

# Compromised Survivorship in Zoo Elephants

Ros Clubb,<sup>1</sup> Marcus Rowcliffe,<sup>2</sup> Phyllis Lee,<sup>3,4</sup> Khyne U. Mar,<sup>2,5</sup> Cynthia Moss,<sup>4</sup> Georgia J. Mason<sup>6\*</sup>

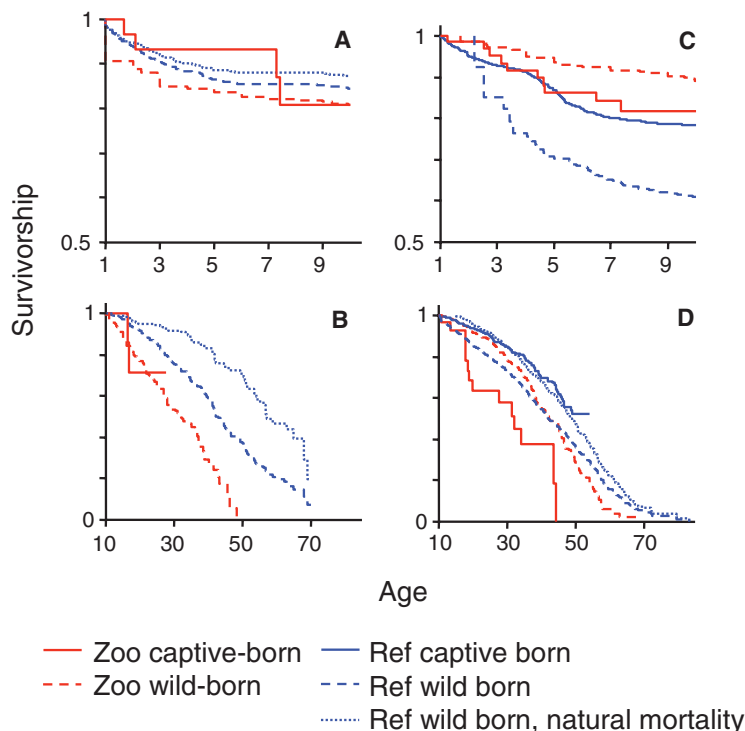
Wild animals can experience poor welfare when held captive (1), an effect with ethical and practical implications. In zoos,

the welfare of African elephants (*Loxodonta africana*) and Asian elephants (*Elephas maximus*) has long caused concern. Infanticide, *Herpes*, tuberculosis, lameness, infertility, and stereotypic behavior are prevalent (2), and zoo elephant populations are not self-sustaining without importation (3). We compiled data from over 4500 individuals to compare survivorship in zoos with protected populations in range countries. Data representing about half the global zoo population (1960 to 2005) came from European "studbooks" and the European Elephant Group (4). We focused on females as relevant to population viability ( $N = 786$ , both wild-caught and captive-born; 302 African and 484 Asian). African elephants in Amboseli National Park, Kenya ( $N = 1089$ ), and Asian elephants in the Burmese logging industry (Myanma Timber Enterprise, M.T.E.,  $N = 2905$ , wild-caught and captive-born) acted as well-provisioned reference populations [for details, see (2) and (5)].

For African elephants, median life spans (excluding premature and still births) were 16.9 years [95% confidence interval (CI) 16.4 to unknown; upper estimate for median not reached] for zoo-born females and 56.0 years (95% CI 51.5 to unknown) for Amboseli females undergoing natural mortality (35.9 years with human-induced deaths, 95% CI 33.8 to 40.3). Neither infant nor juvenile mortality differed between populations (Fig. 1A and tables S1 and S2), but adult females died earlier in zoos than in Amboseli (Fig. 1B and table S2). Zoo adult African survivorship has improved in recent years [ $z = -2.75$ ,  $P < 0.01$  (5)], but mortality risks in our data set's final year (2005) remained 2.8 times higher (95% CI 1.2 to 6.5) than that of Amboseli females undergoing natural mortality.

For Asian elephants, median life spans (excluding premature and still births) for captive-born females were 18.9 years in zoos (95% CI 17.7 to 34.0) and 41.7 years in the M.T.E. population (95% CI 38.2 to 44.6). Zoo infant mortality rates were high

(over double those of M.T.E.): A female's first pregnancy therefore had only a 42% chance of yielding a live year-old in zoos compared with 83% in M.T.E.



**Fig. 1.** Kaplan-Meier survivorship curves for female African (A and B) and Asian (C and D) elephants aged 1 to 10 [juveniles in (A) and (C)] and 10+ years [adults in (B) and (D)]. For wild-born reference (Ref, Amboseli or M.T.E.) populations, natural mortality excludes human-caused deaths; all mortality includes them (5). Results of statistical comparisons are given in table S2.

(table S1). Rates have not significantly improved over time (e.g., live births controlling for parity:  $z = 1.19$ ,  $P > 0.10$ ). For juveniles, captive-born survivorship did not significantly differ between populations, whereas wild-born survivorship was poorer in Burma (Fig. 1C and table S2) because of after-effects of capture (5). In adulthood, however, survivorship was lower in zoos (Fig. 1D and table S2), with no detectable improvement in recent years ( $z = -1.48$ ,  $P > 0.10$ ).

Within zoos, captive-born Asians have poorer adult survivorship than wild-born Asians (Fig. 1D and table S2). This is a true birth origin effect: Whereas zoo-born elephants are more likely to have been born recently and to primiparous dams, neither dam parity ( $z = 0.86$ ,  $P > 0.10$ ) nor recency ( $z = -1.48$ ,  $P > 0.10$ ) predict adult survivorship (controlling for recency makes birth origin more significant:  $z = -3.52$ ,

$P < 0.001$ ). Because the median importation age of wild-born females was about 3.4 years, this suggests that zoo-born Asians' elevated adult mortality risks are conferred during gestation or early infancy.

Interzoo transfers also reduced Asian survivorship (see supporting online text), an effect lasting 4 years posttransfer ( $z = -2.10$ ,  $P < 0.05$ , controlling for birth origin). Additionally, survivorship tended to be poorer in Asian calves removed from mothers at young ages ( $z = -1.92$ ,  $P < 0.10$ ) (5).

Overall, bringing elephants into zoos profoundly impairs their viability. The effects of early experience, interzoo transfer, and possibly maternal loss, plus the health and reproductive problems recorded in zoo elephants [e.g., (2)], suggest stress and/or obesity as likely causes.

## References and Notes

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## Supporting Online Material

www.sciencemag.org/cgi/content/full/322/5908/1649/DC1

Materials and Methods

SOM Text

Tables S1 and S2

References

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<sup>1</sup>Royal Society for the Prevention of Cruelty to Animals (RSPCA), Wilberforce Way, Southwater, West Sussex, RH13 9RS, UK. <sup>2</sup>Institute of Zoology, Zoological Society of London, London NW1 4RY, UK. <sup>3</sup>Psychology Department, University of Stirling, Stirling FK9 4LA, UK. <sup>4</sup>Amboseli Trust for Elephants, Post Office Box 15135, Nairobi, Kenya. <sup>5</sup>Department of Animal and Plant Sciences, University of Sheffield, Western Bank, Sheffield S10 2TN, UK. <sup>6</sup>Animal Sciences Department, University of Guelph, Guelph N1G 2M7, Canada.

\*To whom correspondence should be addressed. E-mail: gmason@uoguelph.ca