Tamil Nadu Forest Department

Advanced Institute for Wildlife Conservation

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Evaluating the use of immunocontraception as a tool in mitigating Human-Elephant Conflict in Tamil Nadu – Phase I

Modernization of Forest Force (MoFF) Scheme

2024-2025

TAMIL NADU FOREST DEPARTMENT

ADVANCED INSTITUTE FOR WILDLIFE CONSERVATION
(Research, Training & Education)

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AIWC TEAM

Thiru. A. Udhayan, I.F.S.,

Principal Chief Conservator of Forests & Director

Selvi. S. Senbagapriya, I.F.S.,

Deputy Director (Administration)

Thiru. D. Eswaran

Deputy Director (Technical)

Dr. S. Siva Ranjani

Forest Veterinary Assistant Surgeon

Thiru. R.M. Perumal

Forest Range Officer

PROJECT TEAM

Dr. Nittu George

Project Scientist-II

Mr. R. Nithesh

Project Associate-II

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For correspondence: **aiwcrte@tn.gov.in**

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ABSTRACT

Human–Elephant Conflict (HEC) is an increasing conservation and governance challenge in India, driven primarily by habitat loss and human encroachment into elephant ranges. The conflict results in significant crop damage, property loss, human casualties, and elephant mortality, imposing serious ecological and socio-economic costs. Existing mitigation measures, including solar-powered fencing, elephant-proof trenches, and Rapid Response Teams (RRTs), have largely delivered short-term relief but have not succeeded in reversing the upward trend in conflict, highlighting the urgent need for innovative and sustainable interventions.

Immunocontraception using Porcine Zona Pellucida (pZP) is internationally recognized as a safe and effective tool for regulating elephant population growth. The method has been implemented in more than 800 female elephants across 26 reserves in South Africa, with no major adverse health effects reported. However, despite its demonstrated success in African elephants, pZP has not yet been scientifically evaluated for application in Indian elephants. To address this gap, the present study assesses HEC dynamics in Tamil Nadu and evaluates the feasibility of pZP immunocontraception under Indian conditions. Accordingly, a systematic assessment was undertaken to understand the conflict dynamics in Tamil Nadu, where elephant populations and HEC incidences are high. This study analyzed secondary HEC data (2022–2024) from the Hosur and Coimbatore Forest Divisions, both identified as high-conflict regions. The analysis revealed that the Hosur Division recorded a higher frequency of crop damage incidents and human fatalities compared to Coimbatore.

In addition, this study evaluated the feasibility of immunocontraceptive vaccination in captive (camp) elephants in Tamil Nadu prior to any potential application in wild populations.

Twelve female camp elephants of reproductive age were selected from the Anamalai Tiger Reserve (ATR), Mudumalai Tiger Reserve (MTR), and the Elephant Rehabilitation and Rejuvenation Centre (ERRC), Trichy. Their reproductive cycles were monitored over five months (February–July 2025) using non-invasive hormonal analysis. One additional month of sampling will be conducted to complete a six-month monitoring period and to establish baseline reproductive profiles.

Findings from Phase I will guide the selection of elephants for vaccine administration in Phase II and support the development of standardized protocols and operational guidelines. The project aims to provide science-based evidence to inform policy decisions on the potential use of immunocontraception as a long-term, non-lethal strategy for mitigating Human–Elephant Conflict in Tamil Nadu.

1. INTRODUCTION

Human–wildlife conflict is an important factor in the modern biodiversity crisis and has negative effects on both humans and wildlife, leading to injury or death for both sides and also property destruction, which can impede conservation efforts for threatened species. These negative outcomes from human–wildlife interactions are most prevalent throughout the continents of Asia and Africa, and most reported incidences of human–wildlife conflict (HWC) in these regions involve large mammals (Torres *et.al.,* 2018). Many conflicts are related to livestock depredation, human deaths and injuries, or crop loss, the last of which is the most frequently reported reason for conflicts worldwide (Sarker & Røskaft, 2011; Torres *et.al.,* 2018). Approximately 20% of the species most frequently involved in HWCs are listed on the International Union for Conservation of Nature (IUCN) Red List (Torres *et.al.,* 2018), including species such as tiger, leopard, wild pig, nilgai, sloth bear, including the African savanna elephant (*Loxodonta africana*) and the Asian elephant (*Elephas maximus*), both of which are listed as endangered and are frequently associated with common conflict situations (Seoraj-Pillai & Pillay, 2016; Anand & Radhakrishna, 2017). Among them, HEC is considered one of the serious negative issues, as the impact on animals and humans is huge. HEC is a significant conservation challenge in countries within the elephant's range. To address and minimise the conflicts, a wide range of management strategies has been designed and applied across different levels. However, human-elephant conflict remains pervasive because most of the preventive measures are site-specific, offering only short-term solutions, while mitigation strategies frequently shift the conflict risk from one place to another (Shaffer *et.al.,* 2019).

The state of Tamil Nadu has considerable portion of the Western Ghats and the Eastern Ghats, the two significant mountain ranges that stretch along the western and eastern coasts of the Indian subcontinent, respectively. Key factors such as deforestation, habitat loss, degradation by invasive alien species, disruption of corridor connectivity, and the expansion of agriculture near forest edges have intensified conflicts, which often result in incidents like crop raiding, elephant electrocution from illegal live wire fences, and deaths on railway tracks, all contributing to HEC in the region. To address these challenges, conservation managers implement various mitigation strategies. Despite these efforts, human–elephant conflicts continue to rise, driven by the complex interplay of multiple underlying causes (Shameer *et.al.,* 2023). According to the Synchronized Elephant Census 2024, Tamil Nadu is home to 3,063 elephants. The Coimbatore and Hosur regions are particularly critical hotspots for HEC. The census highlights a substantial elephant presence in these zones, with 336 individuals recorded in Coimbatore and 240 in Hosur, with both areas experiencing frequent conflict incidents. Between 2016 and 2021, Coimbatore reported 1,899 conflict events, while Hosur recorded a much higher incidence of 4,395 cases, with crop raiding being the most frequently reported issue. In the Hosur-Dharmapuri forest landscape alone, the State Forest Departments register an average of 1,450 cases of crop depredation annually, equating to roughly four incidents per day. Over the past two decades, the region has seen an average of five human casualties or injuries caused by elephants each year, along with approximately five elephants killed annually either in retaliation or due to poaching.

1.1 Current Status of Human-Elephant Conflict

HWC is a critical global issue that poses a significant challenge to elephant conservation (Graham *et. al.,* 2005; Fernando *et. al.,* 2005; Das *et. al.,* 2012; Abrahms, 2021; Salazar *et. al.,* 2024). The Asian Elephant, an *Endangered* umbrella species (Williams *et. al.,* 2020), is facing escalating conflicts with humans (Sukumar, 2016) as its habitats undergo significant transformation to accommodate the needs of a growing human population

(Baskaran *et. al.,* 2011). Consequently, conserving this keystone species in its natural environment has become increasingly challenging across Asia (Baskaran *et.al.,* 2013). Global initiatives for Asian elephant conservation now emphasise the need to thoroughly understand the underlying drivers of human-elephant conflict and to develop and implement sustainable, evidence-based mitigation strategies (Baskaran *et al.,* 2024).

Anthropogenic pressures on natural habitats of wild animals and increasing human population result in changes in land use and the conversion of forested areas into agricultural land, posing potent instances of human-elephant conflict in India (Williams *et al.,* 2001; Chartier *et al.,* 2011; Gubbi, 2012; Wilson *et al.,* 2013). The repercussions of HEC manifest in various ways, including the death and injury of both people and elephants, as well as the destruction of crops and livestock, depletion of water resources, damage to infrastructure, and the emergence of communities living under persistent fear and tension (Mumby & Plotnik, 2018).

1.2 Spatial Patterns of Human-elephant Conflict (HEC)

A recent study by Shameer *et al.* (2024) revealed that HEC incidents were documented across 33 forest divisions in Tamil Nadu, with the highest conflict levels particularly in the Coimbatore and Hosur divisions. The study showed the distribution of HEC across various forest divisions and ranges in Tamil Nadu. High levels of HEC were observed in forest divisions such as Coimbatore and Hosur and in forest ranges like Denkankottai, Hosur, and Jawalagiri. These areas are located in the Krishnagiri district of Tamil Nadu, a region well suited to the cultivation of agricultural and horticultural crops. Major crops grown in these districts include paddy, ragi, corn, groundnut, and horse gram (*Macrotyloma uniflorum*), with coconut as the primary plantation crop. In particular, coconut plantations in the Coimbatore district are frequently subjected to heavy damage by elephants during crop-raiding incidents.

1.3 Temporal Patterns of HEC

Alarming crop raiding patterns persist year-round, fluctuating intensively based on different crops and their respective harvesting seasons (Shameer *et al.,* 2024). A recent study by Baskaran *et al.* (2024) showed that incidents of crop damage are one of the key consequences of HEC, which has surged significantly from 2018 to 2023. This could be due to habitat loss, a decline in habitat quality, fragmentation or an increase in the elephant population within certain sections of the Nilgiri Biosphere Reserve (NBR). Rising human populations and associated pressures, such as cattle grazing and firewood collection, further degrade habitat quality. These anthropogenic activities also drive weed proliferation (Baskaran *et.al.,* 2012) and increase forest fire frequency (Kodandapani *et al.,* 2004), which together reduce the availability of native food plants for elephants and other herbivores, intensifying competition and conflict.

Crop damage has been the leading contributor to Human-elephant conflict in Tamil Nadu over the past years, as highlighted by several studies (Rohini *et.al.,* 2016; Yadav *et.al.,* 2015; Ramkumar *et al.,* 2014; Gubi, 2012; Shameer *et al.,* 2024; Baskaran *et al.,* 2024). Cultivated crops, with more nutritional value than wild fodder, attracts adult bull elephants to raid crop fields as an optimal foraging strategy (Sukumar, 2016)., Additionally changes in land use and land cover (LULC), particularly the change of private and revenue forests into human settlements or agricultural lands are expected to exacerbate HEC (Sukumar, 2016; Baskaran *et al.,* 2018), as elephant clans exhibit strong fidelity to their home ranges and seasonal corridors; furthermore, the size and structural dimensions of elephant habitats also play a crucial role in influencing HEC (Sukumar, 2016; Baskaran *et al.,* 2013b).

1.4 Management of Human-Elephant Conflict (HEC)

Currently, some of the mitigation measures have been proven to be useful in the field, including Elephant-proof trenches (EPTs) and various types of physical barriers, such as wire rope, solar, hanging solar, and steel-wire fences. Early warning systems, which emit alarm sounds when elephants are detected near the villages, and regular elephant-movement monitoring have also contributed to reducing the conflict (Shameer *et al.*, 2024). Additionally, the Forest Department installed AI-powered early warning systems and infrastructural developments like CCTV cameras along the elephant corridors to minimize conflict (Shameer *et al.,* 2024). Elephant-train collisions were significantly reduced by collaborative initiatives of government departments of Forest and Railway (Shameer *et al.,* 2024).

Translocation of conflict elephants from human habitats to protected areas or elephant reserves for release, involve the use of chemical sedatives for darting, followed by immobilisation and transportation (Nyhus *et al.,* 2000; Massei *et al.,* 2010; Saaban *et al.,* 2011; Fernando *et al.,* 2012). As an alternative to culling, the increase in elephant population can be controlled by mitigation measures such as immunological tools to manipulate the female reproductive hormone to induce temporary infertility, which is reversible after a certain period of time by immuno-contraception (Perera, 2009).

The issue of HEC continues to escalate despite the implementation of various mitigation measures in these regions. Measures such as solar fencing, early warning systems, and chasing have been attempted, but HEC remains a growing concern. It is crucial to develop and implement new approaches that can effectively minimize human–elephant conflict and its harmful consequences. Immunocontraceptives, particularly immunocontraceptive vaccines, have emerged as a promising solution in wildlife management programs (Massei, 2023). By reducing fertility, they offer a non-invasive alternative to culling or other invasive methods for controlling overpopulation (Chen, 2024). Immunocontraceptives work by targeting reproductive processes, disrupting fertility without the need for surgical procedures (Howard & Benhabbour, 2023). These vaccines stimulate an immune response against specific proteins involved in reproduction, such as zona pellucida glycoproteins or sperm antigens (Shibahara, 2022), and consequently, interfere with the normal function of the reproductive system (Howard & Benhabbour, 2023). This approach presents a humane and suitable method for managing elephant populations and mitigating long-term HEC.

1.5 History of immunocontraception in wildlife management

Immunological methods for wildlife management were being explored as early as 1987 (Kreeger, 1997). One of the first documented trials involved testing a gonadotropin-releasing hormone (GnRH) vaccine on wild horses at Cumberland Island National Seashore in 1986 (Goodloe *et.al.,* 1996). Shortly thereafter, a porcine zona pellucida (pZP) vaccine was tested in domestic and captive wild horses (Liu *et al.,* 1989). The results of the GnRH trial were not promising, while the pZP trial provided clear evidence of effectively inhibiting fertility in equids. In relatively rapid succession, trials with pZP were successful in captive white-tailed deer (Miller *et.al.,* 1999) and a variety of zoo animals, including Przewalski's horse (*Equus przewalskii*), Banteng (*Bos javanicus*), Formosan sika deer (*Cervus nippon taiouanus*), Spotted deer (*Axis axis*), Himalayan tahr (*Hemitragus jemlahicus*), Roosevelt elk (*Cervus elaphus roosevelti*), Muntjac deer (*Muntiacus reevesi*), and Sambar deer (*Cervus unicolor*) (Kirkpatrick *et al.,* 1996) Later, successful applications were also reported in African elephants (*Loxodonta africana*) (Fayrer-Hosken *et al.,* 1999; Bertschinger *et al.,* 2018).

1.6 The Precision of ZP-based immunocontraception

Immunocontraception is a non-hormonal fertility control method that works similarly to disease prevention through vaccination. It works by inducing the production of antibodies that bind to the zona pellucida, creating a barrier that interferes with fertilization, and effectively preventing pregnancy (Delsink *et al.,* 2015, Hosken *et al.*, 2000). The zona pellucida (ZP) is a non-cellular glycoprotein layer surrounding the mammalian eggs. Some of these ZP glycoproteins act as sperm receptors, which are essential for successful fertilisation. For fertilization to occur, sperm must first attach to these ZP proteins.

The porcine zona pellucida (pZP) vaccine, derived from pig eggs, is administered via intramuscular injection into the target female animal. The vaccine stimulates the immune system to produce antibodies against the ZP proteins. These antibodies bind to the sperm receptors on the ZP and block sperm from attaching thereby preventing fertilization. The antibodies are highly specific to the sperm receptors, ensuring no cross-reactivity with other organs or tissues in the body. As a result, the female does not become pregnant but continues to exhibit a regular estrous cycle every 15-17 weeks (Delsink *et.al.,* 2015). While several reproductive molecules can be targeted for immunocontraception, the primary focus has been on zona pellucida (ZP) proteins and gonadotrophin-releasing hormone (GnRH) (Perdok *et.al.,* 2007).

1.7 Immunocontraception in wildlife: a non-lethal solution for overpopulation

Immunocontraception has been suggested as an effective method to control the population of African elephants in situations where they risk exceeding the carrying capacity of a wildlife reserve (Perdok *et.al.,* 2007). So far, the only immunocontraceptive method that has been tested on female elephants is porcine zona pellucida (pZP)vaccination (Perdok *et al.,* 2007). Previous research on domestic horse mares has proven to be an effective platform for testing both anti-GnRH and pZP immunocontraceptive vaccines. The first documented use of immunocontraceptive vaccines in horses (*5*) involved the trial of a GnRH vaccine (Garza *et.al.,* 1986). This was soon followed by an exploration of pZP vaccination in the species (Liu *et.al.,* 1989). The use of porcine ZP-based vaccines in African elephant cows highlighted the need for refined vaccine formulations and a better understanding of ovarian impacts and safety (Schulman *et al.,* 2019). Despite these challenges, immunocontraceptive vaccines offer a promising, humane and non-invasive approach for managing populations of wildlife and feral species. These vaccines trigger antibody production in response to specific antigens that play a key role in reproductive processes, leading to infertility for a particular time (Fayrer-Hosken. 2008). Vaccines have proven effective in various domestic and wildlife species, providing a potentially cost-efficient, non-invasive, and humane alternative to conventional population control methods like culling and surgical sterilization (Kirkpatrick *et al.,* 2011). The native porcine zona pellucida (pZP) contraceptive vaccine has been used for 20 years in wildlife, including horses, deer, zoo animals, and elephants, effectively controlling populations without significant health effects (Kirkpatrick *et al.,* 2009).

Since 1994, PZP has been successfully used to manage Assateague Island's wild horse population, with mares receiving initial and booster doses via remote darts. After three years of treatment and the birth of a single foal, they were re-treated. Over 14 years, the population decreased from 175 to 125, bringing it close to the management target of 120 (Kirkpatrick *et.al.,* 2009). Similarly, a study conducted between 1979 and 1994, on 813 adult female elephants in Kruger National Park, found that 51% were pregnant, with the pregnancy rates ranging from 36% to 77%. During the same period, the park culled between 16 and 1,846 elephants annually, including individuals of all ages and sexes. When elephants are shielded from hunting and have access to water during droughts, their population can double within a decade, leading to considerable harm to the park's vegetation and threatening other species dependent on the ecosystem. While culling effectively controlled numbers, it remained a highly controversial management strategy.

As a more ethical and non-lethal alternative, using immunocontraception was proposed to control the elephant population (Hosken *et al.,* 2000), requiring the vaccination of 2,250 female elephants annually for 11 years (Whyte *et al.,* 1998, Pimm *et al.,* 2001). The initial immunocontraception program was tested on 41 adult female elephants, of which 21 were vaccinated. After a year, only 44% (8 out of 18) of the vaccinated elephants were pregnant, compared to 89% (16 out of 18) in the control group. In follow-up trials, with a revised vaccination schedule, just 20% (2 out of 10) of the vaccinated elephants became pregnant, much lower than the 89% pregnancy rate in the control group (Hosken *et al.,* 2000). These studies also confirmed that the pZP vaccine is both effective and reversible, vaccinated elephants did not conceive, while untreated elephants did, demonstrating the vaccine's efficacy (Hosken *et al*., 2000; Hosken *et al*., 1997; Bertschinger *et al.*, 2018). Today, the pZP vaccine is widely recognized as an effective and safe tool for managing elephant populations. The method is now implemented in over 800 elephant cows across 26 reserves in South Africa, with no major health concerns reported, apart from mild injection site reactions (Bertschinger *et al.,* 2018).

PZP vaccines have several advantages as immunocontraceptive as they have the efficacy of up to 90%, can be delivered remotely that reduces the risk in handling and stress, the vaccine is reversible and it has no harm to the pregnant animals, does not cause any health effects nor behavioural changes. However, it is target-specific ensuring no impact in the food chain of the animal and proven across worldwide (Kirkpatrick *et.al.,* 1996, Kirkpatrick *et.al.,* 2012, Delsink *et al.,* 2015). SpayVac® (ImmunoVaccine), a PZP-based vaccine providing long-term contraception with a single dose, can be implemented as an effective and cost-efficient method for managing Asian elephant populations. SpayVac® has been successfully used in African elephants, with a study tracking the immune response over seven years using two formulations: non-aqueous (n=3) and aqueous (n=3) emulsions. The non-aqueous have shown the result of consistent elevated immune responses through 7 years period in African elephants (Bechert & Fraker, 2016). The formulation of the SpayVac is 600 µg of pZP glycoprotein, administered via 7.6 cm long, 18 or 20-gauge needles for precise delivery (Bechert & Fraker, 2016, Ahlers *et al.*, 2012)

African and Asian elephants, both globally threatened species, require effective population control management strategies to address the challenges of over population and its ecological impacts. In southern Africa, where approximately 70% of African elephants reside, their numbers increase by 4-5% annually. Asian elephants (*Elephas maximus*) also face similar challenges. In fenced reserves, rising elephant densities can lead to habitat degradation, negatively affecting not only elephants but also numerous other species that share the same ecosystems. (Benavides Valades *et al.*, 2012). Culling the elephants has often been considered for population control; however, it is ethically controversial and socially disruptive, as removing several individuals can cause severe disturbances to herd dynamics (Segalla & Emma, 2021 & 2022). In India, the rise in the elephant population, without a corresponding increase in forest land, creates a high risk in HEC. According to Senthil *et al.* (2016), key reasons for elephants entering farmlands include loss of natural habitats due to conversion of forested areas into agricultural lands and population pressures. The study done by Shameer *et al.* (2024) reveals a growing trend in conflicts caused by Asian elephants (*Elephas maximus*) in recent years, with 9,477 recorded incidents across the state. The highest number of conflicts in Tamil Nadu occurred in the Hosur division (4,395), followed by Coimbatore (1,899). With lethal control measures increasingly discouraged, attention has shifted to non-invasive, humane alternatives. Among these, immunocontraception using porcine zona pellucida vaccines for female elephants has emerged as a promising strategy. This method, already successfully implemented in 43 reserves across South Africa (Delsink *et al.*, 2023), is gaining recognition as a safe, reversible and effective approach for managing elephant populations and mitigating HECs.

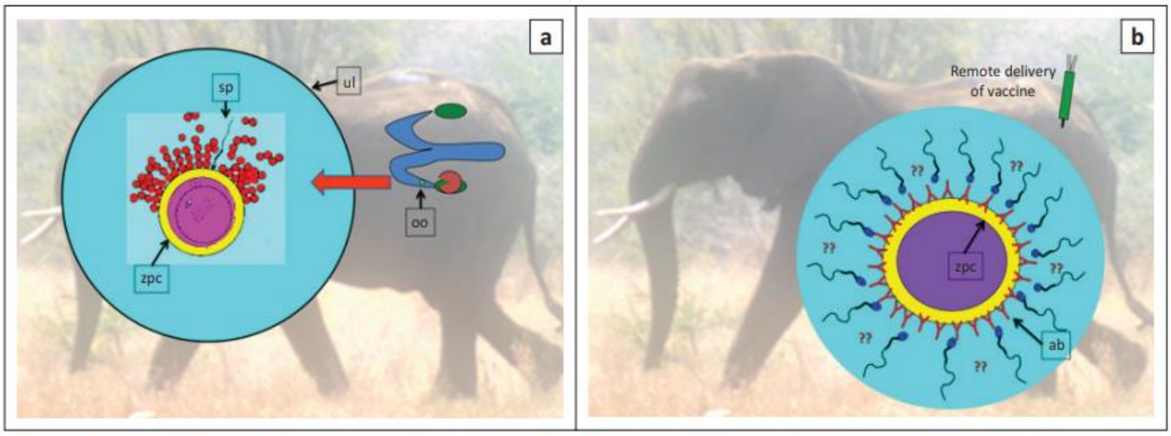
1.8 Mechanism of Immunocontraceptive vaccine

Immunocontraception is a non-hormonal, non-steroidal method of contraception that utilizes porcine zona pellucida (pZP) proteins. pZP immunocontraception has been touted as the most promising option because the vaccines are safe, tissue-specific, cost-effective, and relatively easy to administer (Kirkpatrick *et al.*, 2011; Ahlers *et al.*, 2012). When administered, the pZP vaccine triggers an immunological response in the target animal, producing antibodies that form an antibody layer around the egg cell, which binds to and blocks the sperm receptor sites, thus preventing penetration of the sperm cell and subsequent fertilization. The surface structures of the elephant zona pellucida are very similar to those of the pig zona pellucida. Studies on female zoo elephants have shown that vaccination with pZP combined with an adjuvant leads to the development of antibodies that persist for 12-14 months. (Fayrer-Hosken *et al.*, 1997).

Immunocontraception is a process that induces infertility through stimulation of the immune system and the production of antibodies in response to vaccination against endogenous components critical to the reproductive process. Several antigens have been identified as potential targets for immunocontraception including peptide hormones, oocyte and sperm proteins and other molecules associated with fertilization and early embryonic development. A distinct advantage of ZP-based immunocontraception is that these vaccines appear to have neither hormonal nor other deleterious side effects (Nolan, 2019).

Reproductive cyclicity is presumed to remain undisturbed in the short term, resulting in minimal sex-related behavioural or herd effects, as the inter-oestrous interval would be unaffected. This is particularly important in maintaining the social and reproductive integrity of herds whose behaviour is linked to intact reproductive cycles. Thus, herds of animals whose behaviour and herd integrity are based on intact reproductive cyclicity are unaffected by ZP immunocontraceptives. In both non- and seasonally breeding animals, however, it should be noted that repeated cycling throughout the year is not the norm. Furthermore, the ZP glycoproteins are structurally unique and have very little homology with somatic proteins, and so provide ideal targets for immunocontraception (Nolan, 2019). The ZP protein structures are highly conserved across several phyla and this facilitates potential interspecies use of native proteins. Zona pellucida proteins derived from pigs' ovaries are readily available in high numbers as a by-product of commercial pig slaughterhouses. This conserved homology of the ZP glycoproteins has allowed the use of antigens derived from the pig to be applied in several species. The immune response generated against pZP in combination with a suitable adjuvant cross-reacts with endogenous ZP glycoproteins in targeted females. Differences in the degree of homology between various species' ZP proteins may differ, however, which has consequences for immune recognition (Nolan, 2019). Therefore, immunocontraception on free-ranging African elephants vaccinated with pZP protects against conception and is also safe and reversible; thus, it has been shown as a practical tool for controlling African elephant populations (Fayrer-Hosken *et.al.*, 1997).

The pZP immunocontraception has been touted as the most promising option because the vaccines are safe, tissue-specific, cost-effective, and relatively easy to administer (Kirkpatrick *et al.*, 2011; Ahlers *et al.*, 2012). The potential effect of pZP-based immunocontraception on social structure and behavior in herd animals has been explored by researchers who reported either no differences (Kirkpatrick *et al.*, 1995, Powell, 2000) or minimal differences (Ransom *et al.*, 2010) between vaccinated and control mares with respect to activity budgets, hierarchy within the herd, or interactions with stallions; unlike GnRH vaccines, which suppressed behavioral and physiological estrus (Botha *et al.*, 2008). A study by Delsink *et al.* (2013), demonstrated that PZP vaccination was effective, and had no short-term effects on the sexual or social behavior of the African elephants. Likewise, a study in South Africa's KwaZulu-Natal, immunocontraception in the Munyawana Conservancy showed no impact on the sexual, social, or ranging behavior of elephants over a period of 4.5 years (Druce *et al.*, 2011). Thus, concerns about potential behavioral side effects of pZP vaccines in elephants have been mainly dispelled (Delsink *et al.*, 2013).



Source: Modified from Bertschinger, H.J. & Caldwell, P., 2016, 'Fertility suppression of some wildlife species in southern Africa - A review', *Reproduction in Domestic Animals* 51(Suppl 1), 18–24. https://doi.org/10.1111/rda.12783

Figure 1: Mechanism of action of the pZP vaccine. **a**-action of zona pellucida without pZP vaccine in elephant; **b**-action of pZP vaccine in elephant (Image adopted from: Bertschinger, *et al*., 2018)

1.9 Limitations of pZP vaccines

The primary limitation of current pZP vaccines is the frequency with which they typically need to be administered: initially three times, with two boosters given 2–4 weeks apart, and then annually (Delsink *et al.*, 2006). Moreover, pZP vaccines from South Africa are unregistered and pose challenges in procurement, including risks related to transmissible diseases, which may be even greater than previously realized due to the current globally widespread dissemination of the African swine fever virus. Additionally, research and ethical approval are required for the project to be registered, which states that its use is solely for African elephant cows within South Africa.

1.10. SpayVac: Immunocontraceptive vaccine

A single-dose immunocontraceptive vaccine that can elicit sustained antibody titers over several years with one treatment would be advantageous because elephants would require less frequent handling, thereby minimizing costs as well as exposure to stress and risk of injury. Bechert *et al* (2016), conducted a study in African elephants using an Immuno Vaccine called 'SpayVac®' which is a pZP vaccine that uses a unique liposome technology and has delivered single-dose, long-lasting immunocontraception that has effective for seven years. It was also successful in other variety of species including fallow deer (*Dama dama*) (Fraker *et.al.,* 2002); white-tailed deer (*Odocoileus virginianus*) (Rutberg *et al.,* 2013); horses (*Equus caballus*) (Killian *et al.,* 2008), and grey seals (*Halichoerus grypus*) (Brown *et al.,*1997).

The current project aims to study the efficiency and safety of the pZP immunocontraceptive vaccine in female camp elephants (Asian elephant, *Elephas maximus*) of Tamil Nadu, and this is the first such attempt in India. Based on the study's outcome, we will develop a protocol and guidelines for the effective implementation of this vaccine for wild elephants.

The present study has a duration of nine months. However, since reproductive cycle monitoring of the camp elephants takes 6 to 7 months, only five months of dung sample collection and processing have been completed so far. Sample collection is still ongoing and will continue until September 2025. Following this, laboratory analysis and the selection of individuals for vaccine administration will be carried out, marking the completion of the first phase of the project.

The outcome of the study will serve as the foundation for developing a protocol and guidelines to effectively implement this vaccine in wild elephants. Consequently, the findings could significantly contribute to managing the elephant population and addressing HEC in Tamil Nadu.

2. OBJECTIVES

1) To understand the elephant population status, its recent trends and the pattern of conflicts in Coimbatore and Hosur Forest Divisions.
2) To monitor the reproductive cycle of the female camp elephants of Tamil Nadu for the final selection the individuals for the vaccine administration in the second phase.

3. STUDY AREA

Conflict and population assessment

3.1 Hosur-Dharmapuri Forest Division

The Hosur-Dharmapuri Forest Divisions in Tamil Nadu, along with adjoining areas of the Bannerghatta-Bangalore Forest divisions in Karnataka and the Chittoor Forest Division in Andhra Pradesh, form the primary study area. Located in the Eastern Ghats landscape, this region is a vital habitat for the Asian elephant, supporting an estimated population of 400 elephants within the study site. The area, encompassing approximately 1,000 square kilometres, includes the Hosur and Dharmapuri forest divisions and the North Cauvery Wildlife Sanctuary. It is part of Elephant Reserve 7, a protected network for elephant conservation in India, that also includes the Bannerghatta National Park and the Cauvery Wildlife Sanctuaries.

The terrain is highly undulating, with altitudes up to 1,500 meters above mean sea level, and receives annual rainfall ranging from 600 to 1,300 mm. The vegetation is predominantly deciduous to scrub woodland, with riparian patches along streams. The river Cauvery, flowing eastward through the Hosur district, is a critical water source for wildlife and humans, especially during the dry season.

HEC in this region is intense, particularly during the harvest season between January and May, when crop raiding is intensely prevalent. Between 2017-18 and 2020-21, the Hosur range reported 12 human injuries due to elephant encounters, mainly between January and March. From 2011-12 to 2020-21, there were 14 human casualties, with peak incidents occurring between January and May.

3.2 Coimbatore Forest Division

The Coimbatore Forest Division covers an area of 694 km² in the Coimbatore district of Tamil Nadu, India. It is part of the Nilgiris and Eastern Ghats Landscape, which supports the largest population of Asian elephants. This division falls under Elephant Reserve No. 8, in which Nilambur and Silent Valley of Kerala forms the major portion of the tract. The Coimbatore division is divided into six ranges: Sirumugai, Mettupalayam, Karamadai, Perianaickenpalayam (PN Palayam), Coimbatore, and Boluvampatti.

The terrain of the Coimbatore Forest Division varies significantly, with altitudes ranging from 450 meters to 1,986 meters above mean sea level (MSL). The steepest slopes are observed in the Pillur region, where the elevation drops abruptly from 1,530 meters to 450 meters MSL. The Melur slopes, Hulical Durg, and Nellithurai forests are on lower hill mountains. The Boluvampatti hills range from 450 to 530 meters MSL, rising sharply to the crest of the hill range to the north, west, and south, with the Velliangiri Peak reaching a maximum elevation of 1,986 meters MSL.

This division also includes several valleys: Velliankadu Valley, Nayakkan Palayam Valley, Thadagam Valley, Boluvampatti Valley, and Walayar Valley. The Nayakkan Palayam rises sharply from 460 meters to 1,614 meters at Nadukondanboli, forming a confluence point for three valleys. Numerous streams originate from this network and drain into the Bhavani and Noyyal rivers.

The vegetation types in the Coimbatore Forest Division range from tropical thorn forests at the foothills to evergreen forests at higher altitudes, influenced by terrain, altitude, and rainfall. This diverse vegetation supports a rich biodiversity, including a significant elephant population.

From 2021 to 2023, there were 9,028 instances of elephants entering human habitations, with 147 human deaths due to elephant attacks and 176 elephant deaths due to conflicts recorded between 2011 and 2022. The conflict is particularly intense in the Coimbatore range, which lacks natural water bodies.

Hormonal analysis for reproductive cycle monitoring

3.3 Kozhikamuthi elephant camp, Topslip, Anamalai Tiger Reserve

The Anamalai Tiger Reserve lies between latitude 10º 25’ 01’’ N and 10º 41’ 70” N and longitude 77º 03’ 24” E and 77º 05’ 67” E, in the state of Tamil Nadu. The Anamalai Tiger Reserve is contiguous with three sanctuaries, Parambikulam Wildlife Sanctuary to its east, Eravikulam National Park to its west and Chinnar Wildlife Sanctuary to its south. The Anamalai Tiger Reserve is divided into six ranges, and the Kozhikamuthi elephant camp is located in the Ulandy range. It is surrounded by moist deciduous forest and teak plantations.

Currently, the camp is home to 23 elephants, seven females and sixteen males, ranging in age from 10 to 74 years. Their daily diet includes rice, horse gram, ragi, salt, jaggery, sugarcane, coconut, and a mineral mixture.

3.4 Theppakadu elephant camp, Mudumalai Tiger Reserve

Theppakadu elephant camp is situated within the Mudumalai Tiger Reserve, approximately 5 km from Masinagudi. It was established in 1917 by the British to train elephants for timber extraction in the Nilgiris region. The camp serves as a sanctuary for elephants that are orphaned, injured, or have had serious conflicts with humans. The camp has successfully raised 51 calves since its inception, with 32 of them having been reared and given to temples. There are 27 elephants in the camp, comprising seven females and twenty males, aged between 5.5 and 76 years. Their daily diet consists of rice, horse gram, ragi, salt, jaggery, sugarcane, coconut, and a mineral mixture.

3.5 Elephant Rescue and Rehabilitation Centre (ERRC), Trichy

The Elephant Rescue and Rehabilitation Centre (ERRC) in Trichy is located at MR Palayam, a Reserved Forest, 35 km from Trichy, in the Tiruchirappalli Forest Division. The centre was established in 2017 and is equipped with the necessary infrastructure to rehabilitate elephants in distress. With due permission from the Central Zoo Authority of India, the ERRC houses and cares for sick and stressed elephants. The elephants are attended to by mahouts and cavadis deputed from the Anamalai Tiger Reserve. Each elephant is cared for by one mahout and one cavadi. A Forest Veterinary Assistant Surgeon visits the Centre weekly to monitor the elephants' health. Currently, the camp is home to ten female elephants, aged between 24 and 71 years. Their daily diet includes rice, ragi, green gram, horse gram, jaggery, salt, a mineral mixture, turmeric powder, cumin, coconut, sugarcane, fruits and vegetables, tree leaves, and various types of grass, with quantities prescribed individually by the veterinarian.

4. METHODOLOGY

4.1 Secondary data collection

Raw secondary data, including information on human-elephant conflict in Tamil Nadu over the past six years, and elephant population census data from 2022 to 2024, were collected. These data were then organised division-wise and analysed.

4.2 Dung sample collection and processing

Reproductive processes are regulated by steroid hormones, so gaining insight into endocrine responses is vital for the effective management and breeding of wildlife, both in captivity and in the wild. A non-invasive approach to hormone assessment offers multiple benefits compared to invasive sampling methods, which often induce stress due to blood collection and typically require anaesthesia, physical restraint, or direct handling of animals. In contrast, a non-invasive sampling technique involves minimal or no physical interaction, allowing for the safe, stress-free collection of samples, and making it suitable for long-term monitoring.

To monitor the reproductive cycles of camp elephants, fresh dung samples were collected every alternate day over a period of five months, from February to July. In the field, samples were collected in ziplock bags immediately after defecation and placed under a room heater within 2 hours to remove moisture and prevent fungal growth. Each sample was properly labelled with the elephant's name, date, and time of collection.

Complete drying of the dung samples typically required 8–10 hours. Once thoroughly dried, the samples were ground into a fine powder using a mortar and pestle. The powdered samples were stored at room temperature for up to 15 to 20 days before being transferred to the laboratory. Upon arrival, samples were stored in a deep freezer at -20°C for future analysis.

4.3 Extraction of dung samples for ELISA (Enzyme-linked immunosorbent assay) procedure:

- Weigh 0.2 g of the finely powdered dung sample into a 15 ml centrifuge tube.
- Add 5 ml of 80% methanol to each tube and vortex for 10 minutes.
- Store the samples at -4°C overnight.
- After incubation, vortex the samples briefly and then centrifuge for 10 minutes.
- Carefully transfer the supernatant to a labelled microcentrifuge tube and store at -20°C for future analysis.

5. RESULTS

5.1 Human-Elephant Conflict in Tamil Nadu (Secondary data)

The present study identified the Hosur and Coimbatore Forest Divisions as the areas with the highest incidence of human-elephant conflict, based on findings by Shameer *et al.* (2024). Subsequently, secondary data on human-elephant conflict in these divisions from 2022 to 2024 were collected.

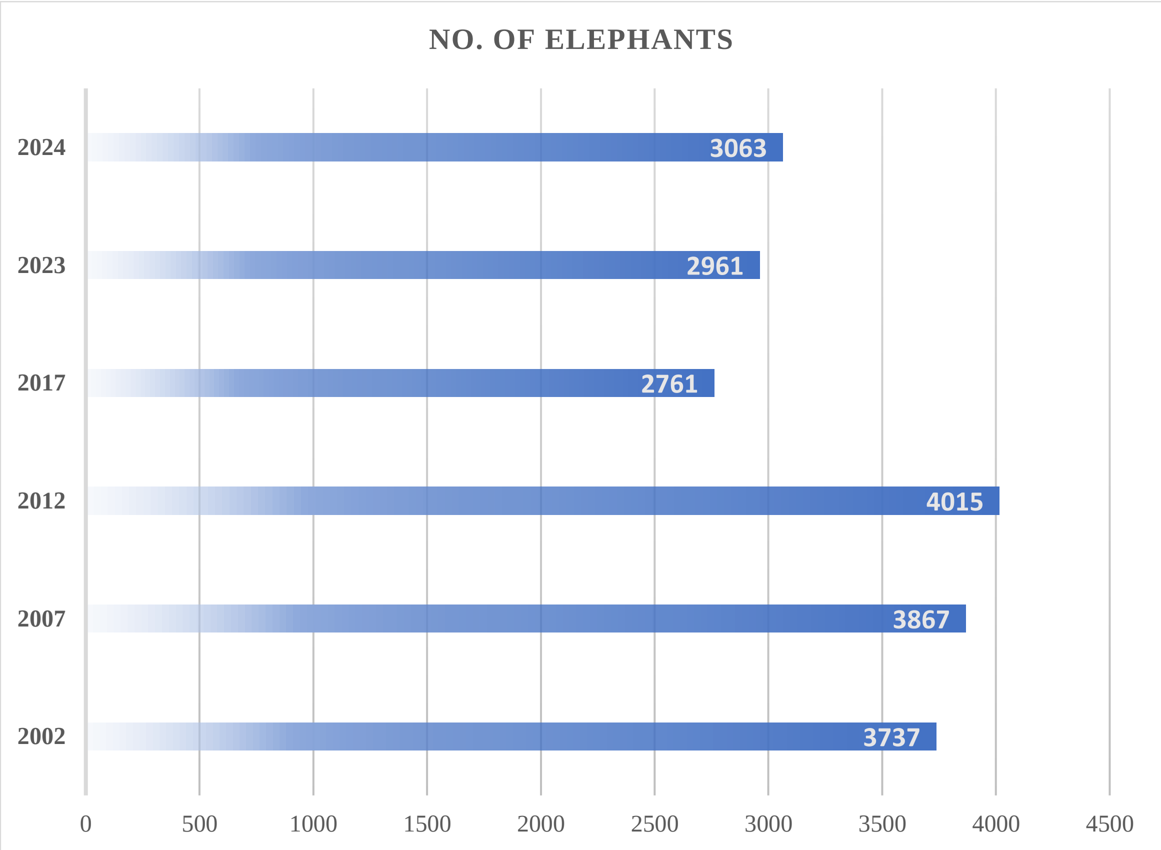


Figure 2: Bar graph showing the Elephant population census data of Tamil Nadu (2002-2024) (Source: Tamil Nadu Forest Department elephant census data (2002-2024))

Intensity of Human Elephant Conflict in Tamil Nadu

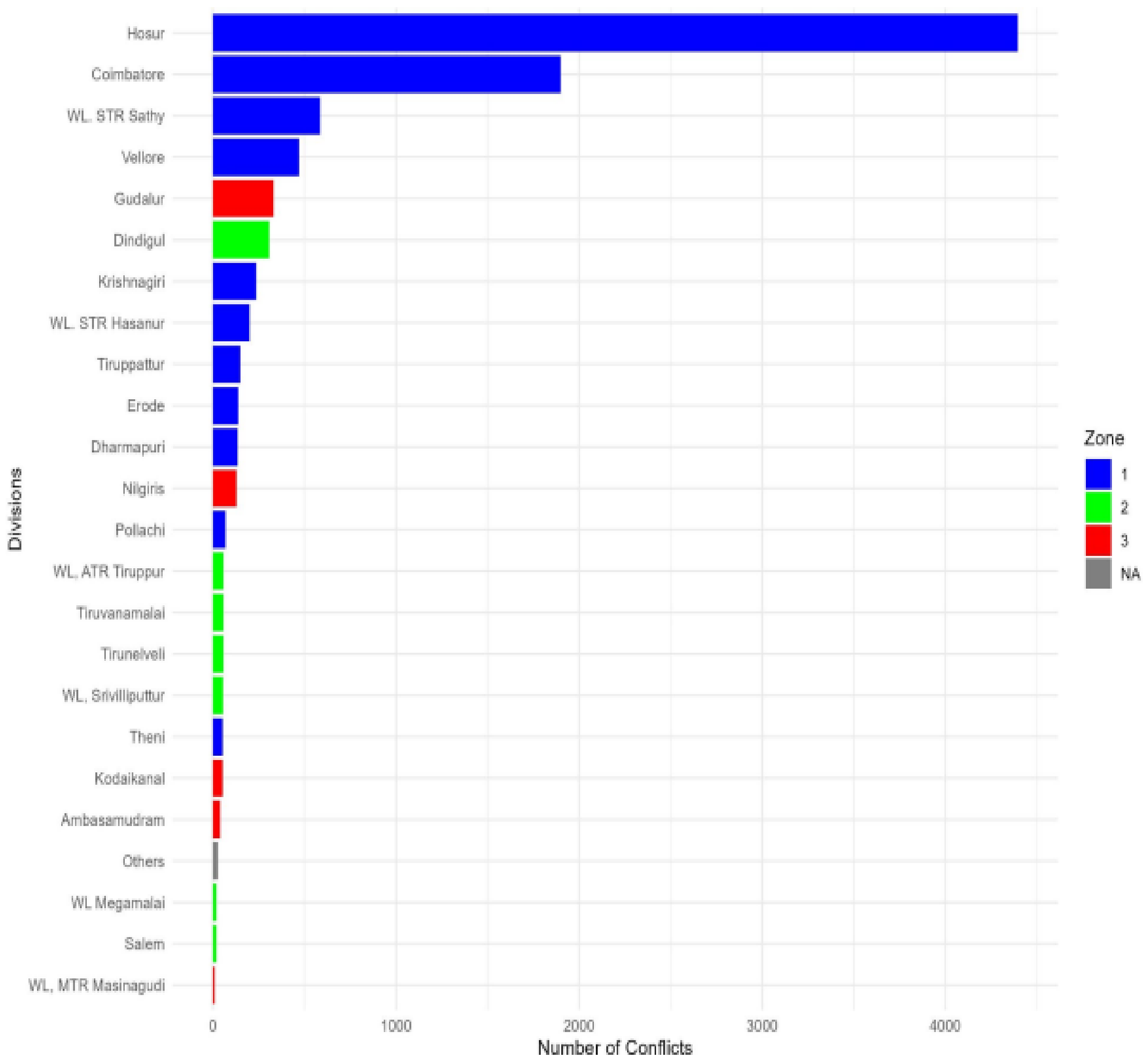


Figure 3: Bar graph showing the frequency of the HEC from 2016-21 in the Forest divisions of Tamil Nadu (Shameer et al. 2024)

Elephant population in Hosur Forest Division

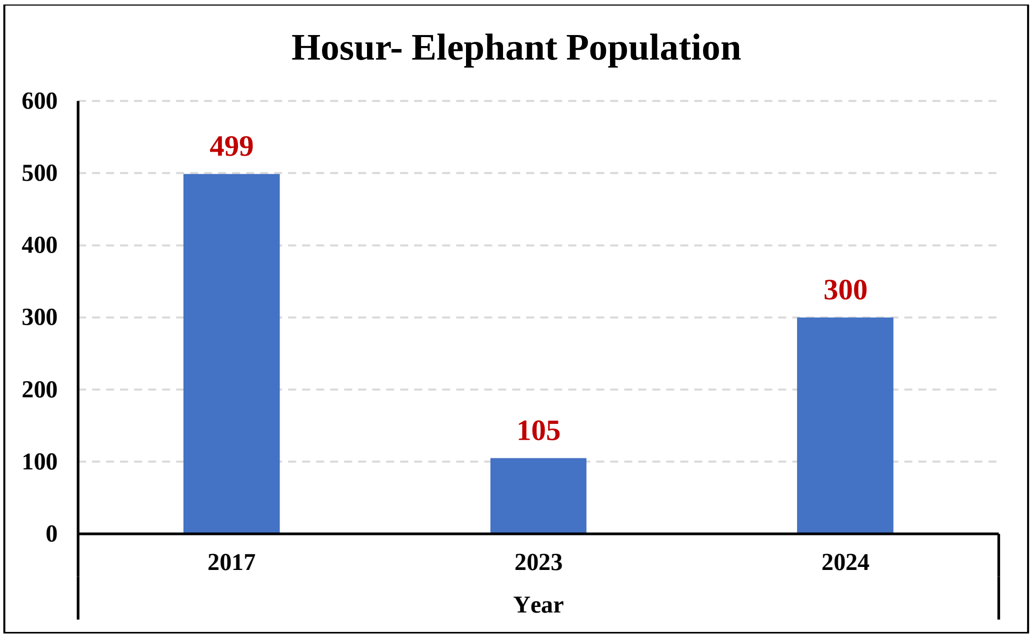


Figure 4: Bar graph showing the elephant population in Hosur Forest Division (2017-2024), (Source: Tamil Nadu Forest Department elephant census data (2017-2024))

Elephant population in Coimbatore Forest Division

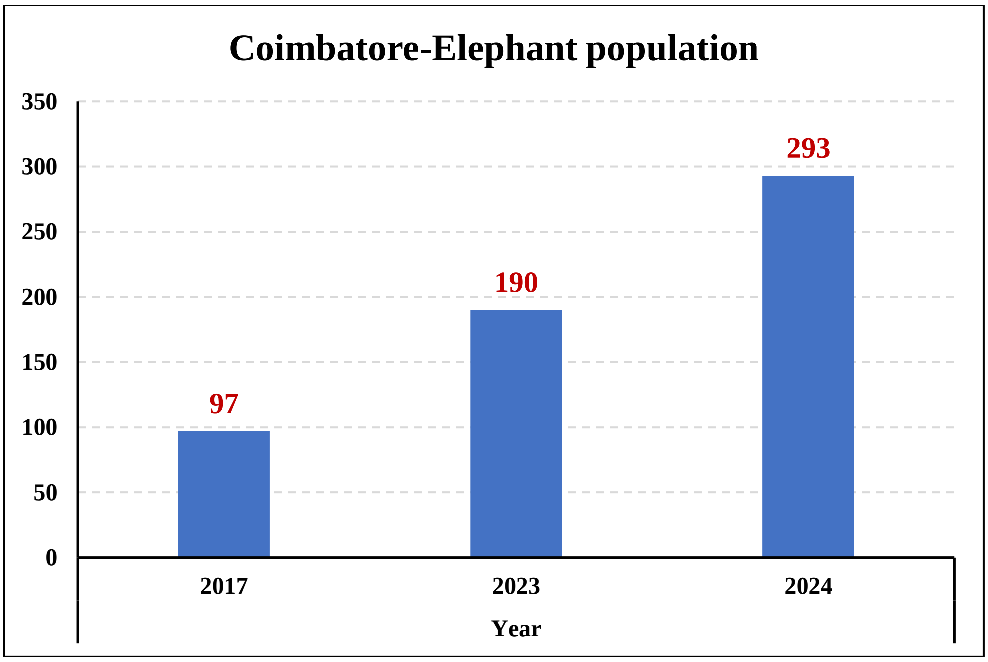


Figure 5: Bar graph showing the elephant population in Coimbatore Forest Division (2017-2024), (Source: Tamil Nadu Forest Department elephant census data (2017-2024))

Combined temporal patterns of Human–Elephant Conflict incidents in Hosur and Coimbatore Forest Divisions

Year	Hosur	Coimbatore
2022	554	45
2023	2993	781
2024	2341	768

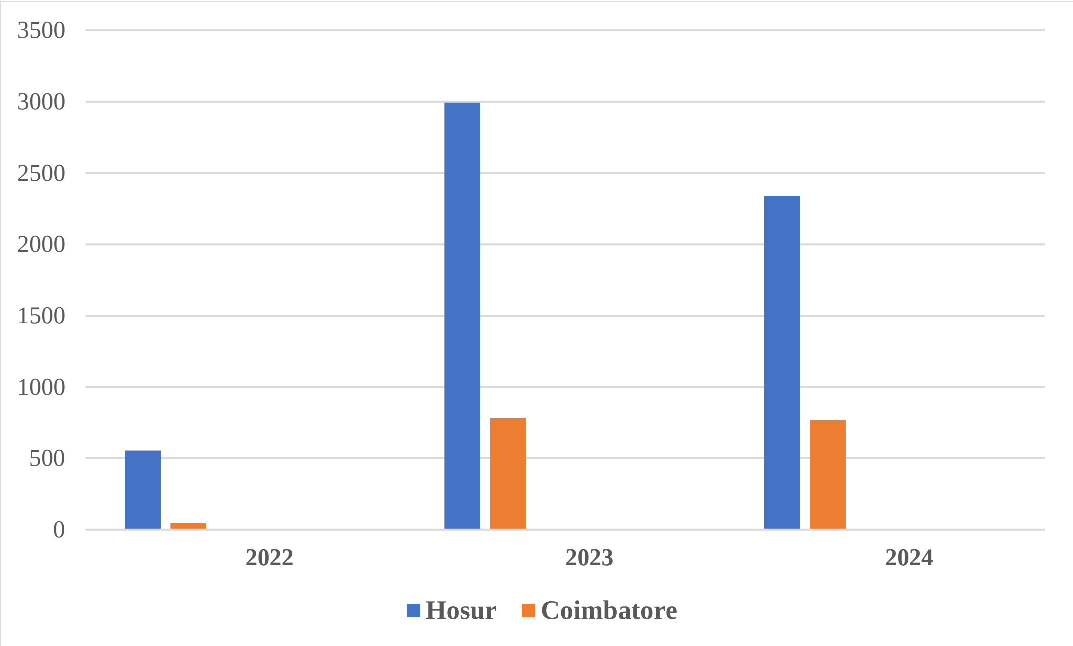


Figure 6: Bar graph showing the combined temporal patterns of HEC incidents in Hosur & Coimbatore FD (2022-2024) (Source: Tamil Nadu Forest Department).

Types of conflicts in Hosur & Coimbatore Forest Divisions

Type of conflicts	Hosur	Coimbatore
Human injury	36	50
Human death	10	29
Animal death	1	1
Crop damage	4896	1288
Property damage	8	91

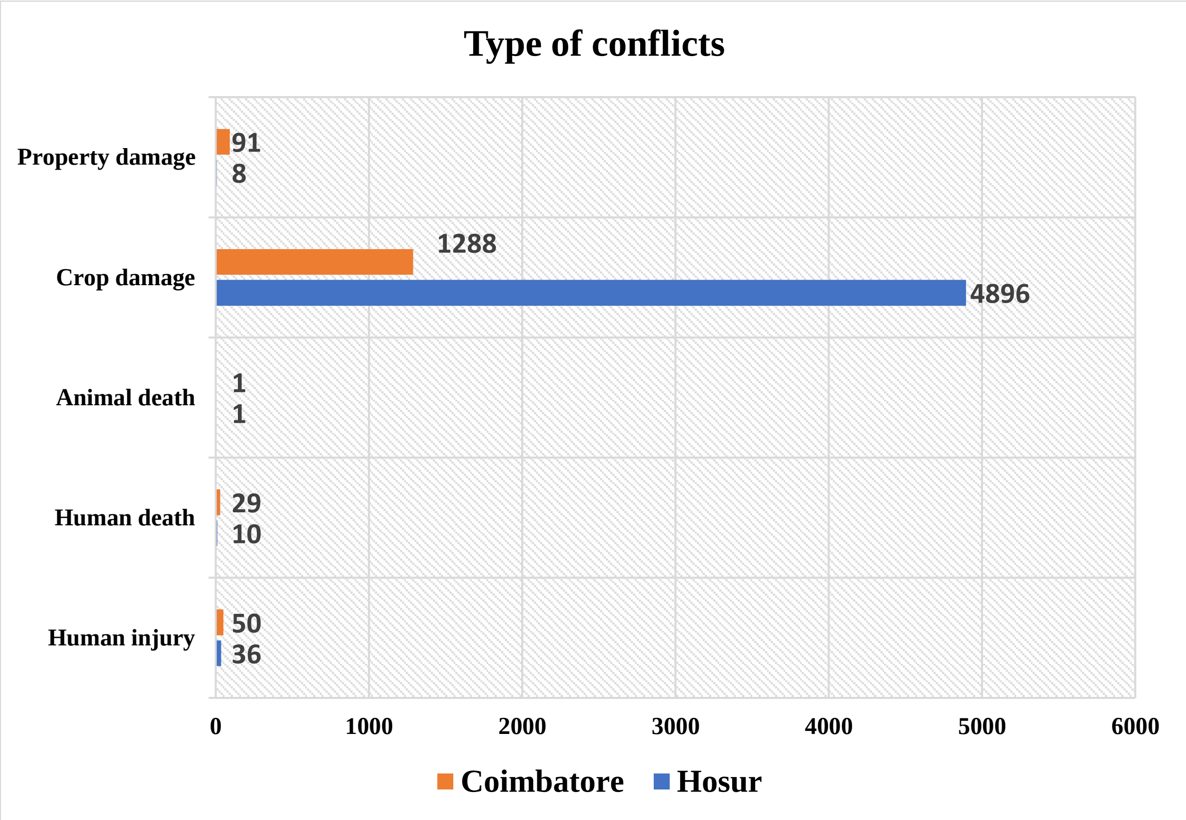


Figure 7: Bar graph showing the types of conflicts in Hosur & Coimbatore FD (2022-2024), (Source: Tamil Nadu Forest Department).

Temporal trend of conflicts in Hosur & Coimbatore Forest Divisions

Hosur FD

Table 1: Table showing the temporal trend of conflicts in Hosur FD (2022-2024) (in percentage) (Source: Tamil Nadu Forest Department).

Year	Human injury	Human death	Animal death	Crop damage	Property damage
2022	0.92%	0%	0%	98.89%	0.18%
2023	0.39%	0%	0%	99.50%	0.12%
2024	0.99%	0.55%	0.06%	98.18%	0.22%

Coimbatore FD

Table 2: Table showing the temporal trend of conflicts in Coimbatore FD (2022-2024) (in percentage) (Source: Tamil Nadu Forest Department).

Year	Human injury	Human death	Animal death	Crop damage	Property damage
2022	0%	0%	0%	92.50%	7.50%
2023	0.30%	0.30%	0%	93.06%	6.35%
2024	4.95%	1.70%	0.14%	86.99%	6.22%

5.2. Reproductive cycle monitoring of camp elephants

Dung samples from three elephant camps were collected between February and July 2025, with sample collection continuing until September 2025 to ensure comprehensive results. Hence, the results presented in this report are based on the data collected from February to July 2025.

Table 3: Details of the camp elephants selected for the study

Sl. No.	Name of the elephant	Name of the camp	Sex	Age (in years)
1.	Senthil Vadivu	MTR	Female	53
2.	Masini	MTR	Female	17
3.	Indra	MTR	Female	28
4.	Sumangala	MTR	Female	36
5.	Durga	ATR	Female	29

6.	Devi	ATR	Female	20
7.	Abinaya	ATR	Female	19
8.	Malachi	ERRC	Female	39
9.	Rupali	ERRC	Female	24
10.	Indu	ERRC	Female	40
11.	Santhiya	ERRC	Female	49
12.	Jayanthi	ERRC	Female	27

Table 4: Processing status of collected samples

Name of elephant camp	Total number of samples collected	No. of samples weighed for ELISA	No. of samples extracted
ERRC	357	244	75
MTR	210	210	66
ATR	93	93	36
Total	**660**	**547**	**177**

6. DISCUSSION

Human-elephant conflict (HEC) poses a growing challenge to biodiversity conservation in Tamil Nadu, particularly as the state's elephant population remains steady or with slight increase while suitable habitat continues to shrink and degrade. The present study examined the combined temporal patterns and types of Human–Elephant Conflict (HEC) incidents in Hosur and Coimbatore Forest Divisions (FD) over a three-year period (2022–2024). The analysis provides valuable insights into the magnitude, nature, and temporal variation of conflicts across the two forest divisions, highlighting spatial differences and management challenges.

The combined temporal analysis revealed a substantial increase in HEC incidents from 2022 to 2023 in both Hosur and Coimbatore Forest Divisions. Hosur FD recorded a sharp rise from 554 incidents in 2022 to 2,993 incidents in 2023, followed by a moderate decline to 2,341 incidents in 2024. A similar pattern was observed in Coimbatore FD, where incidents increased markedly from 45 in 2022 to 781 in 2023 and remained consistently high in 2024 (768 incidents). The pronounced spike in 2023 may be attributed to multiple interacting factors, including increased elephant movement outside forest boundaries, expansion of agriculture near forest fringes and seasonal crop availability. The slight decline in Hosur FD during 2024 suggests that mitigation measures, early warning systems, or adaptive management strategies may have contributed to reducing conflict intensity, although the overall number of incidents remains considerably high. Notably, Hosur FD consistently reported a significantly higher number of conflict incidents compared to Coimbatore FD from 2022 to 2024.

Crop damage emerged as the predominant form of conflict in both forest divisions, accounting for the vast majority of incidents. Hosur FD recorded 4,896 cases of crop damage, while Coimbatore FD reported 1,288 cases during the study period. This dominance underscores agriculture as the primary interface for conflict and reflects elephants' preference for nutrient-dense cultivated crops, particularly during periods of food scarcity in forests.

Human injuries and deaths, though relatively fewer in number, represent serious socio-economic and conservation concerns. Coimbatore FD reported higher instances of human injury (50) and human death (29) compared to Hosur FD (36 injuries and 10 deaths). Property damage incidents were notably higher in Coimbatore FD (91 cases) than in Hosur FD (8 cases), suggesting differences in housing proximity to forest edges, construction types, or elephant movement corridors. The temporal trend analysis further revealed that crop damage consistently constituted over 98% of conflict incidents in Hosur FD across all three years. Human injuries and fatalities showed a slight increase in 2024, alongside the occurrence of the first recorded animal death, indicating a potential escalation in conflict severity in recent years. In Coimbatore FD, crop damage also dominated but showed a declining trend in percentage terms by 2024 (86.99%), accompanied by a noticeable rise in human injuries (4.95%) and deaths (1.70%).

The present project explores immunocontraception as a novel population management tool for wild elephants in Tamil Nadu. This approach, particularly through the administration of porcine zona pellucida (pZP)-based vaccines, has demonstrated significant success across multiple species worldwide, including African elephants (Perdok *et al.*, 2007). This method offers a humane, reversible and minimally invasive approach, and has demonstrated over 90% efficacy in reducing fertility in female elephants without disrupting social behavior or causing physiological harm (Kirkpatrick *et al*., 2009). Its successful application in 43 wildlife reserves across South Africa, including long-term studies using SpayVac®, reinforces its potential as a sustainable and ethical alternative to traditional population control measures such as translocation or culling (Bechert & Fraker, 2016).

In Tamil Nadu, this project is pioneering in evaluating the feasibility and safety of pZP-based immunocontraceptive vaccines in camp elephants, initiating the first controlled trial of its kind in India. Using captive elephants as an initial test group enables close and consistent monitoring of reproductive hormones, behavioral responses, and immunological responses before exploring large-scale implementation in wild populations. The project also recognizes that the success of immunocontraception in African elephants cannot be applied directly to Asian elephants due to differences in physiology, social structure and ecological conditions.

Furthermore, immunocontraceptive strategies have the advantage of preserving elephant social structures, a crucial factor in Asian elephant societies, were matriarchal leadership and family cohesion influence ranging patterns and behavior. Unlike GnRH-based contraceptive methods that may disrupt estrous cycles and lead to social instability, pZP vaccines allow females to continue cycling normally, thus reducing the risk of behavioral disturbances. This balance of efficacy, reversibility and social compatibility positions immunocontraception as a scientifically sound and ecologically responsible strategy for managing conflict-prone elephant populations in Tamil Nadu.

Despite its potential, several challenges remain in implementing immunocontraception for elephant population management. The requirement for annual booster doses in conventional pZP protocols presents significant logistical and financial hurdles, particularly in forested landscapes were locating and tracking wild elephants is difficult. The development of SpayVac®, a single-dose, long-term formulation, offers a promising solution to this challenge;

however, its efficacy and safety in Asian elephants still require thorough validation through controlled studies.

Moreover, the current project is still in its early phase, with sample collection and reproductive monitoring ongoing. A more comprehensive understanding of baseline hormone levels, estrous cyclicity, and immune responses in camp elephants is essential to inform appropriate dosage, delivery protocols, and timing. Furthermore, post-vaccination monitoring will also be critical to evaluate the reversibility of the vaccine, any long-term health effects, and behavioral changes.

In the broader conservation landscape, immunocontraception must be viewed not as a standalone solution but rather as a complementary component of an integrated human-elephant conflict mitigation strategy. Habitat restoration, corridor connectivity, participatory land-use planning, and community-based conflict management must accompany any population control initiative. The real strength of immunocontraception lies in its ability to stabilize elephant population growth in high conflict areas, thereby creating the necessary buffer of time and space for long term ecological, social and policy interventions to take root and deliver sustainable solutions for both elephants and local communities.

7. FUTURE ACTION PLAN

7.1 Project Immunocontraception: Phase II

Zona Pellucida Immunisation (ZPI) Trial in camp elephants:

Progesterone hormone analysis using ELISA will be conducted on dung samples collected from twelve (12) elephants to assess reproductive cycles. Based on the results, four to five (4–5) female elephants with regular reproductive cycles will be selected for pZP vaccination *Baseline Health Assessment:* Pre- and Post-vaccination, haematological and serum biochemical analyses will be conducted to establish baseline health parameters.

- *Stress Assessment:* Cortisol levels will be analyzed to understand the stress levels in each individual elephant before and after vaccination.
- *Vaccination and Monitoring*: The Porcine Zona Pellucida (pZP) vaccine will be administered to four to five selected female elephants exhibiting healthy and regular reproductive cycles. One female elephant will be maintained as an unvaccinated control for comparison.
- Fresh dung samples will be collected weekly for the first 8 weeks. Every 2 weeks for the next 8 weeks, and finally monthly for an additional 5 months to evaluate the contraceptive efficiency of the vaccine.
- *Test the vaccine efficiency:* After vaccination, pregnancy tests need to be carried out every three months to assess the contraceptive efficacy of the vaccine, particularly after the mating of vaccinated females with male elephants.

- *Health monitoring*: Regular health assessments and behavioral observations will be conducted to ensure the health and safety of the elephants throughout the trial. Follow-up evaluations will also be conducted to assess the efficacy and duration of the contraceptive effect.
- *SOP development and implementation*: As the pZP vaccine (SpayVac) is known to provide contraceptive efficacy for five to six years in African elephants, Forest Veterinarians at the relevant elephant camps will continue to monitor the vaccine's efficacy after the first year. Based on these observations, standardized protocols and operational guidelines will then be developed for the potential application of the vaccine in wild elephants of Tamil Nadu as a long-term strategy to mitigate Human–Elephant Conflict.

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9. APPENDIX-1

Table 1: Diet schedule for the selected camp elephants in Ulandy range at Topslip, Anamalai Tiger Reserve, Pollachi

S. No	Name of the Elephant	Age and Sex	Weight as on Dec24	Horse gram (Kg)	Rice (Kg)	Ragi (kg)	Salt	Jaggery (Kg)	Sugarcane kg	Coconut	Min Mix	Horse gram (kg)	Ragi Kg	Salt Kg	Jaggery Kg	Sugar cane	Coconut	Rice Kg.	Min Mix
1	Durga	29 / F	3.205	0	0	0	0	0	0	0	0	3	14	0.100	0.100	2	2	4	0.100
2	Devi	20/F		0	0	0	0	0	0	0	0	3	14	0.100	0.100	2	2	3	0.100
3	Abinaya	19 /F	2.590	0	0	0	0	0	0	0	0	3	12	0.100	0.100	2	4	4	0.150

Table 2: Diet Schedule for the Elephants Maintained at Mudumalai Tiger Reserve (Work diet)

S. No	Name of the elephant	Sex & Age	Horse Gram (Kg)	Ragi (Kg)	Rice (Kg)	Salt (Gm)	Jaggery (Gm)	Mineral Mixture (Gm)	Coconut (Nos)	Sugar cane (Nos)
1	Indra	F/ 28	4	8	2	150	120	100	2	2
2	Sumangala	F/37	4	12	2	150	120	100	2	2
3	Masini	F/17	4	10	4	150	120	100	2	2
4	Senthilvadivu	F/53	4	8	6	150	120	100	2	2

Table 3: Diet schedule for the selected camp elephants maintained at the Elephant Rehabilitation Centre, M.R Palayam, Tiruchirappalli Forest Division

Sl. No	Name of the elephant	Sex & Age	Weight	Rice (kg)	Ragi (kg)	Green gram (kg)	Horse gram (kg)	Jaggery (g)	Salt (g)	Mineral Mixture (g)	Turmeric powder (g)	Cumin (g)	coconut (Nos)	Sugar cane (Nos)	Fruits & Vegetables (kg)	Tree leaves (kg)	Grass items (kg)
1	Malachi	39/F	3850	4.00	12.00	2.00	3.00	0.100	0.100	0.200	0.050	0.050	2	2	30-40	60	120
2	Rupali	24/F	3900	4.00	10.00	2.00	3.00	0.100	0.100	0.200	0.050	0.05	2	2	30-40	70	140
3	Indu	40/F	3500	4.00	12.00	2.00	2.00	0.100	0.100	0.200	0.050	0.050	2	2	30-40	60	120
4	Santhiya	49/F	3480	4.00	12.00	2.00	3.00	0.100	0.100	0.200	0.050	0.050	2	2	30-40	60	120
5	Jayanthi	27/F	4000	4.00	12.00	2.00	3.00	0.100	0.100	0.200	0.050	0.050	2	2	30-40	60	120

Tamil Nadu Forest Department
Advanced Institute for Wildlife Conservation
(Research, Training & Education)
Vandalur, Chennai - 600 048

Contact

Office of the Principal Chief Conservator of Forests & Director
Advanced Institute for Wildlife Conservation
(Research, Training & Education)
Tamil Nadu Forest Department
Vandalur, Chennai, Tamil Nadu- 600048
Phone: 044-29872331.

@Aiwcrteofficial Aiwc_vandalur aiwcrte@tn.gov.in

www.aiwc.res.in