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The Elephant in the Room: Methods, Challenges and Concerns in the Monitoring of Asian Elephant Populations

Sreedhar Vijayakrishnan[1, 2,3]*, Mavatur Ananda Kumar[2] and Anindya Sinha[1,4,5,6]

[1]*National Institute of Advanced Studies, Bangalore, Karnataka, India*
[2]*Nature Conservation Foundation, Mysuru, Karnataka, India*
[3]*Manipal Academy of Higher Education, Manipal, Karnataka, India*
[4]*Indian Institute of Science Education and Research Kolkata, Mohanpur, West Bengal, India*
[5]*Cotton University, Guwahati, Assam, India*
[6]*Centre for Wildlife Studies, Bangalore, Karnataka, India*
**Corresponding author's e-mail: sreedhar@ncf-india.org*

Abstract. Increasing anthropogenic pressures has led to the fragmentation of Asian elephant habitats, affecting their numbers, demography and ranging patterns across their range. Baseline information on the demography and population dynamics of free-ranging Asian elephants is often unavailable. Population monitoring at the landscape level has many constraints, including those of visibility, habitat, terrain and field logistics, among several others. While knowing elephant numbers may be important for managing local populations, demographic parameters and distribution patterns are perhaps more crucial to ascertain long-term trends for conservation.

Introduction

The Asian elephant (*Elephas maximus*) is classified as endangered by the IUCN (Choudhury *et al*. 2008). Persistent poaching across several landscapes contributes to selective removal of males (Blake & Hedges 2004) while recent reports of poaching for skin suggests additional emerging threats. Asian elephant landscapes are increasingly encroached upon, leading to extensive habitat loss and fragmentation (Leimgruber *et al*. 2003). Habitat availability for the species has, in fact, almost halved over the past few decades (Choudhury *et al*. 2008).

In highly populated countries like India and Sri Lanka, around 60–70% of elephants share space with humans, mostly in modified landscapes (Madhusudan *et al*. 2015; Fernando *et al*. in press). This has resulted in increased encounters and interactions, most of which tends to be negative. Thus, conservation efforts need to extend beyond protected areas and into human-dominated landscapes that are increasingly becoming critically important for the conservation of Asian elephants (Madhusudan *et al*. 2015).

Despite decades of research on Asian elephants, information on their distribution, numbers, demography and behaviour remain unavailable across most landscapes (Blake & Hedges 2004; Gray *et al*. 2014; Madhusudan *et al*. 2015). Such information is, however, vital for the long-term conservation of the species, especially in two of its major strongholds: India and Sri Lanka (de Silva *et al*. 2011; Jathanna *et al*. 2015). The paucity of information is primarily due to visibility constraints in most Asian elephant landscapes, which, unlike the African savannahs, are often densely vegetated with deciduous to evergreen forests. Problems in detectability can significantly downgrade density estimates (Karanth & Nichols 1998) and affect observational studies on elephant populations.

As conservation interventions depend heavily on effective monitoring techniques, there is an urgent need to develop reliable techniques and evaluate their applicability across landscapes and vegetation types. Although population-monitoring techniques have improved in recent years, there continues to be a reliance on a few direct methods and on dung counts, primarily

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owing to the unavailability of trained personnel and logistical constraints associated with other techniques, described later in this paper. Moreover, while these traditional methods are usually applicable across a wide range of landscapes, newer methods, such as photographic cataloguing that effectively estimates numbers of elephants (Goswami *et al*. 2019), or alternate approaches, such as assessing elephant distribution through questionnaire surveys (Fernando *et al*. in press), may have wider applications.

In this perspective paper, we outline some of the more important challenges that confront the currently employed elephant population evaluation techniques. We believe that acknowledging some of these constraints may allow for more effectively designed population-monitoring exercises, which could contribute to informed decisions on the management and conservation of elephant populations in the future.

Censusing elephants

The counting of elephants is an exercise widely prioritised across elephant range states. Routine population monitoring, however, is limited by the feasibility of large-scale surveys and methodological sampling constraints in obtaining reliably comprehensive estimates. Depending on whether the counts are made based on direct sightings of the animals and recording their numbers or estimating the same from animal signs, population estimation techniques have been classified as direct and indirect respectively. The direct methods that have been improvised and implemented for elephant population monitoring include line-transect surveys (Jathanna *et al*. 2003; Kumara *et al*. 2012), total block counts, waterhole counts, simultaneous observer counts (foot counts) and vehicle road counts while the indirect sign-based abundance estimations include dung counts (Kumaraguru *et al*. 2010; Baskaran *et al*. 2013) and DNA-based capture-recapture surveys (Chakraborty *et al*. 2014; Gray *et al*. 2014).

Direct sighting methods

The direct methods commonly deployed include line-transect surveys, block counts, waterhole counts, and photographic cataloguing-based capture-recapture surveys. These are primarily adopted in areas where vegetation is relatively sparse, allowing better sighting of animals. Most direct sighting techniques are labour-intensive, however, and require trained personnel. Some of the more commonly adopted direct survey methods are discussed here.

Line transects

Line-transect surveys continue to be one of the most widely accepted and reliable methods for population monitoring of elephants across their range (Varman & Sukumar 1995; Buckland *et al*. 2001; Kumara *et al*. 2012). Synchronised elephant surveys, carried out at the national level by the Project Elephant in India, for instance, rely primarily on this technique (MoEF & CC 2017). Line-transect surveys involve two or more surveyors walking along paths of fixed length, recording species sightings, along with other parameters, such as sighting angle and distance, to arrive at the perpendicular distance of the animal from the surveyor (Varman & Sukumar 1995; Kumara *et al*. 2012).

Although the method provides reliable estimates of distribution and population characteristics (Jathanna *et al*. 2015), it requires the involvement of large groups of trained volunteers to ensure large spatial coverage. The management and coordination of high numbers of volunteers could, however, pose logistic difficulties. While this particular method is fairly robust, it is difficult to execute in undulating and hilly terrains or in habitats with closed vegetation, where the laying of linear transects is a challenge. Poor visibility and detection problems could further bias estimates. To arrive at robust estimates, a minimum of 60–80 detections is usually required (Buckland *et al*. 2001) and this may be difficult to achieve in many tropical habitats, especially evergreen forests with dense vegetation and low densities of elephants.

Block counts

In the block-count method, surveyors typically walk in a zigzag manner and record all elephant sightings within a sampling unit, called a block; these are often defined and demarcated a priori by the surveyors themselves. While the method assumes perfect detectability, not all individuals within a block get detected during surveys, thereby violating its underlying assumption (Jathanna *et al*. 2015). This method is logistically convenient, especially for government forest departments, owing to their familiarity with an area but such surveys in habitats, without systematic stratification, could significantly bias estimates (Kumara *et al*. 2012). For instance, blocks may not even spatially cover the different habitat types across particular landscapes, owing to improper placement of the sampling units.

Waterhole counts

Waterhole counts, where surveyors remain stationary near water bodies counting all elephants that visit the area, reflect an inherent bias in its sampling approach. Many dry habitats across elephant ranges are today dotted with numerous human-made water sources, leading to enhanced congregations of elephants (Dzinotizei *et al*. 2019) and enhanced estimates of their densities. Moreover, waterhole counts are often practised in areas where natural water sources, such as streams, are aplenty and elephants do not necessarily frequent waterholes. In fact, elephants are known to preferentially use natural water bodies, such as streams or rivers, in dry forests (Pastorini *et al*. 2010; Lakshminarayanan *et al*. 2015) or dry streambeds to access subsoil moisture (Sukumar 1989). The failure to take these behavioural strategies into account while planning surveys thus leads to the appearance of systematic biases in waterhole counts.

Photo-based capture-mark-recapture surveys

Photographing elephants to build a database and assessing their population size through capture-recapture techniques have increasingly gained momentum in recent years (Goswami *et al*. 2007, 2019; de Silva *et al*. 2011). This method helps obtain robust estimates, provided there is adequate spatial coverage of the landscape and the various assumptions of the capture-recapture models are verified and accounted for. Considering the large-scale distribution of elephants in closed habitats across tropical Asia, however, the applicability of this method is restricted only to certain areas, where individual elephants can be conveniently photographed, within typically expansive elephant habitats.

Indirect counting methods

In the wake of difficulties encountered with direct sighting-based methods, indirect sign-based surveys have often been adopted to estimate elephant counts. The most widely used of these methods include dung count surveys, DNA-based capture-recapture techniques and camera-trap-based monitoring exercises.

Dung count surveys

Dung surveys are one of the most commonly adopted techniques across tropical Asia, typically in areas constrained by direct visibility of elephants and characterised by low-density populations. Dung-based density estimates rely primarily on three components: dung encounter rates, defecation rates and dung decay rates. Dung encounter rates are primarily determined by dung deposition rates and the disintegration of dung piles. A range of abiotic and biotic factors, such as temperature, rainfall, humidity, shade, animal activity and various anthropogenic disturbances influence dung encounter rates (Dawson 1993; Barnes 2001; Nchanji & Plumptre 2001; Breuer & Hockemba 2007; Pastorini *et al*. 2007; Baskaran *et al*. 2013). Single-site estimations of dung decay rates, used in population estimations, can affect density estimates (Nchanji & Plumptre 2001), warranting site-specific assessments. Additionally, the standardisation of the method by using defecation rates of captive elephants rather than from those in the field could influence the final estimates. Similarly, dung production, defecation rates and dung decay characteristics in a particular landscape are all strongly dependent on seasonality, type of diet, representative age classes of the elephants, their overall health as well as on certain abiotic factors, such as water availability in the area (Nchanji *et al*. 2008). Theuerkauf & Gula (2010) discuss how seasonality and rainfall can be accounted for by extensive sampling in the dry season, although there could well be seasonal influences on the use of certain habitats by elephants.

DNA-based capture-recapture surveys

DNA-based estimations of elephant population characteristics involve dung sample collection and individual identification in a capture-recapture framework (Hedges *et al*. 2013; Chakraborty *et al*. 2014; Gray *et al*. 2014). While this method usually generates reliable estimates once dedicated laboratories with skilled technicians are able to standardise the molecular techniques, it is largely applicable to small elephant populations and areas with low animal densities. It is usually difficult to implement over large areas with high elephant densities, primarily owing to the costs involved. The other constraints typically involve the logistics of collection, handling and storage of dung in the field, which would ensure the availability of non-degraded, uncontaminated faecal samples for sound laboratory analyses.

Camera-trap-based monitoring

Varma *et al*. (2006) discuss the use of camera traps for large-scale population monitoring of elephants. This method has also been used to understand crop-raiding patterns, demography of populations in human-use areas and social behaviour (Ranjeewa *et al*. 2015; Smit *et al*. 2019; Srinivasaiah *et al*. 2019). A critical aspect of camera-trap surveys is the right placement of the units to get usable pictures (Varma *et al*. 2006). This is evident from the large number of generally uninformative elephant images that are produced by camera traps that monitor other sympatric species across protected areas. The rather elaborate process involved in its execution, its labour-intensive nature and often the low-capture rates obtained, accompanied by the high costs involved, could limit the application of this method to relatively restricted areas and small elephant populations. Camera traps can, however, be useful in areas with extremely low animal densities and difficult terrains (Moolman *et al*. 2019).

Population monitoring: Size, structure or dynamics?

One of the primary objectives of elephant population estimation, routinely carried out across range countries, is to understand how the populations are responding to increasing anthropogenic pressures and to understand their changing ranging patterns (Nichols & Karanth 2012; Jathanna *et al*. 2015; MoEF & CC 2017). The loss of elephants to threats such as poaching for ivory or the recent increase in the demand for elephant skin in southeast Asia (Sampson *et al*. 2018) warrant regular monitoring. Poaching for ivory has also led to skewed sex ratios (Sukumar *et al*. 1998) and increase in numbers of tuskless males in certain populations (Sukumar 2003). Baskaran *et al*. (2013) have also reported a significant female bias amongst individuals in the older age classes in the Anamalai landscape of the Western Ghats, indicating a possibly targeted removal of males in the past, as has been described from other landscapes as well (Kumara *et al*. 2012).

In addition to population estimates, therefore, it may also be vital to evaluate the demographic responses of populations to various ecological pressures, as changes in certain demographic parameters allow for the prediction of population fluctuations, including the possibilities of local extinction (Caswell 2000; González *et al*. 2013). Although, globally, various studies have demonstrated the behavioural plasticity of different species populations (Hockings *et al*. 2015), including those of Asian elephants (Srinivasaiah *et al*. 2019), which may allow them to successfully adapt to current anthropogenic regimes, their long-term survival appears to be bleak. Demographic declines have already been documented in several taxa, ranging from insects (Habel *et al*. 2019; Janzen & Hallwachs 2019), amphibians and reptiles (Falaschi *et al*. 2019; Hill *et al*. 2019) to birds (Lee & Bond 2015; Haché *et al*. 2016) and large mammals (Hervieux *et al*. 2013; Hockings *et al*. 2015). Such declines, unfortunately, remain unknown for large-bodied species like Asian elephants, in which demographic changes can be further pronounced due to relatively longer life-history processes.

Abundance estimates: Is just counting elephants enough?

Issues with extrapolation

Population estimation exercises typically provide density estimates for the sampling areas alone and not exact numbers of elephants, which require further extrapolation. The landscape features and distribution patterns of elephants, however, confound such estimations (Baskaran *et al.* 2013). Issues of extrapolation thus constitute an important concern when population estimations are conducted. Similarly, a unified approach in estimating critically important population parameters is still to be arrived at, although synchronised surveys are regularly conducted across elephant range countries. The differences in spatial scales at which surveys are generally executed and the varying methodologies adopted thus often make comparative analyses difficult, as, for example, in the case of the Anamalai elephant populations, for which variable estimates have been obtained by different studies (Sukumar *et al.* 1998; Leimgruber *et al.* 2003; Baskaran *et al.* 2013). Elephant distributions at the landscape level often tend to be non-uniform, especially in large, contiguous, often heterogeneous landscapes, such as those in the Western Ghats, with elephants not using several of its mountainous slopes and human-populated valleys. These problems thus need to be addressed by conducting rigorous surveys that would first effectively establish the distribution patterns of the concerned elephant populations across their range.

Understanding fine-scale distribution patterns of elephants

Although one of the most studied of all mammalian species, our understanding of the fine-scale distribution patterns of Asian elephants still remains limited. The available information on elephant distribution patterns across Asian countries have predominantly been located within protected areas, largely ignoring groups or individuals outside parks (Baskaran *et al.* 2013; Fernando & Pastorini 2011). Several recent studies have, however, considered wide-ranging elephant groups or individuals that often use the matrix of human-dominated areas outside parks while mapping their distribution (Madhusudan *et al.* 2015; Fernando *et al.* in press). The human-dominated Valparai plateau, which forms part of the Anamalai Tiger Reserve in the Anamalai hills of southern India, for example, supports about 100–120 elephants annually (Kumar *et al.* 2010) but is typically ignored during the annual population estimation exercise in the reserve; about 5% of the resident elephant population of the region is thus never evaluated. Mapping such populations is nevertheless crucial, as the prevailing human-elephant conflict could significantly threaten the persistence of some of these unaccounted groups in the long term. Long-term monitoring and reliable mapping exercises could also reveal potential range expansion or reduction over time, as has been observed in certain populations in Sri Lanka (Fernando *et al.* in press).

Conclusions

Asian elephant populations are subject to a wide range of influences that threaten their very survival across their distribution range. These could be direct threats like poaching and conflict-related mortalities, or more indirect ones, such as certain management measures, including drives and captures. Indiscriminate drives, followed by the subsequent confinement of individuals in protected areas, leading to increased competition and eventual mortality of large numbers of elephants, as has happened in Sri Lanka, is an example of such persecution (Fernando 2015). In India, population control measures, including immunocontraception, are now being suggested to attempt the mitigation of rapidly rising negative interactions between elephants and humans across their shared habitats. These practices are reminiscent of those being implemented in African elephant populations that are now largely being maintained within private game reserves with their numbers managed through selective culling and immunocontraception (Pimm & van Aarde 2001).

Reliable countrywide estimates should be made available prior to consideration of such strategies.

There is also no conclusive evidence that increased instances of human-elephant conflict are related to an increase in elephant numbers. Increase in conflict instances is possibly more a reflection of changing distribution and ranging patterns of the species.

Given that certain management interventions have direct bearing on elephant populations, their long-term monitoring becomes crucially important, particularly to take informed decisions in conservation policies. Our own personal observations and a review of the existing literature indicate that there is no single method that can be reliably applied across landscapes while stand-alone survey techniques may not work as well, even at finer landscape levels. Madhusudan *et al*. (2015), on the other hand, ably demonstrate how data from various sources, ranging from systematic surveys to newspaper or other informal reports, can be used to successfully map elephant distributions over large regions. Camera-trap- or sign-based abundance estimates and distribution mapping could similarly be coupled with questionnaire surveys (Fernando et al. *in press*), especially outside protected areas. Different sources of information, therefore, collectively contribute to our knowledge of elephant populations across large swathes of particular landscapes.

With the rapid growth of serious public interest in the survival threats being faced by wildlife in many habitat countries, citizen-science initiatives need to be urgently harnessed to acquire functional information as well as formulate participatory conservation strategies for many threatened taxa and their populations (SoIB 2020). In the case of Asian elephants, such citizen-sourced information could aid the long-term tracking of individual elephants across local habitats and also contribute to the building up of behavioural databases on individual elephants that interact with human communities over the larger landscape.

We also strongly believe that setting up of long-term scientific monitoring stations/groups in critical and important areas across elephant ranges may help better understand the structure and dynamics of local populations in the long term. Finally, informal observation networks can cumulatively produce meaningful group-level data that can be used to understand the structure and dynamics of elephant populations across entire landscapes (Araujo *et al*. 2017).

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