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*Research Article*

# Drivers of Change in Myanmar's Wild Elephant Distribution

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**Abstract**

Myanmar is considered as a stronghold for wild elephants, though past estimates varied widely from 3,000 to 10,000. Results of a 2004 expert workshop showed estimates between 1,430 and 2,065. Building on surveys from 1990 to 1992, we conducted new expert interviews in townships throughout the range, with questions focusing on numbers of elephants living in townships and threats to and from elephants. We used general linear models to analyze characteristics of townships with and without elephants and to understand factors influencing changes in elephant presence. Our results show a major decrease in the geographic distribution of wild elephants in Myanmar between 1992 and 2006 with deforestation being the major driver. While forest cover is important for elephant presence, continuity with other elephant populations had a stonger influence on elephant persistence between surveys. Fragmentation of elephant populations is also a major driver of decline. Increases in forest cover increased elephant presence, while increases in edge and human population had the reverse effect. Deforestation and fragmentation lead to increased human–elephant conflict in some areas, sometimes concluding with the capture of elephants for timber operations and further draining wild populations. A national elephant action plan that includes monitoring of elephant status and threats is urgently needed and critical for Myanmar's wild elephants, particularly as more than 50 years of political isolation are rapidly ending and pressure on the country's natural resources is increasing exponentially.

**Keywords**

Asian elephants, geographic distribution, Myanmar, habitat loss, deforestation, edge effects

## Introduction

Asian elephants are a flagship for endangered species, inspiring intensive conservation effort and attention (Blake & Hedges, 2004; Fernando & Pastorini, 2011; Hedges, Fisher, & Rose, 2009). Yet, the species has long been declining throughout Asia because of loss and degradation of important habitats and the resulting severe human–elephant conflict (Blake & Hedges, 2004; Fernando & Pastorini, 2011; Leimgruber et al., 2003; Sukumar & Santiapillai, 1996). Detailed field data on elephant presence and distribution can be hard to come by, partly due to the difficulty in systematically surveying elephant populations (Blake & Hedges, 2004; Hedges, Johnson, Ahlering, Tyson, & Eggert, 2013). Few such surveys have been carried out at a country level within the species' range (but see Hedges et al., 2013; Hedges et al., 2005).

Myanmar has been considered a stronghold for wild elephant populations and was long believed to have the second largest population after India (e.g., Santiapillai & Jackson, 1990; Sukumar & Santiapillai, 1996). Historically, the country's vast forests may have supported as many as 10,000 wild elephants. However, estimates have varied widely (Leimgruber et al., 2011) and range from 5,000 to 6,000 after World War II (Olivier, 1978; Williams, 1950) up to 10,000 in the late 1950s (Olivier, 1978), 6,500 in the 1970s (Olivier, 1978), and 4,000 to 5,000 in the early 1990s (Aung, 1997). Aung (1997) provided the most detailed information

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on the geographic range of Asian elephants in Myanmar based on a questionnaire survey of experts and reports from private elephant owners. Santiapillai and Jackson (1990) covered all these figures with a wide-ranging population estimate of 3,000 to 10,000 individuals, and a meeting of Asian Elephant Specialist Group of International Union for Conservation of Nature (IUCN) in 2004 listed an estimate of 4,000 to 5,300 (Sukumar, 2006).

More recently emerging evidence has cast doubt on Myanmar's status as an elephant stronghold. During a national workshop in 2004, experts from Myanmar's Forest Department (FD), other government and state agencies, and nongovernment organizations agreed that the number was probably much lower, ranging only between 1,430 and 2,065 (Leimgruber et al., 2011). As reasons for the declines, experts cited habitat loss, increased human–elephant conflict, mining, and live capture of elephants for use in the logging industry. Leimgruber et al. (2008) demonstrated that past and current levels of live elephant captures may have significantly contributed to elephant declines in Myanmar. However, detailed information about the changing geographic distribution of Asian elephants, the drivers of these changes, and the current status of Myanmar's wild elephants is still lacking, despite its obvious value for conservation planning. This was also recognized at the last IUCN Asian Elephant Conservation workshop in Cambodia in 2008, where Myanmar was identified as the range state in most dire need of research to improve population estimates and knowledge of their distributions (Hedges, Fisher, & Rose, 2009).

Here, we present an analysis of the drivers of change in Myanmar's wild elephant distribution and an updated elephant distribution map for the country. In 2006, we conducted township-based expert interviews to update Aung's (1997) study conducted from 1990 to 1992. This allowed us to identify changes in the geographic distribution. By linking the township data with environmental covariates on forest cover, forest edge, and human density, we develop competing statistical models to assess the differential importance of these factors for elephant declines. Our analysis and study provide critical information for developing countrywide elephant conservation management in Myanmar, particularly as more than 50 years of political isolation are rapidly ending and giving way to exponential increases in access and demand for the country's vast natural resources, including elephants.

## Methods

### *Study Area*

Intersecting three biogeographic regions, Myanmar is known for high endemism and its importance as a global biodiversity hotspot and as stronghold for threatened megafauna such as Asian elephants and tigers. It is the most forested country in the region, maintaining approximately two thirds of its forest cover (Leimgruber et al., 2005) and representing diverse ecosystems ranging from mangrove forests in the Ayeyarwady delta to alpine forests in the Himalayas. Over 60 million people live in Myanmar, and most reside in the central dry zone, an area that is now primarily agriculture surrounded by foothills transitioning into rugged hills and into steep terrain of the Himalayas in the north.

### *Elephant Surveys*

Staff of Myanmar's FD collected elephant presence or absence information in townships, which represent third-level administrative boundaries, a subdivision of Myanmar's Districts, dividing the 14 states and divisions of the country. Interviewers collected elephant presence or absence information based on experts' visual observation of elephants or elephant sign (dung or foot prints). Staff used expert informants and targeted townships potentially supporting elephants to find out about elephant distribution during two time periods (1990/1992 and 2005/2006). Expert informants included local FD staff and protected areas rangers, local hunters, private elephant owners, and veterinarians and mahouts working for the Myanmar Timber Enterprise (MTE)—the government-owned logging industry that manages thousands of captive elephants. These informants were selected because they regularly walk through elephant habitat and have experience in visually observing elephants and detecting elephant signs. Both private elephant owners and MTE staff have detailed knowledge about wild elephants because they are involved in capturing them for use as working elephants in timber operations and spend a great deal of time working in and around the forests in their areas.

Interviews were jointly designed with our Myanmar colleagues who then trained FD staff in interview methods, including techniques for avoiding bias and careful data recording. Interviewers then communicated directly with informants and no foreign project members were present at the interviews, reducing the possibility of bias.

Informants were asked whether elephants were present in their township during the last year and how, when, and where they were detected (Appendix). FD staff conducting the surveys were not enforcement or paramilitary staff, but trained and involved in research projects prior to the elephant surveys. Interviewers had no vested interests in the outcome of the survey. Interviewers did not have any authority over the interviewees there were no repercussions or incentives to be gained by interviewees through their responses, and each informant was separately interviewed. There was never a discrepancy between

informants about whether elephants were present in a township or not.

Surveys from 1990 to 1992 included 125 of Myanmar's 284 townships (Aung, 1997). The 159 townships which were not included in the survey had not shown evidence of elephant presence in previous decades. FD staff visited 101 of the 125 survey townships to conduct key informant interviews between October 1990 and April 1991. For each township, two to four key informants were interviewed. A total of 24 townships located within Kachin, Kayah, and Karen states were not visited because they were considered too dangerous for travel during the study period due to ethnic conflict. Results from these areas on phone interviews with township FD staff and questionnaires submitted between 1990 and 1992 by private elephant owners requesting permission to capture wild elephants within a township; therefore, respondents were not in direct contact with those compiling the data.

Townships were resurveyed between October 2005 and April 2006, with interviews conducted within 262 of the country's 286 townships (two new townships were created when two existing townships were each split by the government between 1992 and 2005). The new surveys targeted townships within or adjacent to previously mapped elephant ranges (see map in Leimgruber et al., 2003; Santiapillai & Jackson, 1990). Within each township, an average of 5.7 experts were interviewed (range: 3–11).

## Model Variables

To assess drivers of declines in elephant range, we calculated forest cover and human density variables for 1992 and 2006 from the best available sources. Estimates of human population density are available from Columbia University's CIESIN/SEDAC, Gridded Population of the World (http://sedac.ciesin.columbia.edu/gpw/) in 5-year intervals. We used human density maps for 1990 and 2005 to best represent conditions in 1991/1992 and 2005/2006.

To approximate forest cover and forest edge, we relied on a previous analysis of forest cover change in Myanmar between the 1990s and 2000s (Leimgruber et al., 2005). We extracted estimates of forest cover for the early 1990s to match 1990s elephant surveys and forest cover from the early 2000s to approximate conditions in 2006. Although the time periods do not align precisely, we found in previous research that this land cover provides the highest possible resolution and accuracy for forest delineation currently available for Myanmar (Eames et al., 2005; Leimgruber et al., 2005). To assess the amount of edge habitat, we used a high-pass filter on the forest class maps in ArcMap (ESRI, 2011). The area of each land cover type per township was calculated in ArcMap and transformed by the common logarithm. To assess the degree of isolation from other elephant populations, we calculated a population continuity index based on the number of adjacent townships with elephant presence divided by the total number of surrounding townships and included this index in our modeling equations.

## Generalized Linear Models

We used repeated measures generalized linear models (GLMs) on presence or absence of elephants in all townships for both 1992 and 2006 surveys. We hypothesized that elephant presence would be negatively associated with human population and edge and positively associated with forest cover and the continuity variable. We also included a quadratic term for forest cover because elephants tend to prefer disturbed and open forest habitats over closed forests (Fernando, 2006; Fernando & Leimgruber, 2011; Fernando et al., 2005; Ishwaran, 1993). To determine which of these factors best explained elephant presence, we developed four competing models a priori using R ecological software (R Development Core Team, 2010). These models encompassed (a) a full model including all variables, (b) forest cover and survey year, (c) human population only and survey year, and (d) continuity and survey year only.

We used repeated measures GLMs to assess persistence of elephants in all townships by comparing townships with elephant presence in 1992 and 2006 to townships which had elephant presence in 1992 but not in 2006. We used the same variables as used in the presence or absence model, but added a variable representing population change between 1990 and 2005. These models encompassed (a) a full model including all variables, (b) forest cover, (c) population only and population change, and (d) continuity only. We used Akaike Information Criterion (AIC) to compare the models, which provides a measure of the goodness of fit allowing comparison of model performance within a treatment.

## Improving Range Maps

Elephant survey data were compiled at the township level; however, we know that elephants are not present throughout these townships. To better approximate elephant distribution, we used detailed forest cover data from a 2005 study (Leimgruber et al., 2005) to eliminate areas not suitable for elephants. Our assumption was that wild elephant populations in Myanmar require forest habitats for long-term persistence. We created a raster layer of suitable cover (including forest, deforestation, and reforestation classes), thus eliminating any areas where forest had not been detected in 1990 or 2000. The inclusion of deforested and reforested areas is warranted because elephant populations often thrive in disturbed and early successional forest habitats (Fernando

**Table 1.** Results of Township Presence or Absence Surveys.

| Year | Present | Absent | Total | Percent surveyed |
|---|---|---|---|---|
| 1990–1992 | 88 | 37 | 125 | 44 |
| 2005–2006 | 55 | 207 | 262 | 92 |

& Leimgruber, 2011). We resampled the forest cover data from its 30 m pixel (=900 $m^2$) to a 90 m resolution (8,100 $m^2$) using a $3 \times 3$ majority filter. The resulting patches were overlaid with the boundaries of townships in which elephants were still present in 2006. Only areas that had suitable forest cover and fell within townships with confirmed elephant presence were included in our new range map for Myanmar.

## Results

Myanmar's Asian elephant geographic distribution declined by approximately 15,000 $km^2$ (5%) from 1992 to 2006 and fewer than two thirds of the townships supporting elephants during the early 1990s still had elephants present 15 years later. Survey results from 1990 to 1992 showed that wild elephants remained in 88 townships, representing 13 of the country's 14 states and divisions (Table 1). By the 2005/2006 survey, 33 of these townships no longer had elephants while only 3 gained elephants (Figure 1). Gains may have largely been associated with displacement of elephants from other townships. For example, based on our interviews, agricultural development pushed elephants from Thabeikkyin to Nawnghikop and Mogok townships, explaining two of the three township expansions reported for elephants by 2006. Our updated range map resulting from combining forest cover with township surveys indicates that elephants occupied roughly 143,000 $km^2$ of Myanmar in 2006 (Figure 2).

The full model best explained variation in elephant presence in Myanmar's townships in 1992 and 2006 (Table 2). Simpler, but perhaps more parsimonious models, with forest cover, population, and continuity, had much higher AICs. Percent forest cover and edge were the most important variables, but the continuity index and survey year also came out to be significant (Table 2).

Elephant presence increases with percent forest cover, reaching a peak in probability of presence at about 60% cover and then gradually declined (Figure 3). Percent forest cover decreased between 1991/1992 and 2005/2006 resulting in much lower elephant presence probabilities overall. Increases in percent edge reduce probabilities of elephant presence (Figure 3). Percent edge also declines between 1991/1992 and 2005/2006, but these declines had much less of an impact on probability of elephant presence.

For the elephant persistence models, we found the continuity model best explained persistence between 1991/1992 and 2005/2006, followed closely by the full model (+0.54 AIC), with forest and population models a few points higher, in increasing order (Table 3). Percent edge and continuity were the most important variables explaining persistence in the full model. Probability of elephant persistence increased with increasing continuity to an index of 0.6 where it reached 1.0 probability of presence (Figure 4a). Probability of persistence decreased rapidly with increasing edge (Figure 4b). As in the presence model, probability of persistence increased with percent forest cover, though not as dramatically as degree of continuity, which was a more important predictor of persistence (Figure 4c).

## Discussion

Our results show a major decrease in the geographic distribution of wild elephants in Myanmar between 1992 and 2006 and provide evidence that deforestation is the main driver. Overlapping our survey period, a countrywide deforestation mapping showed that between 1990 and 2000, approximately 12,000 $km^2$ of forest cover was lost at an annual net deforestation rate of 0.3% (Leimgruber et al., 2005). Although the deforestation rate is close to the global average (0.2%), there were 10 deforestation hotspots with annual deforestation rates above average, ranging from 0.4% to 2.2% (Leimgruber et al., 2005). Eight of the townships that overlapped these hotspots, either did not report elephants in 1991/1992 or in 2005/2006 (three townships) or were reported to have lost elephants in the intervening period (five townships). One of these hotspots overlaps with the northern edge of the central dry zone and the Ayeyarwady valley area where we recorded the displacement of the elephants from Thabeikkyin to Nawnghikop and Mogok townships. Only two of the townships overlapping deforestation hotspots reported elephant presence during both the 1991/1992 and 2005/2006 surveys, both were in the Tanintharyi Division.

Our results also provide insights into elephant habitat associations, showing that forest cover and edge are more important than human population in both elephant presence and persistence models. Our models show a positive relationship between percentage forest cover and the probability of elephant presence and persistence. Previous studies have shown that elephants seem to prefer forested areas but benefit from moderate amounts of open, nonforest areas (Fernando, 2006; Fernando & Leimgruber, 2011; Sukumar, 1990). Due to their mixed feeding strategy of switching between grazing and browsing (Dierenfeld, 2006; Sukumar, 2003), elephants often do

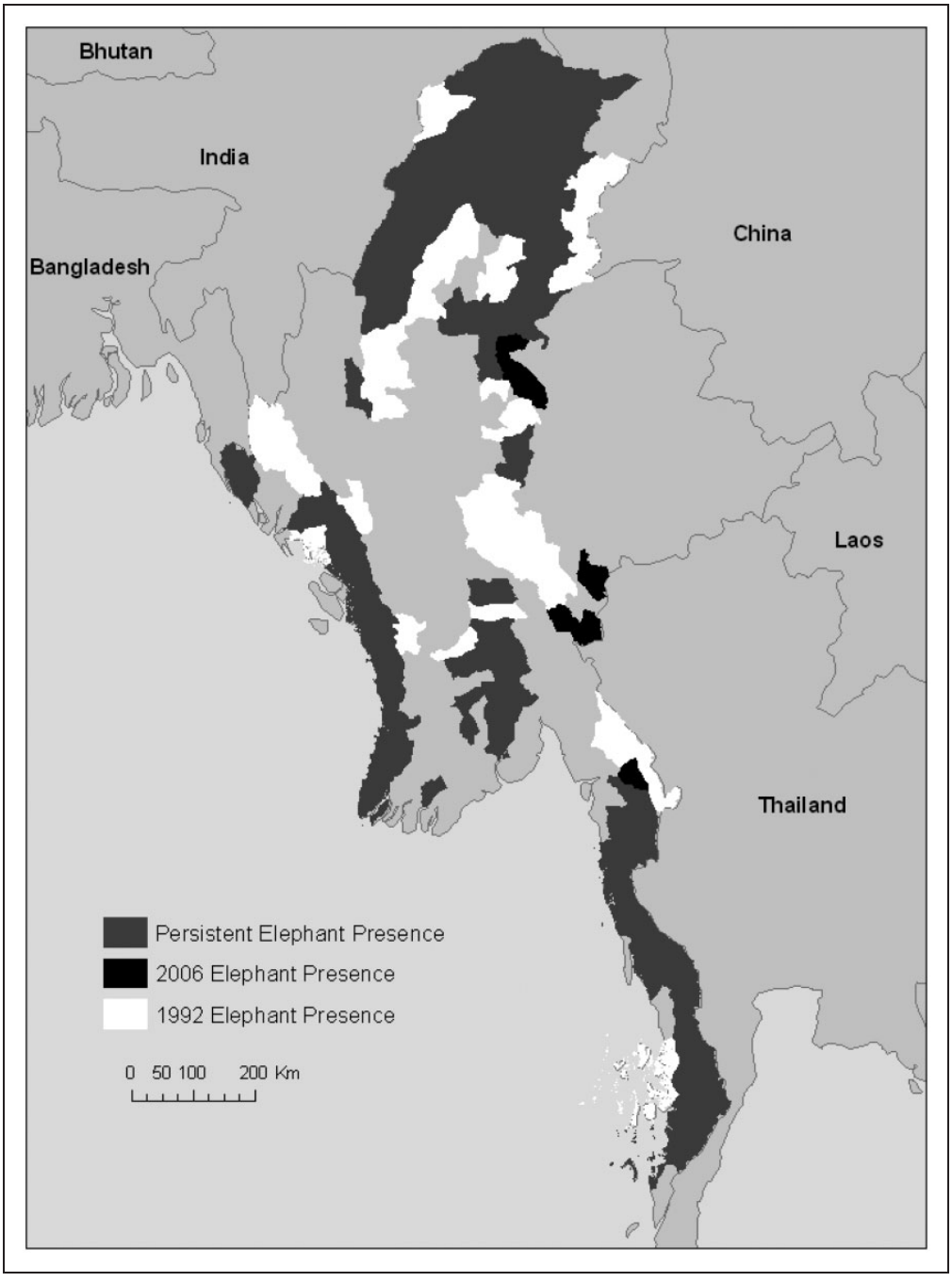


**Figure 1.** Elephant presence by township based on interview surveys in 1991/1992 and 2005/2006. Gray areas = townships with elephants present in 1991/1992 & 2005/2006; black areas = elephants present in 2005/2006 only; white areas = elephants present in 1991/1992 only.

well in open habitats, early successional forests, and along forest edges (Fernando & Leimgruber, 2011). Our presence model supports this conclusion, with probabilities for elephant presence increasing with increasing forest cover until a threshold of 60%, at which point presence probability begins to decline (Figure 3). However, both models show a strong negative relationship between probability of both elephant presence and persistence and the percentage of edge cover. Although the probability of elephant presence and persistence is very high in townships with low forest edge (<10%) which yield elephant presence probability values of >0.6 (Figure 3), there is a rapid decrease in probability of elephant presence and persistence as edge increases. Due to the unit of our analysis, it is likely that at the township level, the percentage of edge cover serves as

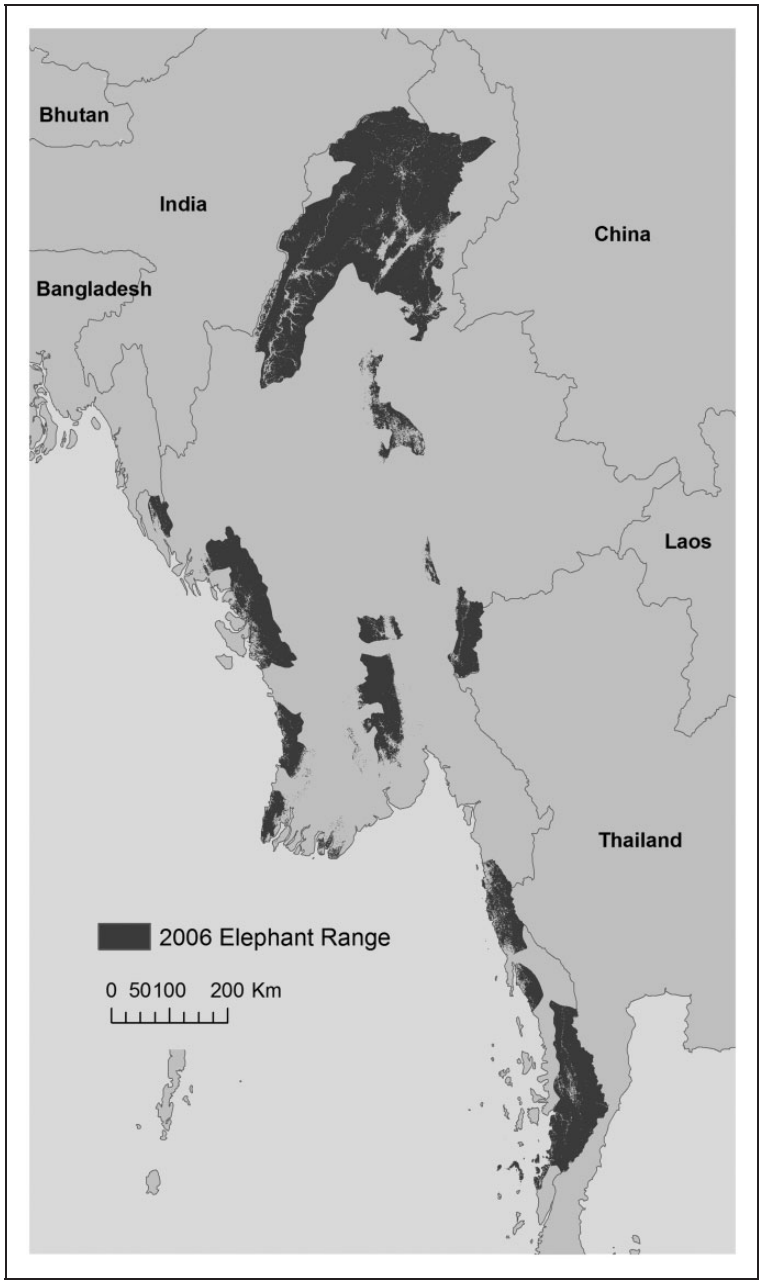


**Figure 2.** Elephant range map based on the intersection of remaining forest cover and townships with elephants present in 2006.

an indicator for fragmentation, and the negative relationship with edge is a result of the negative effects of fragmentation rather than elephant avoiding edges.

While forest cover is clearly an important driver of elephant presence, continuity with other elephant populations is the best predictor of whether an elephant population persisted between 1991/1992 and 2005/2006, providing further support that fragmentation of elephant populations is an important factor in the decline in elephant populations in Myanmar. As elephant populations become smaller and more isolated from other populations, they are at higher risk from stochastic demographic events. Being in areas with more edge and higher human population also puts elephants at greater risk of human–elephant conflict as they are more likely to come into contact with humans and croplands. This often leads to further reduction in elephant population and displacement of elephants.

Our findings are consistent with assumptions about the impacts of deforestation and human–elephant conflict on elephant population. However, it is important to note that overall forest cover is relatively high while deforestation and human–elephant conflict rates are relatively low in Myanmar in comparison to other Asian elephant

**Table 2.** Generalized Linear Model Results for Elephant Presence.

| | Model variables | Estimate | Standard error | z value | AIC | Δ AIC |
|---|---|---|---|---|---|---|
| Full | Intercept | −2.34 | 0.40 | −5.79*** | 469.82 | |
| | Forest | 16.61 | 2.19 | 7.60*** | | |
| | Forest squared | −13.74 | 2.22 | −6.20*** | | |
| | Edge | −16.90 | 2.40 | −7.04*** | | |
| | Continuity | 1.05 | 0.39 | 2.63** | | |
| | Population | $-0.04 \times 10^{-2}$ | $0.05 \times 10^{-2}$ | −0.79 | | |
| | Survey year | −0.56 | 0.23 | −2.378* | | |
| Forest | Intercept | −2.78 | 0.36 | −7.70*** | 539.41 | 152.41 |
| | Forest | 5.80 | 1.55 | 3.75*** | | |
| | Forest squared | −2.46 | 1.58 | −1.56 | | |
| | Survey year | −0.60 | 0.21 | −2.81** | | |
| Population | Intercept | −0.69 | 0.14 | −4.93*** | 632.73 | 162.91 |
| | Population | $-0.09 \times 10^{-1}$ | 0.00 | −1.22 | | |
| | Survey year | −0.56 | 0.20 | −2.80** | | |
| Continuity | Intercept | −1.23 | 0.18 | −6.84*** | 620.83 | 151.01 |
| | Continuity | 1.35 | 0.34 | 3.97*** | | |
| | Survey year | −0.44 | 0.20 | −2.20* | | |

*Note.* AIC = Akaike Information Criterion. Significance codes: '***' 0.001 '**' 0.01 '*' 0.05.

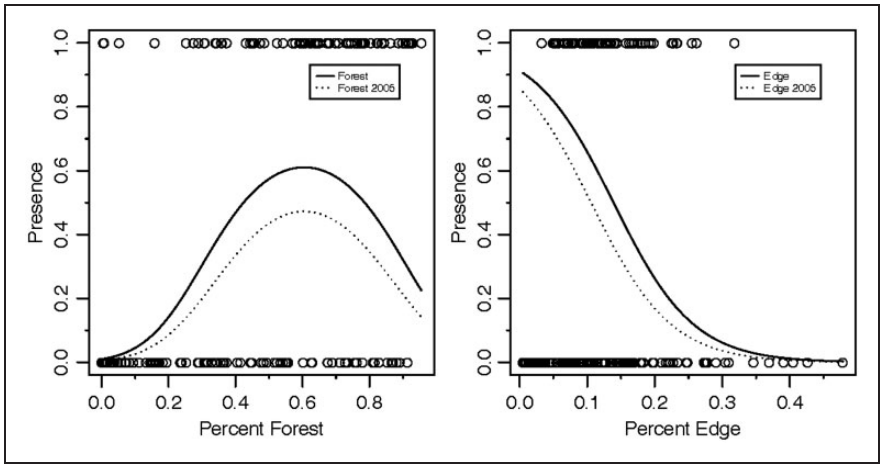


**Figure 3.** Effects of forest cover and edge on probability of elephant presence in Myanmar based on 1992/1993 and 2005/2006 based on repeated measures generalize linear modeling using interview survey data.

range countries. A range-wide analysis for Asian elephants has shown that Myanmar has nearly twice the amount of potential remaining elephant habitat compared with India and nearly 10 times as much as Sri Lanka, the countries with the highest Asian elephant populations (Leimgruber et al., 2003). Both Sri Lanka and India have higher densities of people, lower proportions of forest, and more edge, yet maintain higher elephant numbers and densities than those found in Myanmar. This raises a question about why we find a different pattern in Myanmar than in other Asian countries with larger elephant populations. In Myanmar, areas with high numbers of human–elephant conflict incidents are often targeted for wild elephant capture by the government as a mitigation strategy for reducing conflict (Leimgruber et al., 2008, 2011). As human–elephant conflict also increases with edge, it may partly explain why we are not seeing such a strong negative relationship between elephant presence and persistence with percent edge cover.

In addition to the use of live capture to mitigate human–elephant conflict, Myanmar is unique in its pervasive use of elephants for work, with an estimated 4,000 to 6,000 individuals—far more than any other country.

**Table 3.** Generalized Linear Model Results for Elephant Persistence.

| | Model variables | Estimate | Standard error | z value | AIC | Δ AIC |
|---|---|---|---|---|---|---|
| Continuity | Intercept | −0.45 | 0.41 | −1.09 | 114.29 | |
| | Continuity | 2.41 | 0.96 | 2.51* | | |
| Full | Intercept | 0.75 | 1.18 | 0.63 | 114.83 | 0.54 |
| | Forest | 1.15 | 5.20 | 0.22 | | |
| | Forest squared | −0.46 | 5.15 | −0.09 | | |
| | Edge | −10.83 | 5.02 | −2.16* | | |
| | Continuity | 2.14 | 1.12 | 1.90 | | |
| | Population | −0.92 | 1.85 | −0.50 | | |
| | Deforestation | 4.52 | 4.29 | 1.05 | | |
| Forest | Intercept | 0.81 | 0.97 | 0.84 | 116.98 | 2.69 |
| | Forest | −5.18 | 3.92 | −1.32 | | |
| | Forest squared | 6.92 | 3.84 | 1.80 | | |
| Population | Intercept | 0.51 | 0.34 | 1.51 | 119.91 | 5.62 |
| | Population | 0.02 | 0.01 | 1.51 | | |
| | Population change | −0.09 | 0.05 | −1.63 | | |

*Note.* AIC = Akaike Information Criterion. Significance codes: '*' 0.05.

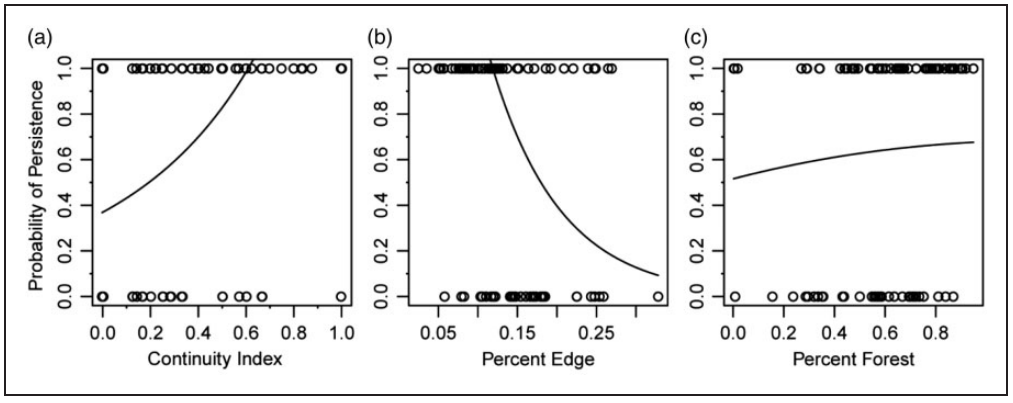


**Figure 4.** Effects of continutity (a), forest edge (b), and forest cover (c) on probability of elephant persistence in Myanmar, based on generalized linear models of information from interview surveys between 1996 and 2006.

In the past, approximately 50 to 100 elephants were captured annually, which had significant impacts on the wild elephant populations. Models of the capture rates demonstrate that that the wild population cannot be self-sustaining at a rate of approximately 100 per year if there are fewer than 4,000 elephants (Leimgruber et al., 2008). If estimates of 1,430 to 2,065 from the national workshop (Leimgruber et al., 2011) are correct, then the model predicts the extinction of elephants in Myanmar within the next three decades.

## *Implications for Conservation*

Our results show that the major threats to elephant conservation in Myanmar are deforestation and the subsequent fragmentation of forests and elephant. This contributes to increased levels of human–elephant conflict and can may lead to captures of elephants from the wild to reduce population as a measure of mitigation. Deforestation drivers are also closely tied with the demand for maintenance of an immense working elephant population, which in turn diminishes wild elephant populations. Myanmar faces a challenge unique within the region because the management of working elephant populations is intricately connected to the fate of the wild elephants.

In the face of these diverse threats, there is an urgent need for an updated national elephant action plan that addresses threats with a multiscale approach. Policies determining logging and elephant capture quotas are decided at a national level. However, crises from human–elephant conflict must be addressed at the

community level, with support and input from national government staff responsible for handling human–elephant conflict. A national elephant action plan should involve the range of impacted stakeholders, including the responsible government agencies (Nature & Wildlife Conservation Division, MTE), leaders from communities affected by human–elephant conflict, national nongovernmental organizations (NGOs) with relevant expertise or working in areas with human–elephant conflict, and pertinent international NGOs. Strategies for better forest management, preventing forest fragmentation, and decreasing human–elephant conflict should be prioritized in the development of the action plan.

Our surveys offer a unique opportunity for analysis of the forces controlling Myanmar's elephant populations and provide important baseline data to inform development of a national elephant action plan. Historical data dating back 25 years are especially valuable and a new survey sometime within the next two to three years will provide key insights to how the situation is changing. Expert interview surveys can be a more cost-effective strategy for assessing distribution and changes of wild elephant populations, particularly in areas with low population densities and inaccessible habitats. These data can be combined with environmental data to test specific hypotheses regarding the factors driving elephant declines and increases. By building on our surveys from 2006, a smaller region can be targeted for surveys, which would ideally be carried out at a finer spatial scale than the township level.

In addition to an updated elephant distribution survey, a threat assessment is needed to inform the action plan. Improved understanding of the intensity and distribution of major threats would allow for more detailed and targeted recommendations for action. Research on developing and testing human–elephant conflict mitigation strategies is especially important because these often need to be tailored to specific situations of the landscape and communities involved.

Significant political reforms in Myanmar during recent years have resulted in a rapid movement away from previous isolation to widespread international interest. There has been a dramatic increase in international involvement in conservation of Myanmar's vast biodiversity, along with increased interest in extracting the country's extensive natural resources. A more recent countrywide deforestation analysis (representing change from 2002 to 2014) shows deforestation has continued at the same rate, slightly higher (0.3%) than the global average, suggesting that the situation has declined since our 2005/2006 survey. However, in recent years, the government has committed to developing resources responsibly and has made important changes, for example, a ban on raw timber export and a decrease in timber extraction quotas, which resulted in no elephant captures planned since 2014.

A decreased demand for elephant labor will reduce the drain on wild elephant populations but also potentially cause another conservation conundrum that was observed after a logging ban was enacted in Thailand in 1989—the problem of feeding long-lived working elephants that are retired early. Retired elephants could also provide a conservation solution if they could be successfully reintroduced to the wild. Research on the reintroduction of working elephants to the wild is critical prior to any release. Returning elephants that are comfortable with people and familiar with their foods will carry risks to both humans and elephants. Although elephant numbers and densities are lower than presumed in the literature, Myanmar still maintains high forest cover and supports large numbers of elephants. With an effective national action plan and commitment to elephant conservation, the declining trend in wild elephant populations in Myanmar could be reversed during our lifetime.

## Appendix

### *Questions Asked During Elephant Surveys*

1. What is your age?
2. What is your profession?
3. What is your education level?
4. Were there wild elephants living in your township during the past year? (yes or no)
5. Did you see wild elephants?
6. How many times did you see wild elephants?
7. Approximately what dates did you see wild elephants?
8. How many wild elephants did you see?
9. Did you see signs of wild elephants (feeding, dung)?
10. How often do you see signs of wild elephants?
11. Did you hear wild elephants?
12. How often did you hear wild elephants?
13. Where did you detect wild elephants?

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