster area declarations. Financial support was provided as compensation. (vii) Efforts have been made to push elephants toward suitable forests and support the development of the local economy. This involved opening up tourism opportunities and for the general public to buy agricultural products from local farmers, thereby generating income for the agricultural community and assisting those affected by the elephant conflict. (viii) Collaboration among all relevant stakeholders was promoted to holistically and sustainably address elephant-related problems. (ix) The encouragement of ecotourism within forest areas was emphasized, utilizing the benefits of elephants to develop sustainable tourism. (x) Integrated forest management was established, with 16 forest groups jointly managing elephant-related issues. (xi) Relevant agencies dealing with elephant conflict resolution enhance public relations and improve public understanding by utilizing online networks and regularly updating information. Collaborative efforts were undertaken with those affected by the conflict, focusing on knowledge-sharing for conflict resolution. (xii) Land use zoning within terrestrial ecosystems was implemented to ensure land use benefits and to manage, prevent, and mitigate HEC. (xiii) Statistical databases for residents affected by elephant conflicts were compiled to ensure the most up-to-date and detailed information was available. (xiv) Support the development of an early warning system and increased use of GPS collars for elephants in problem areas to aid tracking, data utilization, conflict resolution, and community involvement.

#### CONCLUDING REMARKS

This study found that elephant populations decreased significantly throughout their distribution areas. The challenges faced by elephants across their range include increasing HEC. Over 70% of their habitats are located outside conservation areas. Efficiently addressing severe HECs requires various strategies, depending on understanding the issues, elephant behavior, ecology, and different aspects of the problem. Current strategies for managing HEC largely focus on physical separation. However, key approaches for the successful long-term conservation and management of elephants include protecting, preventing, and mitigating conflicts between humans and elephants in a manner that allows coexistence in specific areas on each side within their respective distribution areas. In Thailand, efforts have been made to

establish large, contiguous conservation areas across five forest groups: the Western Forest Group, Eastern Forest Group, Dong Phrayayen-Khao Yai Forest Group, Phu Khieo-Nam Nao Forest Group, and Kaeng Krachan Forest Group, which are crucial for long-term elephant conservation. Therefore, to improve the knowledge base, thorough research was conducted on all aspects, such as GPS tracking collars, electric fencing, obstacle creation, chemical repellents, planting specific crops to reduce food-related conflicts, beehive fences, and community engagement. Additionally, the importance of baseline environmental studies on elephant behavior, dietary habits, and movement patterns has been emphasized. An integrated approach and continuity are necessary to protect elephant populations and their environments and create corridors both within and between various forest groups to ensure the continuity of elephant populations for long-term conservation. This involved enhancing compensation for losses from elephants, improving coexistence in conservation and overlapping areas, efficiently managing the challenges of human activities and forest fires, and maintaining elephant populations. Land-use issues should be addressed locally and nationally to protect and preserve the environment in and around elephant habitats. This includes zoning land use within terrestrial ecosystems to manage, prevent, and mitigate HEC. Therefore, building local capacity and community engagement had to be done by providing basic knowledge of elephant ecology and behavior in response to environmental conditions, researching forage species, tracking elephant movements with satellite signals for conflict resolution, and collaborative management. Sustain and develop new generations of conservationists to continually manage elephant conservation and revise strategies as necessary.

A crucial consideration in resolving major issues is recognizing shared responsibility and the need for collaborative efforts, shared decision-making, and resource utilization to address these challenges effectively. These strategies aim to protect and conserve elephant populations in Thailand over the long term by focusing on increased research and adaptive management approaches. Given the elephants' preference for secondary forests and grasslands and the likely role of humans in maintaining such ecological conditions in the past, it is imperative that societies adequately account for socioeconomic considerations to develop more just and sustainable land use and conservation strategies for the future.

A clear approach to managing the issue of wild elephants to reduce HEC and conserve wild elephants involves recognizing and accepting the existence of HEC as a central tenet for addressing the problem. Key components include elephant habitat management, establishing an HEC mitigation scheme, conducting and improving HEC prevention strategies, and participation of local people in HEC resolution within a framework of learning and awareness of elephant behavior. It also involves improving human livelihoods and developing education and income. All of the above under the framework of coexistence between humans and wild elephants in respective areas, protecting wild elephant and

their habitat and building HEC prevention and mitigation programs. This suggests the need for a fundamental reform of the elephant conservation policy.

## ACKNOWLEDGEMENTS

The authors would like to thank the Department of National Parks Wildlife and Plant Conservation of Thailand for helping to conserve and resolve the human-elephant conflict problem in the human environment. The authors would like to thank Kasetsart University for funding the Long-term management project of wild elephant habitat and population in conflict-critical areas between humans and wild elephants for sustainable management in Thailand, Project No. FF (KU)47.67 and the Department of Forest Biology, Faculty of Forestry, Kasetsart University, Bangkok, Thailand, for supporting our research.

## REFERENCES

- Abdullah-Fauzi NAF, Karuppanan KV, Mohd-Radzi NHS, Gani M, Mohd-Ridwan AR, Othman N, Haris H, Sariyati NH, Aifat NR, Abdul-Latiff MAB, Abdul-Razak MFA, Md-Zain BM. 2022. Determining the dietary preferences of wild Asian elephants (*Elephas maximus*) in Taman Negara National Park, Malaysia based on sex and age using trnL DNA metabarcoding analysis. *Zool Stud* 61: e60. DOI: 10.6620/ZS.2022.61-60.
- Abram NK, Xofis P, Tzanopoulos J, MacMillan DC, Ancrenaz M, Chung R, Peter L, Ong R, Lackman I, Goossens B, Ambu L, Knight AT. 2014. Synergies for improving oil palm production and forest conservation in floodplain landscapes *PLoS One* 9: e95388. DOI: 10.1371/journal.pone.0095388.
- Acharya KP, Paudel PK, Neupane PR, Köhl M. 2016. Human-wildlife conflicts in Nepal: Patterns of human fatalities and injuries caused by large mammals. *PLoS One* 11: 1-18. DOI: 10.1371/journal.pone.0161717.
- Adams TSF, Chase MJ, Rogers TL, Leggett KEA. 2017. Taking the elephant out of the room and into the corridor: can urban corridors work? *Oryx* 51: 347-353. DOI: 10.1017/S0030605315001246
- AERSM. 2017. Asian Elephant Range States Meeting Final Report 2017. Ministry of Environment and Forestry, Government of Indonesia. [www.asesg.org/PDFfiles/2017/AsERSM%202017\\_Final%20Report.pdf](http://www.asesg.org/PDFfiles/2017/AsERSM%202017_Final%20Report.pdf).
- Agarwal P. 2015. 350 Deaths a Year, Thousands of Hectares Damaged in Man-elephant Conflict. [www.timesofindia.indiatimes.com/india/350-deaths-a-year-thousands-of-hectares-damaged-in-man-elephant-conflict/articleshow/49915536.cms?from=mdr](http://www.timesofindia.indiatimes.com/india/350-deaths-a-year-thousands-of-hectares-damaged-in-man-elephant-conflict/articleshow/49915536.cms?from=mdr).
- Ahmad Zafir AW, Magintan D. 2016. Historical review of human-elephant conflict in Peninsular Malaysia. *JWP* 31: 1-19. [www.wildlife.gov.my/images/stories/penerbitan/jurnal/2016/Jilid\\_31/01\\_HISTORICAL\\_REVIEW\\_OF\\_HUMAN-ELEPHANT.pdf](http://www.wildlife.gov.my/images/stories/penerbitan/jurnal/2016/Jilid_31/01_HISTORICAL_REVIEW_OF_HUMAN-ELEPHANT.pdf).
- Amorntiyangkul P, Pattanavibool A, Ochakul W, Chinnawong W, Klanprasert S, Aungkeaw C, Duengkae P, Suksavate W. 2022. Dynamic occupancy of wild Asian elephant: a case study based on the SMART database from the Western Forest Complex in Thailand. *Environ Nat Resour J* 20 (3): 310-322. DOI: 10.32526/enrj/20/202200005.
- Andualem TG, Belay G, Guadie A. 2018. Land use change detection using remote sensing technology. *J Earth Sci Clim Change* 9 (10). DOI: 10.4172/2157-7617.100.
- Ardiantiono S, Johnson PJ, Lubis MI, Amama F, Sukatmoko, Marthy W, Zimmermann A. 2021. Towards coexistence: can people's attitudes explain their willingness to live with Sumatran elephants in Indonesia?. *Conserv Sci Pract* 3. DOI: 10.1111/csp.2520.
- Awasthi B, Singh NB. 2015. Status of human-wildlife conflict and assessment of crop damage by wild animals in Gaurishankar

- conservation area, Nepal. *JIST* 20 (1): 107-111. DOI: 10.3126/JIST.V20I1.13918.
- Badola R, Ahmed T, Gill AK, Dobriyal P, Chandra Das G, Badola S, Hussain SA. 2021. An incentive-based mitigation strategy to encourage coexistence of large mammals and humans along the foothills of Indian Western Himalayas. *Sci Rep* 11: 5235. DOI: 10.1038/s41598-021-84119-7.
- Bahishti AA. 2021. The importance of review articles and its prospects in scholarly literature. *Extensive Rev* 1 (1): 1-6. DOI: 10.21467/exr.1.1.4293.
- Bangthong P, Sukmasuang R, Khoewsree N, Pla-ard M, Paansri P, Kaewdee B, Chairat R, Duengkae P, Siripattaranugul K. 2023. Species diversity, temporal pattern and habitat use of carnivorous mammals in the Khao Yai National Park, Thailand. *J Wildl Biodivers* 7: 128-151. DOI: 10.5281/zenodo.10023306.
- Baskaran N, Kanakasabai R, Desai AA. 2018a. Ranging and spacing behaviour of Asian elephant (*Elephas maximus* Linnaeus) in the tropical forests of southern India. In: Sivaperuman C, Venkataraman (eds). *Indian Hotspots*. Springer, Singapore.
- Baskaran N, Kanakasabai R, Desai AA. 2018b. Influence of ranging and hierarchy on the habitat use pattern by Asian elephant (*Elephas maximus* L.) in the tropical forests of southern India. In: Sivaperuman C, Venkataraman K (eds). *Indian Hotspots*. Springer, Singapore. DOI: 10.1007/978-981-10-6605-4\_15.
- Baskaran N, Varma S, Sar CK, Sukumar R. 2011. Current status of Asian elephants in India. *Gajah* 35: 47-54. DOI: 10.1007/978-981-10-6605-4\_17.
- Belgrano A, Cucchiella F, Jiang D, Rotilio M. 2023. Anthropogenic modifications: impacts and conservation strategies. *Sci Rep* 13: 12009. DOI: 10.1038/s41598-023-38940-x.
- Billah MM, Md. Rahman M, Abedin J, Akter H. 2021. Land cover change and its impact on human-elephant conflict: a case from Fashiakhali forest reserve in Bangladesh. *SN Appl Sci* 3: 649. DOI: 10.1007/s42452-021-04625-1.
- Cabral de Mel SJ, Seneweera S, de Mel RK, Dangolla A, Weerakoon DK, Maraseni T, Allen BL. 2022. Current and future approaches to mitigate conflict between humans and Asian elephants: the potential use of aversive geofencing devices. *Animals* 12 (21): 2965. DOI: 10.3390/ani12212965.
- Calabrese A, Calabrese JM, Songer M, Wegmann M, Hedges S, Rose R, Leimgruber. 2017. Conservation status of Asian elephants: the influence of habitat and governance. *Biodivers Conserv* 26: 2067-2081. DOI: 10.1007/s10531-017-1345-5.
- Chaiyarat R, Wettasin M, Youngpoy N, Cheachean N. 2023. Use of human-dominated landscape as connectivity corridors among fragmented habitats for wild Asian elephants (*Elephas maximus*) in the eastern part of Thailand. *Diversity* 15: 6. DOI: 10.3390/d15010006.
- Chakraborty K, Mondal J. 2013. Perceptions and patterns of human-elephant conflict at Barjora block of Bankura district in West Bengal, India: insights for mitigation and management. *Environ Dev Sustain* 15: 547-565. DOI: 10.1007/s10668-012-9392-2.
- Chandran BP, D'Souza A, Athulya VVH, Lydia P, Ashwini VVH, Prais J. 2023. Managing human-elephant cohabitation: strategies for mitigating conflict and encouraging coexistence. *E3S Web Conf* 405: 04018. DOI: 10.1051/e3sconf/202340504018.
- Chandranaik BM, Patl V, Rathamma D, Mamatha GS, Umashankar KS, Nagaraju DN, Byregowda SM. 2022. Drought may severely reduce the ability of wild Asian elephants *Elephas maximus* (Mammalia: Proboscidea: Elephantidae) to resist opportunistic infections. *J Threat Taxa* 14 (5): 20951-20963. DOI: 10.11609/jot.7835.14.5.20951-20963.
- Chanthasene S, Phimmavong S, Baral H, Wayakone S, Wanneng P. 2022. Willingness to pay for conservation of the Asian elephant in Nakai Nam Theun National Protected Area in Laos. *Open J Business Manag* 10: 1167-1179. DOI: 10.4236/ojbm.2022.103063.
- Chatterjee ND. 2016. Man-elephant conflict: A case study from forests in west Bengal, India. *Springer Briefs in Environmental Science*, Springer International Publishing, Switzerland. DOI: 10.1007/978-3-319-31162-3.
- Cheah C, Yoganand K. 2022. Recent estimate of Asian elephants in Borneo reveals a smaller population. *Wildl Biol* 2022 (2): e01024. DOI: 10.1002/wlb3.01024.
- Chen Y, Marino J, Chen Y, Tao Q, Sullivan CD, Shi K, Macdonald DW. 2016. Predicting hotspots of human-elephant conflict to inform mitigation strategies in Xishuangbanna, Southwest China. *PLoS ONE* 11 (9): e0162035. DOI: 10.1371/journal.pone.0162035.
- Chokcharoen R, Sukmasuang R. 2012. Ecology of Asian elephant (*Elephas maximus*) in Phu Wua Wildlife Sanctuary, Bueng Kan Province. *Thai J For* 19 (1): 13-22.
- CITES. 2021. *Illegal Trade in Live Asian Elephants: A Review of Current Legislative, Regulatory, Enforcement, and Other Measures Across Range States*. [www.cites.org/sites/default/files/eng/cop/17/WorkingDocs/E-CoP1757-01-A5.pdf](http://www.cites.org/sites/default/files/eng/cop/17/WorkingDocs/E-CoP1757-01-A5.pdf)
- Clutton-Brock J. 2012. *Animals as Domesticates: A World View Through History*. Michigan State University Press, Michigan, USA.
- Cook RM, Henley MD, Parrin F. 2015. Elephant movement patterns in relation to human inhabitants in and around the great Limpopo Transfrontier Park. *Koedoe* 57 (1): 1-7. DOI: 10.4102/koedoe.v57i1.1298.
- Coverdale TC, Kartzinel TR, Grabowski KL, Shriver RK, Hassan AA, Goheen JR, Palmer TM, Pringle RM. 2016. Elephants in the understory: opposing direct and indirect effects of consumption and ecosystem engineering. *Ecology* 97: 3219-3230. DOI: 10.1002/ecy.1557.
- Das G, Selvan K, Lahkar B, Gopi GV. 2022. Effectiveness of physical barriers in mitigating human-elephant negative interactions in North-East India. *Front Conserv Sci Sec Human-Wildlife Interact* 3: 2022. DOI: 10.3389/fcosc.2022.956568.
- Das JP, Lahkar BP, Sahu HK, Singha H. 2020. Population estimation of Asian elephants in a tropical forest of Northeast India. *Gajah* 52: 15-23.
- de la Torre JA, Cheah C, Lechner AM, Wong EP, Tuuga A, Saaban S, Goossens B, Campos-Arceiz A. 2022. Sundaic elephants prefer habitats on the periphery of protected areas. *J Appl Eco* 59 (12): 2947-2958. DOI: 10.1111/1365-2664.14286.
- de Sharma R, Davidar P, Arumugam N, Sedhupathy A, Puyravaud JP, Selvan KM, P.P. Rahim A, Udayraj S, Parida J, Digal DK, Kanagaraj R, Kakati K, Nigam P, Williams AC, Habib B, Goyal SP. 2021. Pan-India population genetics signifies the importance of habitat connectivity for wild Asian elephant conservation. *Glob Ecol Conserv* 32: e01888. DOI: 10.1016/j.gecco.2021.e01888.
- de Silva S, Wu T, Nyhus P, Weaver A, Thieme A, Johnson J, Wadey J, Mossbrucker A, Vu T, Neang T, Chen BS, Songer M, Leimgruber P. 2023. Land-use change is associated with multi-century loss of elephant ecosystems in Asia. *Sci Rep* 13: 5996. DOI: 10.1038/s41598-023-30650-8.
- Department of Wildlife Conservation [DWC]. 2019. *Elephant Census in Sri Lanka 2019*. [www.ceylonexpeditions.com/elephant-census-in-sri-lanka-2019](http://www.ceylonexpeditions.com/elephant-census-in-sri-lanka-2019).
- Department of Wildlife National Parks and Plant Conservation [DNP]. 2023. *Current Wild Elephant Situation in Thailand*. Wildlife Conservation Office, Bangkok. [Thailand]
- Desai AA, Riddle H. 2015. *Human-Elephant Conflict in Asia*. US Fish and Wildlife Service, Asian Elephant Support. [www.asianelephantsupport.org/current-projects/tag/human-elephant+conflict](http://www.asianelephantsupport.org/current-projects/tag/human-elephant+conflict).
- Dhaka, Bangladesh IUCN/SSC. 2013. *Guidelines for Reintroductions and Other Conservation Translocations*. Version 1.0. Gland, Switzerland: IUCN Species Survival Commission. [www.iucn.org/content/guidelines-reintroductions-and-other-conservation-translocations](http://www.iucn.org/content/guidelines-reintroductions-and-other-conservation-translocations).
- Dhillon P. 2021. How to write a good scientific review article. *FBES J* 289 (13): 3592-3602. DOI: 10.1111/febs.16565.
- Dror S, Harich F, Duangphakdee O, Savini T, Pogány A, Roberts J, Geheran J, Treyde AC. 2020. Are Asian elephants afraid of honeybees? Experimental studies in northern Thailand. *Mamm Biol* 100: 355-363. DOI: 10.1007/s42991-020-00042-w.
- Dubost JM, Deharo E, Palamy S, Her C, Phaekovilay C, Vichith L, Duffillot S, Krief S. 2022. Interspecific medicinal knowledge and MahoutElephant interactions in Thongmyxay District, Laos. *Revue d'ethnécologie* 22: 1-36. DOI: 10.4000/ethnecologie.9705.
- Fadillah R, Yoza D, Sribudiani E. 2014. Distribution and estimated production of food elephant Sumatera (*Elephas maximus* Temminck) around Duri, Mandau District, Bengkalis Regency. *Jurnal Online Mahasiswa* 1 (2): 1-9. [www.neliti.com/publications/201643/sebaran-dan-perkiraan-produksi-pakan-gajah-sumatera-elephas-maximus-sumatranus-#cite](http://www.neliti.com/publications/201643/sebaran-dan-perkiraan-produksi-pakan-gajah-sumatera-elephas-maximus-sumatranus-#cite).
- Fernando P, De Silva MCR, Jayasinghe LKA, Janaka HK, Pastorini J. 2021. First country-wide survey of the Endangered Asian elephant:

- towards better conservation and management in Sri Lanka. *Oryx* 55 (1): 46-55. DOI:10.1017/S0030605318001254
- Fernando P, Leimgruber P, Prasad T, Pastorini J. 2012. Problem-elephant translocation: translocating the problem and the elephant? *PLoS One*. 7 (12): e50917. DOI: 10.1371/journal.pone.0050917.
- Fernando P. 2015. Managing elephants in Sri Lanka: Where we are and where we need to be. *Ceylon J Sci Biol Sci* 44 (1): 1-11. DOI: 10.4038/cjsbs.v44i1.7336.
- Goossens B, Sharma R, Othman N, Kun-Rodrigues C, Sakong R, Ancrenaz M, Ambu LN, Jue NK, O'Neill RJ, Bruford MW, Chikhi L. 2016. Habitat fragmentation and genetic diversity in natural populations of the Bornean elephant: Implications for conservation. *Biol Conserv* 196: 80-92. DOI: 10.1016/j.BIOCON.2016.02.008.
- Goswami VR, Medhi K, Nichols JD, Oli MK. 2015. Mechanistic understanding of human-wildlife conflict through a novel application of dynamic occupancy models. *Conserv Biol* 29 (4): 1100-1110. DOI: 10.1111/cobi.12475.
- Gunaryadi D, Sugiyo, Hedges S. 2017. Community-based human-elephant conflict mitigation: The value of an evidence-based approach in promoting the uptake of effective methods. *PLoS One* 12 (5): e0173742. DOI: 10.1371/journal.pone.0173742.
- Gunawansa TD, Perera K, Apan A, Hettiarachchi NK, Bandara DY. 2023. Greenery change and its impact on human-elephant conflict in Sri Lanka: a model-based assessment using Sentinel-2 imagery. *J Remote Sens* 44 (16): 5121-5146. DOI: 10.1080/01431161.2023.2244644.
- Gunawansa TD, Perera K, Apan A, Hettiarachchi NK. 2023. The human-elephant conflict in Sri Lanka: history and present status. *Biodivers Conserv* 32: 3025-3052. DOI: 10.1007/s10531-023-02650-7.
- Guru BK, Das A. 2021. Cost of human-elephant conflict and perceptions of compensation: Evidence from Odisha, India. *J Environ Plan Manag* 64 (4): 1770-1794. DOI: 10.1080/09640568.2020.1838264.
- Hoare R. 2012. Lessons from 15 years of human-elephant conflict mitigation: Management considerations involving biological, physical and governance issues in Africa. *Pachyderm* 51: 60-74.
- Huang C, Li X, Khanal L, Jiang X. 2019. Habitat suitability and connectivity inform a co-management policy of protected area network for Asian elephants in China. *Peer J* 7: e6791. DOI: 10.7717/peerj.6791.
- Innoi P, Trisurat Y, Sukmasuang R. 2021. Population structure and foraging activities of Asian elephants (*Elephas maximus*) in the Salakpra Wildlife Sanctuary, Kanchanaburi Province, Thailand. *Thai J For* 40 (2): 128-141.
- Islam MA, Mohsanin S, Chowdhury GW, Chowdhury SU, Aziz MA, Uddin M, Saif S, Chakma S, Akter R, Jahan I, Azam I. 2011. Current status of Asian elephants in Bangladesh. *Gajah* 35: 21-24.
- IUCN Bangladesh. 2016. Status of Asian Elephants in Bangladesh. IUCN, International Union for Conservation of Nature, Bangladesh Country Office. [www.portals.iucn.org/library/sites/library/files/documents/2016-085.pdf](http://www.portals.iucn.org/library/sites/library/files/documents/2016-085.pdf).
- Jadhav S, Barua M. 2012. The elephant vanishes: impact of human-elephant conflict on people's wellbeing. *Health Place* 18 (6): 1356-1365. DOI: 10.1016/j.healthplace.2012.06.019.
- Jerang J, Vanitha V, Baskaran N. 2020. Demography, feeding and keeper status of captive Asian elephants in Eastern Arunachal Pradesh, North-eastern India. *Gajah* 52: 30-38.
- Jigme K, Williams AC. 2011. Current status of Asian elephants in Bhutan. *Gajah* 35: 25-28.
- Kalam T, Baishya HK, Smith D. 2018. Lethal fence electrocution: A major threat to Asian elephants in Assam, India. *Trop Conserv Sci* 11 (4): 194008291881728. DOI: 10.1177/1940082918817283.
- Karant K, Gopalaswamy AM, Prasad PK, Dasgupta S. 2013. Patterns of human-wildlife conflicts and compensation: Insights from Western Ghats protected areas. *Biol Conserv* 166: 175-185. DOI: 10.1016/j.biocon.2013.06.027.
- Karant K, Vanamamalai A. 2020. Wild seve: A novel conservation intervention to monitor and address human-wildlife conflict. *Front Ecol Evol* 8: 198. DOI: 10.3389/fevo.2020.00198.
- Kariyawasam CS, Kumar L, Ratnayake SS. 2020. Potential risks of plant invasions in protected areas of Sri Lanka under climate change with special reference to threatened vertebrates. *Climate* 8 (4): 51. DOI: 10.3390/cli8040051.
- Khounboline K. 2011. Current status of Asian elephants in Lao PDR. *Gajah* 35: 62-66.
- Köpke S, Withanachchi SS, Pathiranage R, Withanachchi CR, Gamage DU, Nissanka TS, Thiel A. 2021. Human-elephant conflict in Sri Lanka: a critical review of causal explanations. *Sustainability* 13 (15). DOI: 10.3390/su13158625.
- Koshy J. 2021. Common survey to count India's elephant and tiger populations. [www.thehindu.com/news/national/common-survey-to-count-indias-elephant-and-tiger-populations/article35885595.ece](http://www.thehindu.com/news/national/common-survey-to-count-indias-elephant-and-tiger-populations/article35885595.ece).
- Kroutnoi L, Sriburi T, Wijitkosum S, Nuanyai K. 2020. Determination of stimulating factors of wild Asian elephant (*Elephas maximus*) dispersal from the Kaeng Krachan National Park to surrounding land use in Thailand. *Walailak J Sci Tech* 17 (4): 392-404. DOI: 10.48048/wjst.2020.4087.
- Kumar MA, Vijayakrishnan S, Singh M. 2018. Whose habitat is it anyway? Role of natural and anthropogenic habitats in conservation of charismatic species. *Trop Conserv Sci* 11: 1-5. DOI: 10.1177/1940082918788451.
- Kuswanda W, Garsetiasih R, Gunawan H, Situmorang ROP, Hutapea FJ, Kwatrina RT, Karlina E, Atmoko T, Zahrah M, Takandjandji M, Gunaryadi D. 2022. Can humans and elephants coexist? a review of the conflict on Sumatra Island, Indonesia. *Diversity* 14 (6): 420. DOI: 10.3390/d14060420.
- La Grange M, Matema C, Nyamukure B, Hoare R. 2022. The virtual fence dynamic: a real through for low-cost and sustainable mitigation of human-elephant conflict in subsistence agriculture? *Front Conserv Sci* 3:863180. DOI: 10.3389/feosc.2022.863180.
- Lamichhane BR, Subedi N, Pokhrel CP, Dhakal M, Acharya KP, Pradhan NMB, Smith JLD, Malla S, Thakuri BS, Yackulic CB. 2018. Using interviews and biological sign surveys to infer seasonal use of forested and agricultural portions of a human-dominated landscape by Asian elephants in Nepal. *Ethol Ecol Evol* 30: 331-347. DOI: 10.1080/03949370.2017.1405847.
- Leimgruber P, Zaw Min OO, Aung M, Kelly DS, Wemmer C, Senior B, Songer M. 2011. Current status of Asian elephants in Myanmar. *Gajah* 35: 76-86.
- Li W, Liu P, Guo X, Wang L, Wang Q, Yu Y, Dai Y, Li L, Zhang L. 2018. Human-elephant conflict in Xishuangbanna prefecture, China: distribution, diffusion, and mitigation. *Glob Ecol Conserv* 16: e00462. DOI: 10.1016/j.gecco.2018.e00462.
- Liefting Y, de Jong JF, Prins HHT. 2018. A new type of elephant fence: Permeable for people and game but not for elephant. *Gajah* 49: 11-19.
- Lim T, Campos-Arceiz A. 2022. A review of human-elephant ecological relations in the Malay Peninsula: Adaptations for coexistence. *Diversity* 14: 36. DOI: 10.3390/d14010036.
- Ling LE, Ariffin M, Manaf LA. 2016. A qualitative analysis of the main threats to Asian elephant conservation. *Gajah* 44: 16-22.
- Liu P, Wen H, Harich FK, He C, Wang L, Guo X, Zhao J, Luo A, Yang H, Sun X, Yu Y, Zheng S, Guo J, Li L, Zhang L. 2017. Conflict between conservation and development: Cash forest encroachment in Asian elephant distributions. *Sci Rep* 7: 6404. DOI: 10.1038/s41598-017-06751-6.
- Lueders I, Young D, Maree L, van der Horst G, Luther I, Botha S, Tindall B, Fosgate G, Ganswindt A, Bertschinger HJ. 2017. Effects of GnRH vaccination in wild and captive African elephant bulls (*Loxodonta africana*) on reproductive organs and spermatogenesis. *Plos One* 12 (9): e0178270. DOI: 10.1371/journal.pone.0178270.
- Madden F, McQuinn B. 2014. Conservation's blind spot: the case for conflict transformation in wildlife conservation. *Biol Conserv* 178: 97-106. DOI: 10.1016/j.biocon.2014.07.015.
- Majumder R. 2022. Human-elephant conflict in West Bengal, India: present status and mitigation measures. *Eur J Wildl Res* 68 (3). DOI: 10.1007/s10344-022-01583-w.
- Maltby M, Bouchier G. 2011. Current status of Asian elephants in Cambodia. *Gajah* 35: 36-42.
- Mariki SB, Svarstad H, Benjaminsen TA. 2015. Elephants over the cliff: Explaining wildlife killings in Tanzania. *Land Use Policy* 44: 19-30. DOI: 10.1016/j.landusepol.2014.10.018.
- Mekonen, S. 2020. Coexistence between human and wildlife: the nature, causes and mitigations of human-wildlife conflict around Bale Mountains National Park, Southeast Ethiopia. *BMC Ecol* 20: 51. DOI: 10.1186/s12898-020-00319-1.
- Menkham K, Sukmasuang R, Pla-Ard M, Charaspet K, Panganta T, Trisurat Y, Bhumpakphan N. 2019. Population and habitat use of Asian elephants (*Elephas maximus*) and five ungulate species in Khao Ang Rue Nai Wildlife Sanctuary, Chachoengsao Province, Thailand. *Biodiversitas* 20 (8): 2213-2221. DOI: 10.13057/biodiv/d200815
- Menkham K, Pannapalakool M, Sukmasuang R, Charaspet K, Pangunta T, Plala-ard M, Phumpakphan N. 2018. Abundance and distribution of wild elephant even-toed ungulates in Khao Ang Rue Nai Wildlife

- Sanctuary. In: Taophimai L. (ed). Forestry Conference 2018: National Forest Reform, Bangkok, 23 August 2018. [Thailand]
- Menon V, Bhattacharyya K, Sinha SK, Tiwari SK, Kaul R. 2022. Shared landscapes: optimizing conservation strategies using tiger and elephant sympatry in India. *Diversity* 14: 1055. DOI: 10.3390/d14121055.
- Menon V, Tiwari SK. 2019. Population status of Asian elephants *Elephas maximus* and key threats. *Intl Zoo Yearb* 53 (1): 17-30. DOI: 10.1111/izy.12247.
- Mohd-Radzi NHS, Karuppannan KV, Abdullah-Fauzi NAF, Mohd-Ridwan AR, Othman N, Abu M, Bakar AL, Gani M, Abdul-Razak MFA, Md-Zain BM. 2022. Determining the diet of wild Asian elephants (*Elephas maximus*) at human-elephant conflict areas in Peninsular Malaysia using DNA metabarcoding. *Biodivers Data J* 10: e89752. DOI: 10.3897/BDJ.10.e89752.
- Montez D, Leng A. 2021. Status of Asian elephant and human-elephant conflict (HEC) in Asia: A brief and updated review. *J Nat Appl Res* 1 (1): 28-35.
- Mukeka JM, Ogotu JO, Kanga E, Røskaft E. 2019. Human-wildlife conflicts and their correlates in Narok County, Kenya. *Glob Ecol and Conserv* 18: e00620. DOI: 10.1016/j.gecco.2019.e00620.
- Mumby HS, Plotnik JM. 2018. Taking the elephants' perspective: remembering elephant behavior, cognition and ecology in human-elephant conflict mitigation. *Front Ecol Evol* 6: 122. DOI: 10.3389/fevo.2018.00122.
- Nad C, Roy R, Roy TB. 2022. Human elephant conflict in changing land-use land-cover scenario in an adjoining region of Buxa tiger reserve, India. *Environ Chall* 7: 100384. DOI: 10.1016/j.envc.2021.100384.
- Naeem S, Ingram JC, Varga A, Agardy T, Barten P, Bennett G, Bloomgarden E, Bremer LL, Burkill P, Cattau M, Ching C, Colby M, Cook DC, Costanza R, DeClerck F, Freund C, Gartner T, Goldman-Benner R, Gunderson J, Jarrett D, Kinzig AP, Kiss A, Koontz A, Kumar P, Lasky JR, Masozera M, Meyers D, Milano F, Naughton-Treves L, Nichols E, Olander L, Olmsted P, Perge E, Perrings C, Polasky S, Potent J, Prager C, Quéfier F, Redford K, Saterson K, Thoumi G, Vargas MT, Vickerman S, Weisser W, Wilkie D, Wunder S. 2015. Environment and development get the science right when paying for nature's services. *Science* 347 (6227): 1206-1207. DOI: 10.1126/science.aaa1403.
- Naha D, Dash SK, Chettri A, Roy A, Sathyakumar S. 2020. Elephants in the neighborhood: patterns of crop-raiding by Asian elephants within a fragmented landscape of Eastern India. *PeerJ* 8: e9399. DOI: 10.7717/peerj.9399.
- Neupane B, Khatiwoda B, Budhathoki S. 2018. Effectiveness of solar-powered fence in reducing human-wild elephant conflict (HEC) in Northeast Jhapa District, Nepal. *J For Nepal* 15: 13-27. DOI: 10.3126/forestry.v15i0.24917.
- Neupane D, Johnson RL, Risch TS. 2017. How do land-use practices affect human-elephant conflict in Nepal? *Wildlife Biol* (4). DOI: 10.2981/wlb.00313.
- Nguyen VV, Nguyen HTT, Phan TTT, Lee CH. 2023. Determinants of locals' willingness to participate in human-elephant conflict management: Evidence from Dong Nai Biosphere Reserve, Vietnam. *Trees For People* 14: 100435. DOI: 10.1016/j.tfp.2023.100435.
- Nguyen VV, Phan TTT, Lee Chun-Hung L. 2022. Integrating multiple aspects of human-elephant conflict management in Dong Nai Biosphere Reserve, Vietnam. *Glob Ecol Conserv* 39: e02285. DOI: 10.1016/j.gecco.2022.e02285.
- Nsoni F, Heymans J, Diamouangana J, Mavinga FB, Breuer T. 2018. Perceived human-elephant conflict and its impact for elephant conservation in northern Congo. *Afr J Ecol* 56: 208-215. DOI: 10.1111/aje.12435.
- Ntuyey LT, Munishi LK, Kohi E, Treyde AC. 2022. Land use/cover change reduces elephant habitat suitability in the Wami Mbiki-Saadani Wildlife Corridor, Tanzania. *Land* 11 (2): 307. DOI: 10.3390/land11020307.
- Osei-Owusu Y. 2018. Human-Wildlife Conflict: Elephants-Technical Manual. [www.africanelephantfund.org/sites/default/files/gbb-uploads/elephant-technical.pdf](http://www.africanelephantfund.org/sites/default/files/gbb-uploads/elephant-technical.pdf).
- Othman N, Fernando P, Yoganand K, Ancrenaz M, Alfred RJ, Nathan S, Goossens B. 2013. Elephant conservation and mitigation of human-elephant conflict in Government of Malaysia-UNDP multiple-use forest landscapes project area in Sabah. *Gajah* 39: 19-23.
- Pastorini J, Nishantha HG, Janaka HK, Isler K, Fernando P. 2010. Waterbody use by Asian elephants in Southern Sri Lanka. *Trop Conserv Sci* 3: 412-422. DOI: 10.1177/194008291000300406.
- Perera BMAO. 2009. The human-elephant conflict: a review of current status and mitigation methods. *Gajah* 30: 41-52.
- Pla-Ard M, Khioesree N, Keawdee B, Hungheng W, Chattrakuldee P, Pengthong P, Thongbanthum J, Paansri P, Charaspet K, Panganta T, Chanachai Y, Duengkae P, Marod D, Uthairasmees S, Kaewkrachang T, Bhumpakphan N, Trisurat, Suksavate W, Sungkaew S, Pongpattananurak N, Racharak P, Wiwatwittaya D, Tasen W, Sukmasuang R. 2021. Monitoring the diversity, abundance, activity period and habitat use of wildlife species around the wildlife corridor that connects the natural world heritage site in Thailand. *Biodiversitas* 22 (11): 1-16. DOI: 10.13057/biodiv/d221134.
- Pla-ard M, Khioesree N, Sungkalak B, Nathalang A, Thomas W, Uthairatsamee S, Paansri P, Chanachai Y, Sukmasuang R. 2021. Population characteristics and habitat suitability of Khao Yai National Park, Thailand for Asian elephant and five ungulate species. *Biodiversitas* 23 (1): 231-243. DOI: 10.13057/biodiv/d230129.
- Pla-ard M, Sukmasuang R, Srinopawan K. 2019. Population characteristics and habitat suitability of Asian elephants (*Elephas maximus* Linnaeus, 1758) in the Khao Yai National Park, Thailand. *Eur J Ecol* 5 (2): 62-71. DOI: 10.2478/eje-2019-0012.
- Pla-ard M, Sukmasuang R, Uthairasmees S. 2022. Some population characteristics and viability of captive Asian elephant (*Elephas maximus*) in Thailand. *Biodiversitas* 23: 1072-1081. DOI: 10.13057/biodiv/d230251.
- Plotnik JM, Jacobson SL. 2022. A "thinking animal" in conflict: studying wild elephant cognition in the shadow of anthropogenic change. *CRBS* 46: 101148. DOI: 10.1016/j.cobeha.2022.101148.
- Pozo RA, Cusack JJ, McCulloch G, Stronza A, Songhurst A, Coulson T. 2018. Elephant space use is not a good predictor of crop damage. *Biol Conserv* 228: 241-251. DOI: 10.1016/j.biocon.2018.10.031.
- Pradhan NMB, Williams AC, Dhakal M. 2011. Current status of Asian elephants in Nepal. *Gajah* 35: 87-92. DOI: 10.3126/janr.v4i2.33828.
- Prakash TGSL, Wijeratne AW, Fernando P. 2020. Human-elephant conflict in Sri Lanka: patterns and extent. *Gajah* 51: 16-25.
- Promlao P, Bhunpakphan N, Mianmit N. 2019. Mitigation on people-elephant conflicts around Salakpra Wildlife Sanctuary, Kanchanaburi Province. *Thai J For* 38 (1): 1-12.
- Putthiphong P, Sukmasuang R. 2022. Problems of conflict between people and wild elephants in the area of Khao Yai National Park. In: Duengkae P, Bhmpakphan N (eds). *Proceeding of the 41<sup>st</sup> Thailand Wildlife Seminar, 30 November-2 December 2022*, Kasetsart University, Bangkok. [Thailand]
- Puyravaud JP, Cushman SA, Davidar P, Madappa D. 2017. Predicting landscape connectivity for the Asian elephant in its largest remaining subpopulation. *Anim Conserv* 20: 225-234. DOI: 10.1111/acv.12314.
- Radhakrishnan S. 2018. A note on wildlife poisoning cases from Kerala, South India. *Eur J Wildl Res* 64 (5): 58. DOI: 10.1007/s10344-018-1218-6.
- Rakdee R, Tasen W, Sukmasuang R. 2020. Opinions on the management of human-elephant conflict, Salakpra Wildlife Sanctuary area Kanchanaburi Province. In: Yangklang P (ed). *Proceeding of the 8th National Academic Conference 2020, Faculty of Management Science Silpakorn University, 22 May 2020, Nakhon Pathom.* [Thailand]
- Ram AK, Mondol S, Subedi N, Lamichhane BR, Baral HS, Natarajan L, Amin R, Pandav B. 2021. Patterns and determinants of elephant attacks on humans in Nepal. *Ecol Evol* 11 (17): 11639-11650. DOI: 10.1002/ece3.7796.
- Ram AK, Yadav NK, Subedi N, Pandav B, Mondol S, Khanal B, Kharal DK, Acharya HB, Dhakal BK, Acharya KP, Baral HS, Dahal BR, Mishra R, Naha D, Pradhan NMB, Natarajan L, Lamichhane BR. 2022. Landscape predictors of human-elephant conflicts in Chure Terai Madhesh Landscape of Nepal. *Environ Chall* 7: 100458. DOI: 10.1016/j.envc.2022.100458.
- Rattanawanawong N, Bhumpakphan N, Kutintara U, Sukmasuang R. 2022. Wildlife-vehicle collisions in Khao Yai National Park, Thailand: Impact on native species for some conservation management. *Biodiversitas* 23 (6): 3050-3061. DOI: 10.13057/biodiv/d230632.
- Reonsomboon T, Sukmasuang R. 2016. Distribution of some wildlife species along the electric elephant keep-out fence around Salakpra Wildlife Sanctuary, Kanchanaburi province. In: Taophimai L (ed). *Proceedings of the Forestry Annual Conference 2016: Eco-efficiency based on forestry*, Kasetsart University, 1-4 May 2016, Bangkok. [Thailand]

- Rogers A, Treves A, Karamagi R, Nyakoojo M, Naughton-Treves L. 2023. Trenches reduce crop foraging by elephants: Lessons from Kibale National Park, Uganda for elephant conservation in densely settled rural landscapes. *PLoS ONE* 18 (7): e0288115. DOI: 10.1371/journal.pone.0288115.
- Roy M, Sukumar R. 2015. Elephant corridors in Northern West Bengal. *Gajah* 43: 26-35.
- Roy M, Sukumar R. 2017. Railways and wildlife: A case study of train-elephant collisions in northern west Bengal, India. In: Borda-de-Água L, Barrientos R, Beja P, Pereira H (eds). *Railway Ecology*. Springer. DOI: 10.1007/978-3-319-57496-7\_10.
- Saaban S, Othman NB, Yasak MNB, Nor BM, Zafir A, Campos-Arceiz A. 2011. Current status of Asian elephants in peninsular Malaysia. *Gajah* 35: 67-75.
- Saha SK. 2020. Innovative way of human-elephant competition mitigation. *J Threat Taxa* 12 (11): 16494-16501. DOI: 10.11609/jott.5886.12.11.16494-16501.
- Sajla JSF, Famees MF. 2022. Human-elephant conflict: challenges in agriculture Sector in Polonnaruwa District; A study based on literature review. *Sri Lanka J Soc Sci Humanity* 2: 73-84. DOI: 10.4038/sljssh.v2i1.58
- Sakamoto M. 2017. Recent topics on CITES related to Asian elephants in particular. *Gajah* 47: 42-44.
- Sampson C, Leimgruber P, Rodriguez S, McEvoy J, Sotherden E, Tonkyn D. 2019. Perception of human-elephant conflict and conservation attitudes of affected communities in Myanmar. *Trop Conserv Sci* 12:1-17. DOI: 10.1177/1940082919831242.
- Sampson C, McEvoy J, Oo ZM, Chit AM, Chan AN, Tonkyn D, Soe P, Songer M, Williams AC, Reisinger K, Wittemyer G, Leimgruber P. 2018. New elephant crisis in Asia: Early warning signs from Myanmar. *PLoS One* 13 (3): e0194113. DOI: 10.1371/journal.pone.0194113.
- Schliesinger J. 2015. *Elephants in Thailand vol 1: Mahouts and Their Cultures Today*. White Lotus Press, Bangkok, Thailand.
- Sengupta A, Binoy VV, Radhakrishna S. 2020. Human-elephant conflict in Kerala, India: A rapid appraisal using compensation records. *Hum Ecol* 48, 101-109. DOI: 10.1007/s10745-020-00128-6.
- Shaffer LJ, Khadka KK, Van Den Hoek J, Naithani KJ. 2019. Human-elephant conflict: a review of current management strategies and future directions. *Front Ecol Evol* 6: 235. DOI: 10.3389/fevo.2018.00235.
- Sharma P, Chettri N, Wangchuk K. 2021. Human-wildlife conflict in the roof of the world: Understanding multidimensional perspectives through a systematic review. *Ecol Evol* 11 (17): 11569-11586. DOI: 10.1002/ece3.7980.
- Sharma P, Panthi S, Yadav SK, Bhatta M, Karki A, Duncan T, Poudel M, Acharya KP. 2020. Suitable habitat of wild Asian elephant in Western Terai of Nepal. *Ecol Evol* 10: 6112-6119. DOI: 10.1002/ece3.6356.
- Sharma R, Goossens B, Heller R, Rasteiro R, Othman N, Bruford MW, Chikhi L. 2018. Genetic analyses favour an ancient and natural origin of elephants on Borneo. *Sci Rep* 8 (1): 880. DOI: 10.1038/s41598-017-17042-5.
- Shrestha S, Shrestha J. 2021. Asian elephants and their status in Nepal: a review. *J Agric Nat Resour* 4 (2): 227-237. DOI: 10.3126/janr.v4i2.33828.
- Siripon S, Trisurat Y, Sukmasuang R. 2014. Impact of land use change on wild elephant habitat in Salakpra Wildlife Sanctuary, Kanchanaburi province. *J Wildlife Thailand* 21 (1): 138-149. [Thailand]
- Songer M, Aung M, Allendorf TD, Calabrese JM, Leimgruber P. 2016. Drivers of change in Myanmar's wild elephant distribution. *Trop Conserv Sci* 9 (4): 1-10. DOI: 10.1177/1940082916673749.
- Songmanee N, Sukmasuang R, Pothitan R, Sariman S. 2017. Opinions of people on human and elephant conflict problem solution by moat around Khao Ang Rue Nai Wildlife Sanctuary, Chachoengsao province. *Thai J For* 36 (2): 107-118.
- Su K, Ren J, Yang J, Hou Y, We Y. 2020. Human-elephant conflicts and villagers' attitudes and knowledge in the Xishuangbanna Nature Reserve, China. *Intl J Environ Res* 17 (23): 8910. DOI: 10.3390/ijerph17238910.
- Sukmantoro YW, Alikodra HS, Kartono AP, Efransjah. 2019. Distribution and habitat preferences of Sumatran elephant (*Elephas maximus sumatranus*) in Riau, Indonesia. *Biodiversitas* 20 (1): 226-235. DOI: 10.13057/biodiv/d200126.
- Sukmasuang R, Thongtip N, Bhumpakphan N. 2013. *The Studies of Ecology, Population, Distribution and Health to Solve Elephant Problems in Thailand*. Research and Development Projects to Enhance Integrated Competitiveness Agricultural Research Project, Kasetsart University Research and Development Institute, Bangkok. [Thailand]
- Sukmasuang R, Vinitpornsawan S, Jitvijak W, Chairat R, Siripunkaw C, Noonto B, Savini C, Charoedong T, Godfree A. 2022. Updating Wild Elephant Status from Thailand. In: Thongtip N (ed). *The 2<sup>nd</sup> International Conference of Elephant and Wildlife Health Management in Asia (ICEW 2022)*, 15-16 June 2022, Nakhon Pathom Thailand.
- Sukmasuang R. 2003. Ecology and population of wild elephants in Huai Kha Khaeng Wildlife Sanctuary. *Thai Wildl J* 11 (1): 13-36.
- Sukmasuang R. 2009. Population density of Asian elephant in Huai Kha Khaeng Wildlife Sanctuary. *Thai J For* 28 (1): 40-50.
- Sukmasuang R. 2014. Solving the wild elephant problem in Thailand. In: Duengkae P, Pongchareon (eds). *Proceeding of the 35th Thai Wildlife Seminar, 18-19 December 2014*, Bangkok. [Thailand]
- Sukmasuang R. 2015. Status of wild elephants in Thailand. In: Pongchareon C (ed). *Proceeding of Biodiversity Academic Conference*, Bangkok. 11 March 2015. [Thailand]
- Sukmasuang R. 2016. Current situation and conflict problems between people and wild elephants in Thailand. In: Kamolnorranath S (ed). *the10<sup>th</sup> Zoo Wildlife Seminar, The Future of Wildlife is in Our Hands*, Bangkok, 15 July 2016. [Thailand]
- Sukmasuang R. 2018. *Conservation of Elephants in Thailand*. IUCN SSC Public Symposium A Global Perspective on Conservation, Bangkok. [Thailand]
- Sukmasuang R. 2019. *The Problem of Wild Elephants Falling into the Abyss and Solutions to the Problem, Meeting to Consider Solutions to the Problem of Wild Elephants Falling into Haew Narok Waterfall, Khao Yai National Park, Nakhon Ratchasima, Thailand*. [Thailand]
- Suksavate W, Duengkae P, Chaiyees A. 2019. Quantifying landscape connectivity for wild Asian elephant populations among fragmented habitats in Thailand. *Glob Ecol Conserv* 19: e00685. DOI: 10.1016/j.gecco.2019.e00685.
- Sukumar R, Varma S, Tiwari SKr, Menon V. 2016. Sustainable landscapes and corridors to conserve Asian elephants in India. In: Aguirre AA, R. Sukumar (eds). *Tropical Conservation Perspectives on Local and Global Priorities*. Oxford University Press, London.
- Thant ZM, May R, Røskaft E. 2022. Human-elephant coexistence challenges in Myanmar: An analysis of fatal elephant attacks on humans and elephant mortality. *J Nat Conserv* 69: 126260. DOI: 10.1016/j.jnc.2022.126260.
- Thongchai S, Dejchaisri S, Sukmasuang R, Thongtipsiridech S, WajjwalkuW, Kaolim N. 2011. Genetic diversity of wild elephant (*Elephas maximus* Linnaeus, 1758) in the northeastern part of Thailand. *Thai Wildlife J* 18 (1): 16-33.
- Thouless CR, Dublin HT, Blanc JJ, Skinner DP, Daniel TE, Taylor RD, Maisels F, Frederick HL, Bouché P. 2016. *African Elephant Status Report* 2016. [www.portals.iucn.org/library/sites/library/files/documents/SSC-OP-060\\_A.pdf](http://www.portals.iucn.org/library/sites/library/files/documents/SSC-OP-060_A.pdf).
- Tiller L, King L, Lala F, Pope F, Thouless C, Wall J, Douglas-Hamilton I. 2022. The outcome of an elephant translocation from Isiolo to Tsavo East National Park, Kenya. *Pachyderm* 63: 91-98.
- Tripathy BR, Liu X, Songer M, Kumar L, Kaliraj S, Chatterjee ND, Wickramasinghe WMS, Mahanta KK. 2021. Descriptive spatial analysis of human-elephant conflict (HEC) distribution and mapping HEC hotspots in Keonjhar Forest Division. *India Front Ecol Evol* 9: 640624. DOI: 10.3389/fevo.2021.640624.
- van de Water A, King LE, Arkajak R, Arkajak J, van Doormaal N, Ceccarelli V, Sluiter L, Doornwaard SM, Praet V, Owen D, Matteson K. Beehive fences as a sustainable local solution to human-elephant conflict in Thailand. *Conserv Sci Pract* 2: e260. DOI: 10.1111/csp2.260.
- van de Water A, Matteson K. 2018. Human-elephant conflict in western Thailand: Socio-economic drivers and potential mitigation strategies. *PLoS One* 13 (6): e0194736. DOI: 10.1371/journal.pone.0194736.
- Vanitha V, Thiyagesan K, Baskaran N. 2010. Daily routine of captive Asian elephants (*Elephas maximus*) in three management systems of Tamil Nadu, India and its implications for elephant welfare. *J Sci Trans Environ Technov* 3 (3): 116-122. DOI: 10.20894/stet.116.003.003.002.
- Wahed MA, Ullah MR, Irfanullah HMd. 2016. *Human-Elephant Conflict Mitigation Measures: Lessons from Bangladesh*. IUCN, International Union for Conservation of Nature, Bangladesh Country Office, Dhaka, Bangladesh.

- Wang H, Wang P, Zhao X, Zhang W, Li J, Xu C, Xie P. 2021. What triggered the Asian elephant's northward migration across southwestern Yunnan? *Innovation* 2 (3): 100142. DOI: 10.1016/j.xinn.2021.100142.
- Wang J, Chen Y, Sun Y, Lyu Z, Shi K. 2023. Inferring human-elephant coexistence based on characteristics of human-elephant interactions in Nangunhe of Yunnan, China. *Chin Geogr Sci* 33 (2): 363-376. DOI: 10.1007/s11769-023-1332-6.
- Wang J, Chen Y, Sun Y. 2023. Inferring human-elephant coexistence based on characteristics of human-elephant interactions in Nangunhe of Yunnan, China. *Chin Geogr Sci* 33: 363-376. DOI: 10.1007/s11769-023-1332-6.
- Wang W, Wronski T, Yang L. 2024. The status of wildlife damage compensation in China. *Animals* 14 (2): 292. DOI: 10.3390/ani14020292.
- Wannasathit W, Sukmasuang R. 2019. People's opinions on reducing conflicts between people and wild elephants Khao Ang Rue Nai Wildlife Sanctuary Kaeng Hang Maeo District area Chanthaburi Province. *RRBR* 14 (2): 160-169.
- Warapitiya, CC, Nissanka BM, Ranasinghe NN, Senarathna CD. 2021. Human-elephant conflict in Sri Lanka: A critical review of causal explanations. *Sustainability* 13: 8625. DOI: 10.3390/su13158625.
- Wettasin M, Chaiyarat R, Sukmasuang R, Tanhan P. 2022. The effects of environmental factors on the distribution of Asian elephants (*Elephas maximus*) in the eastern region of Thailand. In: Thapthong S (ed) *Proceeding of the National-level Academic Conference on Science and Technology*, Phetchabun Rajabhat University, Thailand, 19 March 2022. DOI: 10.1038/s41598-023-40070-3. [Thailand]
- Wettasin M, Chaiyarat R, Youngpoy N, Jieychien N, Sukmasuang R, Tanhan P. 2023. Environmental factors induced crop raiding by wild Asian elephant (*Elephas maximus*) in the Eastern Economic Corridor, Thailand. *Sci Rep* 13: 13388. DOI: 10.1038/s41598-023-40070-3.
- Wijayagunawardane MPB, Short RV, Samarakone TS, Nishany KBM, Harrington H, Perera BVP, Rassool R, Bittner EP. 2016. The use of audio playback to deter crop-raiding Asian elephants. *Wildl Soc Bull* 40: 375-379. DOI: 10.1002/wsb.652.
- Williams C, Tiwari SK, Goswami VR, de Silva S, Kumar A, Baskaran N, Yoganand K, Menon V. 2020. *Elephas maximus*. The IUCN Red List of Threatened Species 2020: e.T7140A45818198. DOI: 10.2305/IUCN.UK.2020-3.RLTS.T7140A45818198.en
- Wilson G, Desai AA, Sim DA, Linklater WL. 2013. The influence of the invasive weed *Lantana camara* on elephant habitat use in Mudumalai Tiger Reserve, southern India. *J Trop Ecol* 29: 199-207. DOI: 10.1017/S0266467413000205.
- Wilson S, Davies TE, Hazarika N, Zimmermann A. 2015. Understanding spatial and temporal patterns of human-elephant conflict in Assam, India. *Oryx* 49: 140-149. DOI: 10.1017/S0030605313000513.
- Xu J, Wei J, Liu W. 2019. Escalating human-wildlife conflict in the Wolong Nature Reserve, China: A dynamic and paradoxical process. *Ecol Evol* 9 (12): 7273-7283. DOI: 10.1002/ece3.5299.
- Yamamoto-Ebina S, Saaban S, Campos-Arceiz A, Takatsuki S (2016) Food habits of Asian elephants (*Elephas maximus*) in a rainforest of northern Peninsular Malaysia. *Mamm Stud* 41 (3): 155-161. DOI: 10.3106/041.041.0306.
- Yuphong A, Potithaen R, Sukmasuang R. 2015. People's responses to human-wild elephant conflict: A case study of Salakpra Wildlife Sanctuary, Kanchanaburi Province. In: Phawongrat R (ed). *Following in His Majesty's Footsteps; Proceeding of the National Academic Conference*. Kasetsart University Kamphaeng Saen Campus, Nakhon Pathom, 8-9 December 2015. [Thailand]