



# The historical development of zoo elephant survivorship



Lara Scherer | Laurie Bingaman Lackey | **Marcus Clauss** | Katrin Gries |  
David Hagan | Arne Lawrenz | Dennis W. H. Müller | Marco Roller |  
**Christian Schiffmann** | Ann-Kathrin Oerke

\*Clinic for Zoo Animals, Exotic Pets and Wildlife, Vetsuisse Faculty, University of Zurich, Switzerland

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## UK TO BAN KEEPING ELEPHANTS CAPTIVE IN ZOOS

The British government is slated to prohibit the captivity of elephants in zoos and safaris under the broader Kept Animals Bill set to be passed this year.

*by* ANNA STAROSTINETSKAYA

JUNE 24, 2021



First Session, Forty-fourth Parliament,  
70-71 Elizabeth II, 2021-2022

SENATE OF CANADA

# BILL S-241

An Act to amend the Criminal Code and the  
Wild Animal and Plant Protection and  
Regulation of International and  
Interprovincial Trade Act (great apes,  
elephants and certain other animals)

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# A Review of the Welfare of Zoo Elephants in Europe

A report commissioned by the RSPCA

**Ros Clubb and Georgia Mason**

University of Oxford,  
Animal behaviour research group, Department of  
Zoology, South Parks Road, Oxford OX1 3PS



## Compromised Survivorship in Zoo Elephants

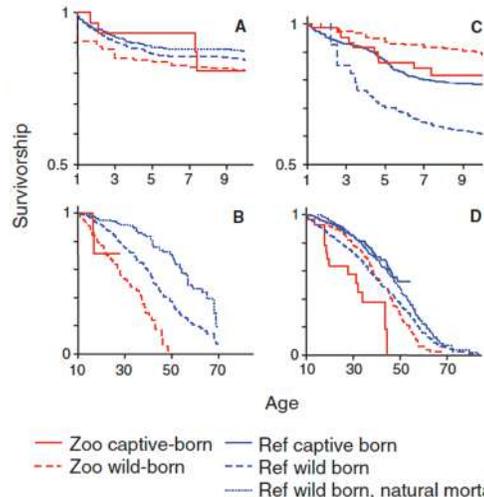
Ros Clubb,<sup>1</sup> Marcus Rowcliffe,<sup>2</sup> Phyllis Lee,<sup>3,4</sup> Khyne U. Mar,<sup>2,5</sup> Cynthia Moss,<sup>4</sup> Georgia J. Mason<sup>6\*</sup>

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 (Myanmar 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

- R. Clubb, G. Mason, *Nature* **425**, 473 (2003).
- R. Clubb, G. Mason, *A Review of the Welfare of Zoo Elephants in Europe* (RSPCA, Horsham, UK, 2002).
- M. Hutchins, M. Keele, *Zoo Biol.* **25**, 219 (2006).
- European Elephant Group, "Elefanten in zoos und safariparks Europa" (European Elephant Group, Grünwald, Germany, 2002).
- Methods and supplementary results are available as supporting material on Science Online.
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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 151335, 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

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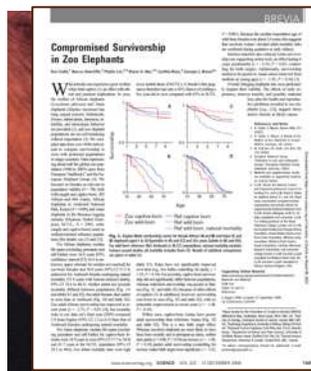
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## How Should the Psychological Well-Being of Zoo Elephants be Objectively Investigated?

Georgia J. Mason<sup>1\*</sup> and Jake S. Veasey<sup>2</sup>

<sup>1</sup>Canada Research Chair in Animal Welfare, Animal Science Department, University of Guelph, Guelph, Ontario, Canada

<sup>2</sup>Department of Animal Management and Conservation, Woburn Safari Park, Woburn, Bedfordshire, United Kingdom

Animal welfare (sometimes termed “well-being”) is about feelings – states such as “suffering” or “contentment” that we can infer but cannot measure directly. Welfare indices have been developed from two main sources: studies of suffering humans, and of research animals deliberately subjected to challenges known to affect emotional state. We briefly review the resulting indices here, and discuss how well they are understood for elephants, since objective welfare assessment should play a central role in evidence-based elephant management. We cover behavioral and cognitive responses (approach/avoidance; intrusion; redirected and displacement activities; vigilance/startle; warning signals; cognitive biases; apathy and depression-like changes; stereotypic behavior); physiological responses (sympathetic responses; corticosteroid output – often assayed non-invasively via urine, feces or even hair; other aspects of HPA function, e.g. adrenal hypertrophy); and the potential negative effects of prolonged stress on reproduction (e.g. reduced gametogenesis; low libido; elevated still-birth rates; poor maternal care) and health (e.g. poor wound-healing; enhanced disease rates; shortened lifespans). The best validated, most used welfare indices for elephants are corticosteroid outputs and stereotypic behavior. Indices suggested as valid, partially validated, and/or validated but not yet applied within zoos include: measures of preference/avoidance; displacement movements; vocal/postural signals of affective (emotional) state; startle/vigilance; apathy; salivary and urinary epinephrine; female acetylty; infant mortality rates; skin/foot infections;

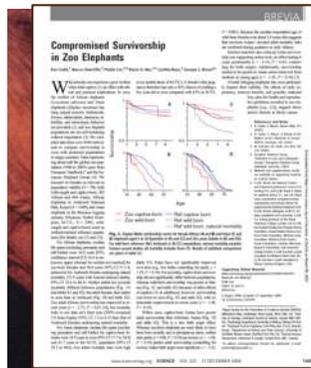
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\*Correspondence to: Georgia J. Mason, Canada Research Chair in Animal Welfare, Animal Science Department, University of Guelph, Guelph, Ontario, Canada N1G 2W1. E-mail: gmason@uoguelph.ca

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## An Epidemiological Approach to Welfare Research in Zoos: The Elephant Welfare Project

Kathy Carlstead,<sup>1</sup> Joy A. Mench,<sup>2</sup> Cheryl Meehan,<sup>3</sup> and Janine L. Brown<sup>4</sup>

<sup>1</sup>Honolulu Zoo Society, Honolulu, Hawaii

<sup>2</sup>Center for Animal Welfare, University of California, Davis

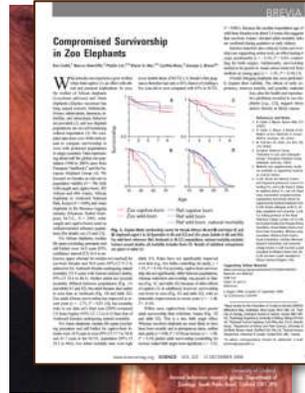
<sup>3</sup>Vistalagic Inc., Portland, Oregon

<sup>4</sup>Center for Species Survival, Smithsonian Conservation Biology Institute, National Zoological Park, Front Royal, Virginia

Multi-institutional studies of welfare have proven to be valuable in zoos but are hampered by limited sample sizes and difficulty in evaluating more than just a few welfare indicators. To more clearly understand how interactions of husbandry factors influence the interrelationships among welfare outcomes, epidemiological approaches are needed as well as multifactorial assessments of welfare. Many questions have been raised about the housing and care of elephants in zoos and whether their environmental and social needs are being met in a manner that promotes good welfare. This article describes the background and rationale for a large-scale study of elephant welfare in North American zoos funded by the (U.S.) Institute of Museum and Library Services. The goals of this project are to document the prevalence of positive and negative welfare states in 291 elephants exhibited in 72 Association of Zoos and Aquariums zoos and then determine the environmental, management, and husbandry factors that impact elephant welfare. This research is the largest scale nonhuman animal welfare project ever undertaken by the zoo community, and the scope of environmental variables and welfare outcomes measured is unprecedented.

**Keywords:** elephant, welfare, husbandry, management, epidemiology

Correspondence should be sent to Kathy Carlstead, Honolulu Zoo Society, 151 Kapahulu Ave., Honolulu, HI 96815. Email: KCarlstead@honzooosoc.org



## How Should the Psychological Well-Being of Zoo Elephants be Objectively Investigated?

Georgia J. Mason<sup>1\*</sup> and Jake S. Veasey<sup>2</sup>  
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<sup>2</sup>Department of Animal Management and Conservation, Woburn Safari Park, Woburn, Bedfordshire, United Kingdom

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<sup>1</sup>Honolulu Zoo Society, Honolulu, Hawaii  
<sup>2</sup>Center for Animal Welfare, University of California, Davis  
<sup>3</sup>Vistalodge Inc., Portland, Oregon  
<sup>4</sup>Center for Species Survival, Smithsonian Conservation Biology Institute, National Zoological Park, Front Royal, Virginia

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**Keywords:** elephant, welfare, husbandry, management, epidemiology

Correspondence should be sent to Kathy Carlstead, Honolulu Zoo Society, 151 Kapahulu Ave., Honolulu, HI 96813. E-mail: carlstead@hoznosoc.org

## Determining Connections between the Daily Lives of Zoo Elephants and Their Welfare: An Epidemiological Approach

Cheryl L. Mench<sup>1,2\*</sup>, Joy A. Mench<sup>3</sup>, Kathy Carlstead<sup>4</sup>, Jennifer N. Hoggan<sup>5</sup>  
<sup>1</sup>ABRHS Institute, Portland, Oregon, United States of America, <sup>2</sup>Center for Animal Welfare, University of California, Davis, California, United States of America, <sup>3</sup>Department of Biomedical Sciences, University of California, Davis, California, United States of America, <sup>4</sup>Honolulu Zoo Society, Honolulu, Hawaii, United States of America, <sup>5</sup>Department of Psychology, University of Oregon, Eugene, Oregon, United States of America

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**Abstract**  
 Concerns about animal welfare have increasingly shaped people's views about the acceptability of keeping animals for food production, biomedical research, and in zoos. The field of animal welfare science has developed over the past 50 years as a method of investigating these concerns via research that assesses how living in human-controlled environments influences the behavior, health and affective states of animals. Ideally, animal welfare research focused on animals in agricultural settings, but the fact has expanded to zoos because good animal welfare is essential to zoos' mission of promoting connections between animals and visitors and raising awareness of conservation issues. A particular challenge for zoos is ensuring good animal welfare for large, highly social species like elephants. Our main goal in conducting an epidemiological study of African (*Loxodonta africana*) and Asian (*Elephas maximus*) elephants in 72 accredited North American zoos was to understand the prevalence of welfare indicators in the population and determine the aspects of elephant life environment, social life and management that are most important to prevent and reduce a variety of welfare problems. In this review, we provide a history of the findings of the nine papers in the collection that document our epidemiological investigation of North American Zoo Elephant Welfare with a focus on the history, social, housing and management factors that have been associated with particular aspects of elephant welfare, including the performance of abnormal behaviors, head and joint problems, reproductive health, and reproductive behavior. Social and management factors were found to be important to the health and welfare of elephants, but the most important was found to be the social and management factors that have been associated with particular aspects of elephant welfare, including the performance of abnormal behaviors, head and joint problems, reproductive health, and reproductive behavior. The body of work results from the largest prospective zoo-based animal welfare study conducted to date and will inform the progress of using science-based welfare benchmarks to optimize care of zoo elephants.

**Introduction**  
 Scientifically addressing questions regarding the elephant welfare in a timely and accurate manner is the best public service we can offer zoo and elephant management and visitors alike.

## Elephant Management in North American Zoos: Environmental Enrichment, Feeding, Exercise, and Training

Brian J. Ganes<sup>1,2\*</sup>, Cheryl L. Mench<sup>3</sup>, Lance J. Miller<sup>4</sup>, David J. Shepherdson<sup>5</sup>, Karl A. Mullaney<sup>6</sup>, Jeff Anderson<sup>7</sup>, Anne M. Kelly<sup>8</sup>, Kathy Carlstead<sup>9</sup>, Joy A. Mench<sup>3</sup>  
<sup>1</sup>Department of Animal Science and Center for Animal Welfare, University of California, Davis, California, United States of America, <sup>2</sup>ABRHS Institute, Portland, Oregon, United States of America, <sup>3</sup>Department of Biomedical Sciences, University of California, Davis, California, United States of America, <sup>4</sup>Department of Psychology, University of Oregon, Eugene, Oregon, United States of America, <sup>5</sup>Department of Psychology, University of Oregon, Eugene, Oregon, United States of America, <sup>6</sup>Department of Psychology, University of Oregon, Eugene, Oregon, United States of America, <sup>7</sup>Department of Psychology, University of Oregon, Eugene, Oregon, United States of America, <sup>8</sup>Department of Psychology, University of Oregon, Eugene, Oregon, United States of America, <sup>9</sup>Honolulu Zoo Society, Honolulu, Hawaii, United States of America

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 Editor: David A. Reardon, University of Florida, UNITED STATES

**Abstract**  
 The management of African (*Loxodonta africana*) and Asian (*Elephas maximus*) elephants in zoos involves a range of practices including feeding, exercise, training, and environmental enrichment. These practices are necessary to meet the elephants' nutritional, health, and husbandry needs. However, these practices are not standardized, resulting in likely variation among zoos as well as differences in the way they are applied to individual elephants within a zoo. To characterize elephant management in North America, we conducted a survey of 221 elephants and the housing environments of 227 elephant zoos. We identified 26 variables, generated population level descriptive statistics, and analyzed them to identify differences attributable to zoo and species. Sixty-seven zoo submitted surveys describing the management of 221 elephants and the housing environments of 227 elephant zoos. Asian elephants spent more time managed (defined as interacting directly with humans) than African elephants (mean ± SD: 1.83 ± 0.53 vs. 1.14 ± 0.47 hours per day) and managed time increased by 20.2% for every year of age for both species. Enrichment, feeding, and exercise programs were evaluated using diversity indices, with mean scores across zoos in the mid-range for these measures. There was an average of 7.2 feedings every 24-hour period, with only 1.2 occurring during the nighttime. Feeding activities were predictable at 47.2% of zoos. We also calculated the relative use of rewarding and aversive techniques employed during training interactions. The population median was selected on a scale from one (implying only aversive stimuli to one (implying only rewarding stimuli). The results of this study provide essential information for developing management guidelines that could be relevant to welfare. Furthermore, the variables we created have been used in subsequent elephant welfare analyses.

## Assessment of Body Condition in African (*Loxodonta africana*) and Asian (*Elephas maximus*) Elephants in North American Zoos and Management Practices Associated with High Body Condition Scores

Karl A. Mullaney<sup>1,2\*</sup>, Cheryl L. Mench<sup>3</sup>, Jennifer N. Hoggan<sup>4</sup>, Cheryl L. Mench<sup>3</sup>, Joy A. Mench<sup>5</sup>, Stephanie Pant<sup>6</sup>, Karla A. Mullaney<sup>7</sup>, Kathy Carlstead<sup>8</sup>  
<sup>1</sup>Department of Psychology, University of Oregon, Eugene, Oregon, United States of America, <sup>2</sup>Department of Psychology, University of Oregon, Eugene, Oregon, United States of America, <sup>3</sup>Department of Biomedical Sciences, University of California, Davis, California, United States of America, <sup>4</sup>Department of Psychology, University of Oregon, Eugene, Oregon, United States of America, <sup>5</sup>Department of Psychology, University of Oregon, Eugene, Oregon, United States of America, <sup>6</sup>Department of Psychology, University of Oregon, Eugene, Oregon, United States of America, <sup>7</sup>Department of Psychology, University of Oregon, Eugene, Oregon, United States of America, <sup>8</sup>Honolulu Zoo Society, Honolulu, Hawaii, United States of America

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**Abstract**  
 Obesity has a negative effect on health and welfare of many species, and has been reported to be a problem for zoo elephants. To address this concern, we assessed the body condition of 291 elephants housed in North American zoos based on a set of 18 standardized photographs using a 5-point body condition score index (1 = emaciated, 5 = obese). A multivariate regression analysis was used to determine how demographic, management, housing, and social factors were associated with an elevated body condition score in 132 African (*Loxodonta africana*) and 159 Asian (*Elephas maximus*) elephants. The highest body condition score of obesity was observed in 34% of zoo elephants. In both species, the majority of elephants had elevated BCS, with 24% in the BCS 4 (overly) and 25% in category 5. Only 2% of elephants had BCS 2, and less than 1% of the population were assigned the lowest BCS category (BCS 1 and 2). The increased multi-variable model demonstrated that elephants with high body condition scores were associated with increased feeding frequency, increased exercise, and increased management practices that help prevent and mitigate obesity may need to be implemented in welfare of zoo elephants.

## Reproductive Health Assessment of Female Elephants in North American Zoos and Association of Husbandry Practices with Reproductive Dysfunction in African Elephants (*Loxodonta africana*)

Jennifer L. Hoggan<sup>1,2\*</sup>, Stephanie Pant<sup>3</sup>, Karla A. Mullaney<sup>4</sup>, Cheryl L. Mench<sup>5</sup>, Cheryl L. Mench<sup>3</sup>, Joy A. Mench<sup>6</sup>, Kathy Carlstead<sup>7</sup>  
<sup>1</sup>Department of Psychology, University of Oregon, Eugene, Oregon, United States of America, <sup>2</sup>Department of Psychology, University of Oregon, Eugene, Oregon, United States of America, <sup>3</sup>Department of Psychology, University of Oregon, Eugene, Oregon, United States of America, <sup>4</sup>Department of Psychology, University of Oregon, Eugene, Oregon, United States of America, <sup>5</sup>Department of Biomedical Sciences, University of California, Davis, California, United States of America, <sup>6</sup>Department of Psychology, University of Oregon, Eugene, Oregon, United States of America, <sup>7</sup>Honolulu Zoo Society, Honolulu, Hawaii, United States of America

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 Editor: David A. Reardon, University of Florida, UNITED STATES

**Abstract**  
 As part of a multi-institutional study of zoo elephant welfare, we evaluated female elephants managed by zoos accredited by the Association of Zoos and Aquariums and applied epidemiological methods to determine what factors in the zoo environment are associated with reproductive problems, including ovarian anovulation and hyperandrogenism. We used blood samples were collected from 50 African (*Loxodonta africana*) and 27 Asian (*Elephas maximus*) (8–55 years of age) elephants over a 12-month period for analysis of ovarian and reproductive parameters. Females were categorized as normal cycling (regular 15h to 17-week cycles), irregular cycling (cycles longer or shorter than normal) or anovulatory (no cycling, progesterone < 1 ng/ml throughout), and having low Normal (4.14 to 18 ng/ml) or high (17.4 to 18 ng/ml) progesterone for Asian and African elephants, respectively. Rates of normal cycling, anovulation, and irregular cycling were 73.2, 0.5, and 4.2% for Asian, and 48.4, 0.0, and 13.7% for African elephants, respectively. All of which differed between species ( $P < 0.001$ ). For African elephants, ultimate assessment found that social isolation, decreased and higher environmental diversity increased the chance a female would cycle normally. Only 3% of Asian elephants were found to be hyperandrogenic as compared to 28% of African elephants. In predictive analyses of reproductive status were conducted on African elephants only. The strongest multi-variable model included Age (postnatal), Environment Diversity (negative), Abnormal Cycling Methods (negative), and Social Group Cohesion (positive) in predicting rates of hyperandrogenism. In summary, the incidence of ovarian cycle problems and

## Housing and Demographic Risk Factors Impacting Foot and Musculoskeletal Health in African Elephants (*Loxodonta africana*) and Asian Elephants (*Elephas maximus*) in North American Zoos

Michael A. Miller<sup>1,2\*</sup>, Jennifer N. Hoggan<sup>3</sup>, Cheryl L. Mench<sup>4</sup>  
<sup>1</sup>Department of Statistics and Technology/Behavior Research Foundation Center of Excellence for the Study of Complex Systems, University of Oregon, Eugene, Oregon, United States of America, <sup>2</sup>Department of Psychology, University of Oregon, Eugene, Oregon, United States of America, <sup>3</sup>Department of Psychology, University of Oregon, Eugene, Oregon, United States of America, <sup>4</sup>Department of Biomedical Sciences, University of California, Davis, California, United States of America

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**Abstract**  
 Foot and musculoskeletal health problems are common in zoo elephants and have been documented among both Asian (*Elephas maximus*) and African (*Loxodonta africana*) elephants in zoos. Although environmental factors have been hypothesized to play a contributing role in the development of foot and musculoskeletal pathology, there is a paucity of evidence-based research assessing risk. We investigated the associations between foot and musculoskeletal health conditions with demographic characteristics, species, housing, exercise, enrichment, and body condition for elephants housed in North American zoos during 2012. Clinical examinations and medical records were used to assess health indicators and proprioceptive access to quantitative conditions. Using multivariate regression models, associations were found between foot health and age ( $P = 0.076$ , Odds Ratio = 1.048), time spent in the exhibit ( $P = 0.044$ , Odds Ratio = 1.008), and percent of time spent in enrichment activities during the day ( $P = 0.001$ , Odds Ratio = 0.303). Similarly, the main risk factors for musculoskeletal diseases included time in herd ( $P = 0.003$ , Odds Ratio = 1.008) and species experienced in musculoskeletal ailments ( $P = 0.028$ , Odds Ratio = 1.937). These results suggest that facility and management changes that decrease time spent in herd activities will improve elephant welfare through better foot and musculoskeletal health.

## Elephant Management in North American Zoos: Environmental Enrichment, Feeding, Exercise, and Training

Brian J. Ganes<sup>1,2\*</sup>, Cheryl L. Mench<sup>3</sup>, Lance J. Miller<sup>4</sup>, David J. Shepherdson<sup>5</sup>, Karl A. Mullaney<sup>6</sup>, Jeff Anderson<sup>7</sup>, Anne M. Kelly<sup>8</sup>, Kathy Carlstead<sup>9</sup>, Joy A. Mench<sup>3</sup>  
<sup>1</sup>Department of Animal Science and Center for Animal Welfare, University of California, Davis, California, United States of America, <sup>2</sup>ABRHS Institute, Portland, Oregon, United States of America, <sup>3</sup>Department of Biomedical Sciences, University of California, Davis, California, United States of America, <sup>4</sup>Department of Psychology, University of Oregon, Eugene, Oregon, United States of America, <sup>5</sup>Department of Psychology, University of Oregon, Eugene, Oregon, United States of America, <sup>6</sup>Department of Psychology, University of Oregon, Eugene, Oregon, United States of America, <sup>7</sup>Department of Psychology, University of Oregon, Eugene, Oregon, United States of America, <sup>8</sup>Department of Psychology, University of Oregon, Eugene, Oregon, United States of America, <sup>9</sup>Honolulu Zoo Society, Honolulu, Hawaii, United States of America

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**Abstract**  
 The management of African (*Loxodonta africana*) and Asian (*Elephas maximus*) elephants in zoos involves a range of practices including feeding, exercise, training, and environmental enrichment. These practices are necessary to meet the elephants' nutritional, health, and husbandry needs. However, these practices are not standardized, resulting in likely variation among zoos as well as differences in the way they are applied to individual elephants within a zoo. To characterize elephant management in North America, we conducted a survey of 221 elephants and the housing environments of 227 elephant zoos. We identified 26 variables, generated population level descriptive statistics, and analyzed them to identify differences attributable to zoo and species. Sixty-seven zoo submitted surveys describing the management of 221 elephants and the housing environments of 227 elephant zoos. Asian elephants spent more time managed (defined as interacting directly with humans) than African elephants (mean ± SD: 1.83 ± 0.53 vs. 1.14 ± 0.47 hours per day) and managed time increased by 20.2% for every year of age for both species. Enrichment, feeding, and exercise programs were evaluated using diversity indices, with mean scores across zoos in the mid-range for these measures. There was an average of 7.2 feedings every 24-hour period, with only 1.2 occurring during the nighttime. Feeding activities were predictable at 47.2% of zoos. We also calculated the relative use of rewarding and aversive techniques employed during training interactions. The population median was selected on a scale from one (implying only aversive stimuli to one (implying only rewarding stimuli). The results of this study provide essential information for developing management guidelines that could be relevant to welfare. Furthermore, the variables we created have been used in subsequent elephant welfare analyses.

## The Days and Nights of Zoo Elephants: Using Epidemiology to Better Understand Stereotypic Behavior of African Elephants (*Loxodonta africana*) and Asian Elephants (*Elephas maximus*) in North American Zoos

Brian J. Ganes<sup>1,2\*</sup>, Cheryl L. Mench<sup>3</sup>, Jeff Anderson<sup>4</sup>, Katherine A. Lagley<sup>5</sup>, Jill Miller<sup>6</sup>, Joy A. Mench<sup>7</sup>, Anne M. Kelly<sup>8</sup>, Kathy Carlstead<sup>9</sup>, Joy A. Mench<sup>3</sup>  
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**Abstract**  
 Stereotypic behavior is an important indicator of compromised welfare. Zoo elephants are documented to perform stereotypic behaviors, but the factors that contribute to performance have not been systematically investigated. We collected behavioral data on 88 elephants at 47 African (*Loxodonta africana*) and 42 Asian (*Elephas maximus*) zoos in North America during the summer and winter. Elephants were observed for a median of 1.2 elephant hours per day. A subset of 52 elephants (19 African, 13 Asian) was also observed for a median of 10.8 elephant hours. Percentages of visible behavior states were calculated from the total instantaneous samples. Stereotypic behavior was the second most commonly observed behavior after resting, making up 15.5% of observations during the daytime and 24.8% at nighttime. Negative binomial regression models that used generalized estimating equations were used to determine which social, housing, management, the history, and demographic variables were associated with daytime and nighttime stereotypic behavior states. Species, management practices, and housing variables were associated with daytime stereotypic behavior states (daytime  $P = 0.001$ , Risk Ratio = 0.887, Nighttime  $P = 0.013$ , Risk Ratio = 0.813). For both species, spending time housed separately ( $P = 0.021$ , Risk Ratio = 1.908), and having a predator in the exhibit were associated with daytime stereotypic behavior states (daytime  $P = 0.021$ , Risk Ratio = 1.778, Nighttime  $P = 0.003$ , Risk Ratio = 1.778), increased the risk of performing higher rates of stereotypy during the day, while spending more time with conspecifics ( $P = 0.018$ , Risk Ratio = 0.888), and engaging with zoo staff reduced the risk ( $P = 0.018$ , Risk Ratio = 0.888). Nighttime stereotypy was more in environments with both indoor and outdoor areas ( $P = 0.013$ , Risk Ratio = 0.887) and a larger body group ( $P = 0.003$ , Risk Ratio = 1.782) compared with reduced rates of performing higher rates of stereotypy while having experienced more zoo predators ( $P = 0.023$ , Risk Ratio = 1.115) increased the risk of performing higher rates of stereotypy.







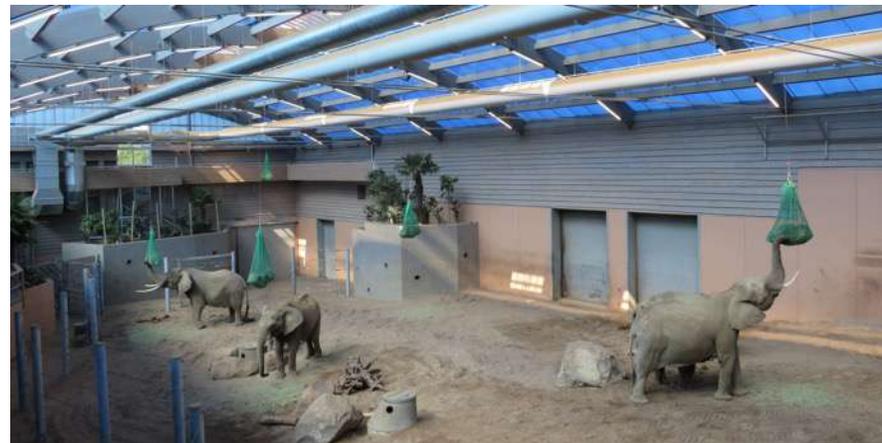
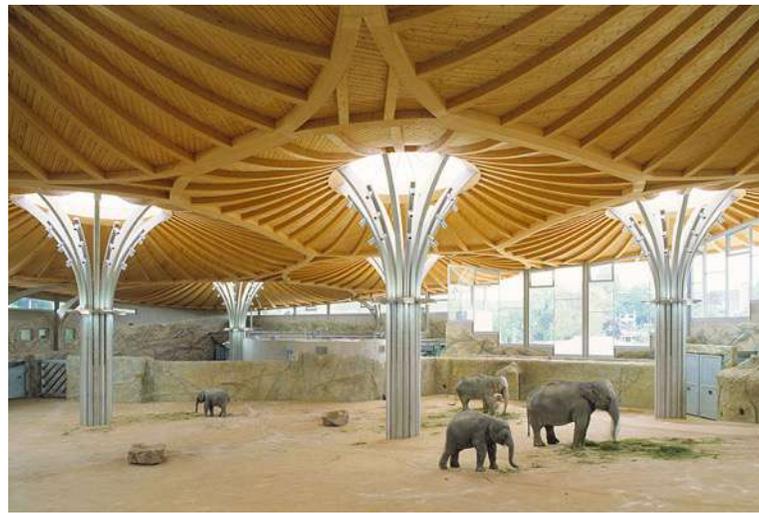
**Compromised Survivorship in Zoo Elephants**

**W**ild elephants in Africa and Asia are declining in number, and zoo elephants are also declining in number. A study published in the journal *Science* in 2002 found that zoo elephants have a significantly lower survival rate than wild elephants. The study found that zoo elephants have a higher mortality rate, especially in the first few years of life, and a lower reproductive rate. The study also found that zoo elephants have a shorter lifespan than wild elephants.

The study was based on data from the International Elephant Roundtable (IER), which tracks the population of elephants in zoos and sanctuaries around the world. The IER data shows that the number of zoo elephants has declined by 50% since 1980. The study also found that zoo elephants have a higher mortality rate than wild elephants, especially in the first few years of life. The study found that zoo elephants have a higher mortality rate than wild elephants in all age groups, but the difference is most pronounced in the first few years of life.

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## Compromised Survivorship in Zoo Elephants

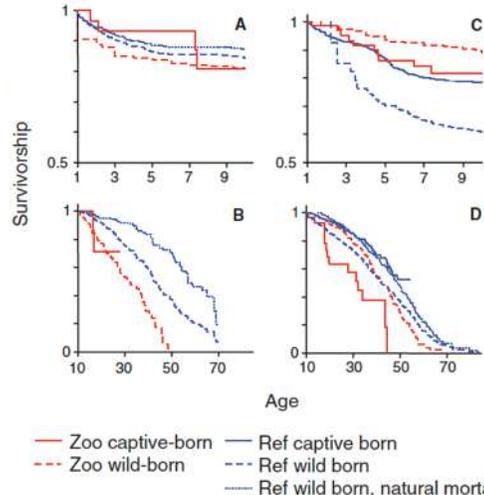
Ros Clubb,<sup>1</sup> Marcus Rowcliffe,<sup>2</sup> Phyllis Lee,<sup>3,4</sup> Khyne U. Mar,<sup>2,5</sup> Cynthia Moss,<sup>4</sup> Georgia J. Mason<sup>6\*</sup>

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 (Myanmar 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

- R. Clubb, G. Mason, *Nature* **425**, 473 (2003).
- R. Clubb, G. Mason, *A Review of the Welfare of Zoo Elephants in Europe* (RSPCA, Horsham, UK, 2002).
- M. Hutchins, M. Keele, *Zoo Biol.* **25**, 219 (2006).
- European Elephant Group, “Elefanten in zoos und safariparks Europa” (European Elephant Group, Grünwald, Germany, 2002).
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- G.J.M. thanks the Natural Science and Engineering Research Council for funding; R.C. and G.J.M. thank R. Ripley for statistical advice; P.L. and C.M. thank many conservation nongovernmental organizations and private donors for supporting the Amboseli Elephant Trust; K.U.M. thanks colleagues at M.T.E. for data compilation and comments. G.J.M. is a visiting professor at The Royal Veterinary College, London, UK. K.U.M. has received funding from Prospect Burma Foundation, Charles Wallace Burma Trust, Three Oaks Foundation, Whitney-Laing Foundation (Rufford Small Grants), Toyota Foundation, Fantham Memorial Research Scholarship, and University College London. K.U.M. has been a paid consultant for Woburn Safari Park, UK. G.J.M. has been a paid consultant to Disney’s Animal Kingdom, USA.

### Supporting Online Material

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

Materials and Methods

SOM Text

Tables S1 and S2

References

6 August 2008; accepted 22 September 2008

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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 2W7, Canada.

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



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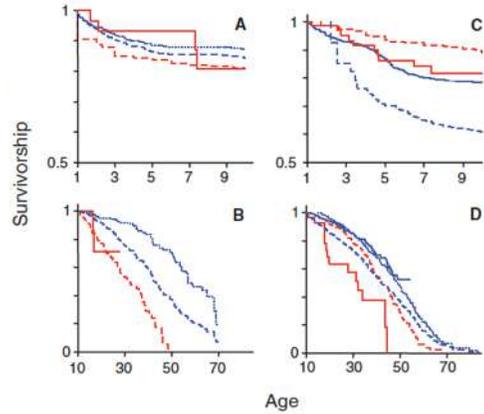
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# as Compared to Some Selected *in situ* Populations Declared ‘Benchmarks’



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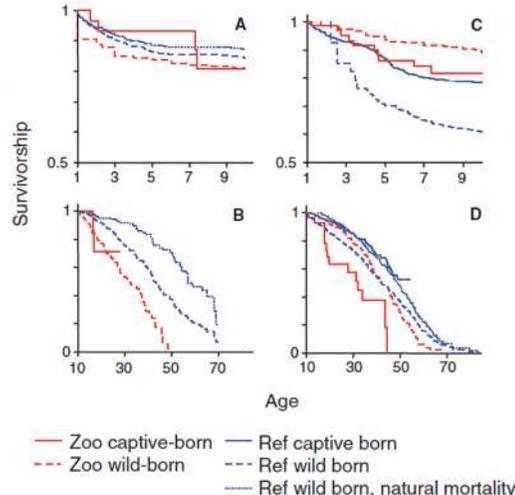
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### References and Notes

- R. Clubb, G. Mason, *Nature* **425**, 473 (2003).
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Data from 1960-2008



# Compromised Survivorship in Zoo Elephants

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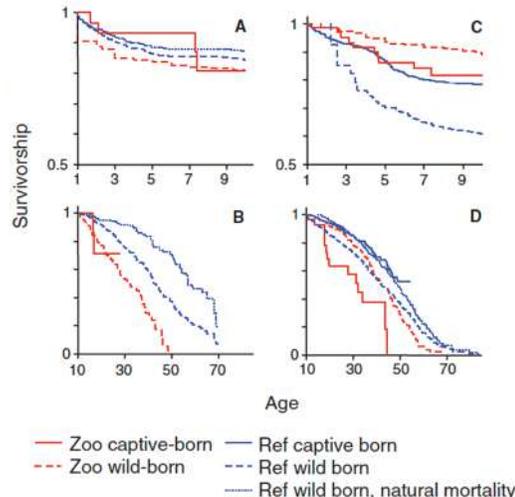
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Data from 1960-2008

### 1. Average lifespan is lower in zoos than *in situ*

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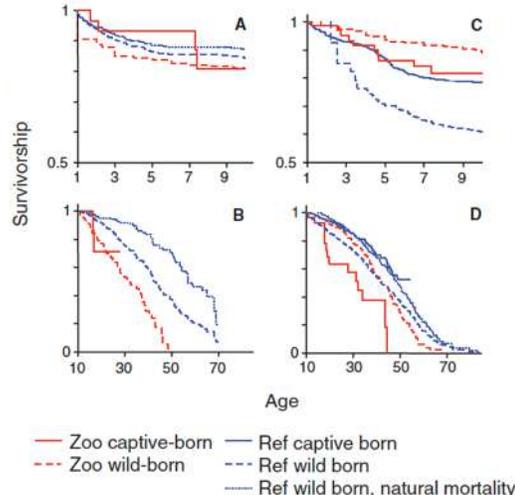
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1. Average lifespan is lower in zoos than *in situ*
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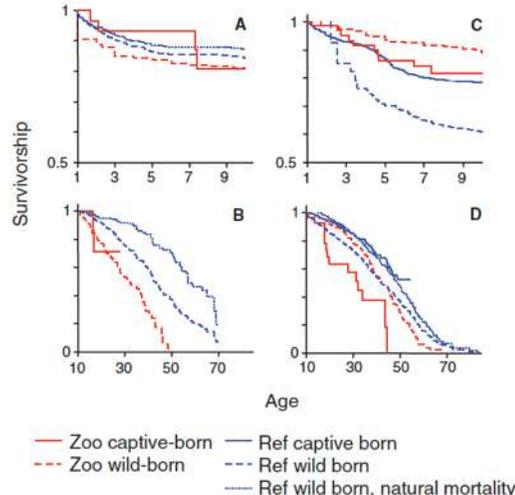
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2. Survivorship is lower in zoos than *in situ*
3. Although there was some improvement in survivorship in African elephants since 1960, there was no such improvement in Asian elephants



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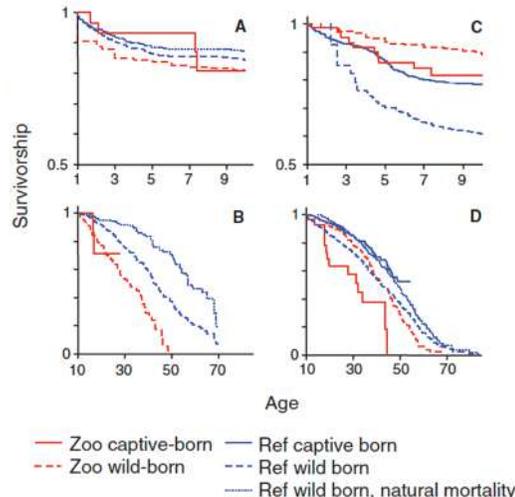
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# Calculating 'average' or 'median lifespan'

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Age



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Age



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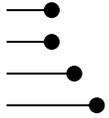


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Age



# Calculating 'average' or 'median lifespan'

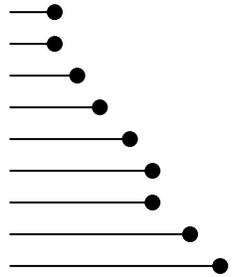


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Age



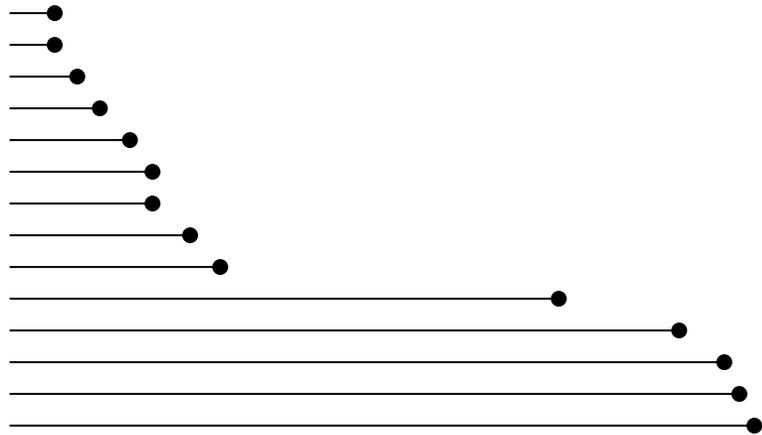
# Calculating 'average' or 'median lifespan'



Age



# Calculating 'average' or 'median lifespan'

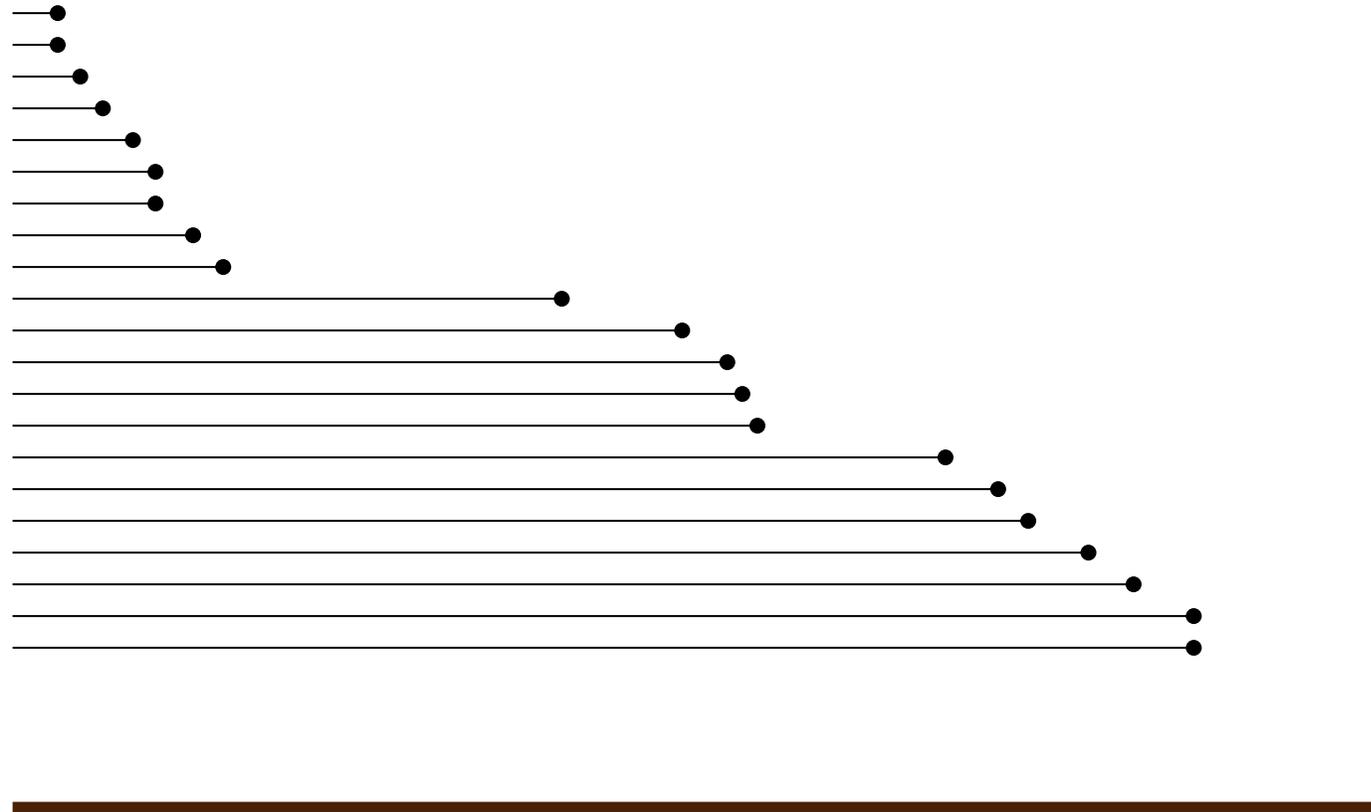


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Age



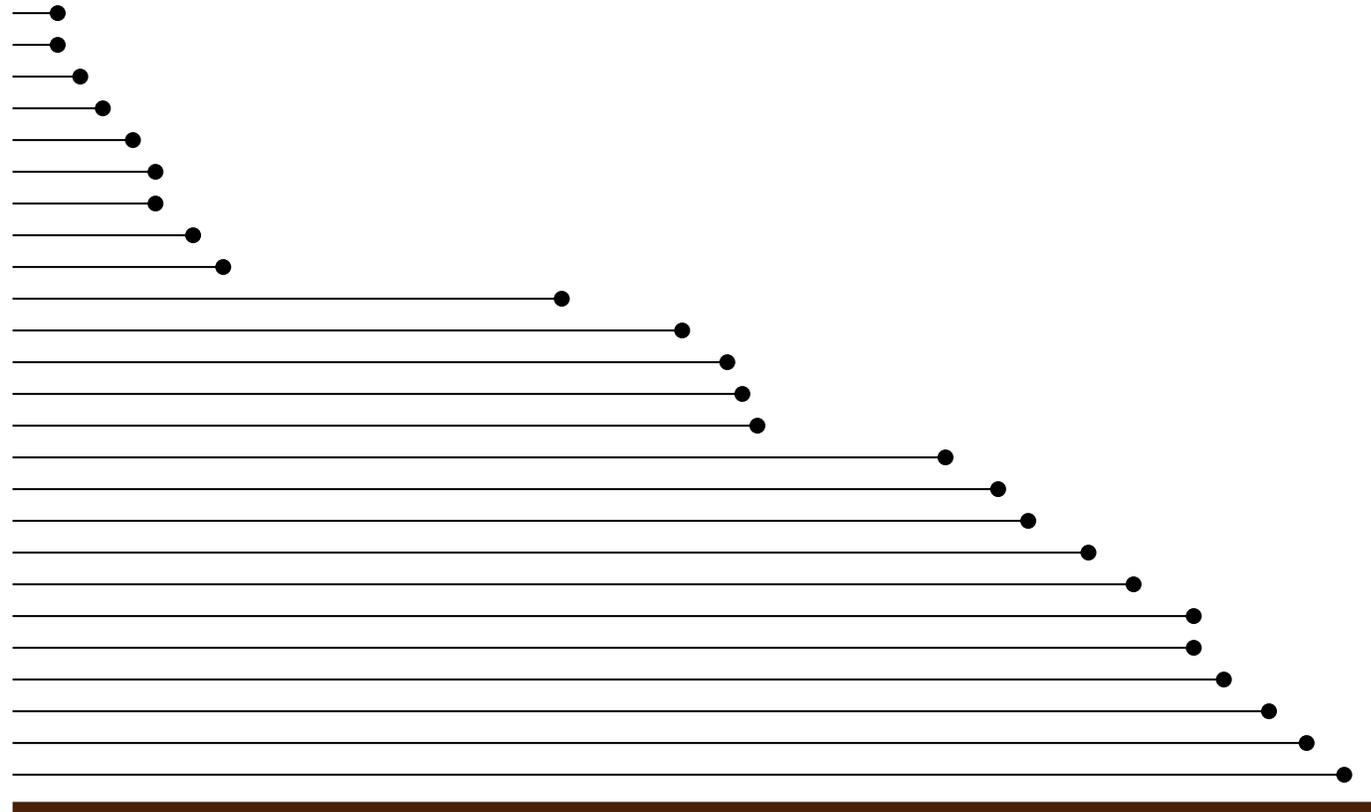
# Calculating 'average' or 'median lifespan'



Age



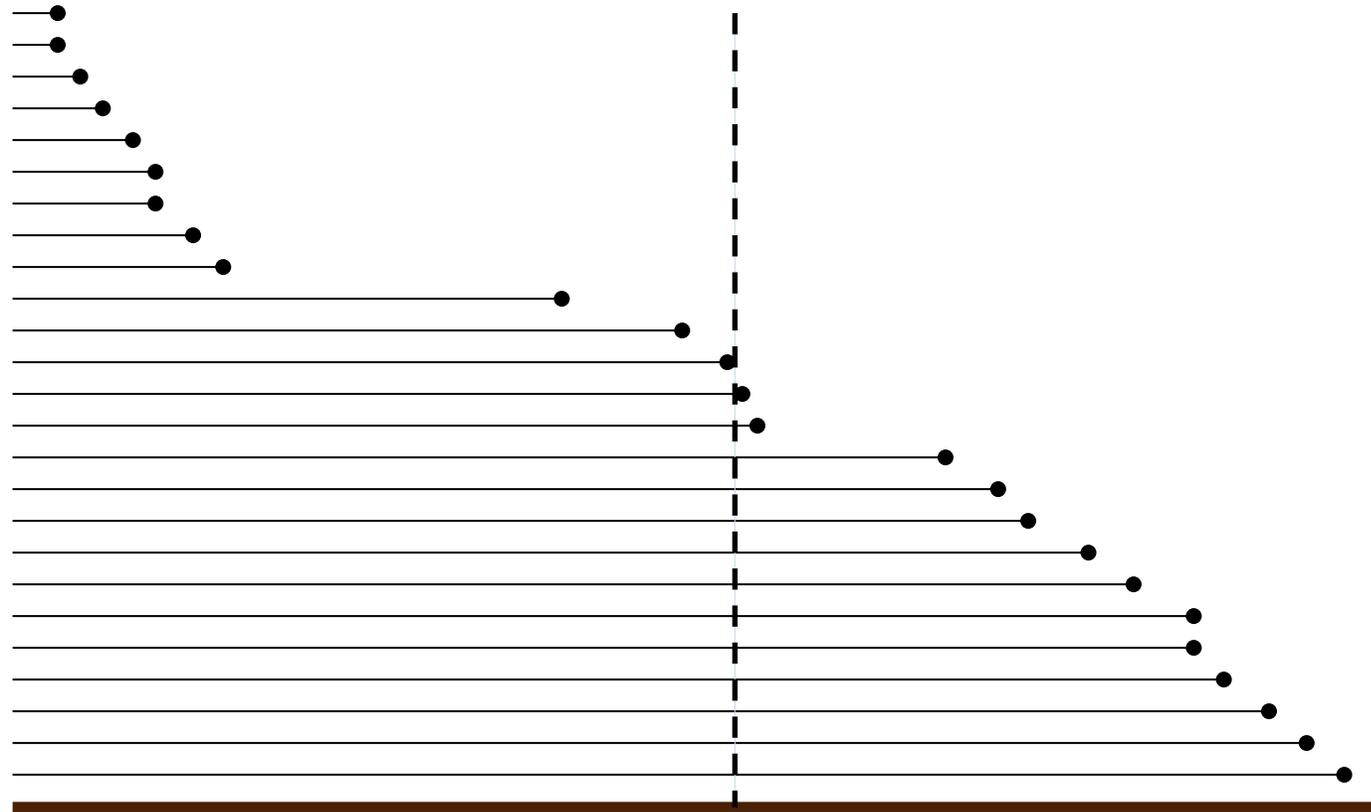
# Calculating 'average' or 'median lifespan'



Age



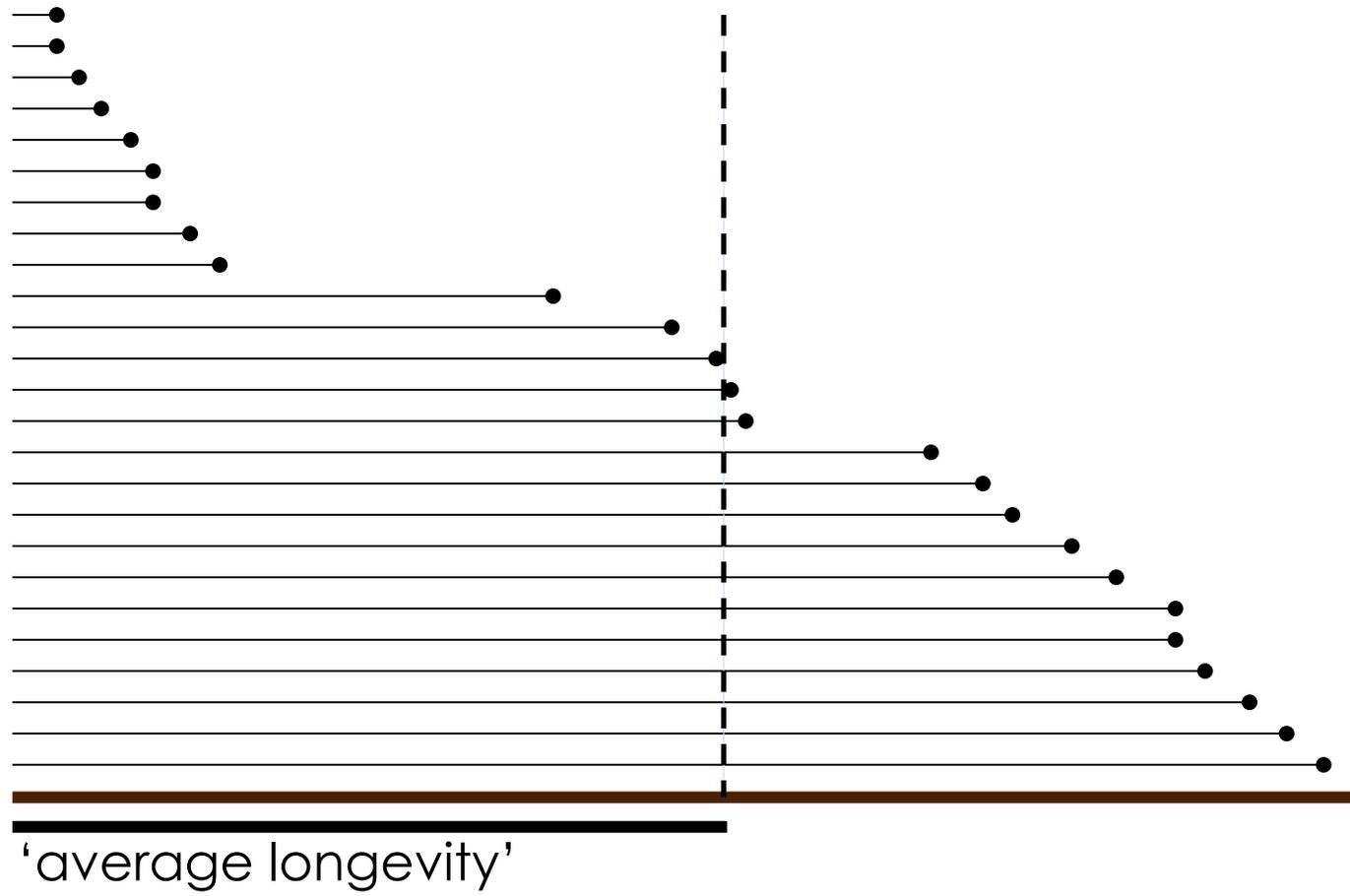
# Calculating 'average' or 'median lifespan'



Age



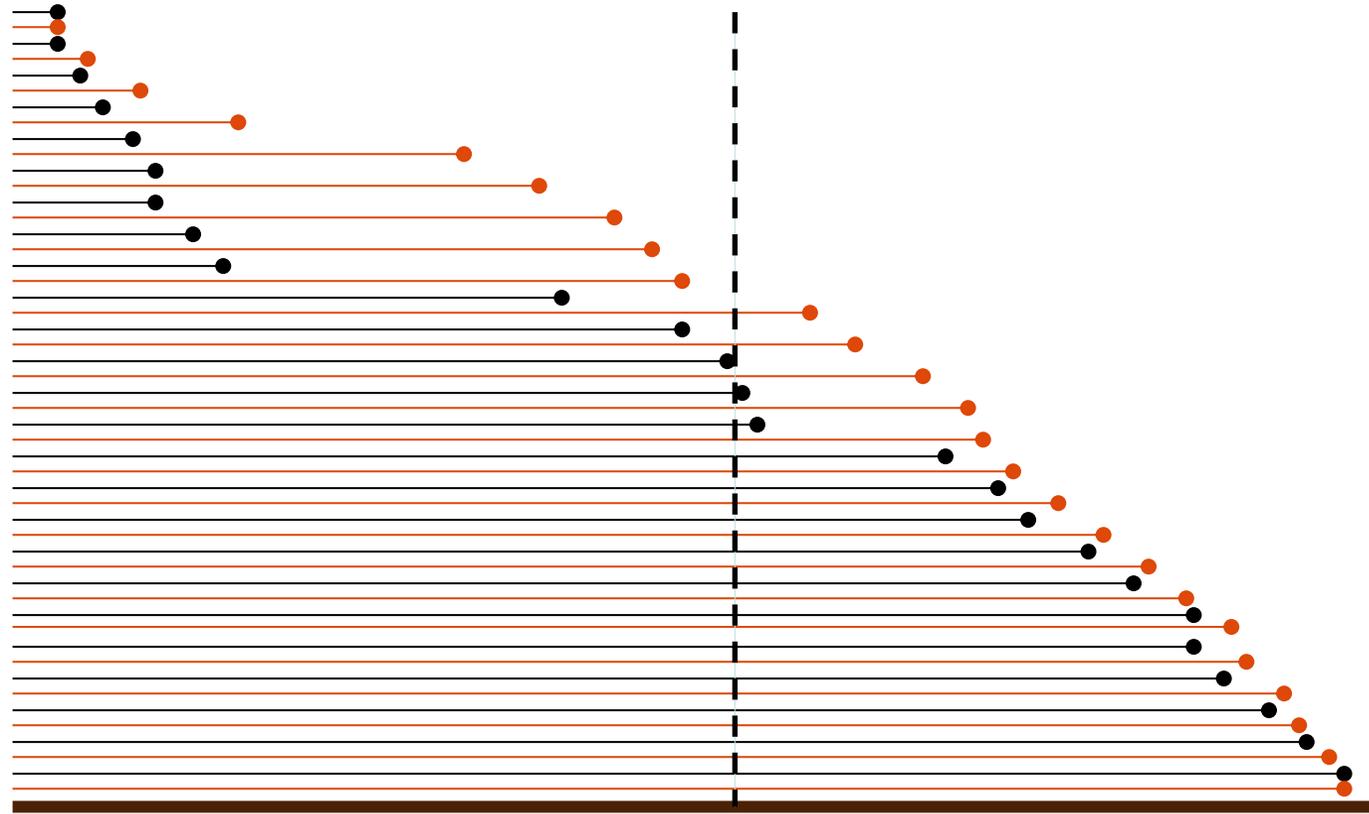
# Calculating 'average' or 'median lifespan'



Age



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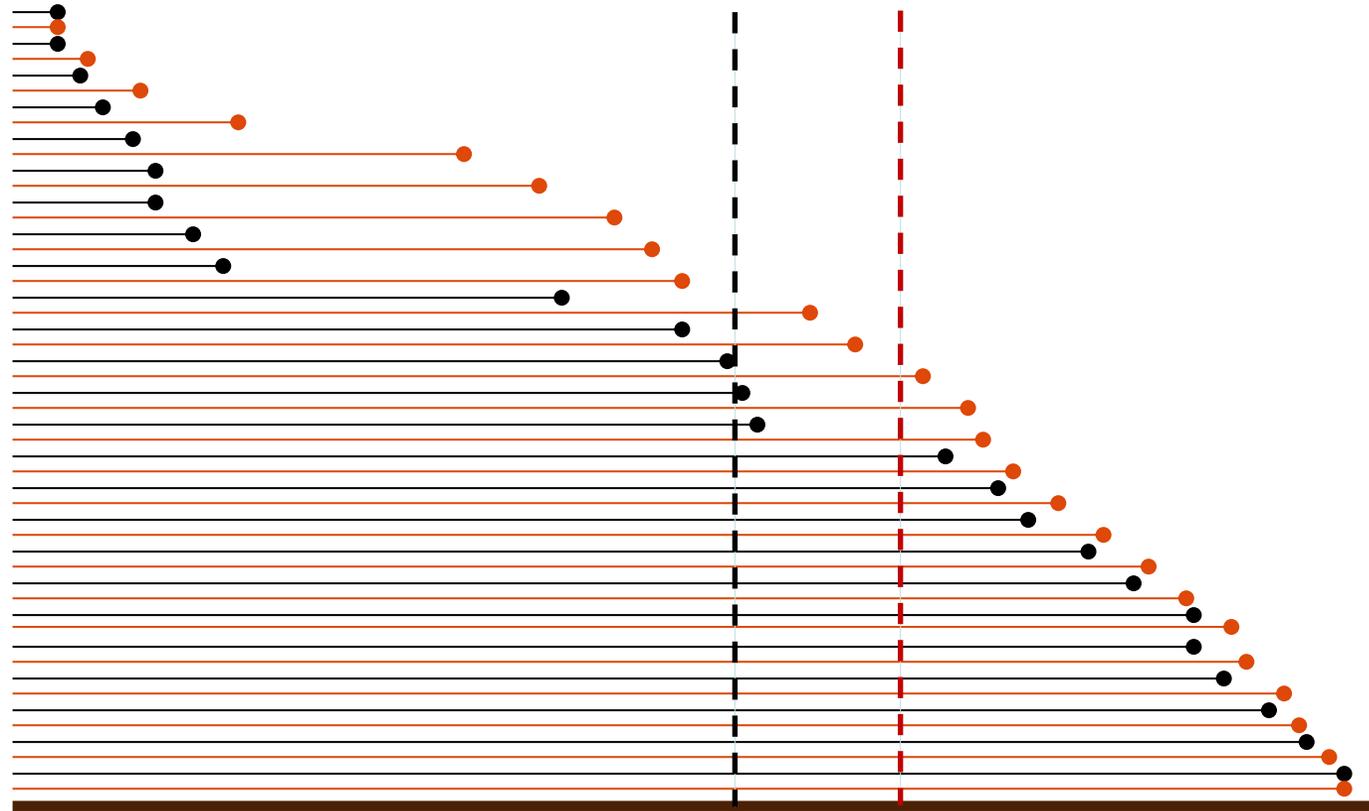


'average longevity'

Age



# Calculating 'average' or 'median lifespan'

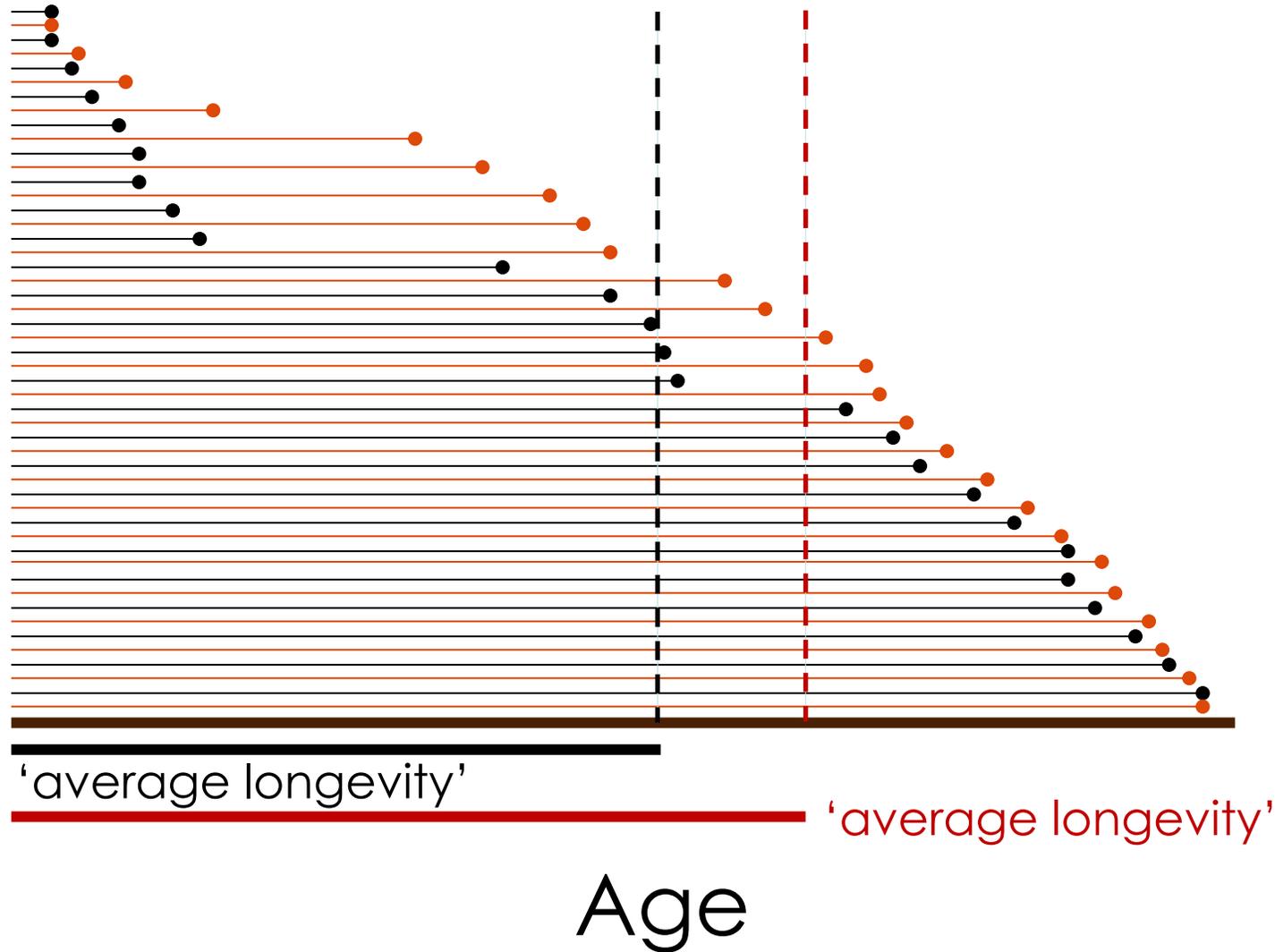


'average longevity'

Age

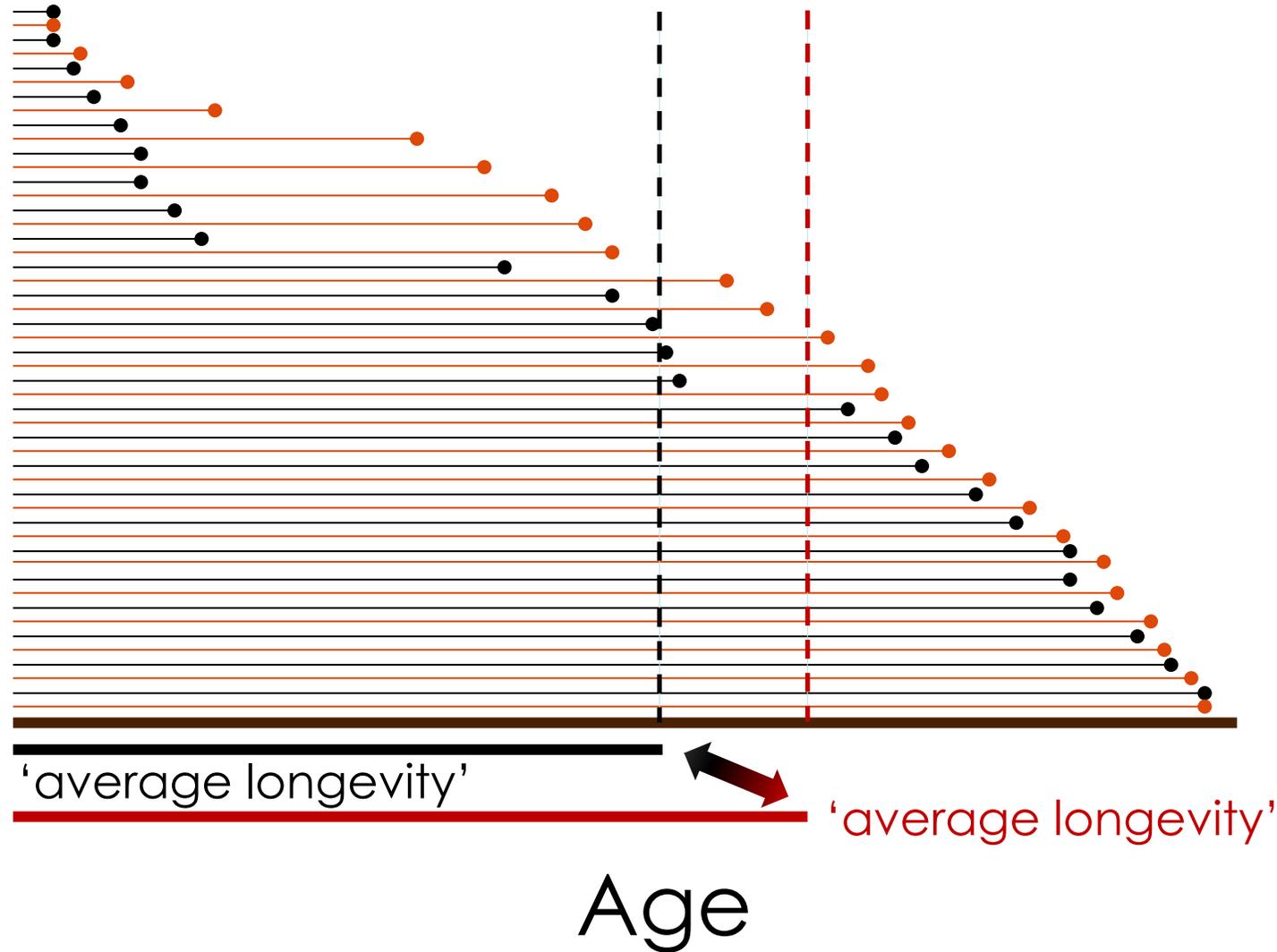


# Calculating 'average' or 'median lifespan'



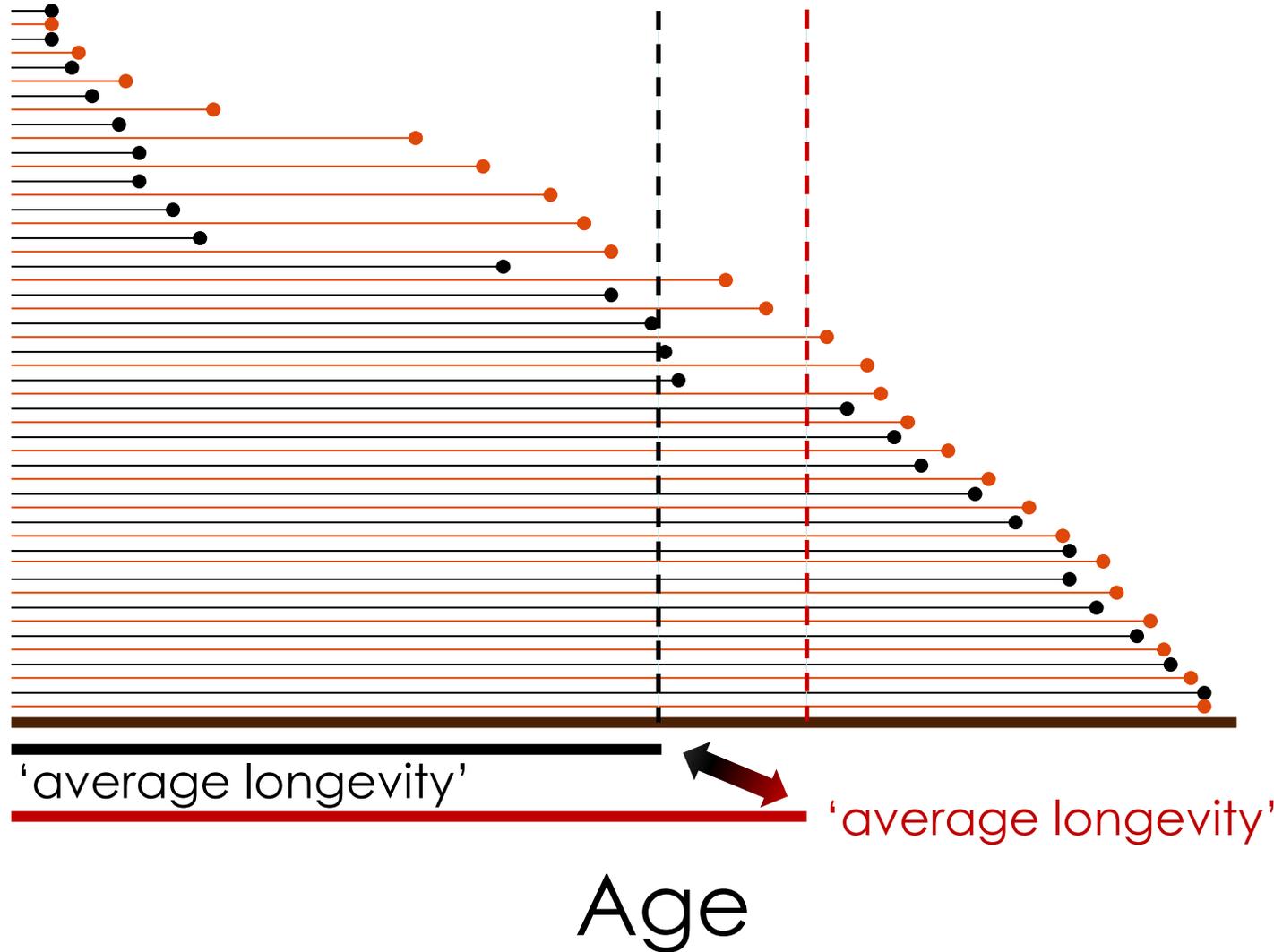


# Calculating 'average' or 'median lifespan'





# Calculating 'average' or 'median lifespan'



'complete cohorts' (all animals died)

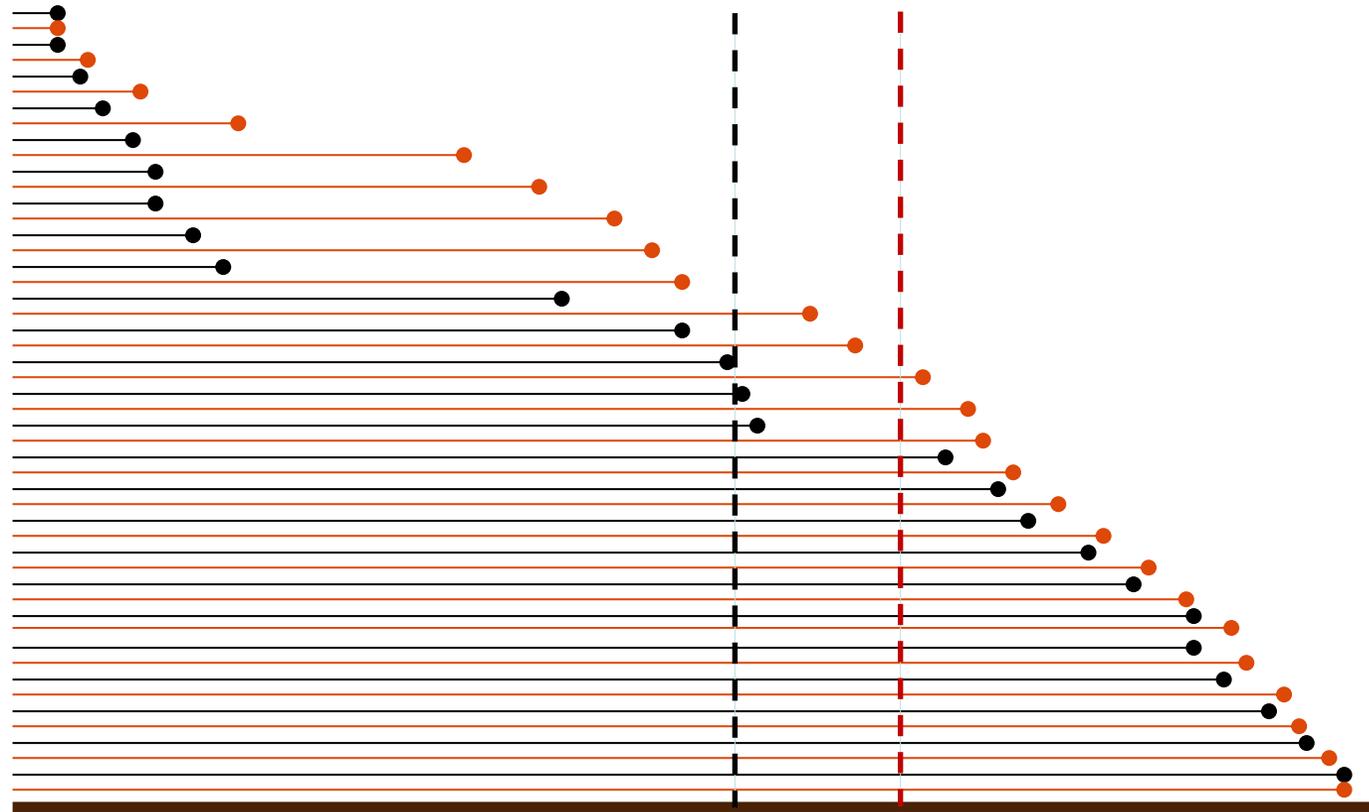
impractical in long-lived species if more recent developments should be investigated



# Calculating 'average' or 'median lifespan'

historical *in situ* population —●

zoo population —●



'average longevity'

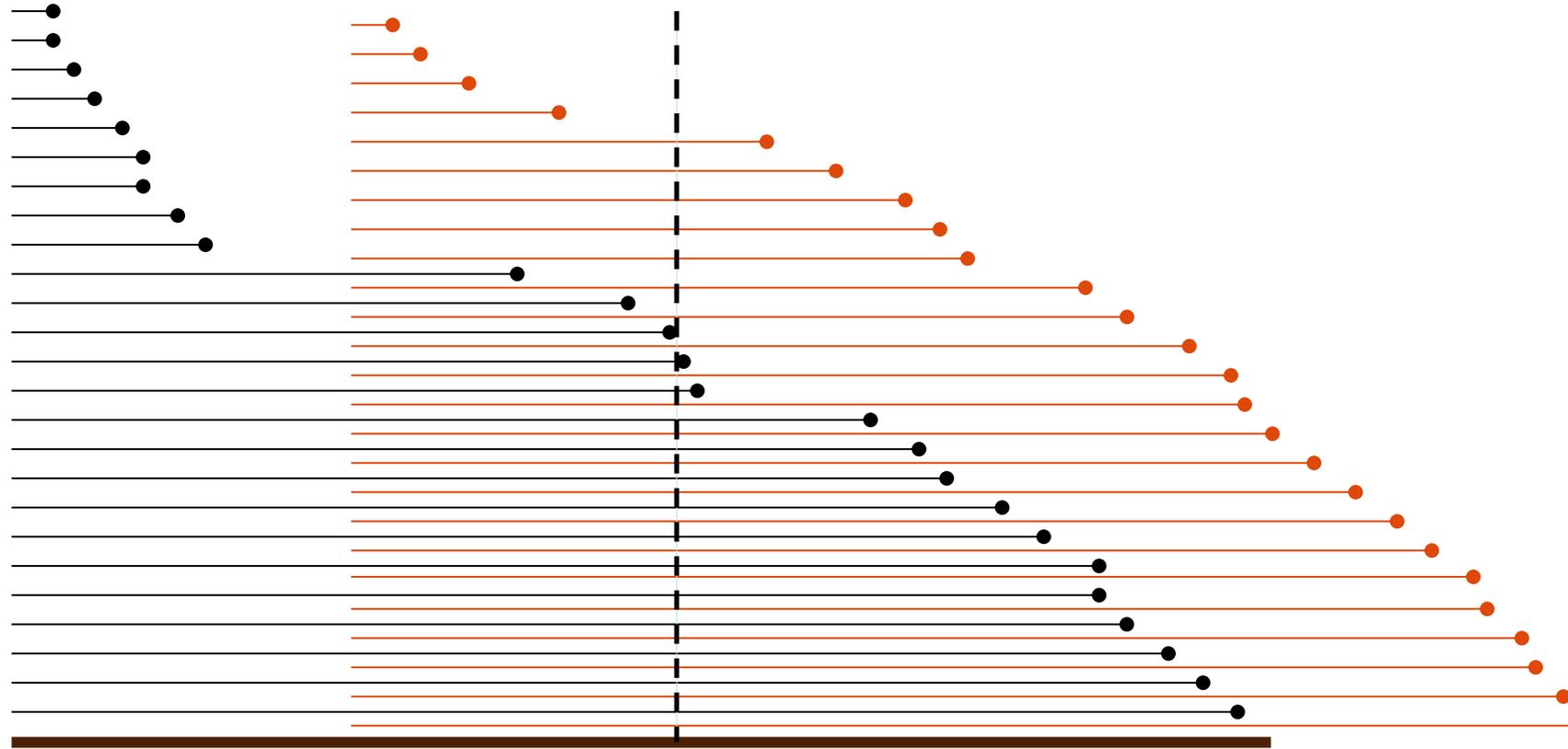
Time



# Calculating 'average' or 'median lifespan'

historical *in situ* population —●

zoo population —●



'average longevity'

today

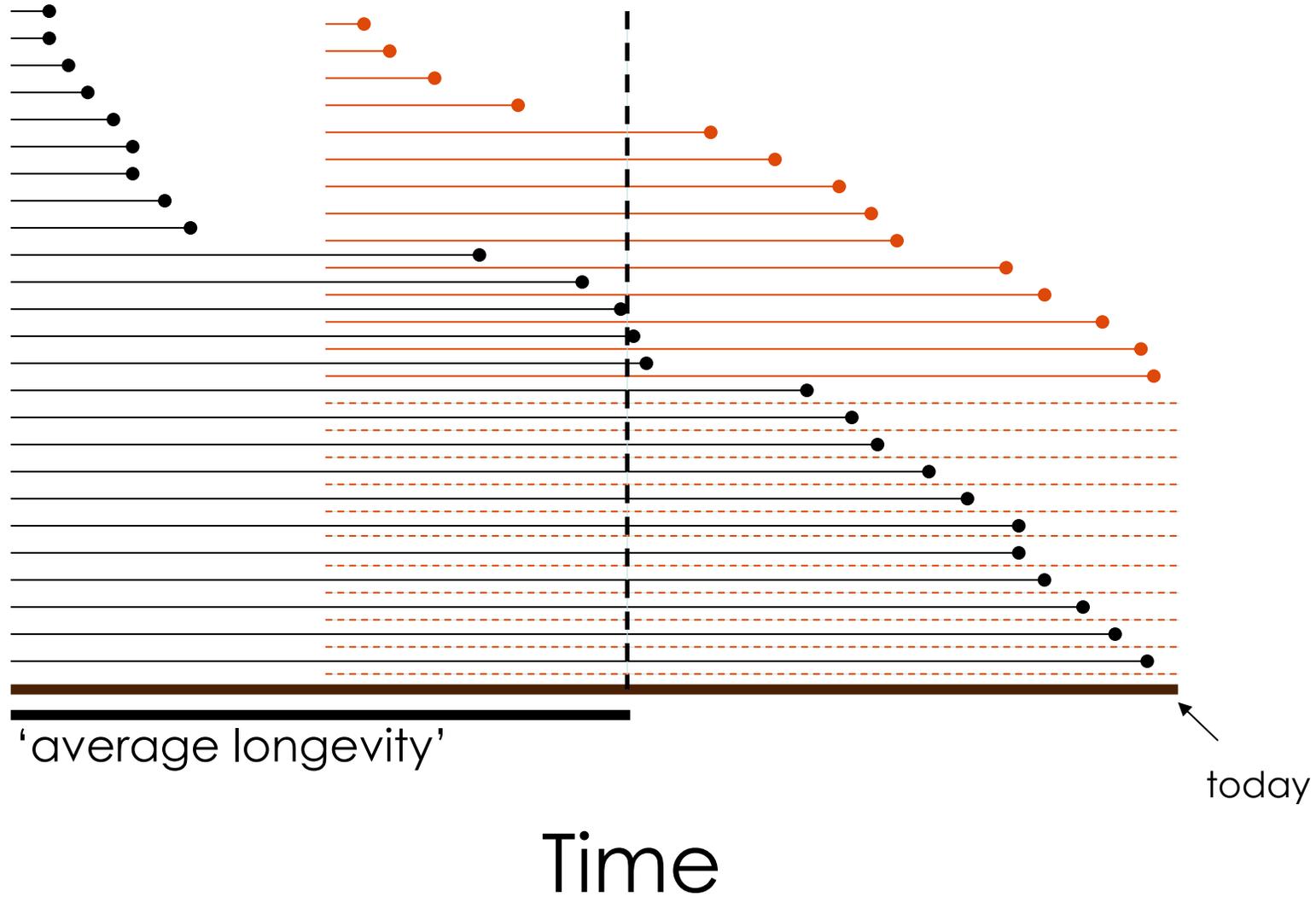
Time



# Calculating 'average' or 'median lifespan'

historical *in situ* population —●

zoo population —●

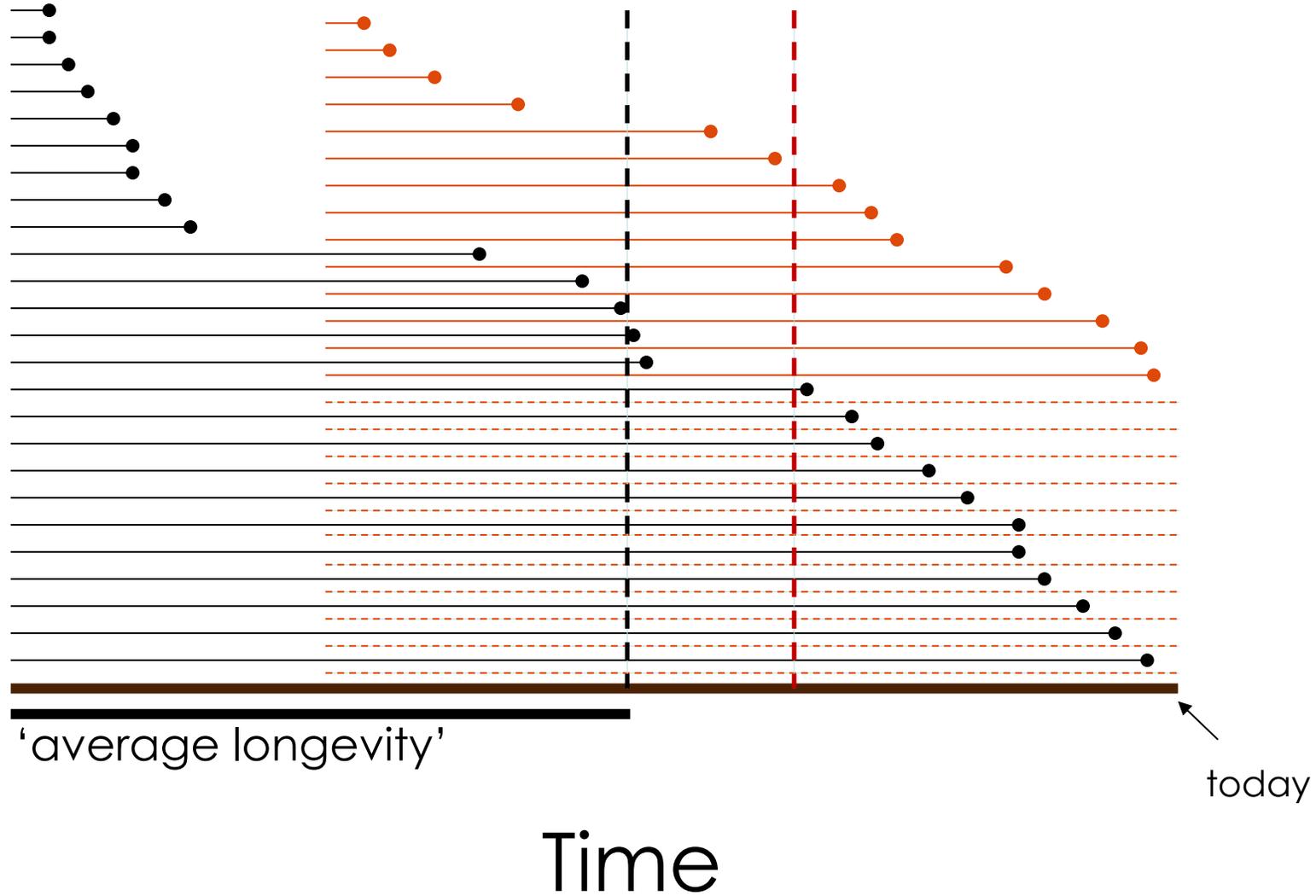




# Calculating 'average' or 'median lifespan'

historical *in situ* population —●

zoo population —●

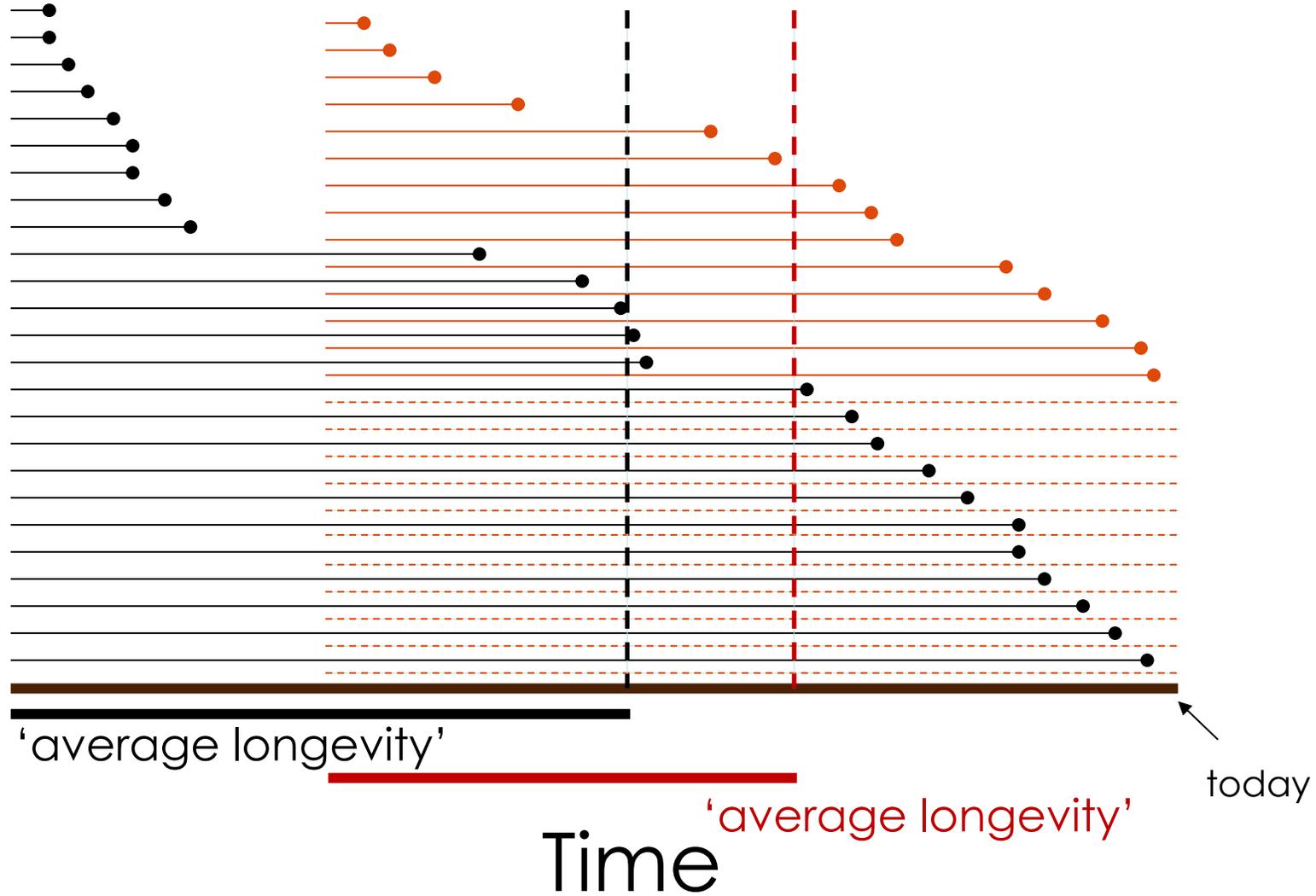




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zoo population —●

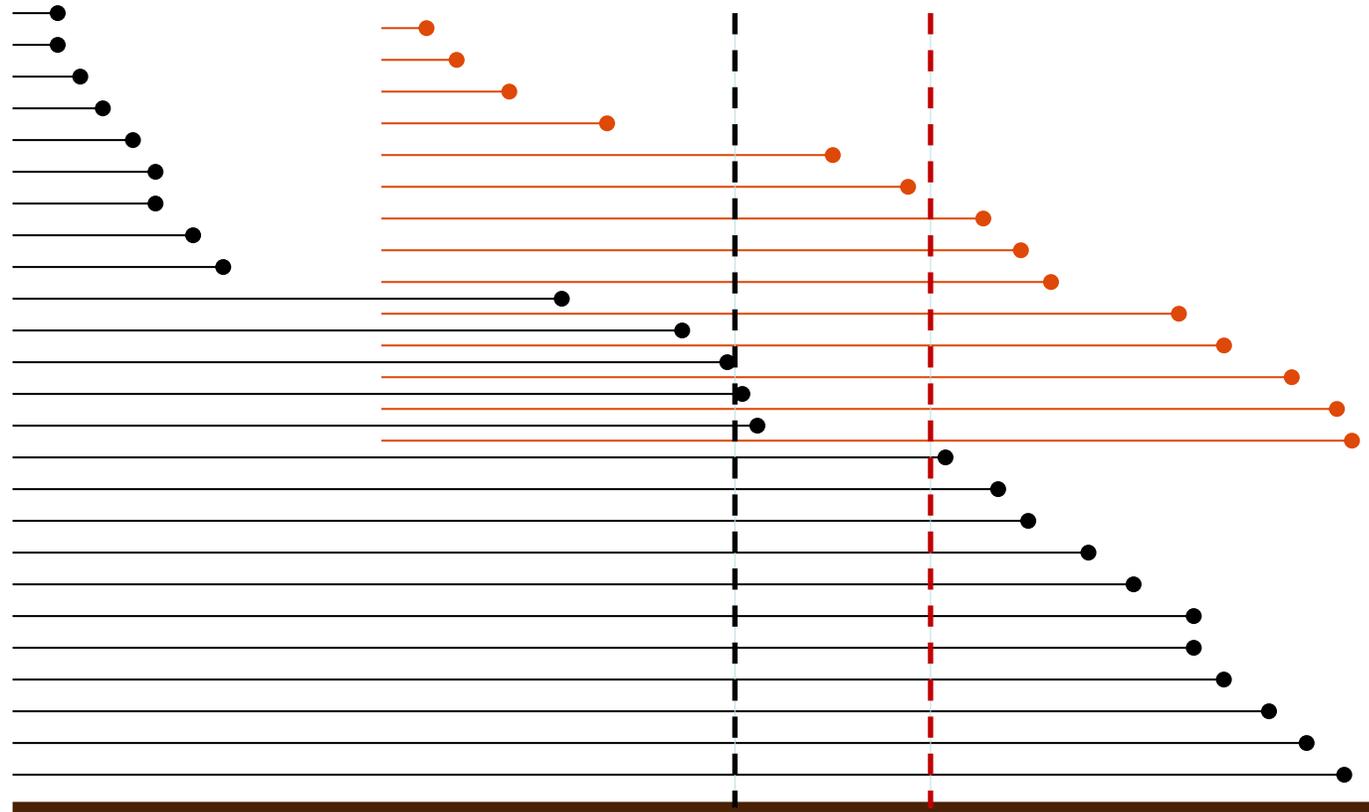




# Calculating 'average' or 'median lifespan'

historical *in situ* population —●

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'average longevity'

'average longevity'

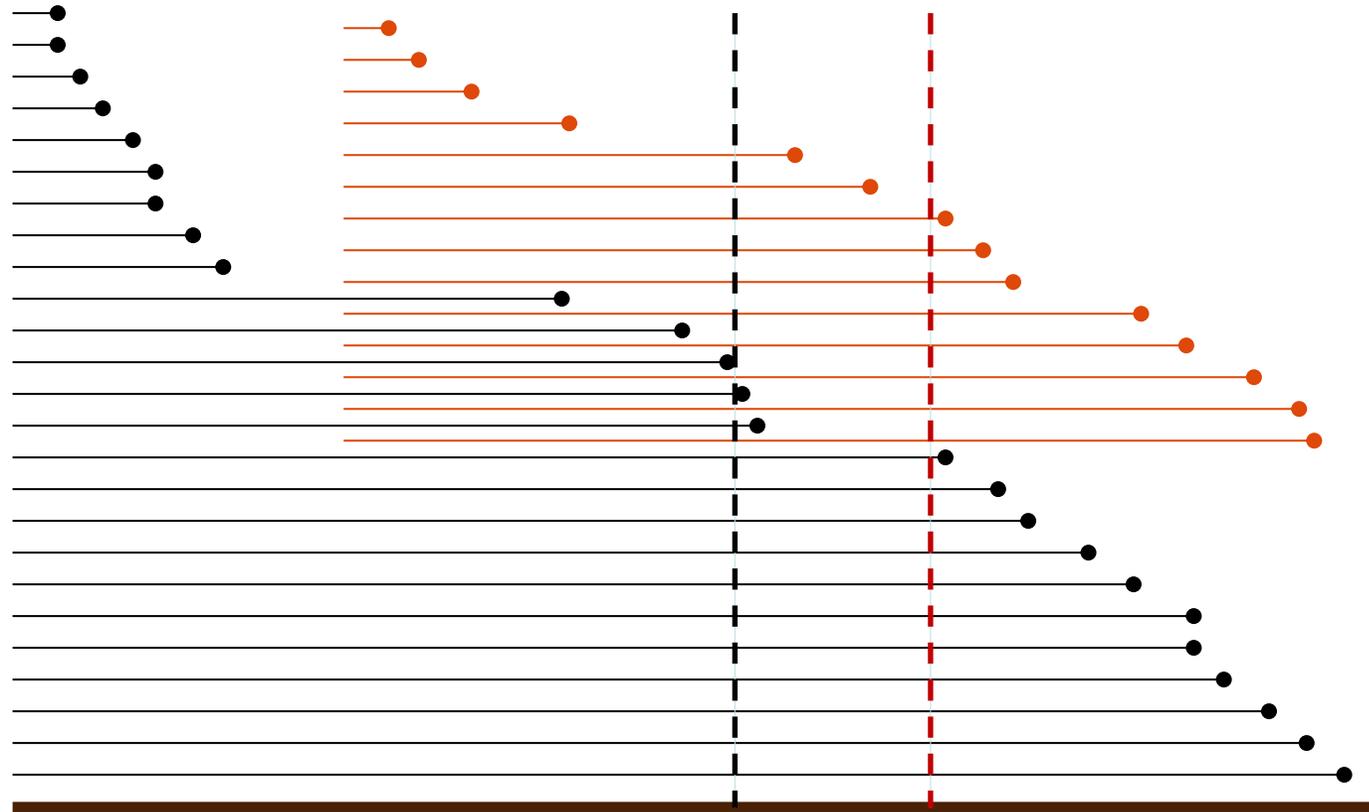
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historical *in situ* population —●

zoo population —●



'average longevity'

'average longevity'

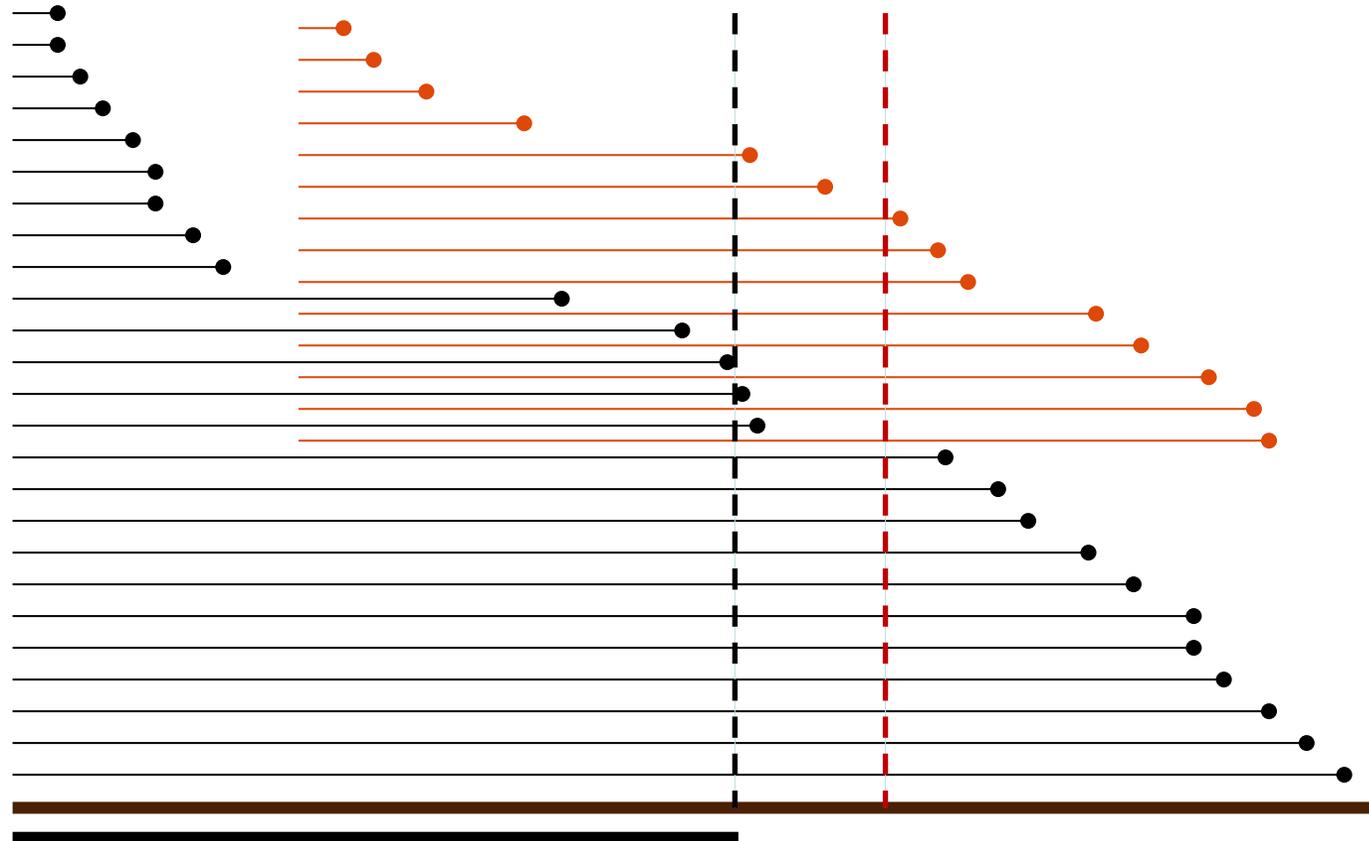
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historical *in situ* population —●

zoo population —●



'average longevity'

'average longevity'

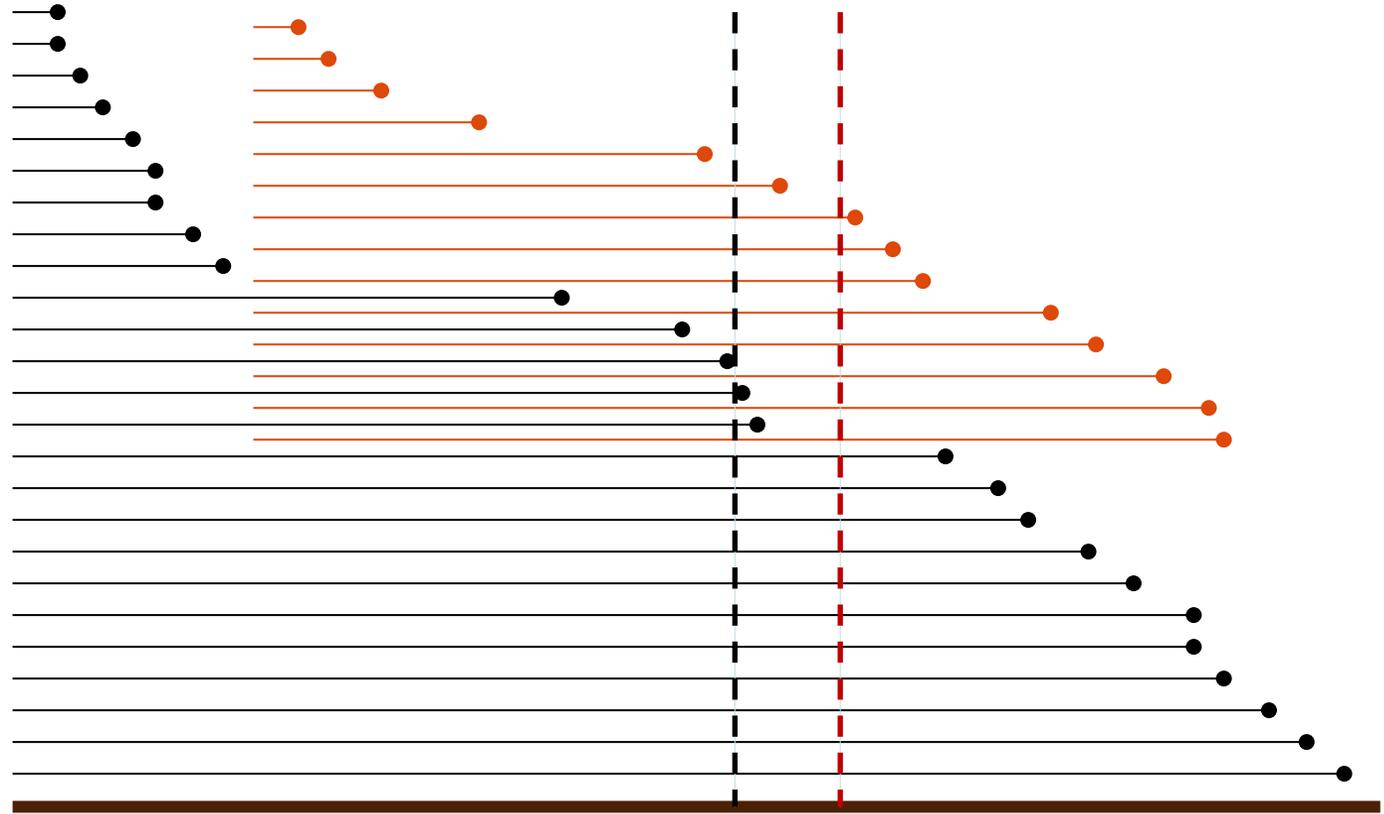
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zoo population —●



'average longevity'

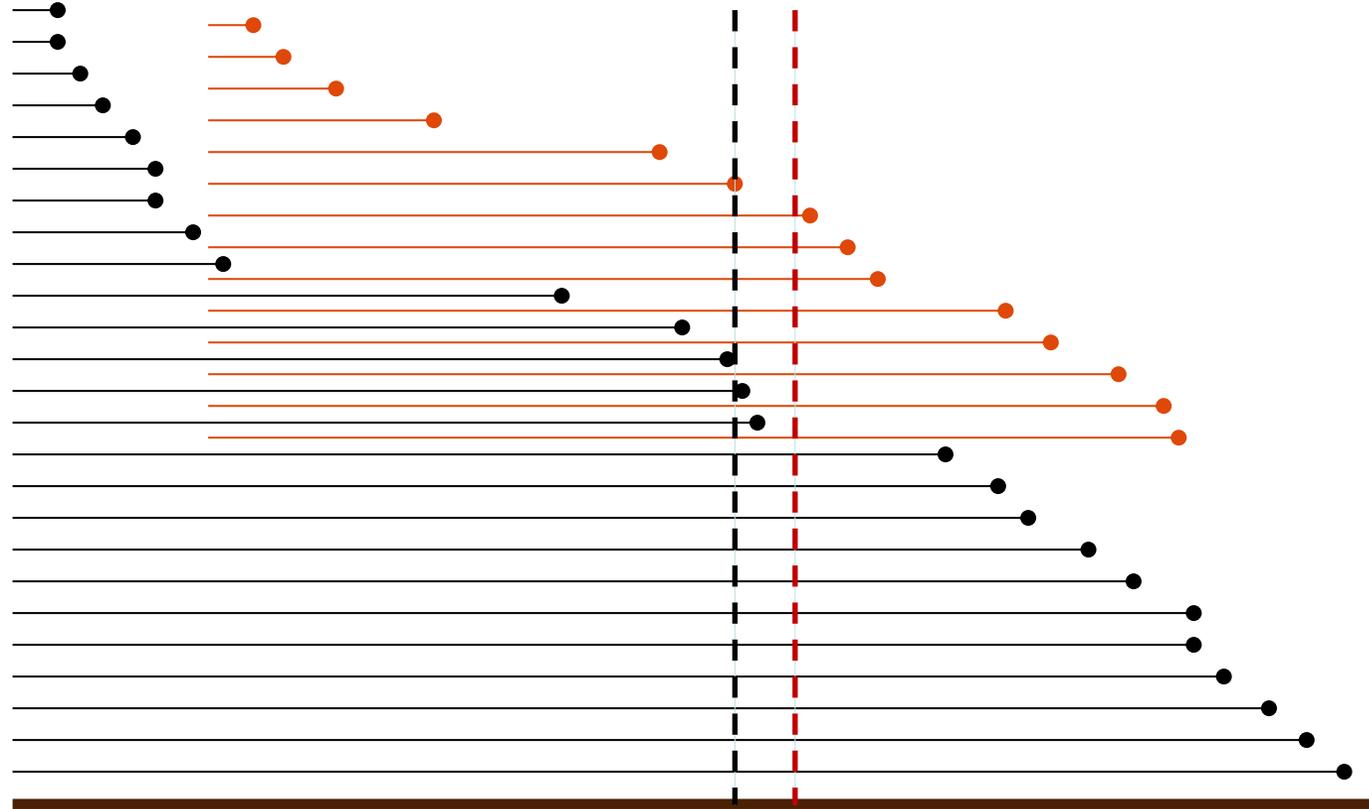
'average longevity'  
Age



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historical *in situ* population —●

zoo population —●



'average longevity'

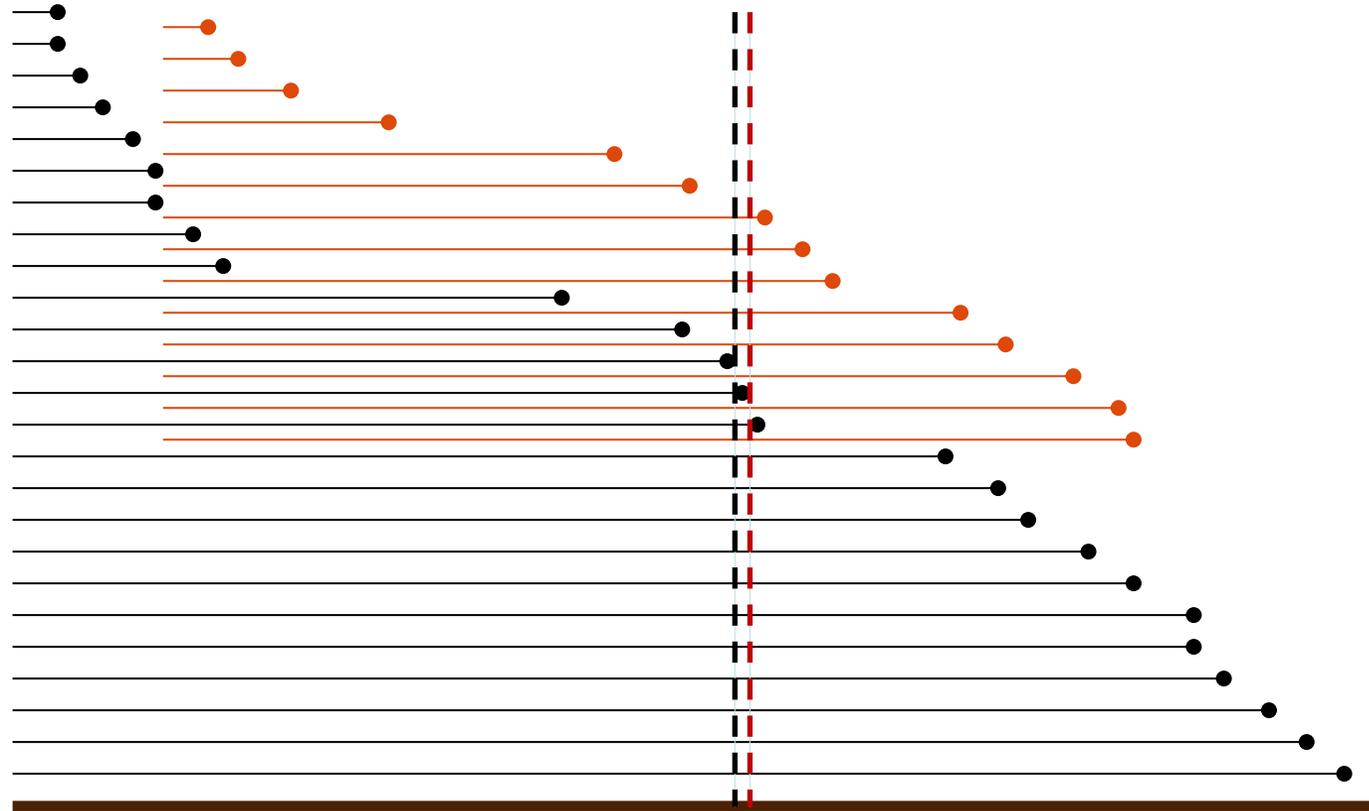
'average longevity'  
Age



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historical *in situ* population —●

zoo population —●



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'average longevity'

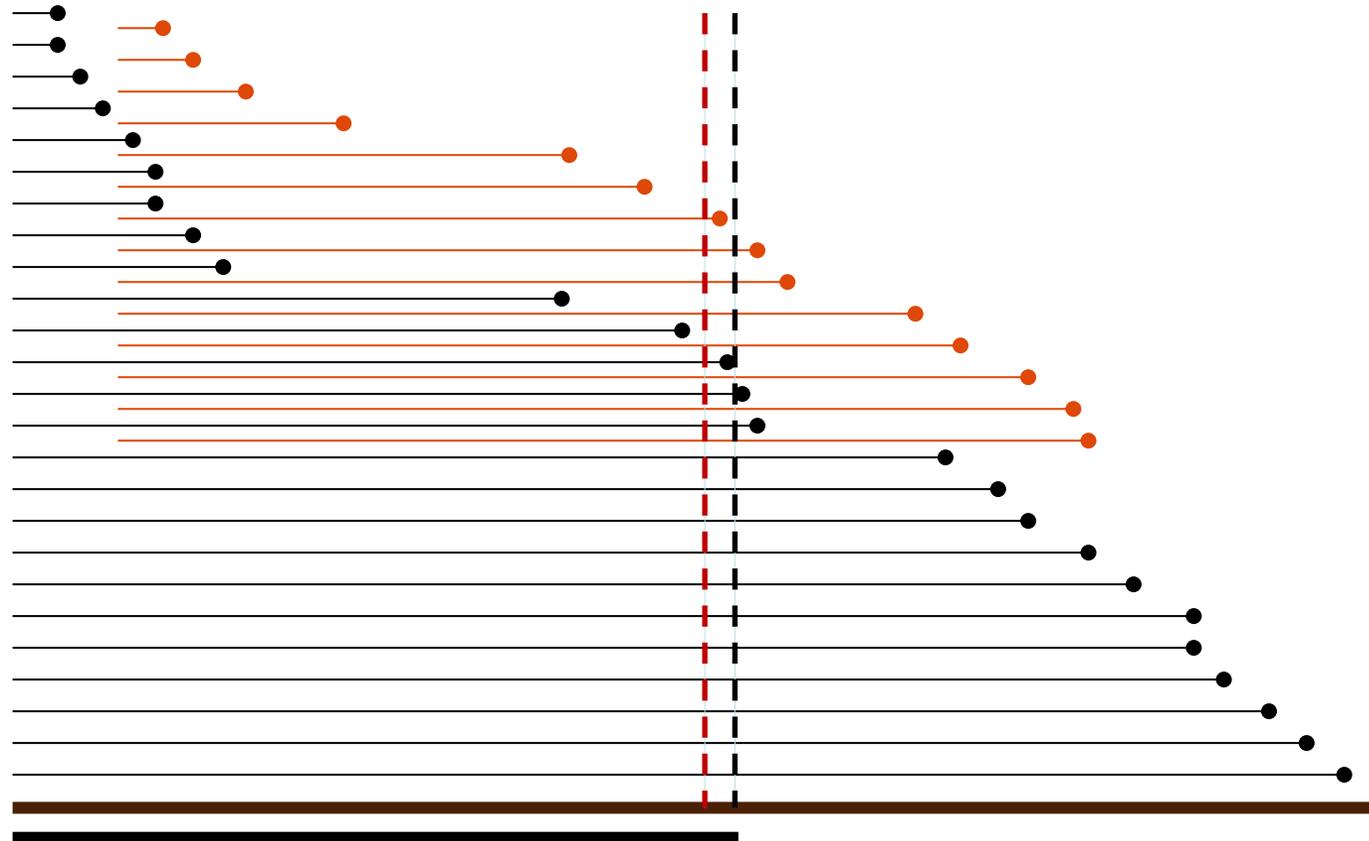
Age



# Calculating 'average' or 'median lifespan'

historical *in situ* population —●

zoo population —●



'average longevity'

'average longevity'

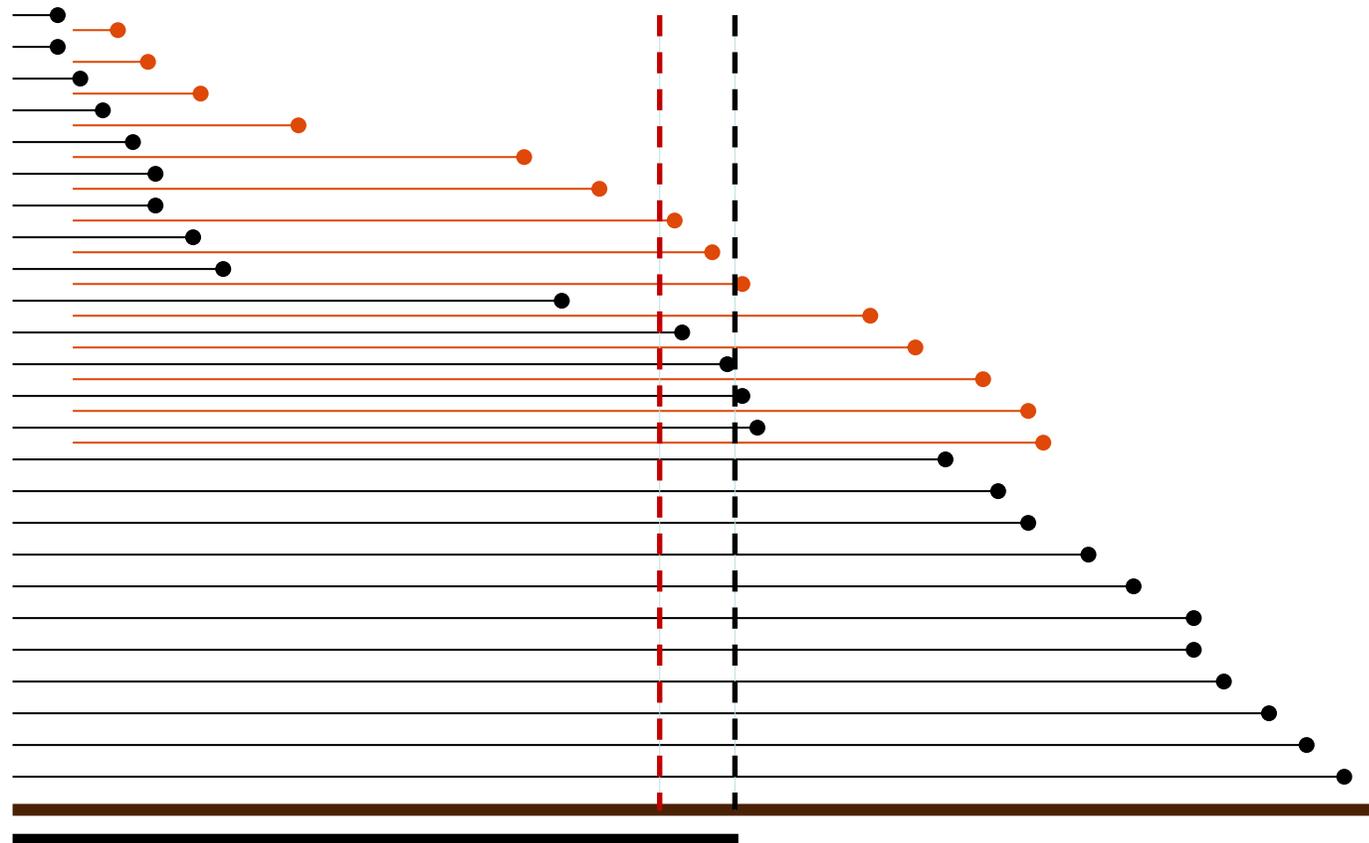
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zoo population —●



'average longevity'

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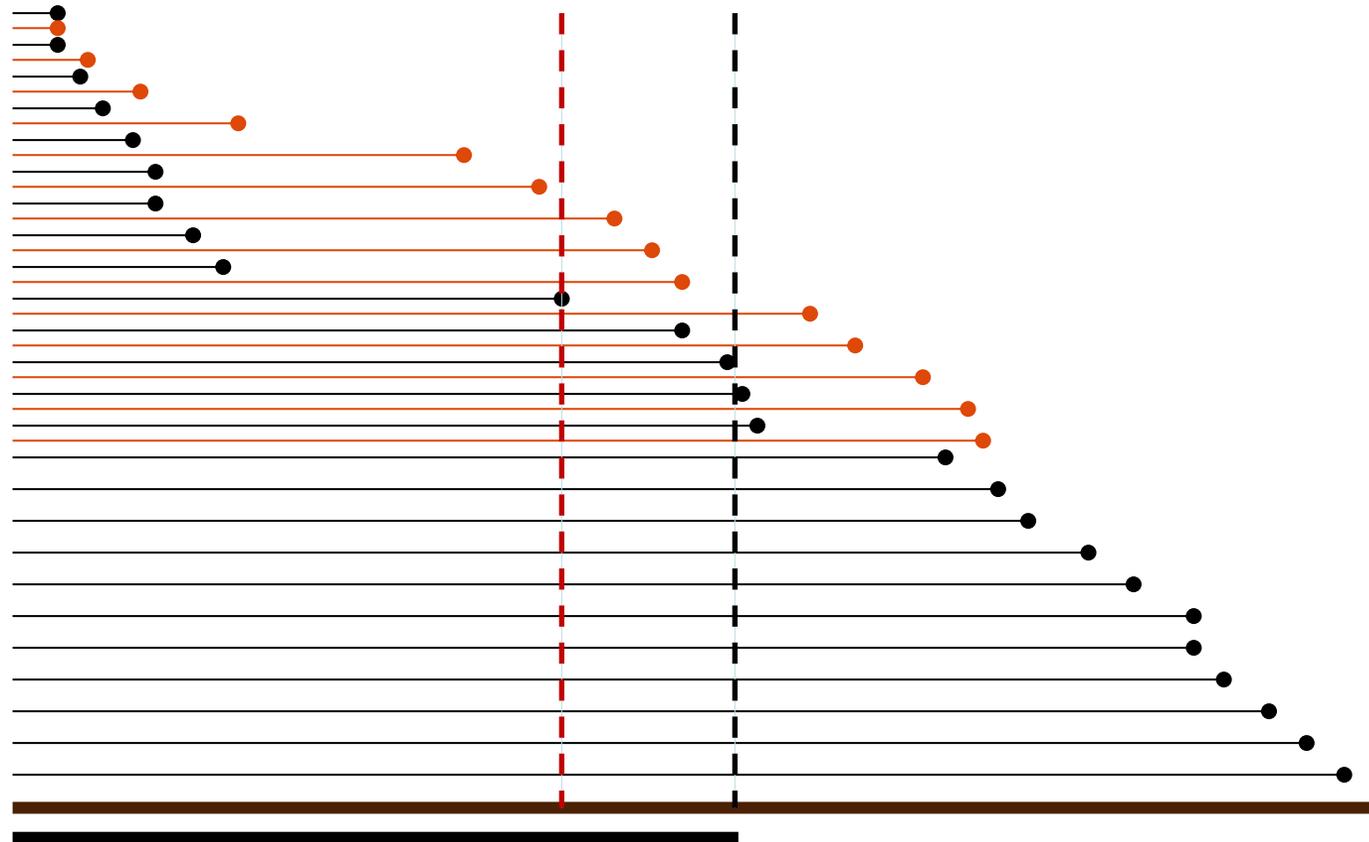
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historical *in situ* population —●

zoo population —●



'average longevity'

'average longevity'

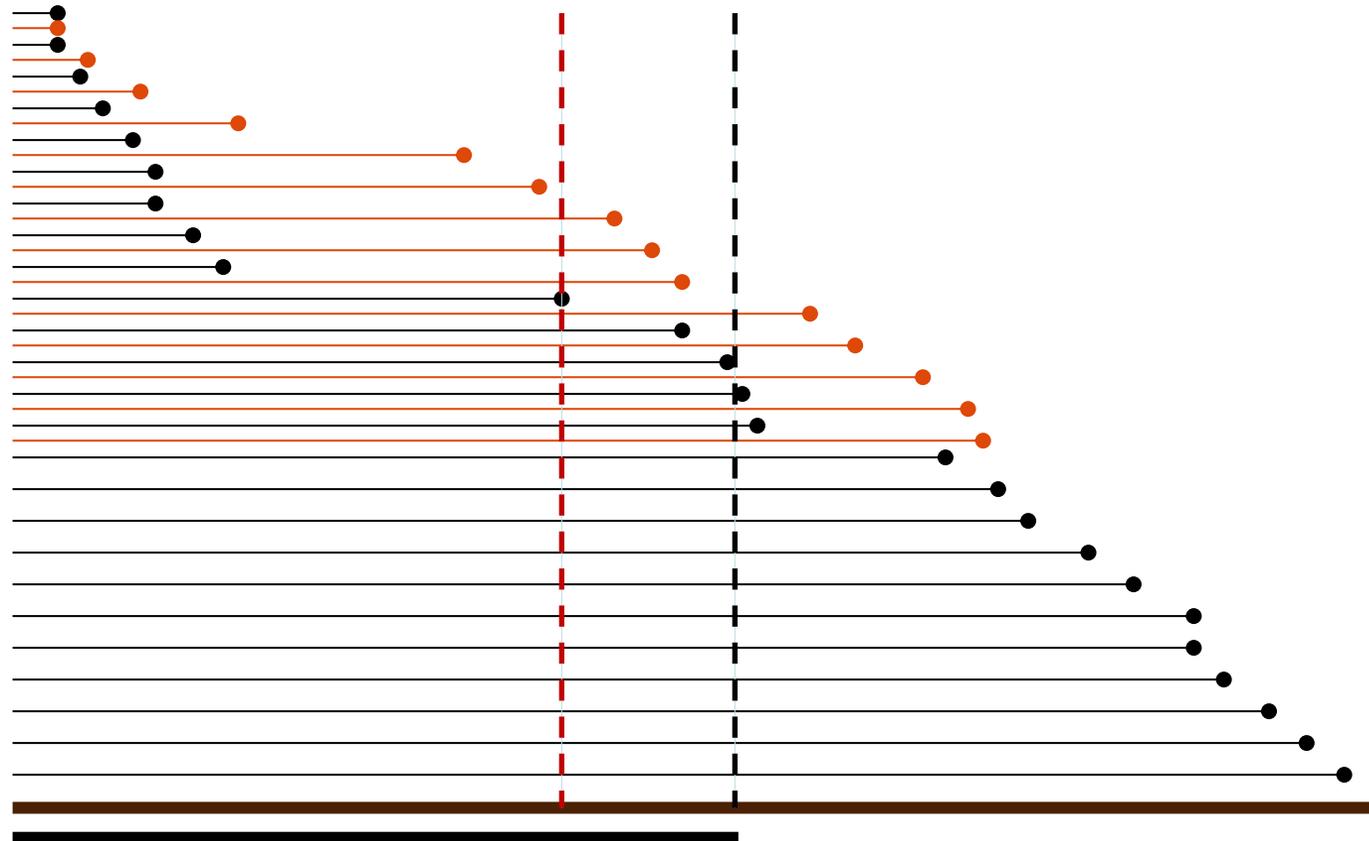
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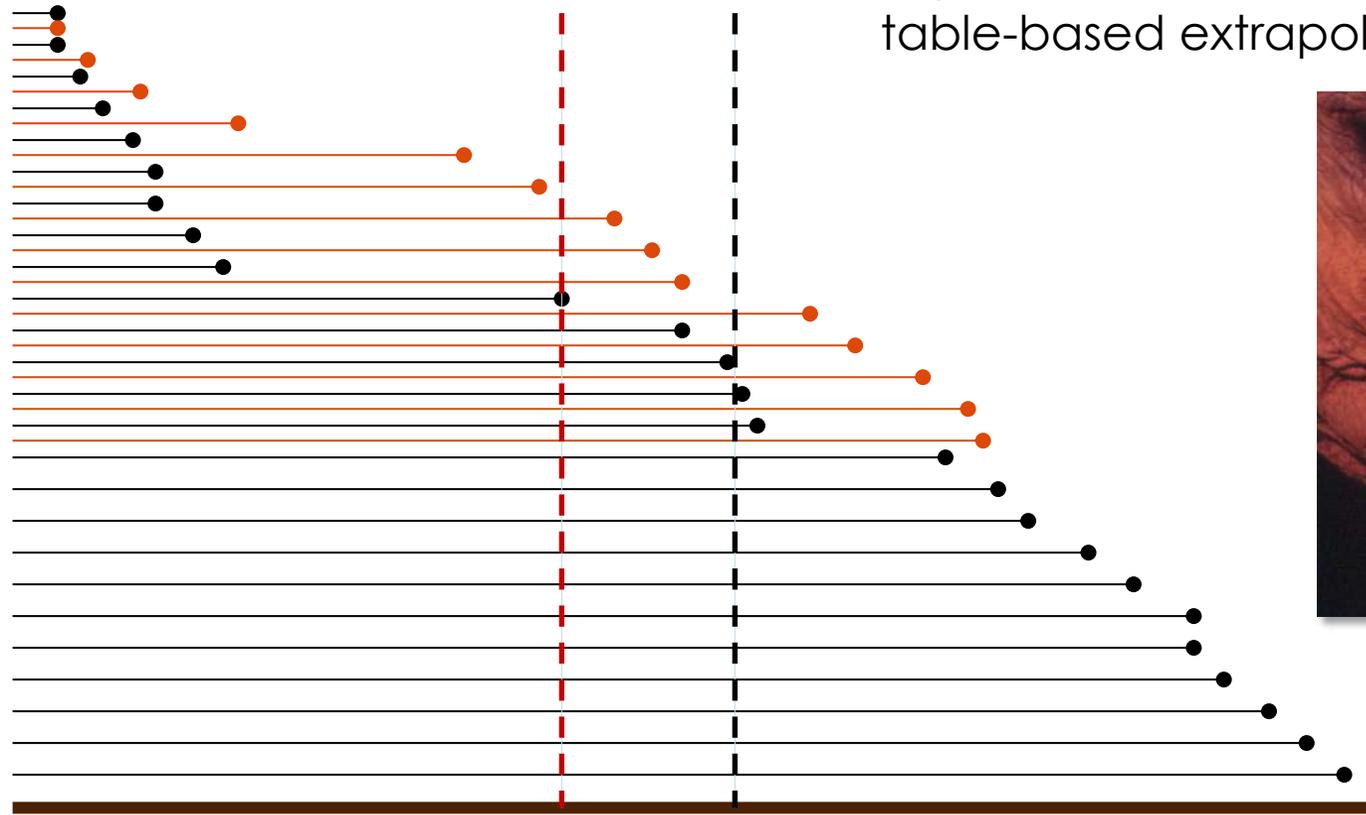
Age



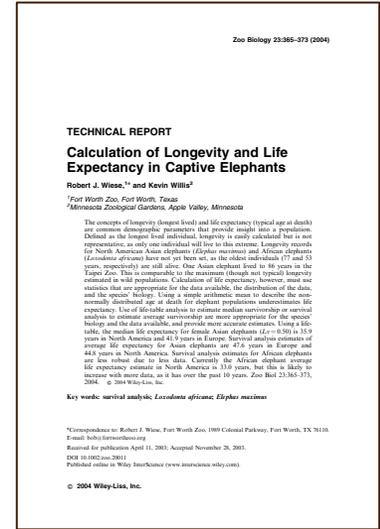
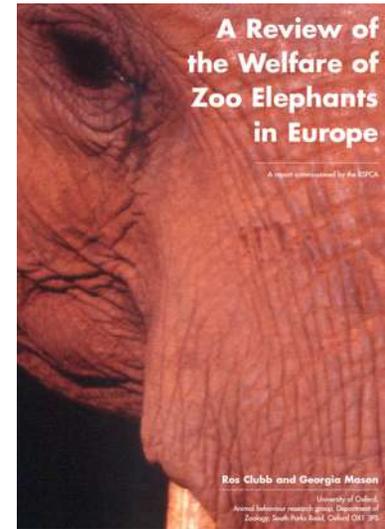
# Calculating 'average' or 'median lifespan'

historical *in situ* population —●

zoo population —●



'average' or 'median' lifespan can only be compared on equal conditions – either similar cohorts, or only using life table-based extrapolation



'average longevity'

'average longevity'



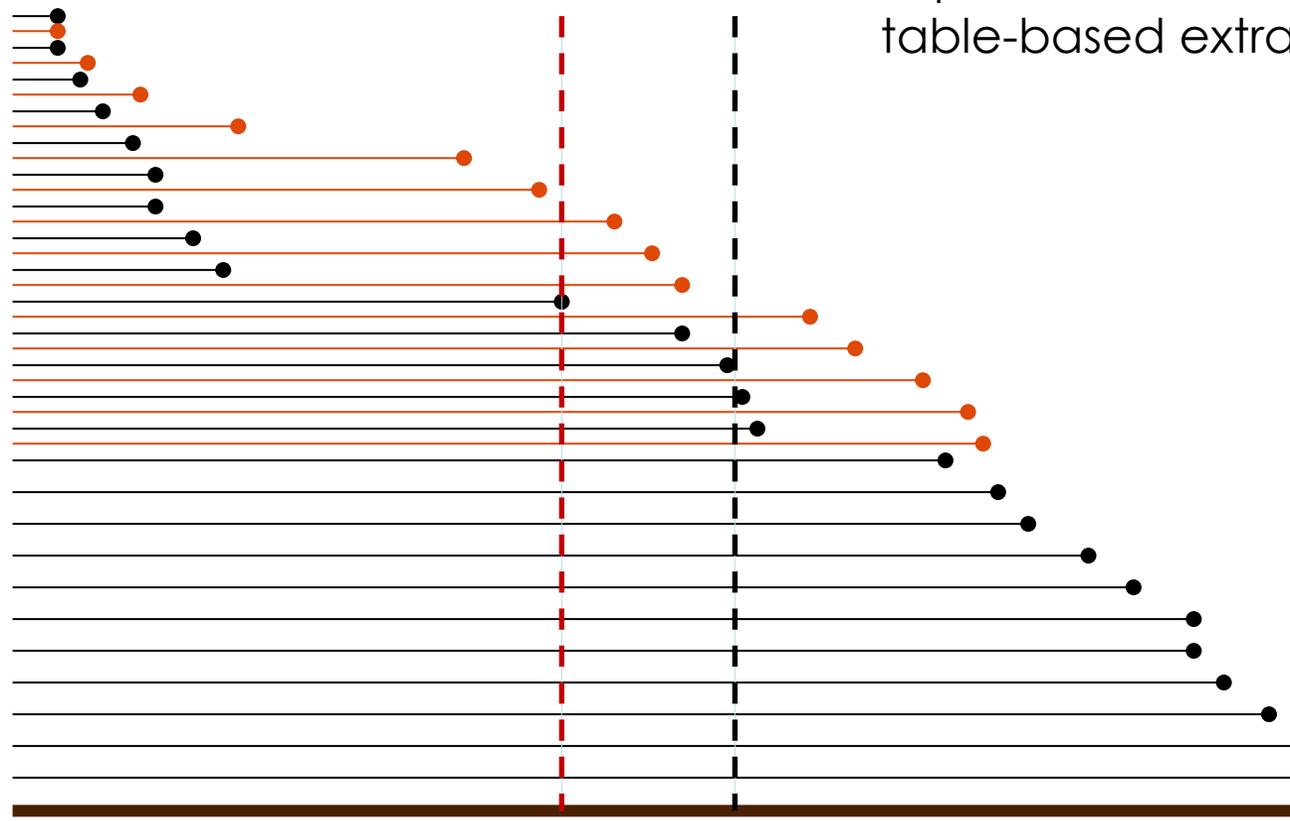
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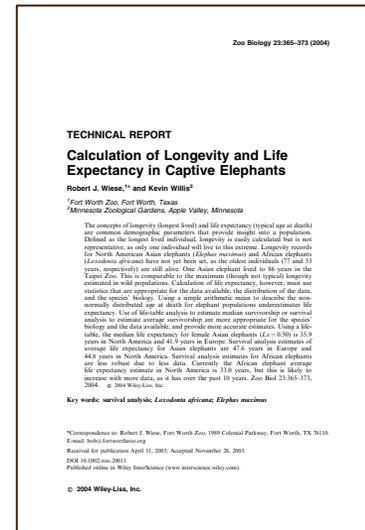
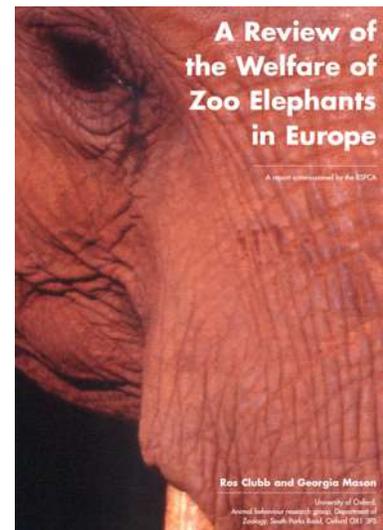
'average longevity'

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## What Do Population-Level Welfare Indices Suggest About the Well-Being of Zoo Elephants?

Georgia J. Mason<sup>1\*</sup> and Jake S. Veasey<sup>2</sup>

Zoo Biology 29: 256–273 (2010)

criticized as simplistic by Wiese and Willis [2004],

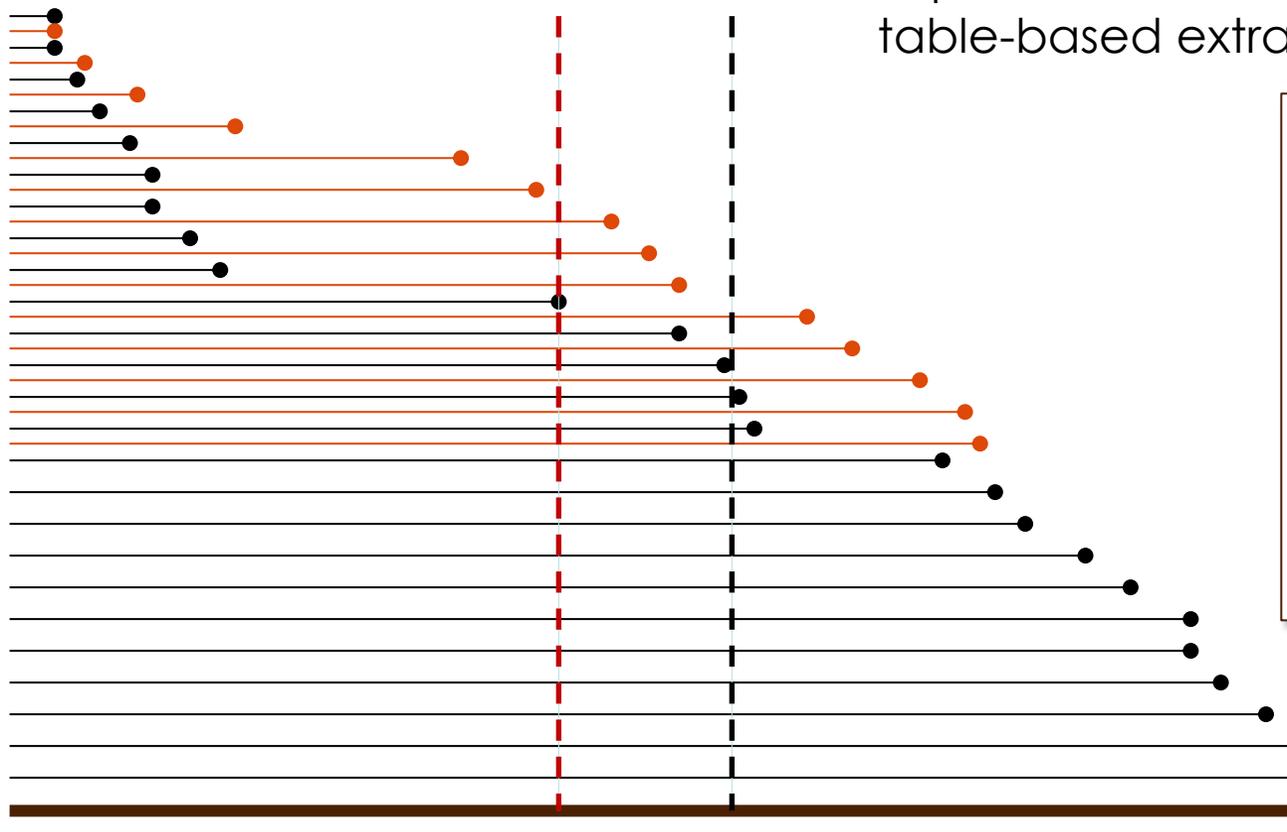
Their calculations were correctly



# Calculating 'average' or 'median lifespan'

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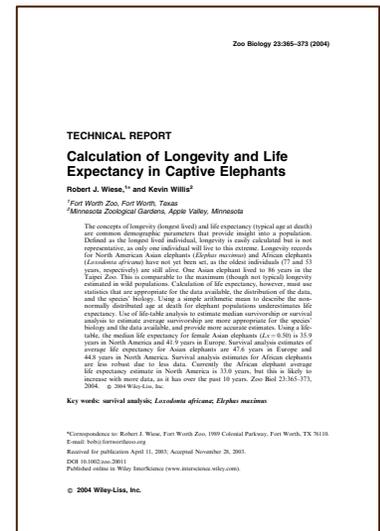
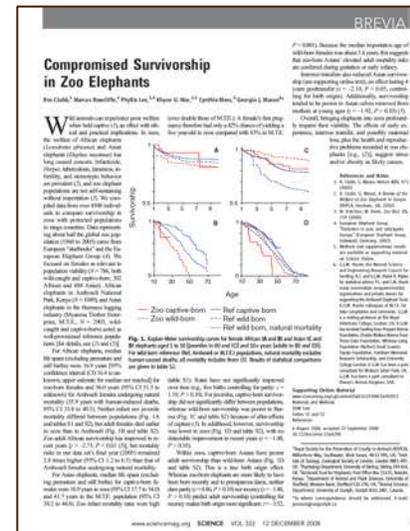
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\*Correspondence to: Robert J. Wiese, Fort Worth Zoo, 1000 Grand Parkway, Fort Worth, TX 76103. E-mail: bob@fortworthzoo.com  
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Published online in Wiley InterScience (www.interscience.wiley.com).  
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# 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 (Myanmar Timber Enterprise, M.T.E., N = 2905, wild-caught and captive-born) acted as well-provisioned reference populations [for details, see (2) and (5)].

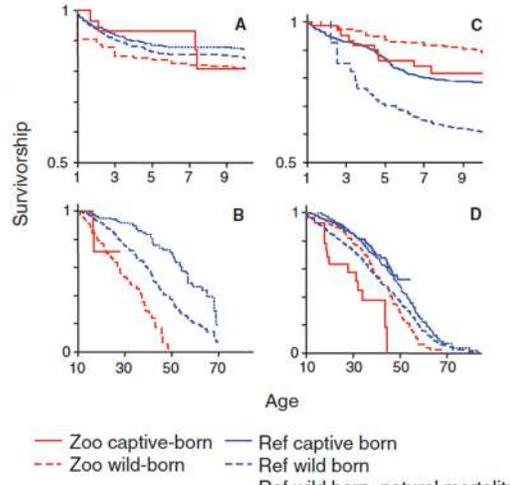
For African elephants, median life spans (excluding premature and still births) were 16.9 years [95% confidence interval (CI) 16.4 to unknown; upper estimate for median not reached] for zoo-born females and 56.0 years (95% CI 51.5 to unknown) for Amboseli females undergoing natural mortality (35.9 years 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.

ling 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.



**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:  $z = -3.52,$

**References and Notes**  
1. R. Clubb, G. Mason, *Nature* 425, 473 (2003).  
2. R. Clubb, G. Mason, *A Review of the Welfare of Zoo Elephants in Europe* (RSPCA, Horsham, UK, 2002).  
3. M. Hutchins, M. Keele, *Zoo Biol.* 25, 219 (2006).  
4. European Elephant Group, "Elefanten in zoos und safari-parks Europa" (European Elephant Group, Grünwald, Germany, 2002).  
5. Methods and supplementary results are available as supporting material on Science Online.  
6. G.J.M. thanks the Natural Science and Engineering Research Council for funding; R.C. and G.J.M. thank R. Ripley for statistical advice; P.L. and C.M. thank many conservation nongovernmental organizations and private donors for supporting the Amboseli Elephant Trust; K.U.M. thanks colleagues at M.T.E. for data compilation and comments. G.J.M. is a visiting professor at The Royal Veterinary College, London, UK. K.U.M. has received funding from Prospect Burma Foundation, Charles Wallace Burma Trust, Three Oaks Foundation, Whitney-Laing Foundation (Rufford Small Grants), Toyota Foundation, Fantham Memorial Research Scholarship, and University College London. K.U.M. has been a paid consultant for Woburn Safari Park, UK. G.J.M. has been a paid consultant to Disney's Animal Kingdom, USA.

**Supporting Online Material**  
www.sciencemag.org/cgi/content/full/322/5908/1649/DC1  
Materials and Methods  
SOM Text  
Tables S1 and S2  
References  
6 August 2008; accepted 22 September 2008  
10.1126/science.1164298

<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

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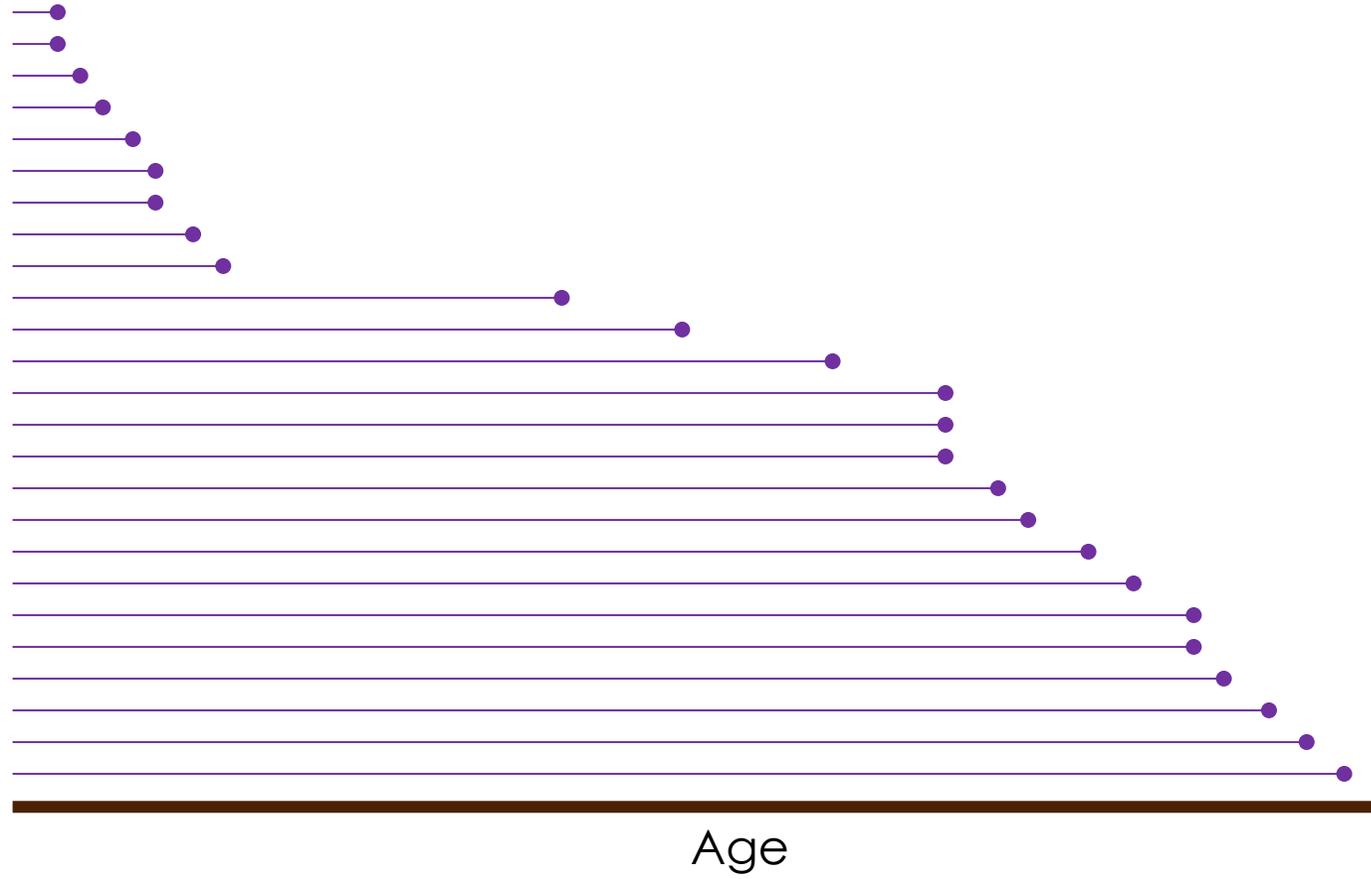
## as Compared to Some Selected *in situ* Populations Declared 'Benchmarks'

Data from 1960-2008

- 1. Average lifespan is lower in zoos than *in situ*
- 2. Survivorship is lower in zoos than *in situ*
- 3. Although there was some improvement in survivorship in African elephants since 1960, there was no such improvement in Asian elephants

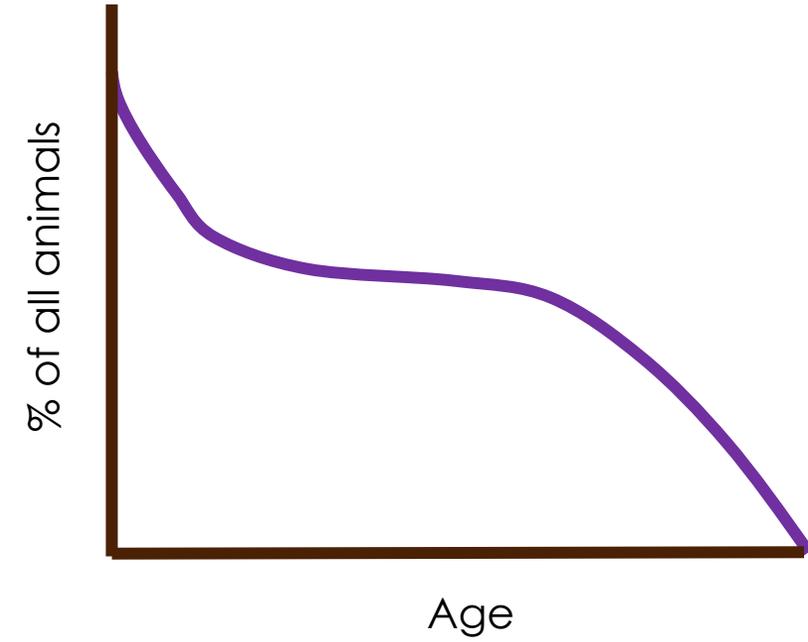
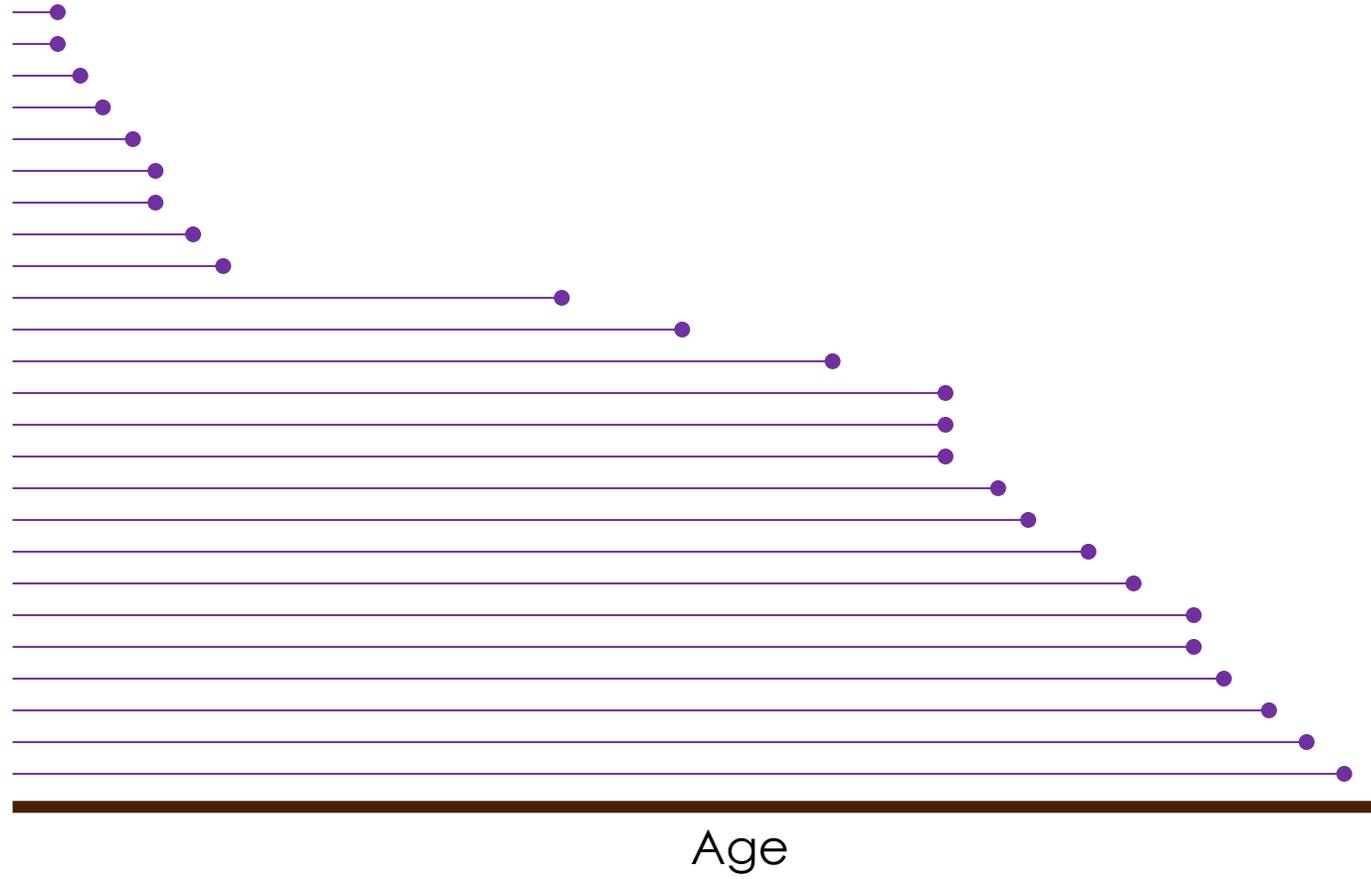


# Survivorship



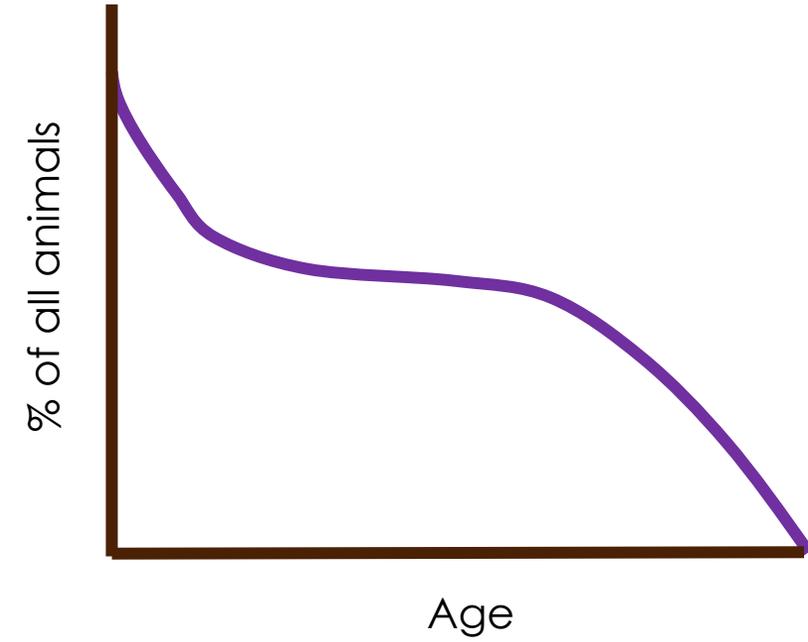
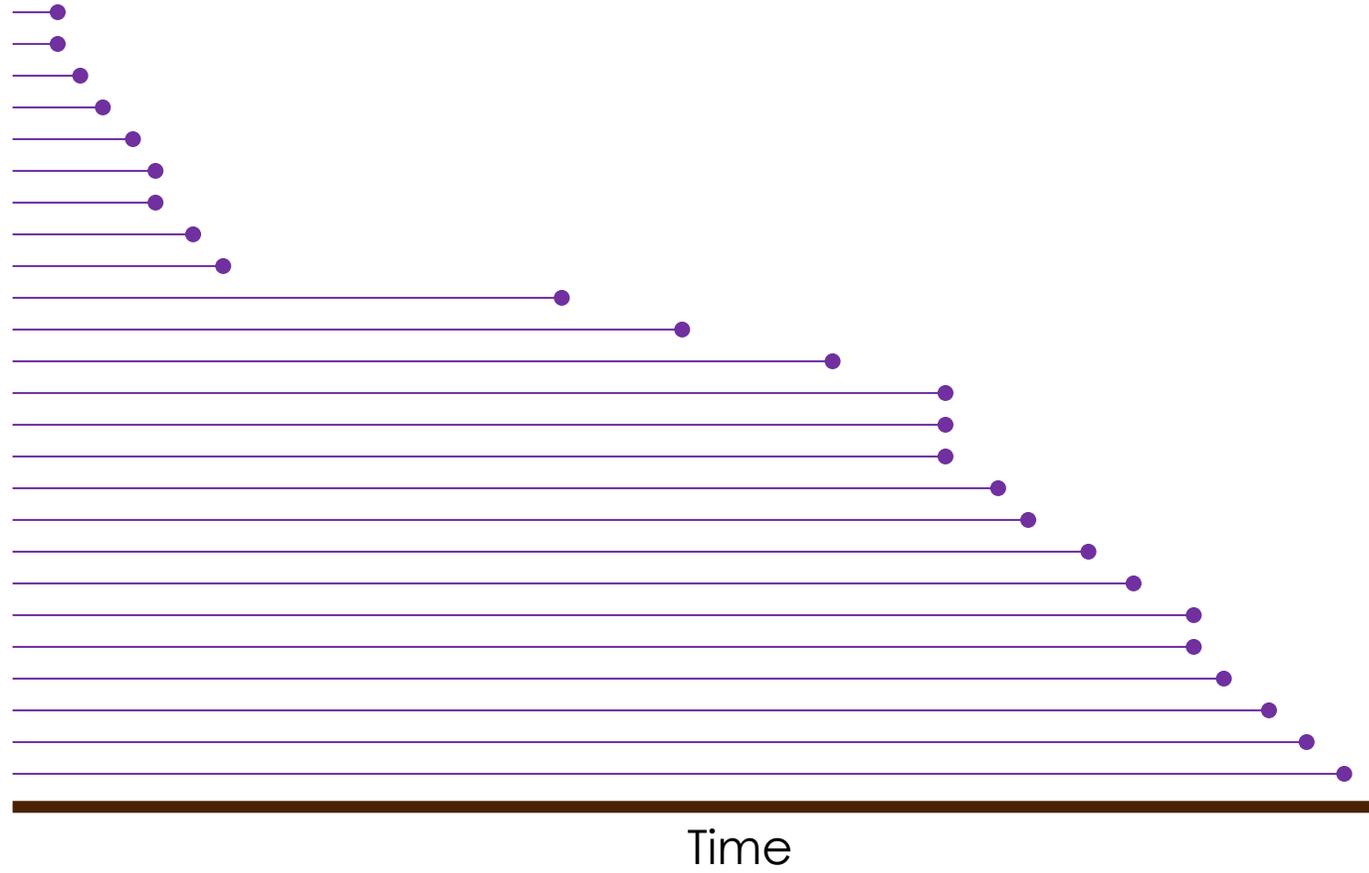


# Survivorship



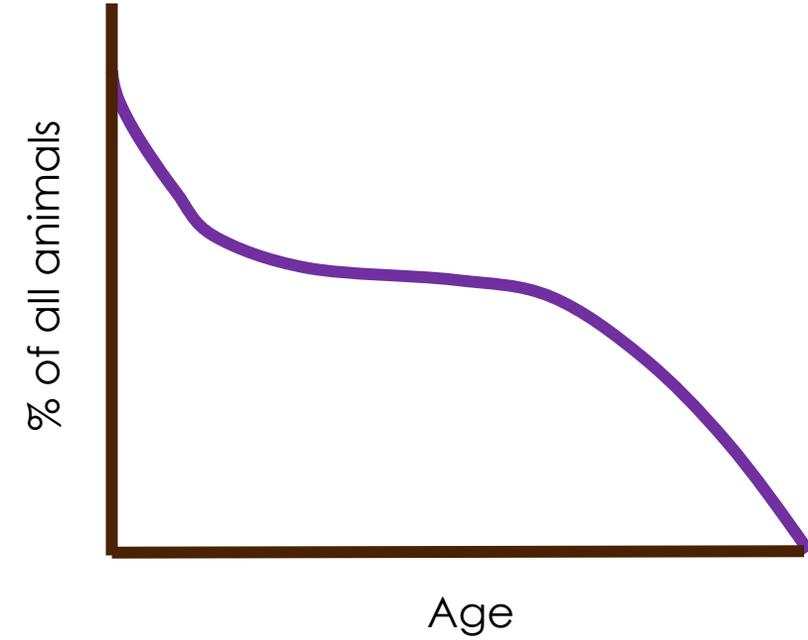
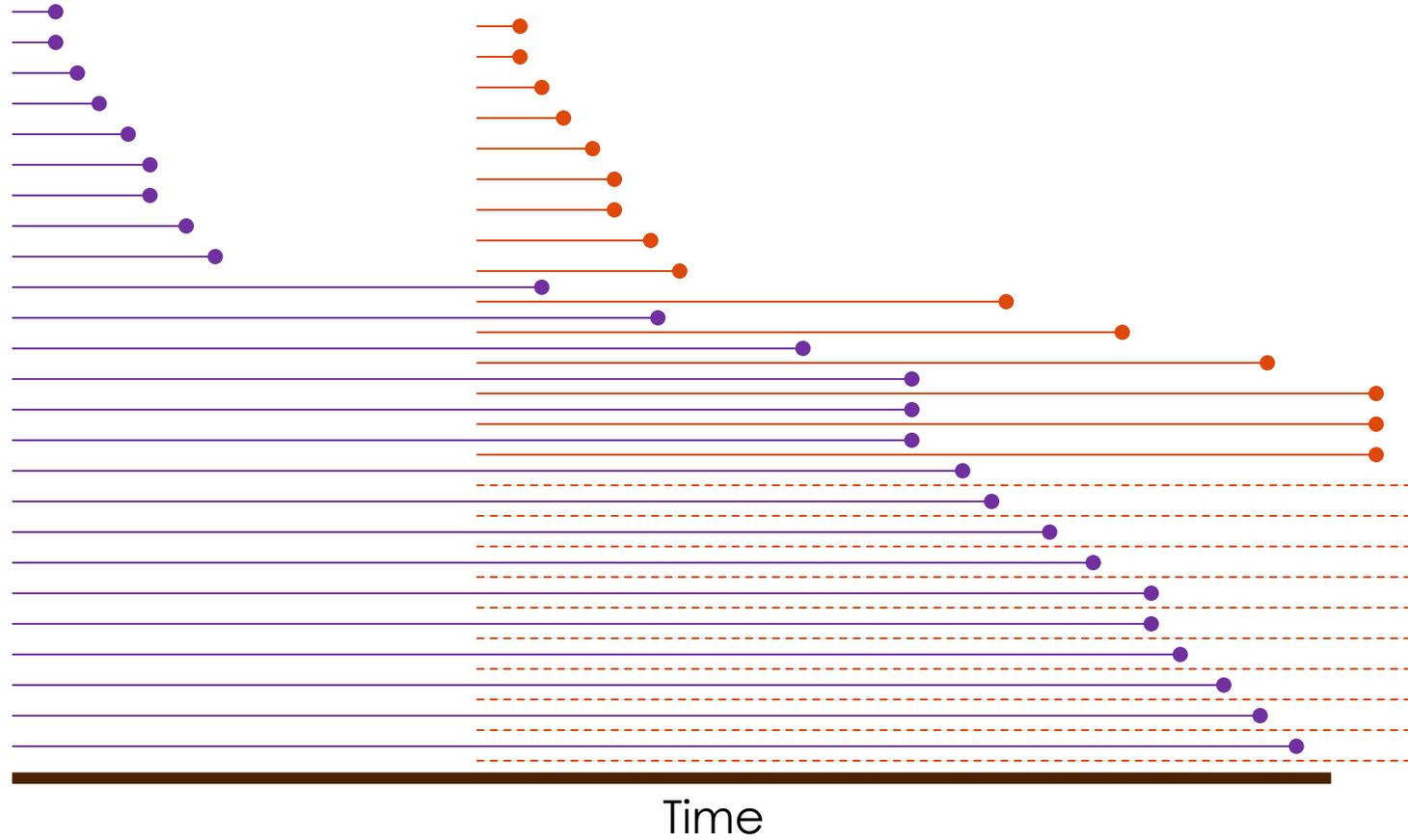


# Survivorship



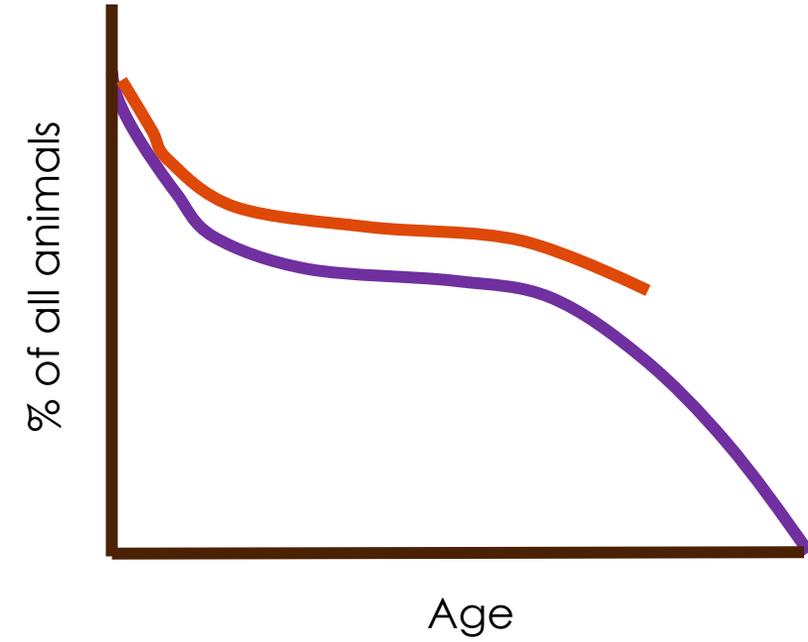
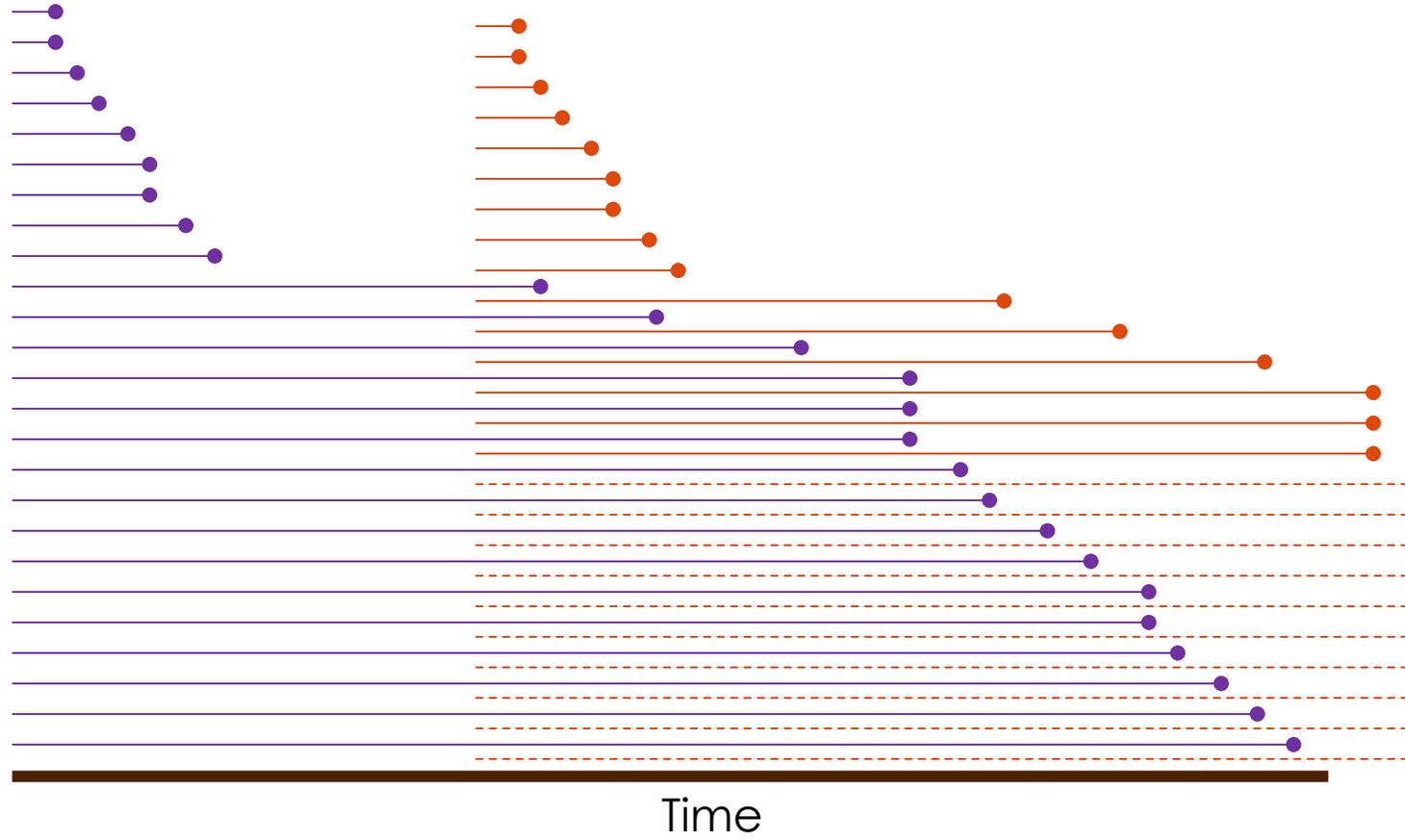


# Survivorship



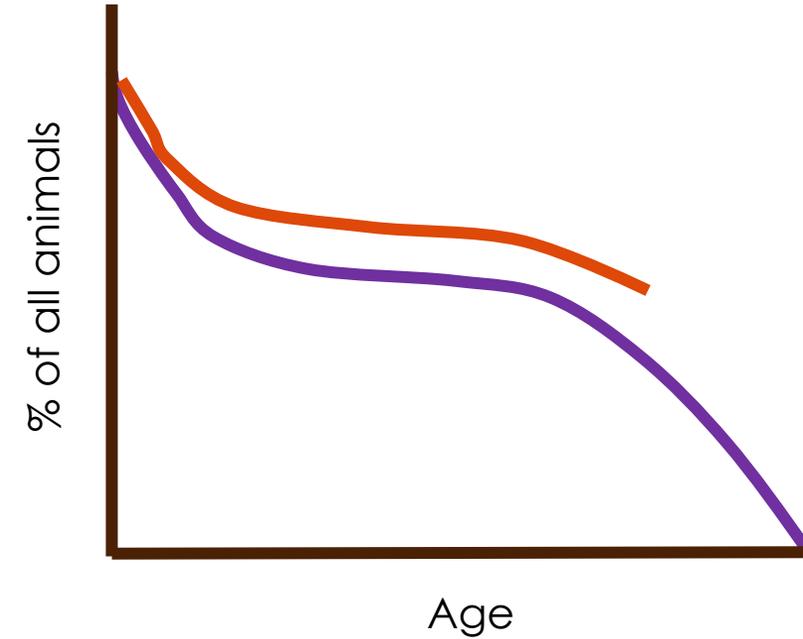
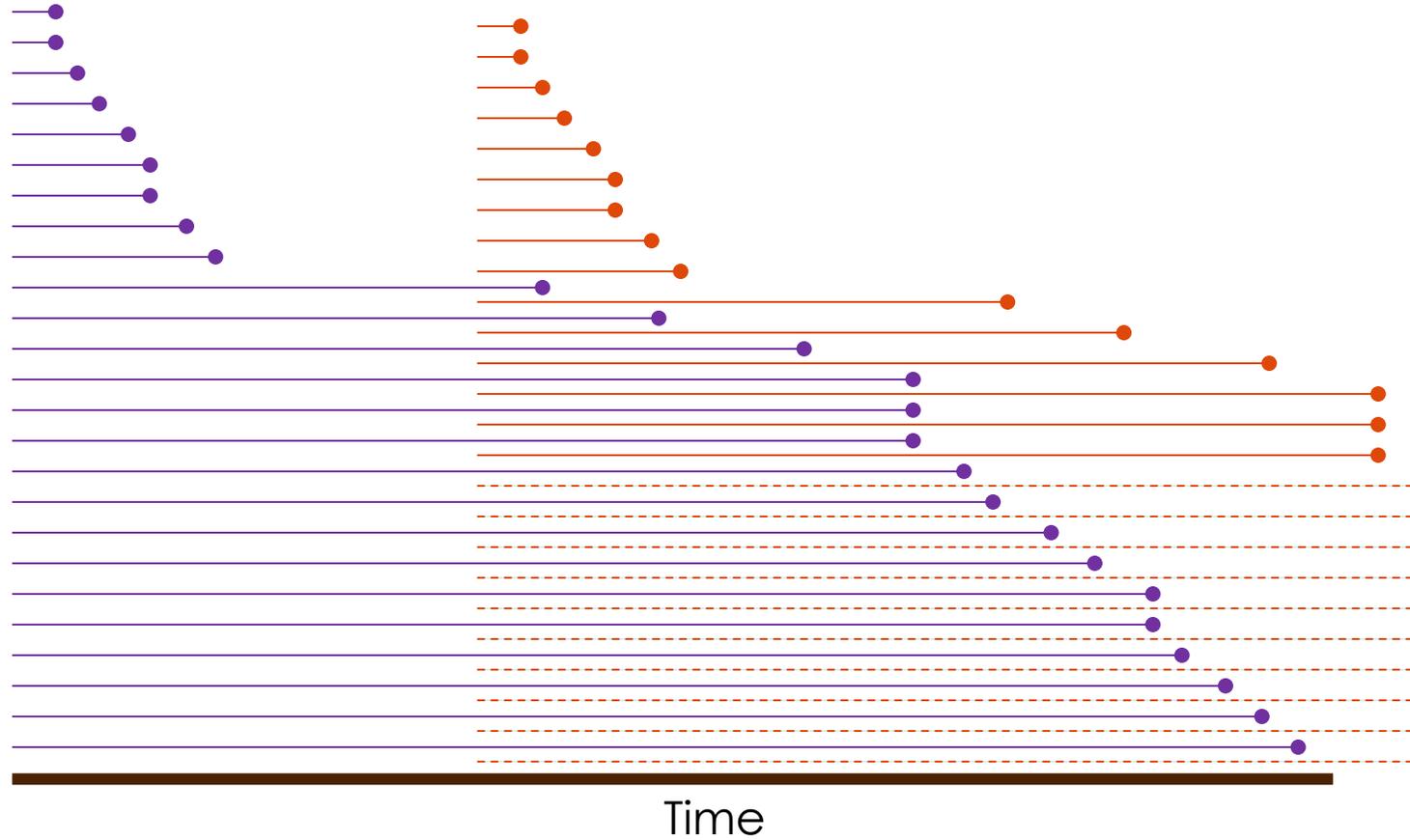


# Survivorship





# Survivorship



Cox Proportional Hazard analysis:

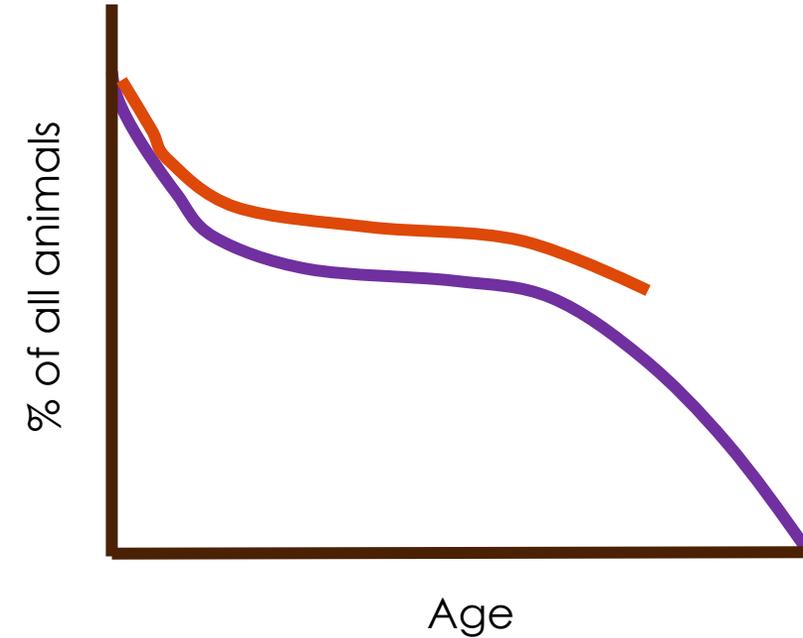
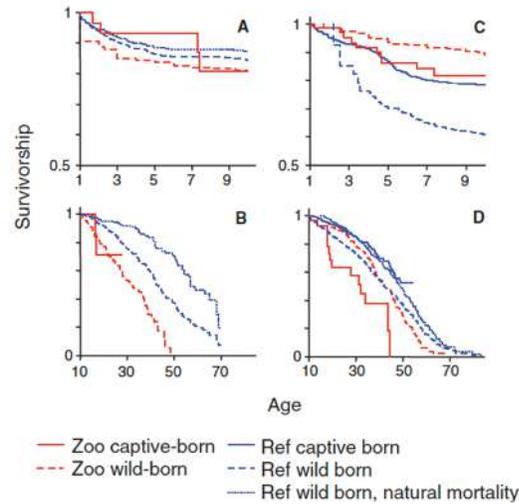
is the survivorship different between the groups ?



# Survivorship

## 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>



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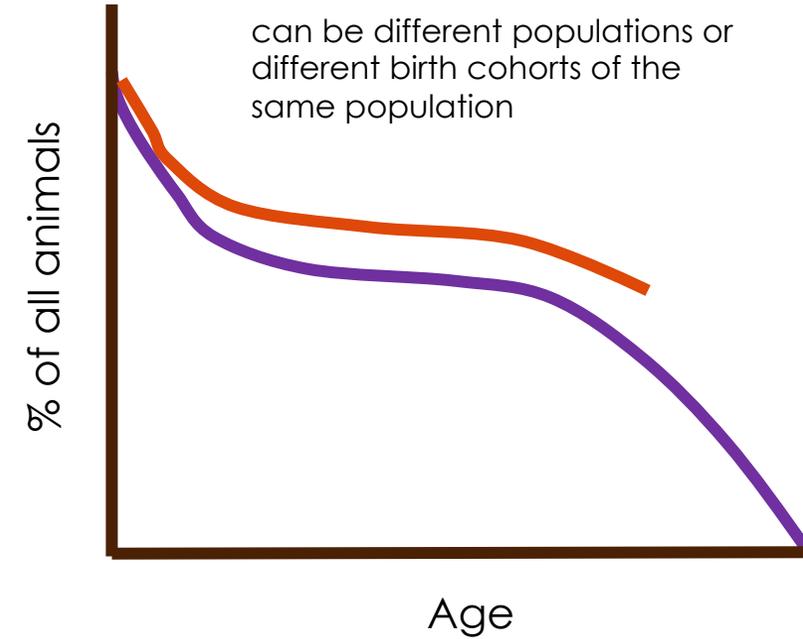
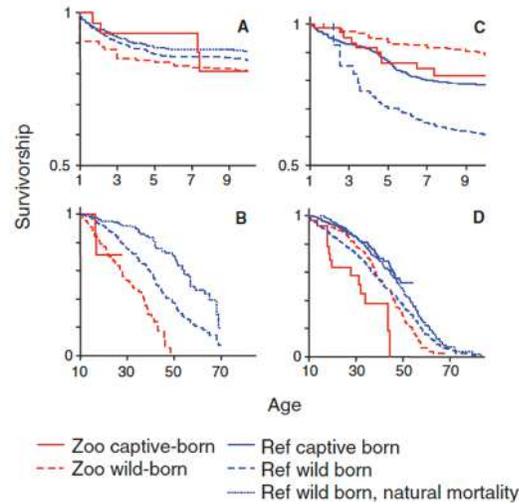
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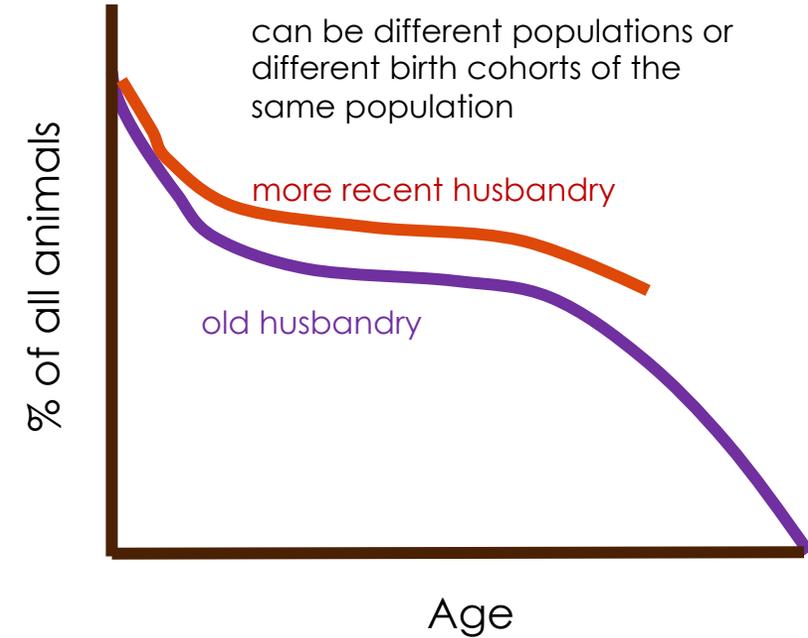
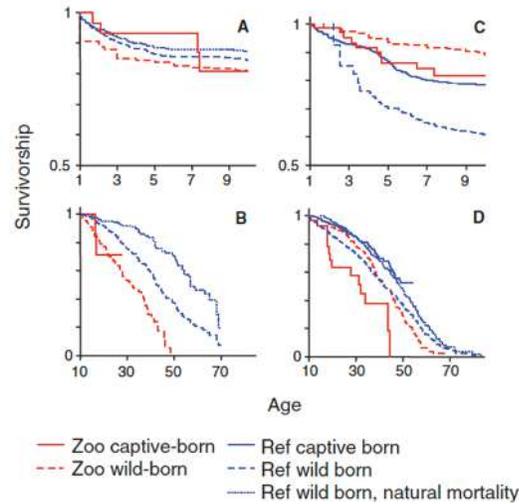
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Cox Proportional Hazard analysis:

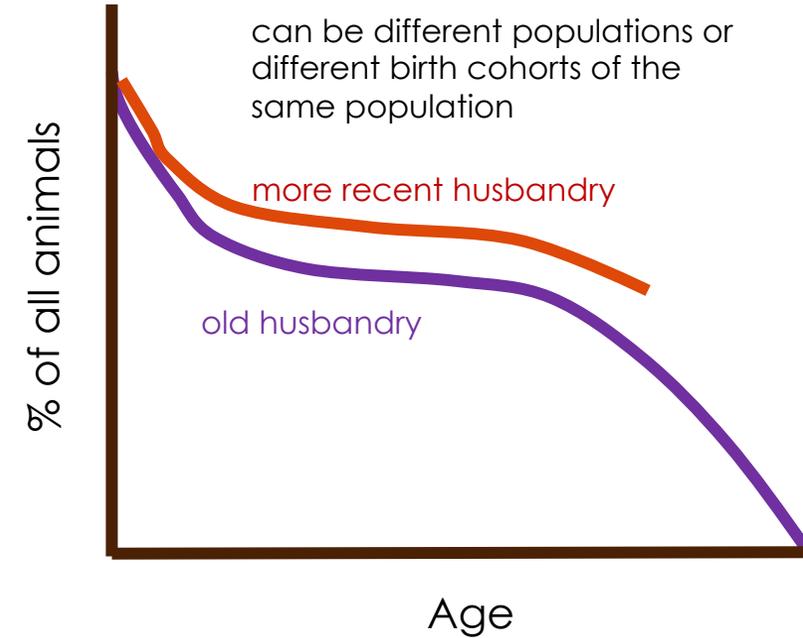
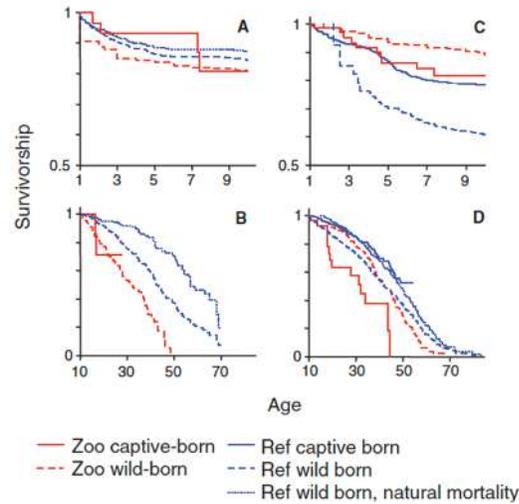
is the survivorship different between the groups ?



# Survivorship

## 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>



Cox Proportional Hazard analysis: is the survivorship different between the groups ?

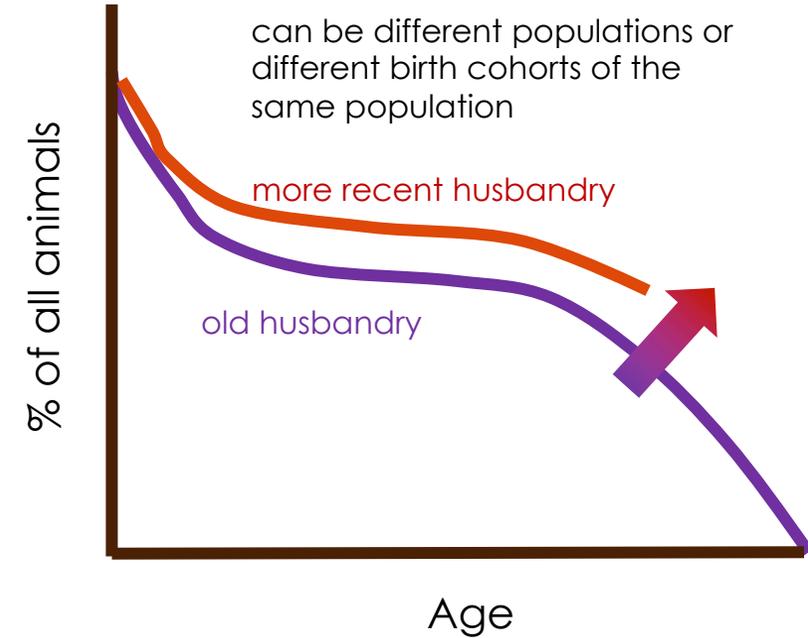
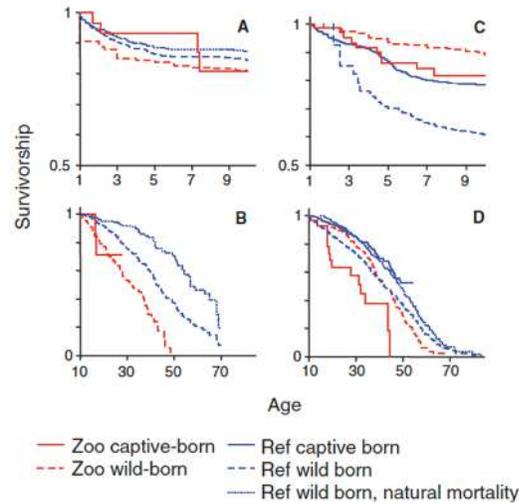
e.g. coefficient  $< 1$  means that the red group has better survivorship than the purple baseline



# Survivorship

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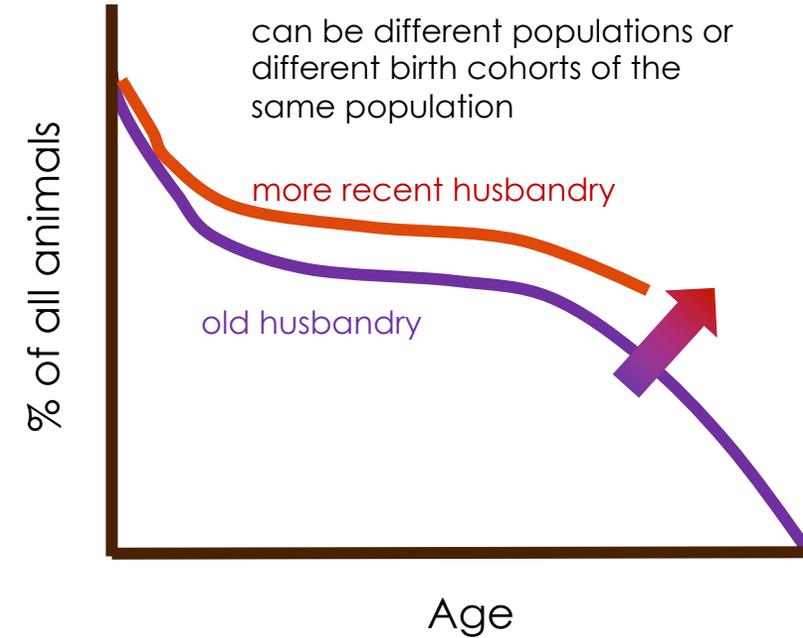
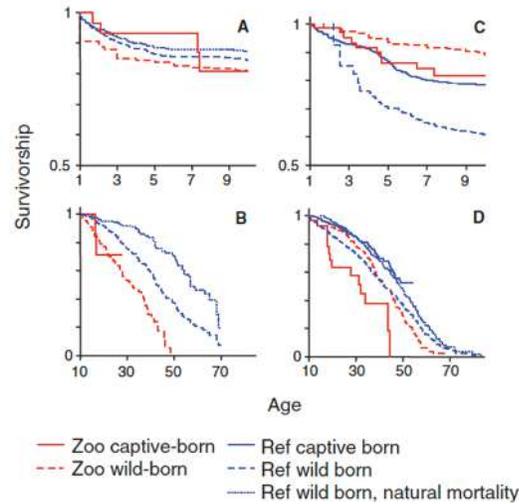
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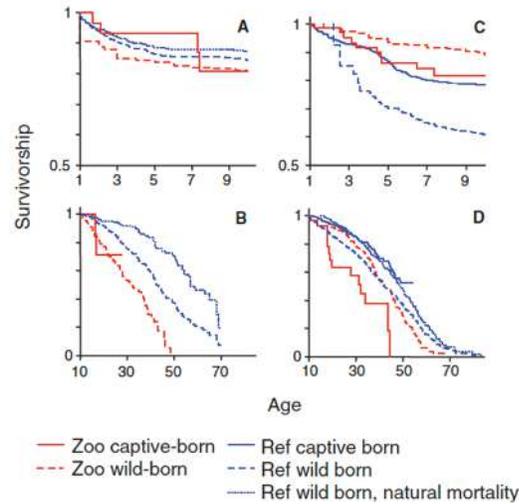
is the survivorship different between the groups ?  
is there significant change with time (birth date) ?



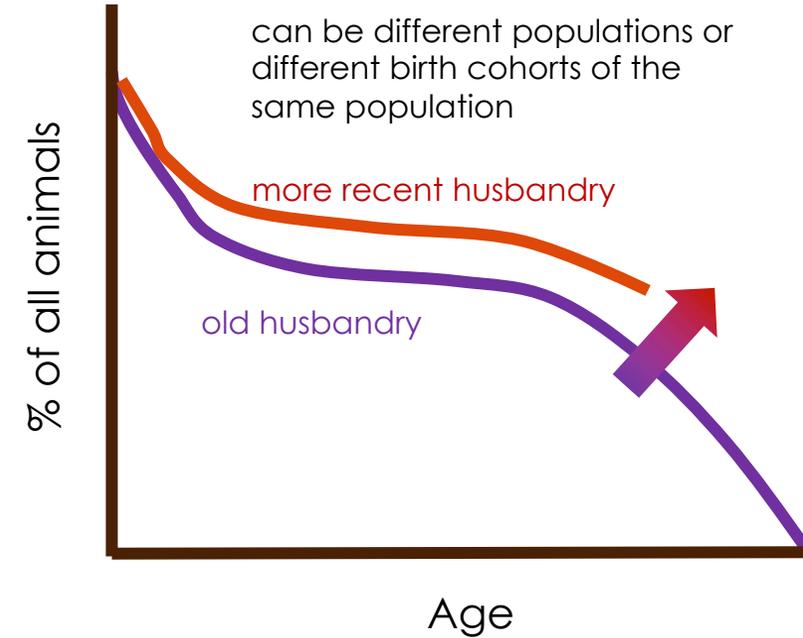
# Survivorship

## Compromised Survivorship in Zoo Elephants

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Zoo adult African survivorship has improved in recent years [ $z = -2.75, P < 0.01$  (5)]



Cox Proportional Hazard analysis:

is the survivorship different between the groups?  
is there significant change with time (birth date)?

# A fundamental distinction: science and rhetoric

## BREVIA

### Compromised Survivorship in Zoo Elephants

### as Compared to Some Selected *in situ* Populations Declared 'Benchmarks'

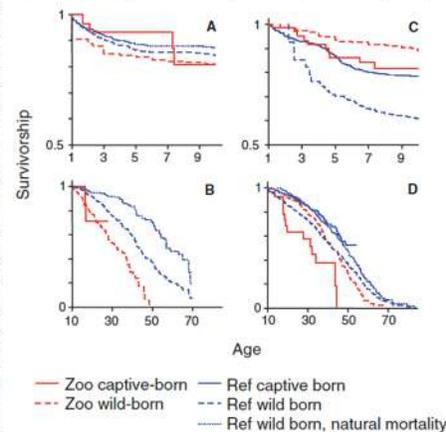
Ros Clubb,<sup>1</sup> Marcus Rowcliffe,<sup>2</sup> Phyllis Lee,<sup>3,4</sup>

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 (Myanmar 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.

tend 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

- R. Clubb, G. Mason, *Nature* 425, 473 (2003).
- R. Clubb, G. Mason, *A Review of the Welfare of Zoo Elephants in Europe* (RSPCA, Horsham, UK, 2002).
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- G.J.M. thanks the Natural Science and Engineering Research Council for funding; R.C. and G.J.M. thank R. Ripley for statistical advice; P.L. and C.M. thank many conservation nongovernmental organizations and private donors for supporting the Amboseli Elephant Trust; K.U.M. thanks colleagues at M.T.E. for data compilation and comments. G.J.M. is a visiting professor at The Royal Veterinary College, London, UK. K.U.M. has received funding from Praecepta Burma Foundation, Charles Wallace-Burma Trust, Three Oaks Foundation, Whitney-Laing Foundation (Rufford Small Grants), Toyota Foundation, Farinham Memorial Research Scholarship, and University College London. K.U.M. has been a paid consultant for Woburn Safari Park, UK. G.J.M. has been a paid consultant to Disney's Animal Kingdom, USA.

#### Supporting Online Material

www.sciencemag.org/cgi/content/full/322/2590/1649/DC1

Materials and Methods

SOM Text

Tables S1 and S2

References

6 August 2008; accepted 22 September 2008

10.1126/science.1164298

<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 2W1, Canada.

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

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# A fundamental distinction: science and rhetoric

BREVIA

## Compromised Survivorship in Zoo Elephants

Ros Clubb,<sup>1</sup> Marcus Rowcliffe,<sup>2</sup> Phyllis Lee,<sup>3,4</sup>

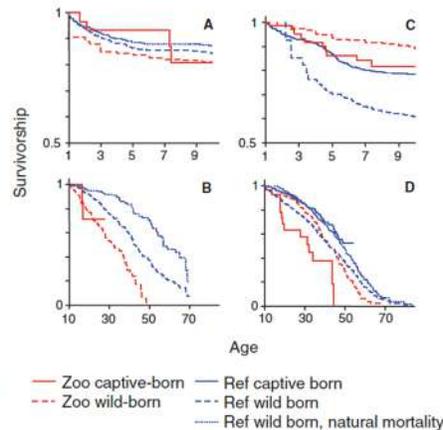
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\*to whom correspondence should be addressed. E-mail: gmason@uoguelph.ca

There should be little debate about the data.

**The data itself is all correct (MC).**

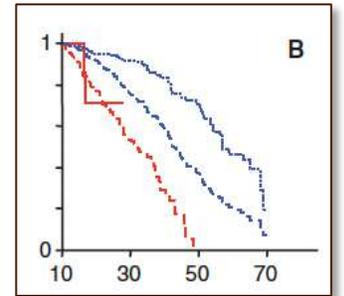
The debate is about the methods of calculation ...

**... but most of all about the rhetorical conclusions.**

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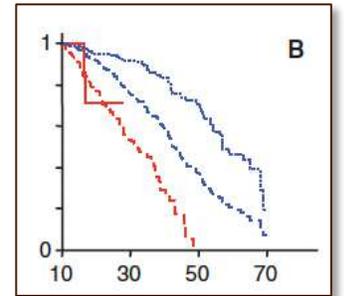
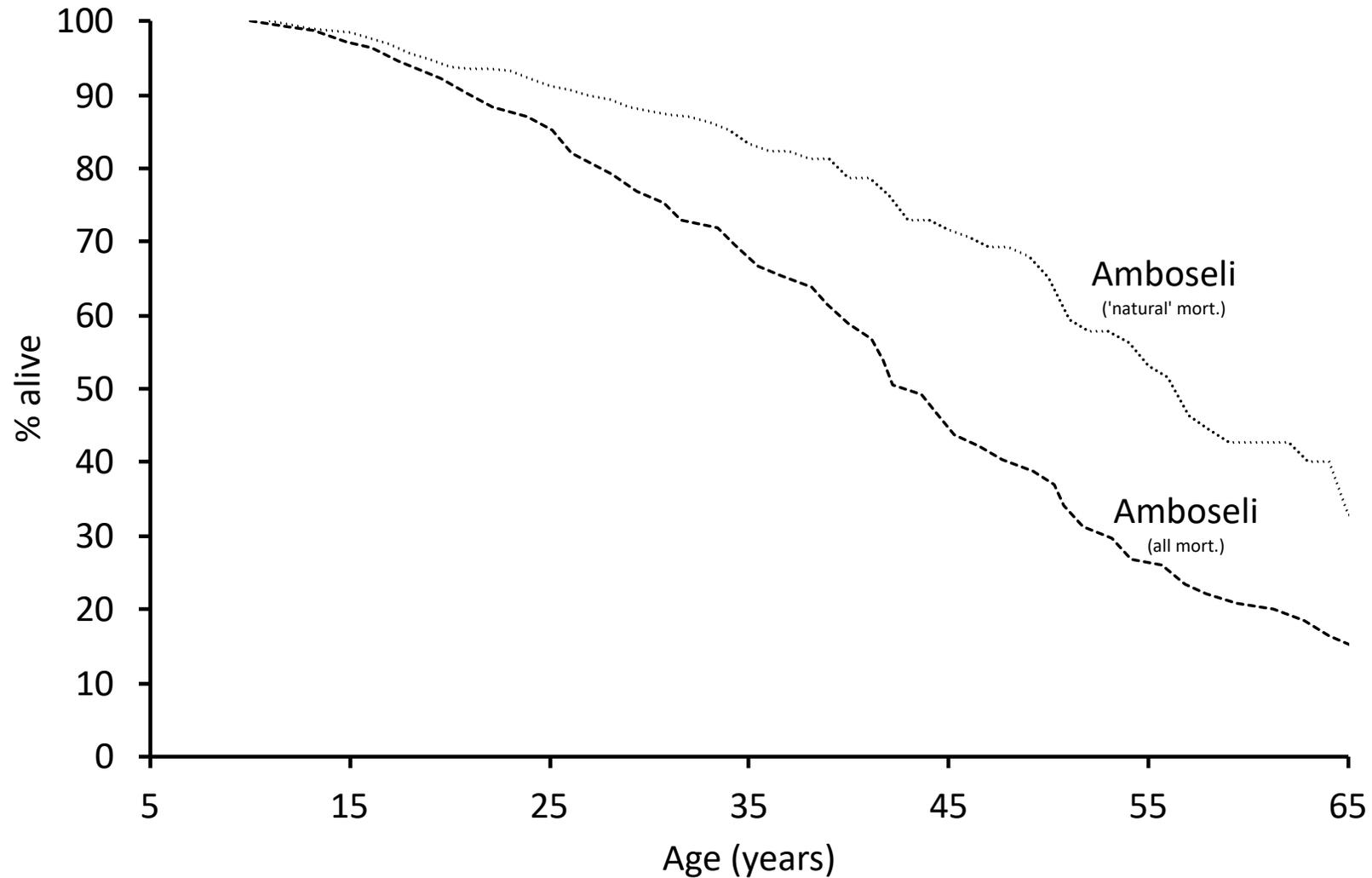


# 'Benchmark' populations ?





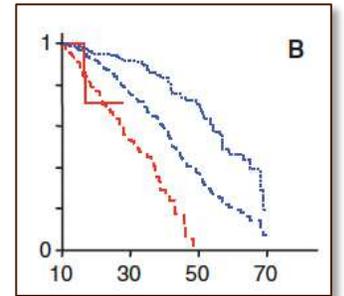
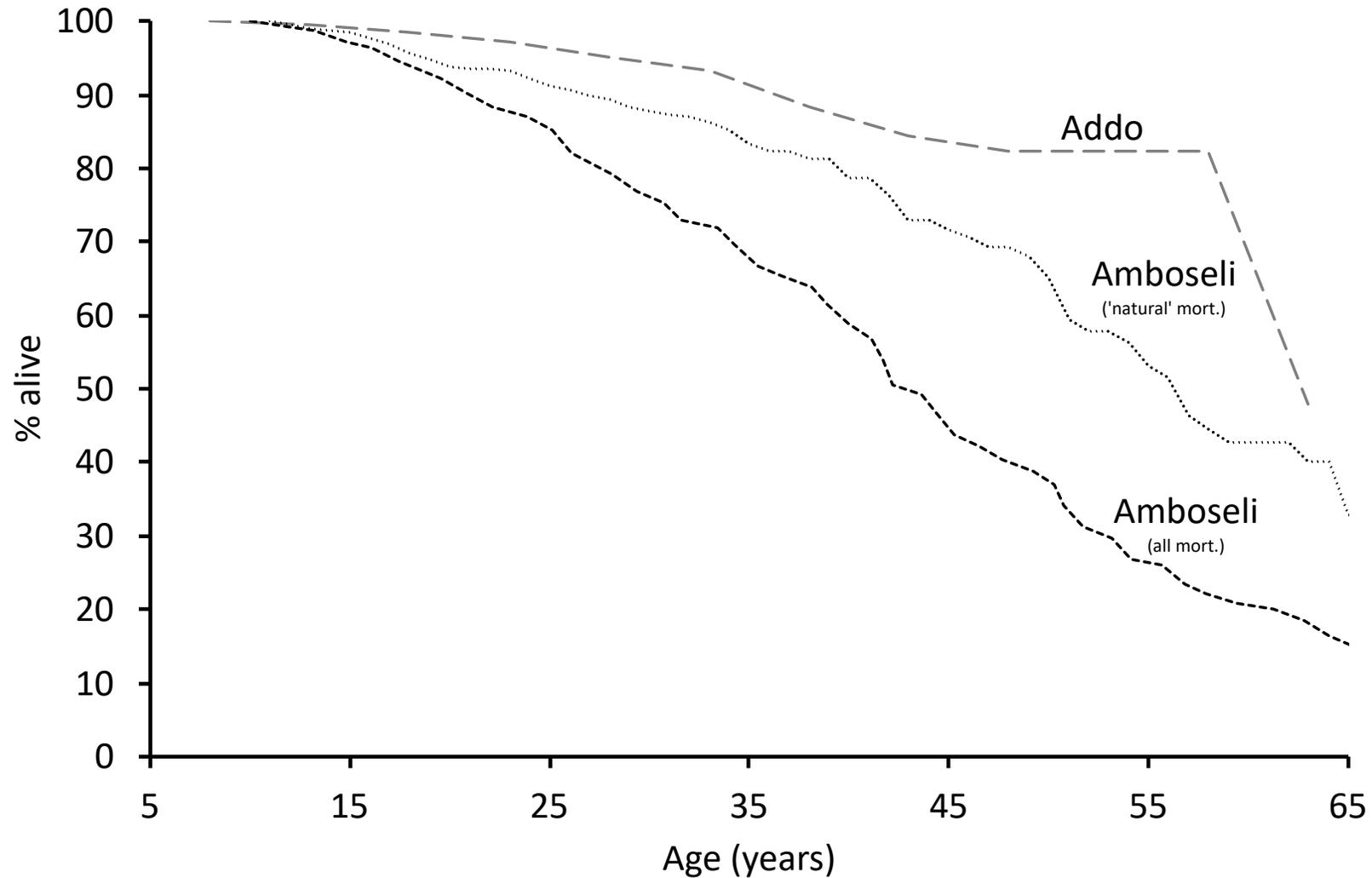
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Moss et al. (2001)  
Amboseli Natl Park,  
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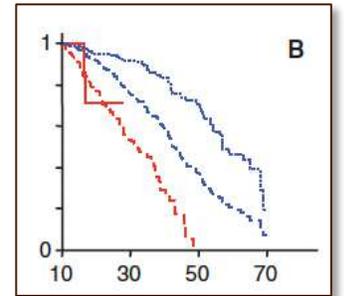
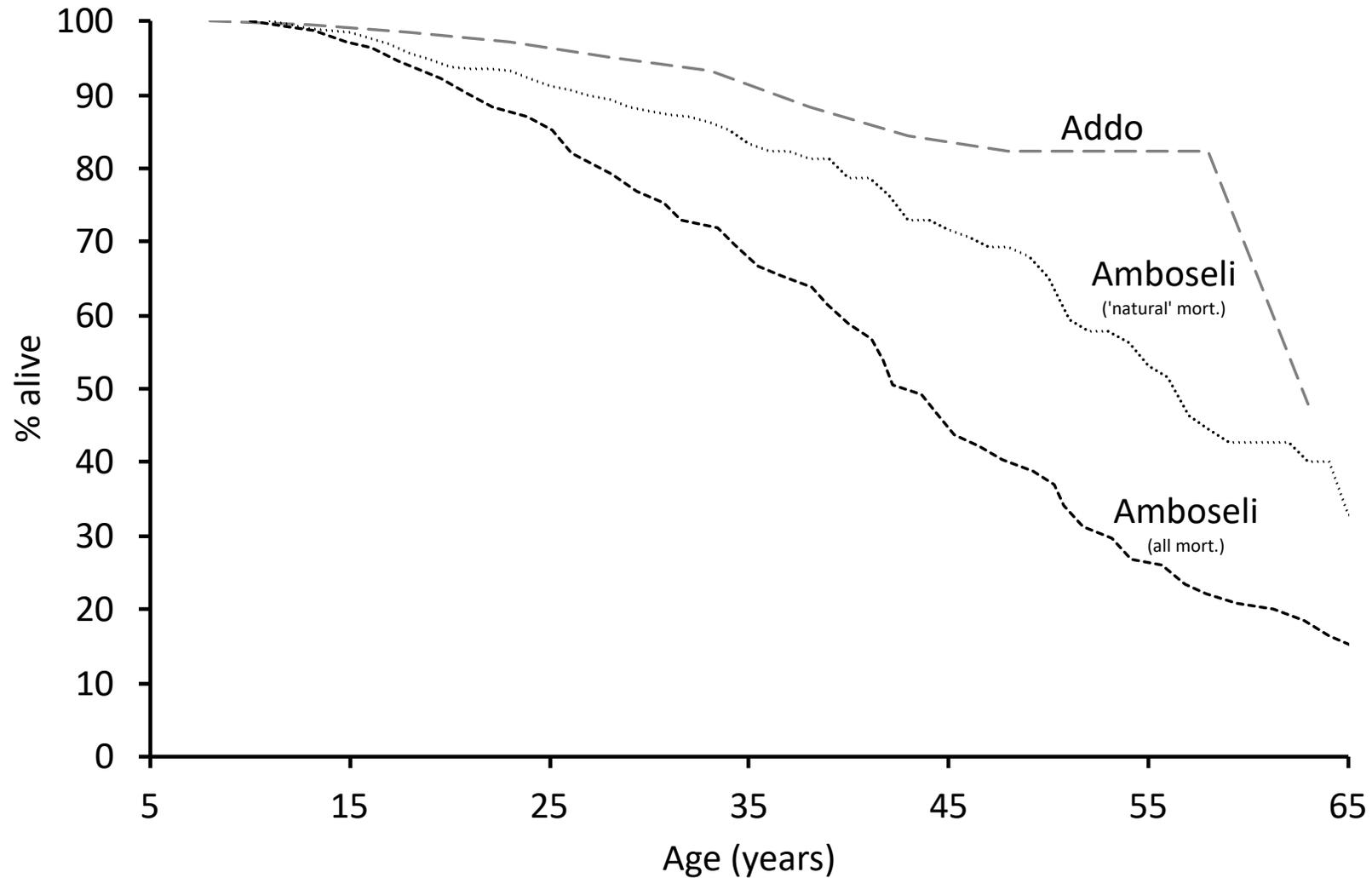
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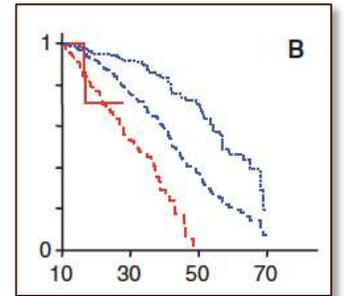
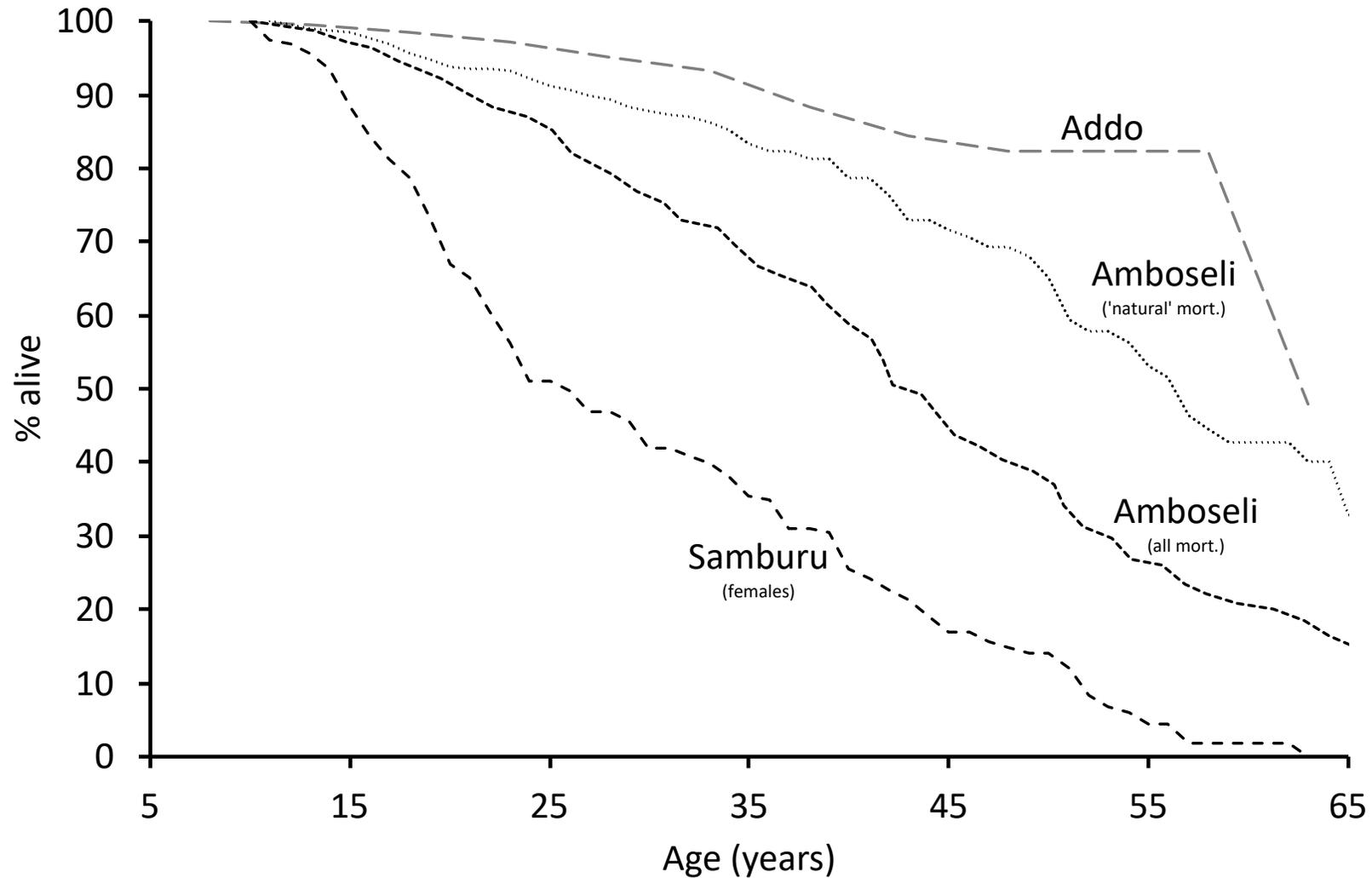


Gough & Kerley (2006) Addo  
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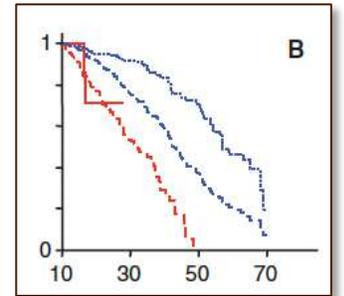
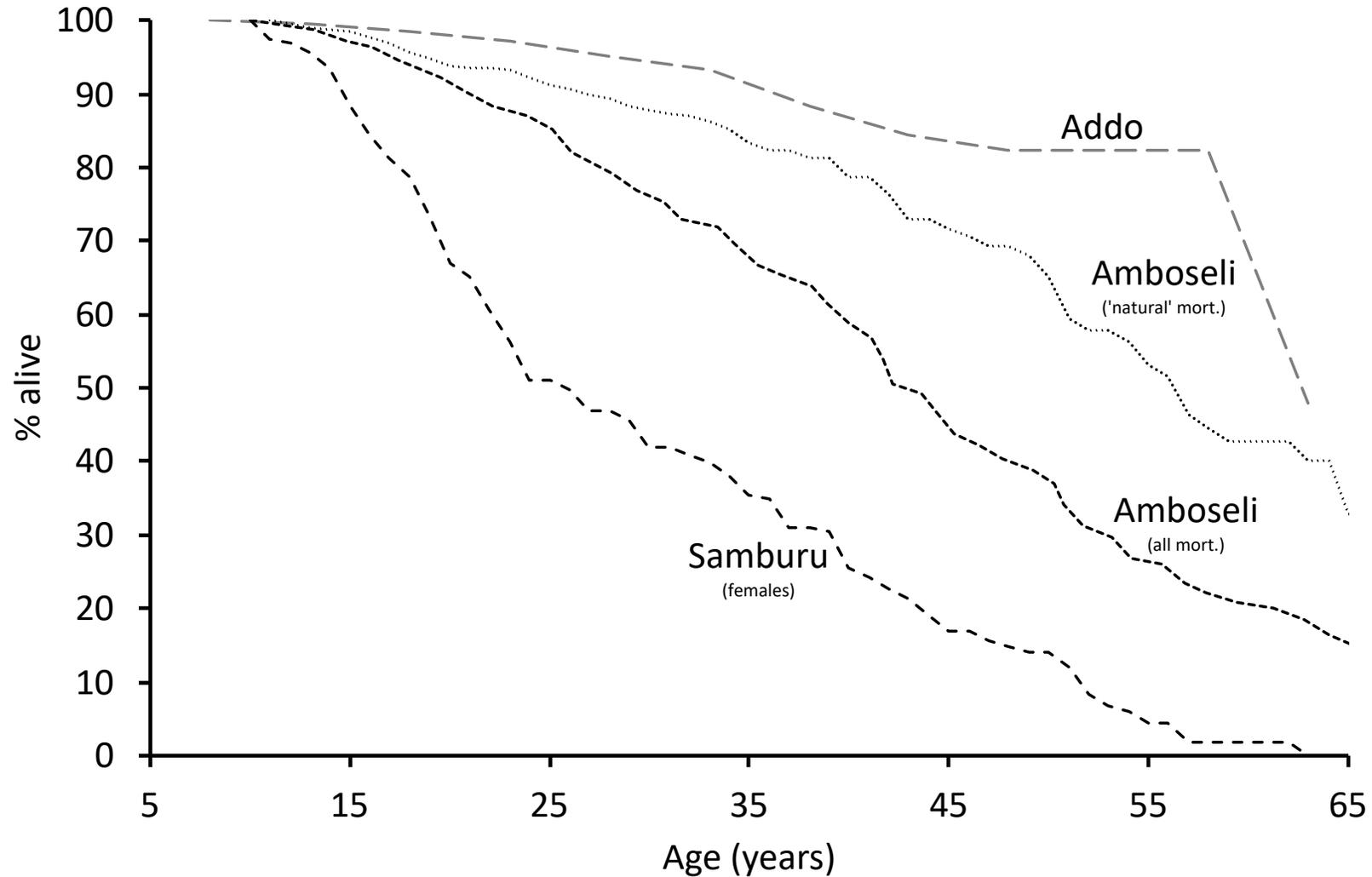


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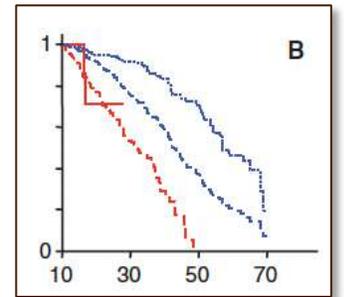
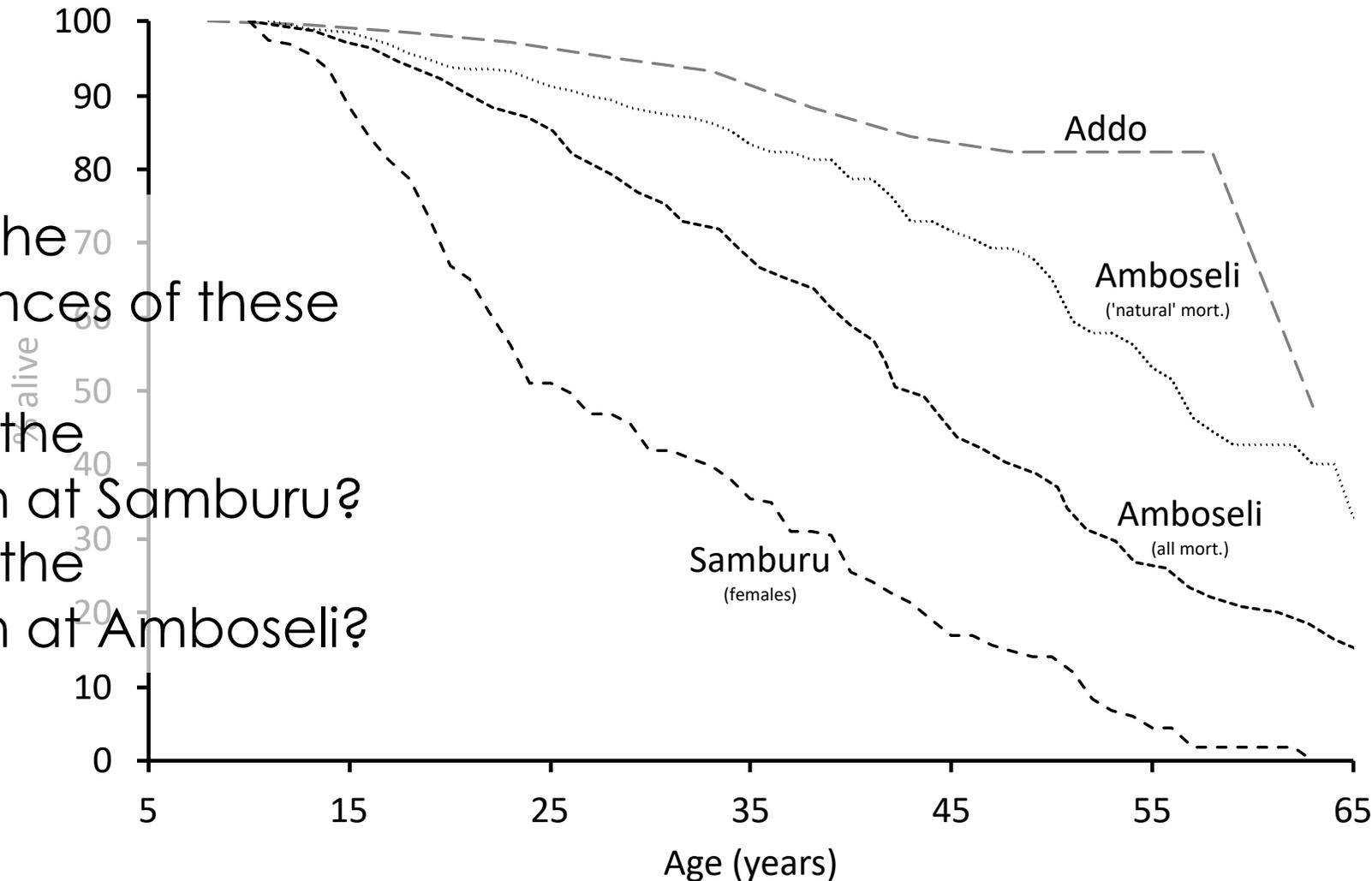
Wittemyer et al. (2013) Samburu Natl  
Reserve, Kenya  
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What are the consequences of these data?  
 Phase out the population at Samburu?  
 Phase out the population at Amboseli?



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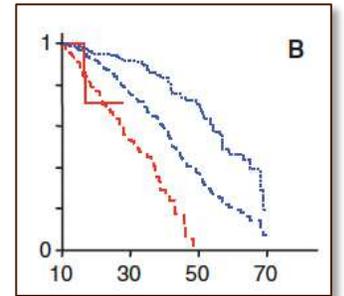
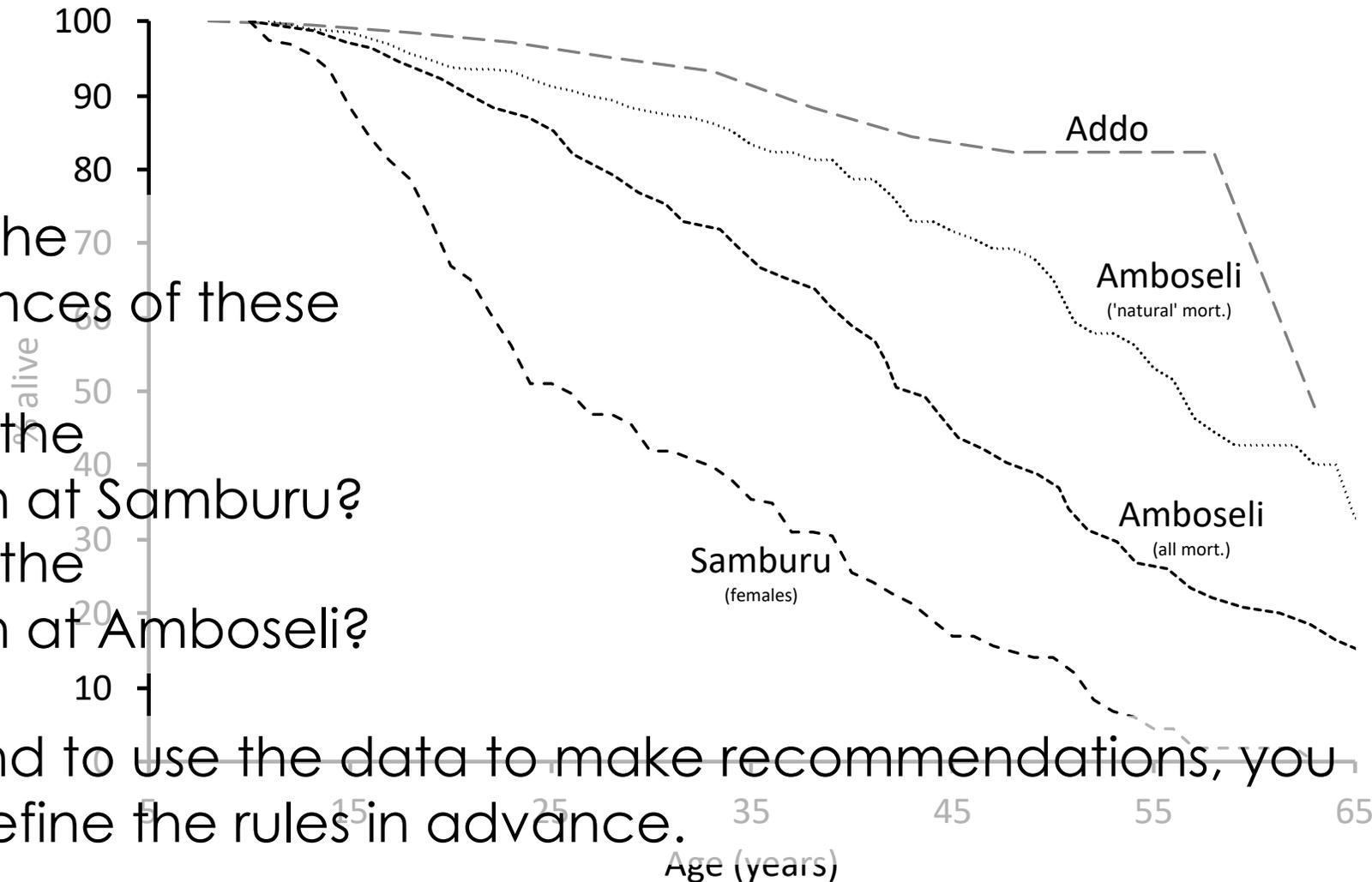


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 Phase out the population at Samburu?  
 Phase out the population at Amboseli?

If you intend to use the data to make recommendations, you need to define the rules in advance.



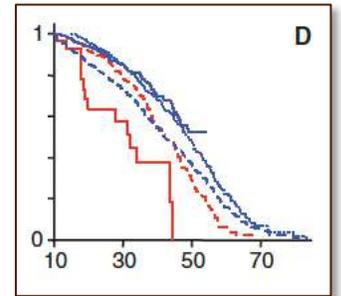
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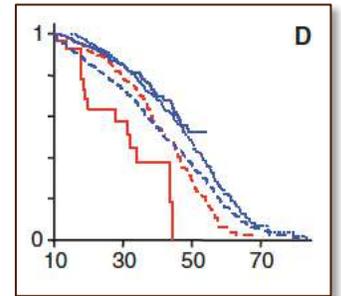
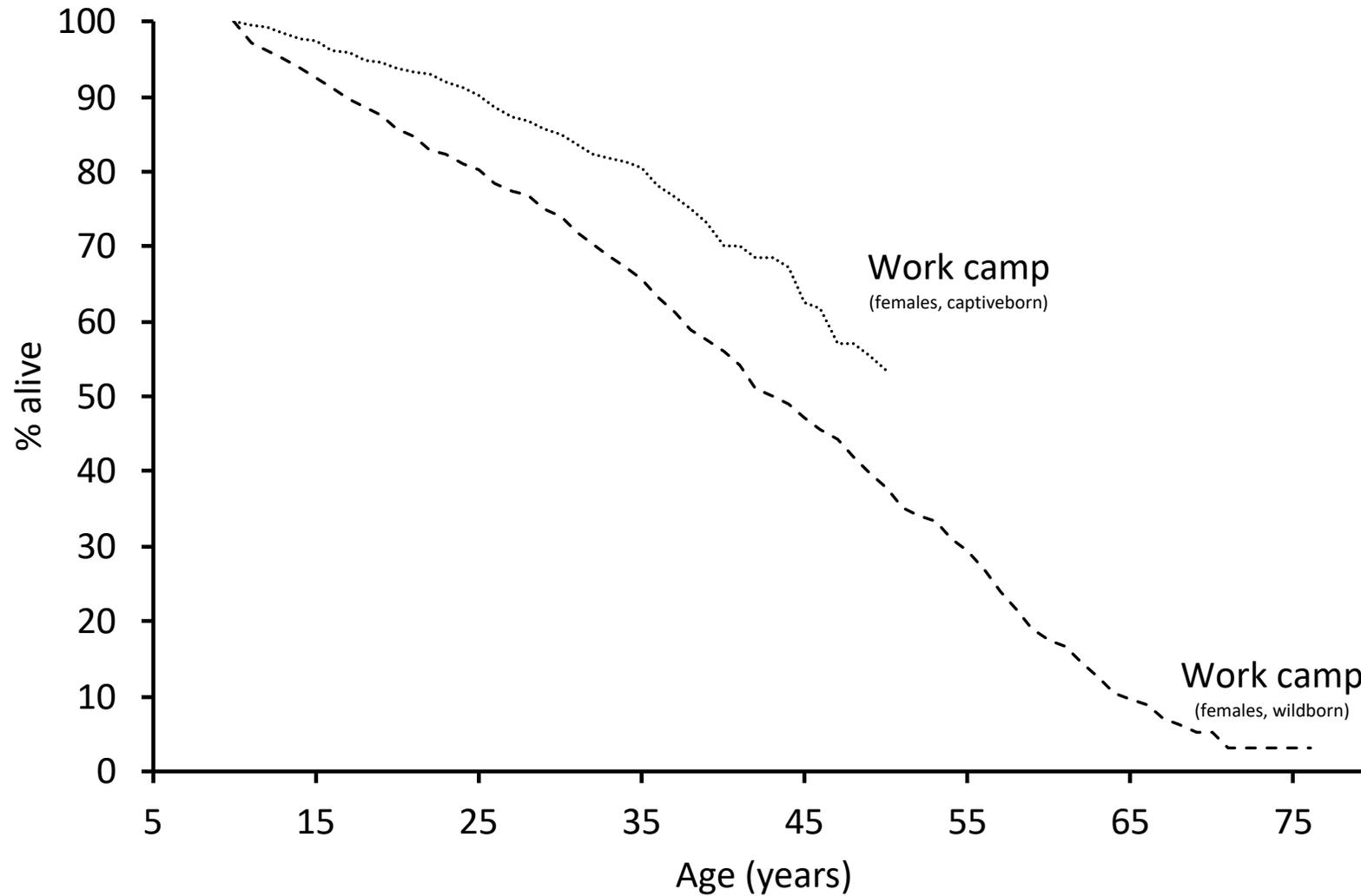


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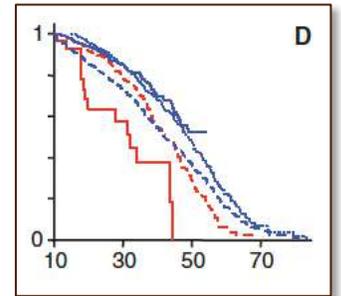
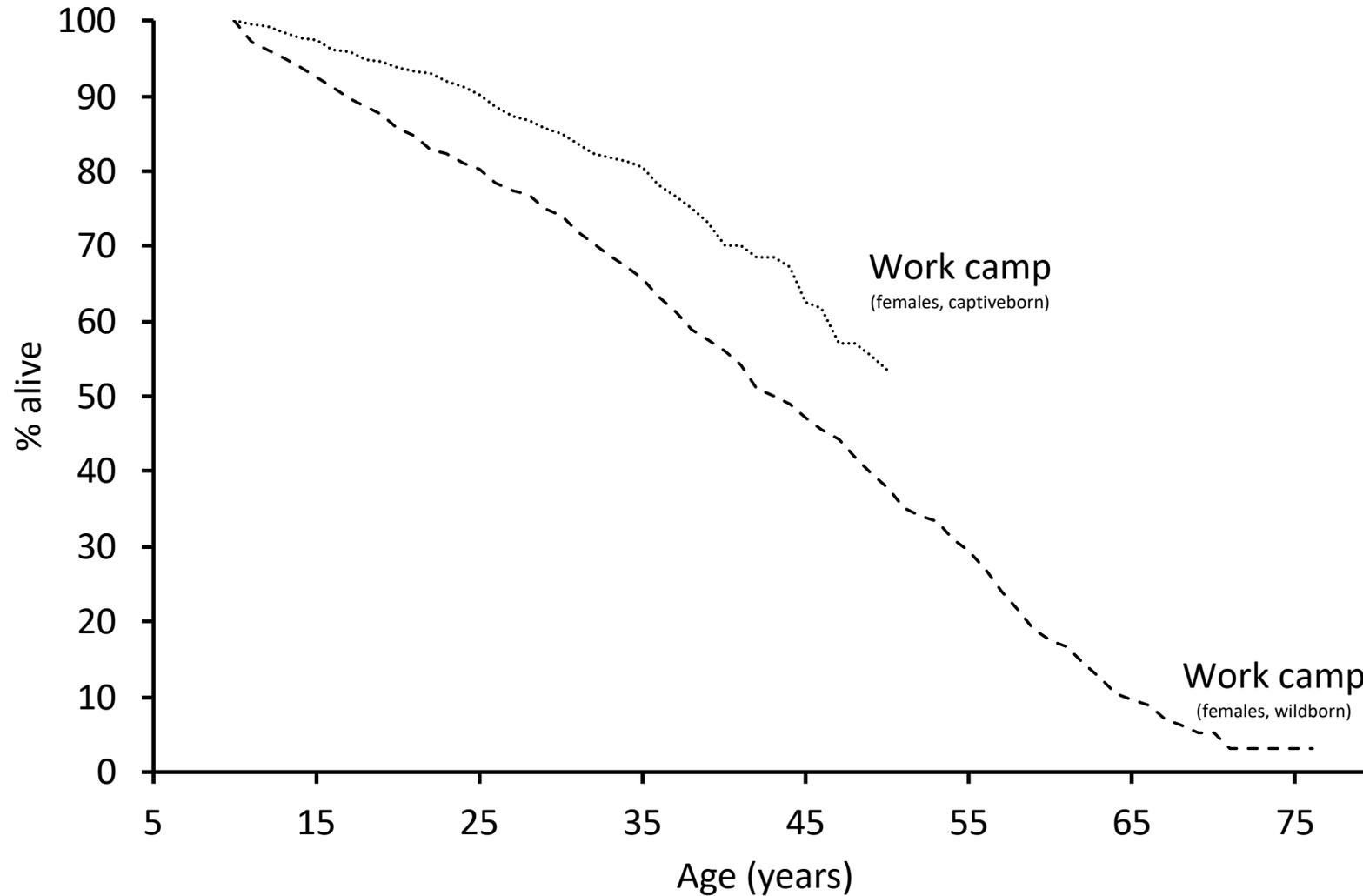


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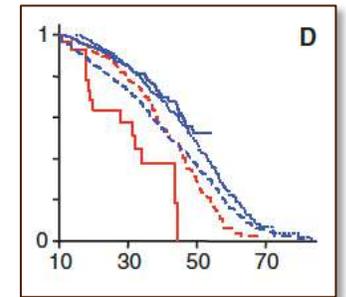
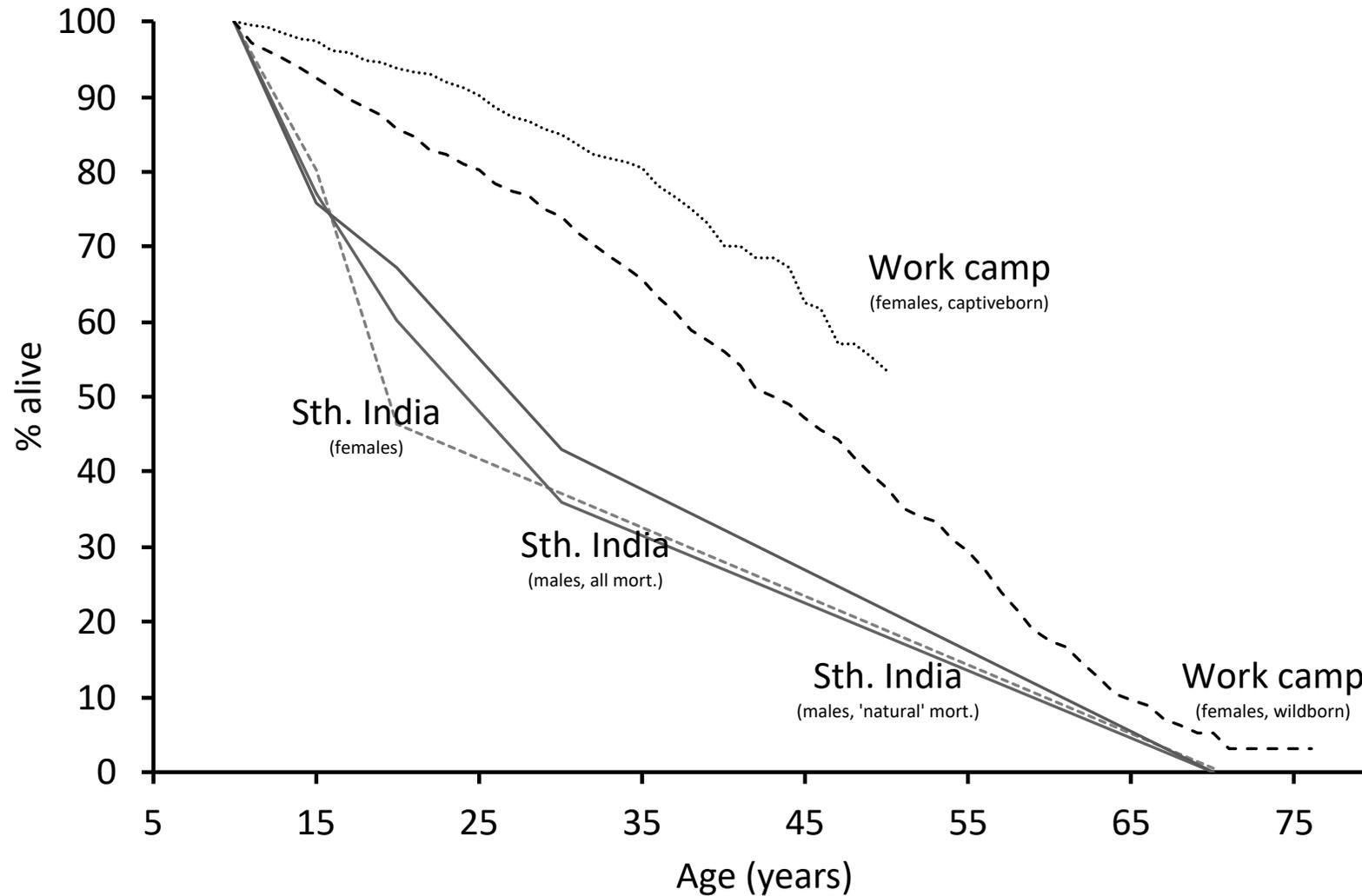
# 'Benchmark' populations ?



Mar (2007)  
Myanmar Timber  
(1950-2000)



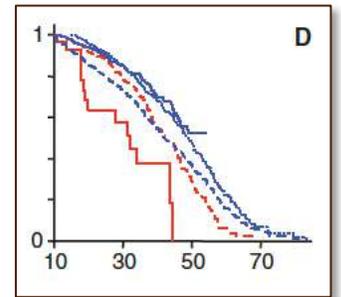
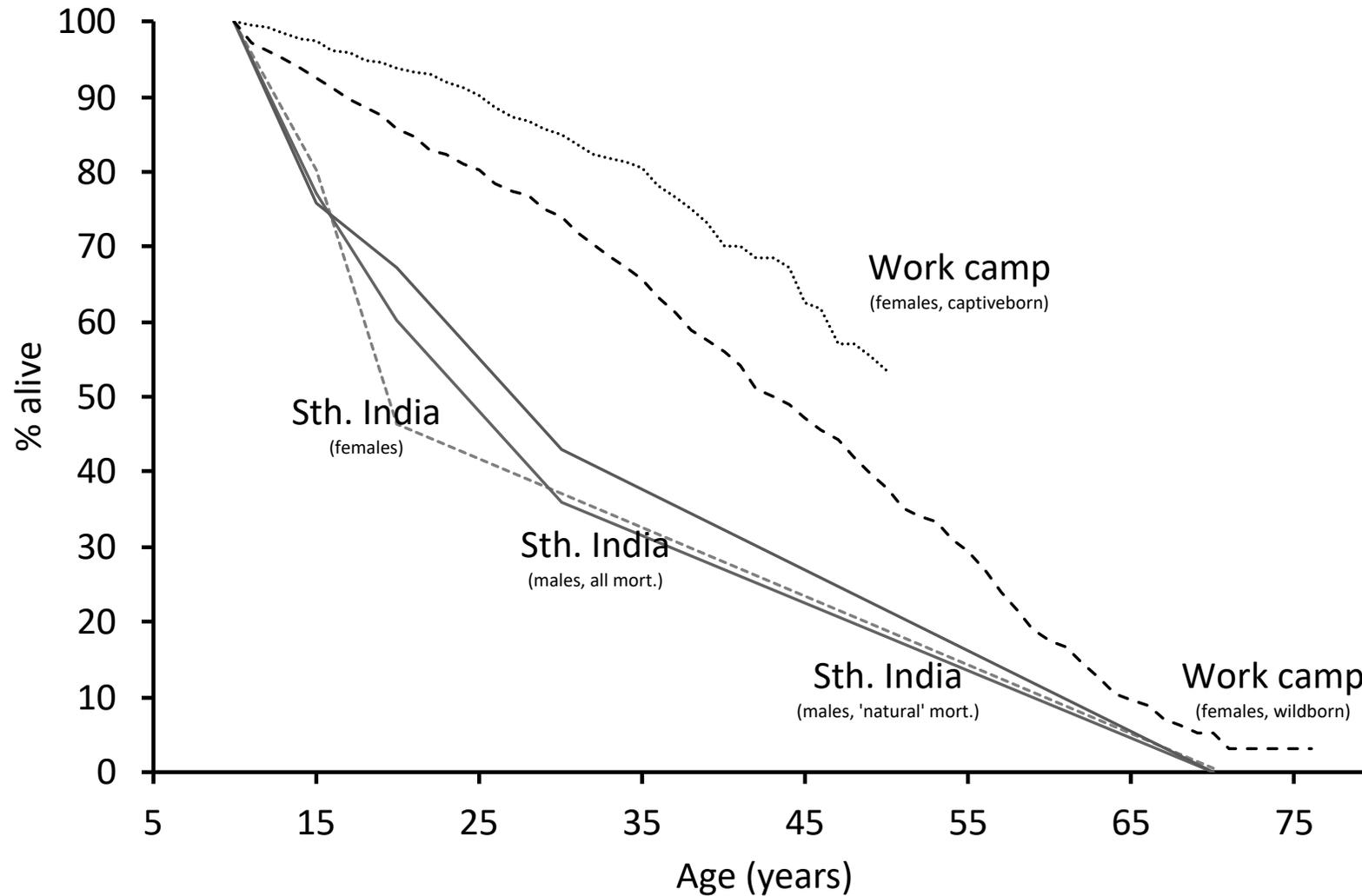
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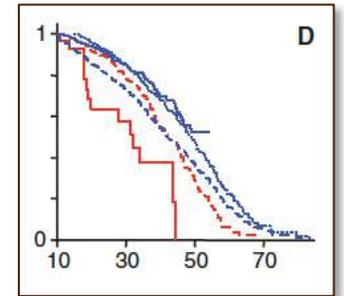
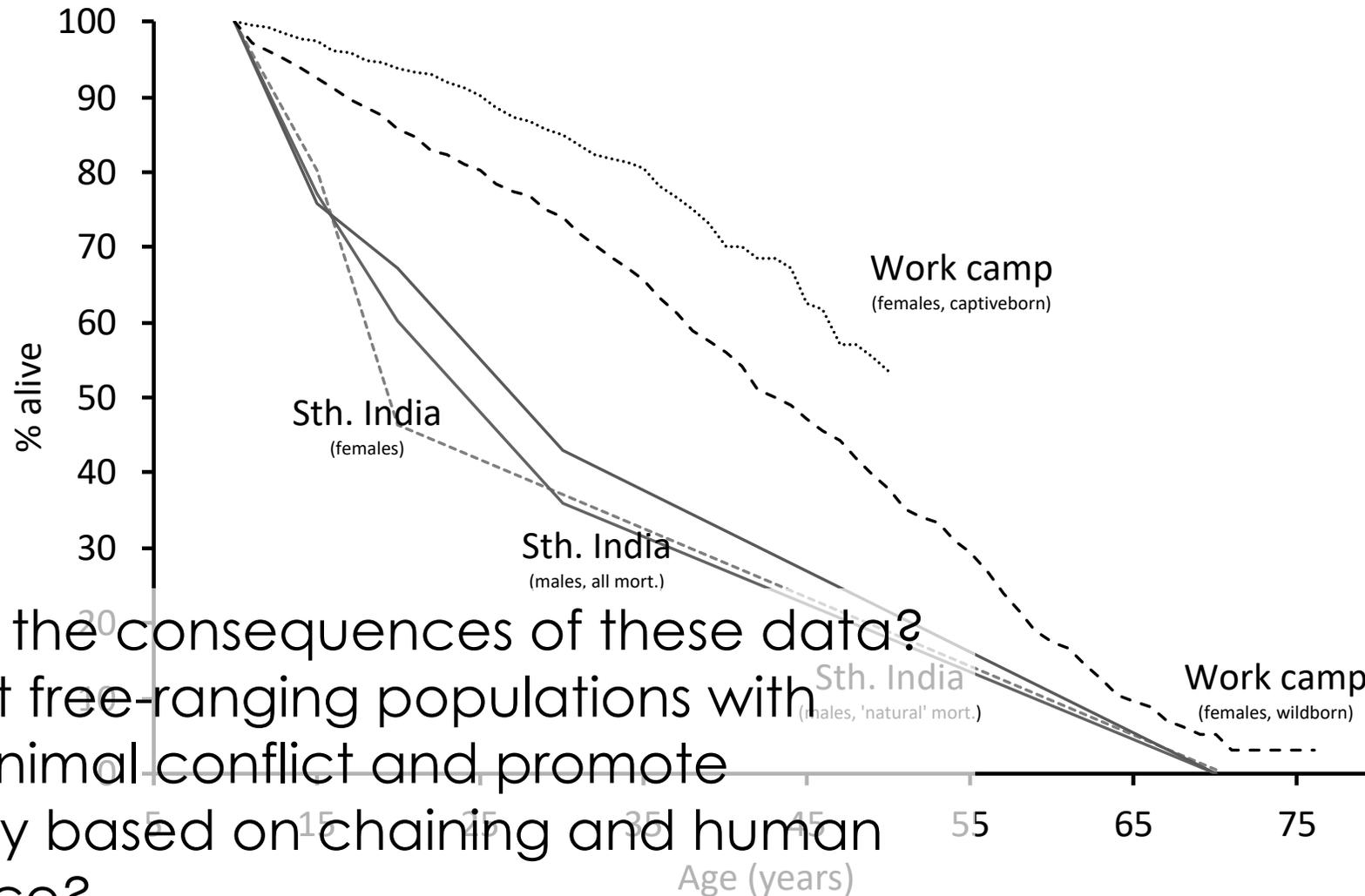


Mar (2007)  
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 (1950-2000)

Sukumar (1989)  
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 (1981-1983)



# 'Benchmark' populations ?



Mar (2007)  
 Myanmar Timber  
 (1950-2000)

Sukumar (1989)  
 Southern India  
 (1981-1983)

What are the consequences of these data?  
 Phase out free-ranging populations with  
 human-animal conflict and promote  
 husbandry based on chaining and human  
 dominance?

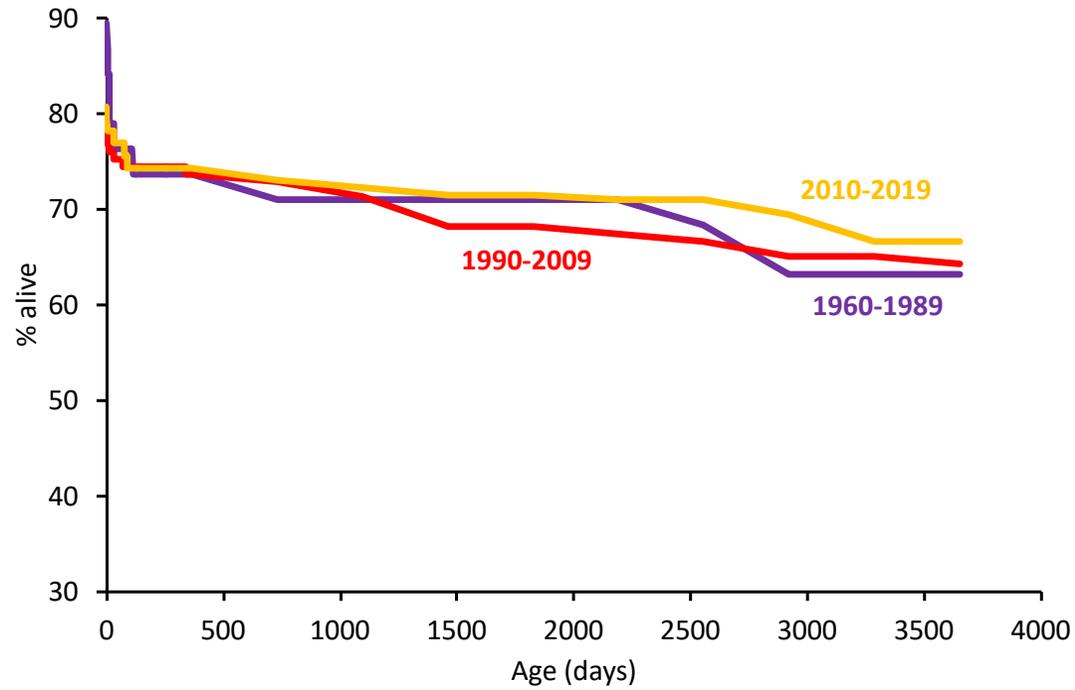


# Juvenile mortality (zooborn only)



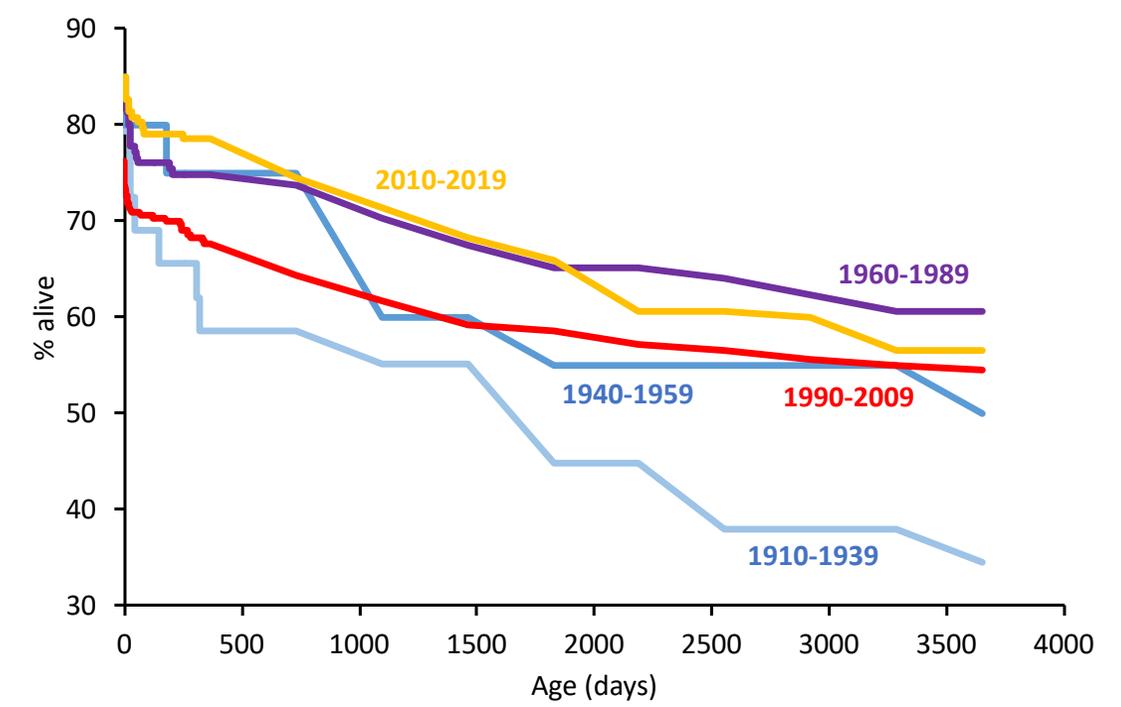
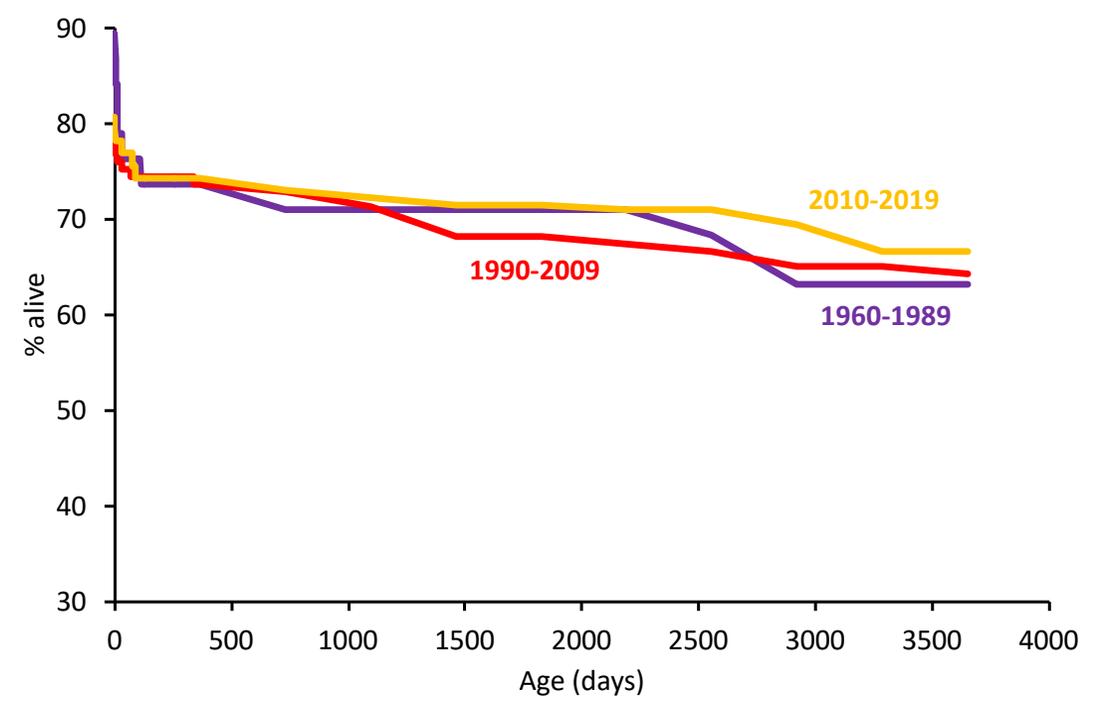


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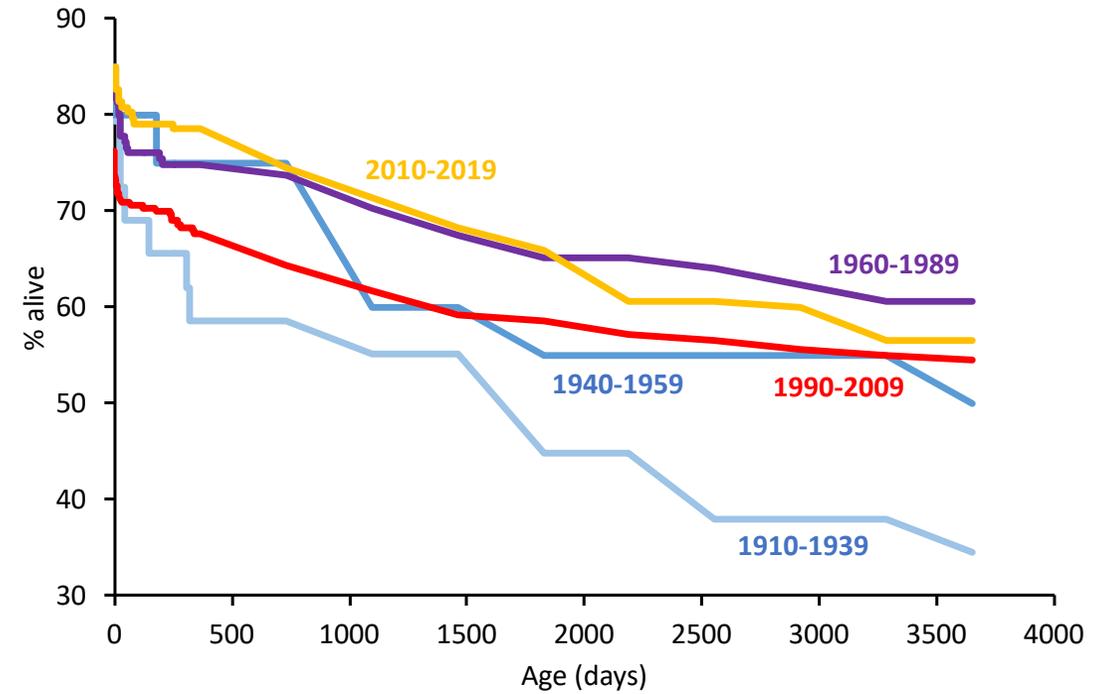
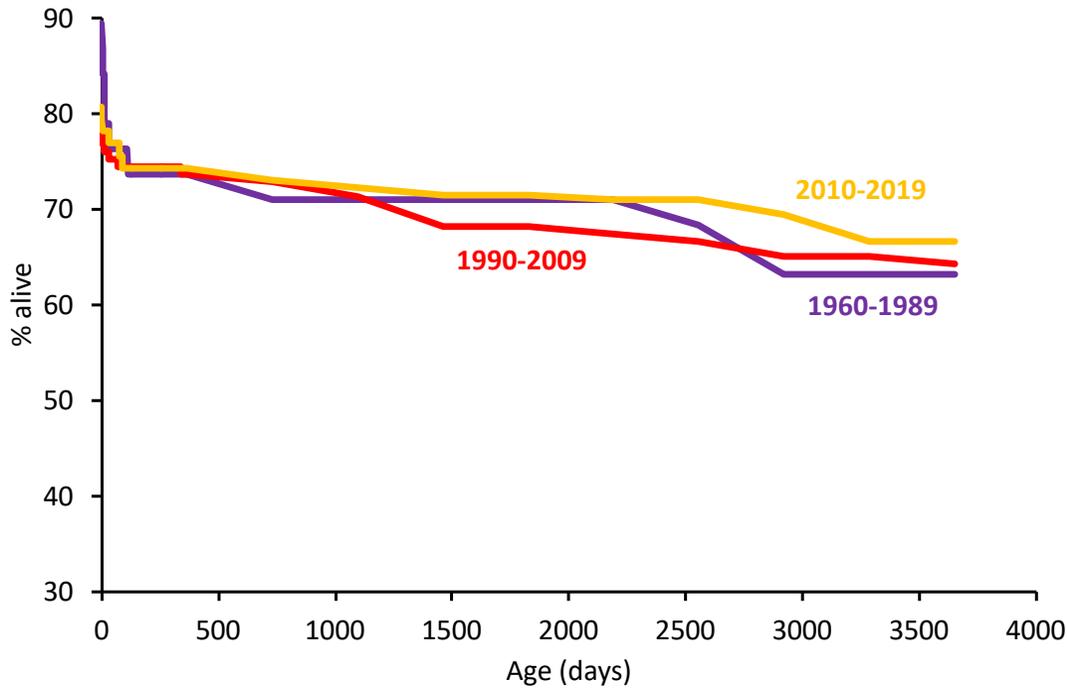


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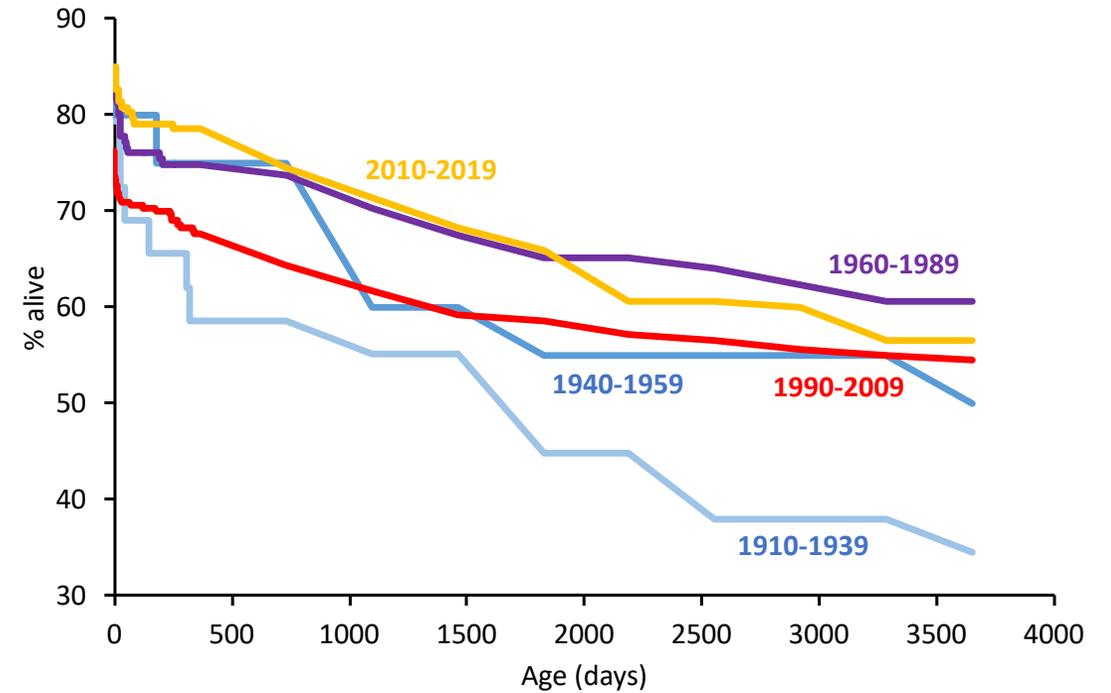
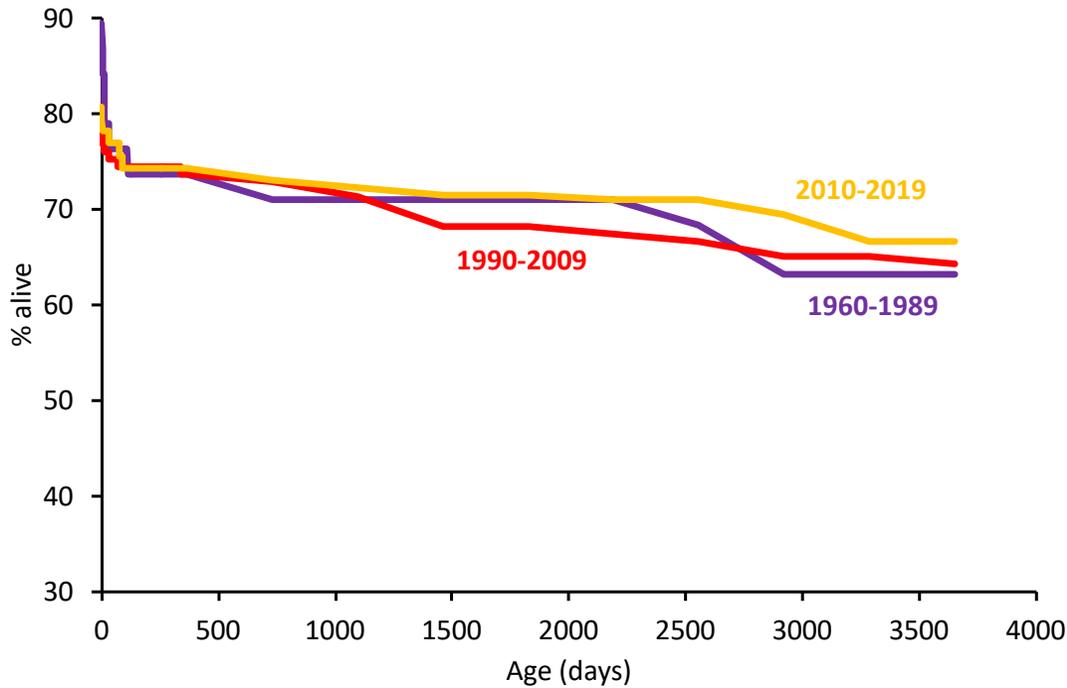
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no significant change over time (except in Asians compared to 1910-1939)



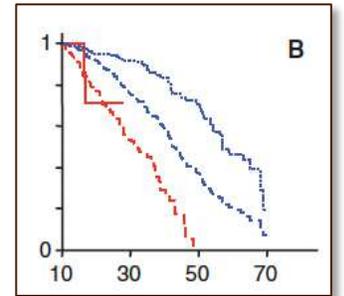
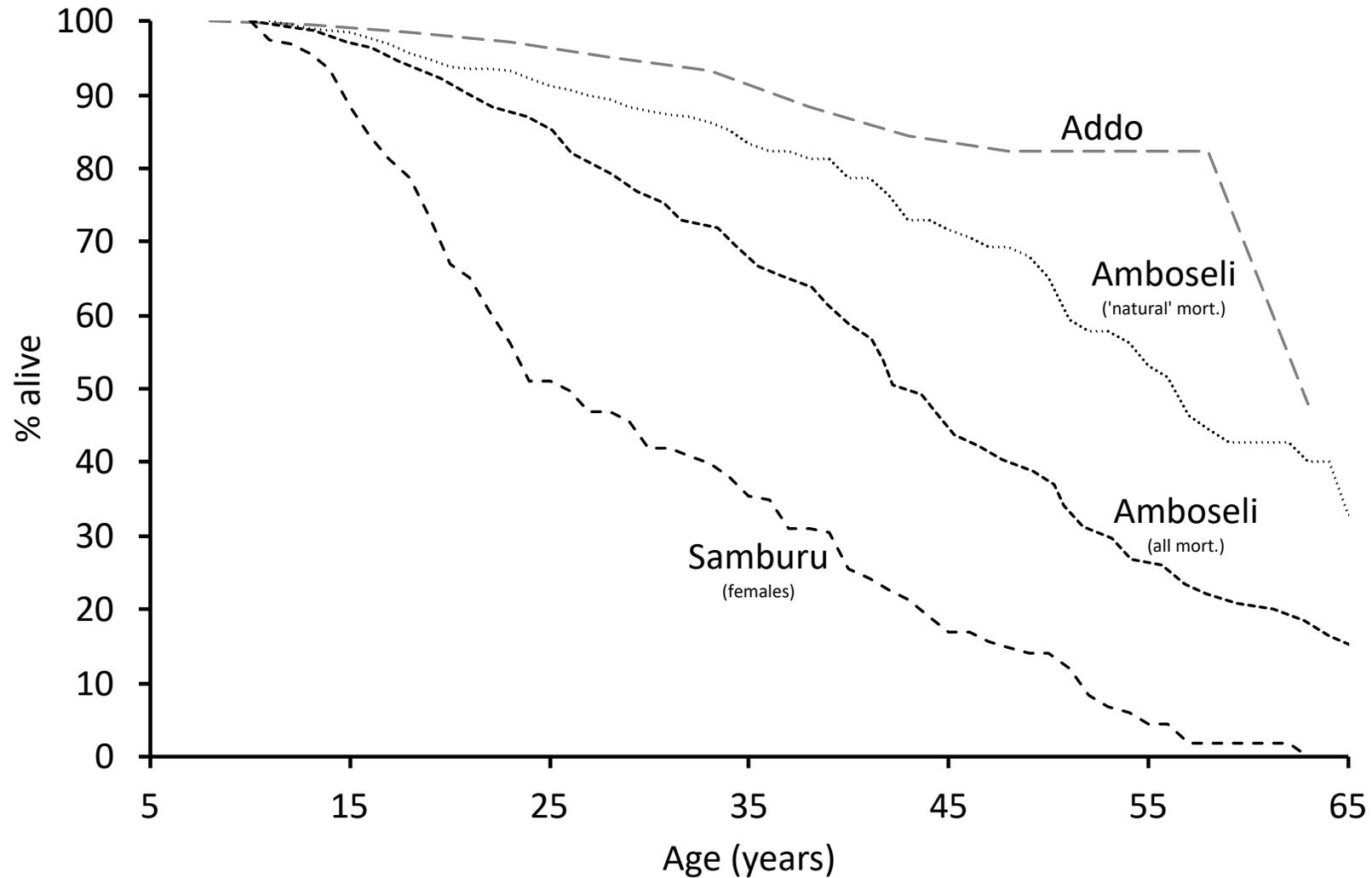
# Juvenile mortality (zooborn only)



no significant change over time (except in Asians compared to 1910-1939)  
since 1960: Asian elephants tend towards lower survivorship compared to African elephants ( $P = 0.080$ )

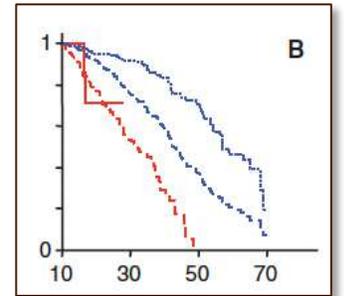
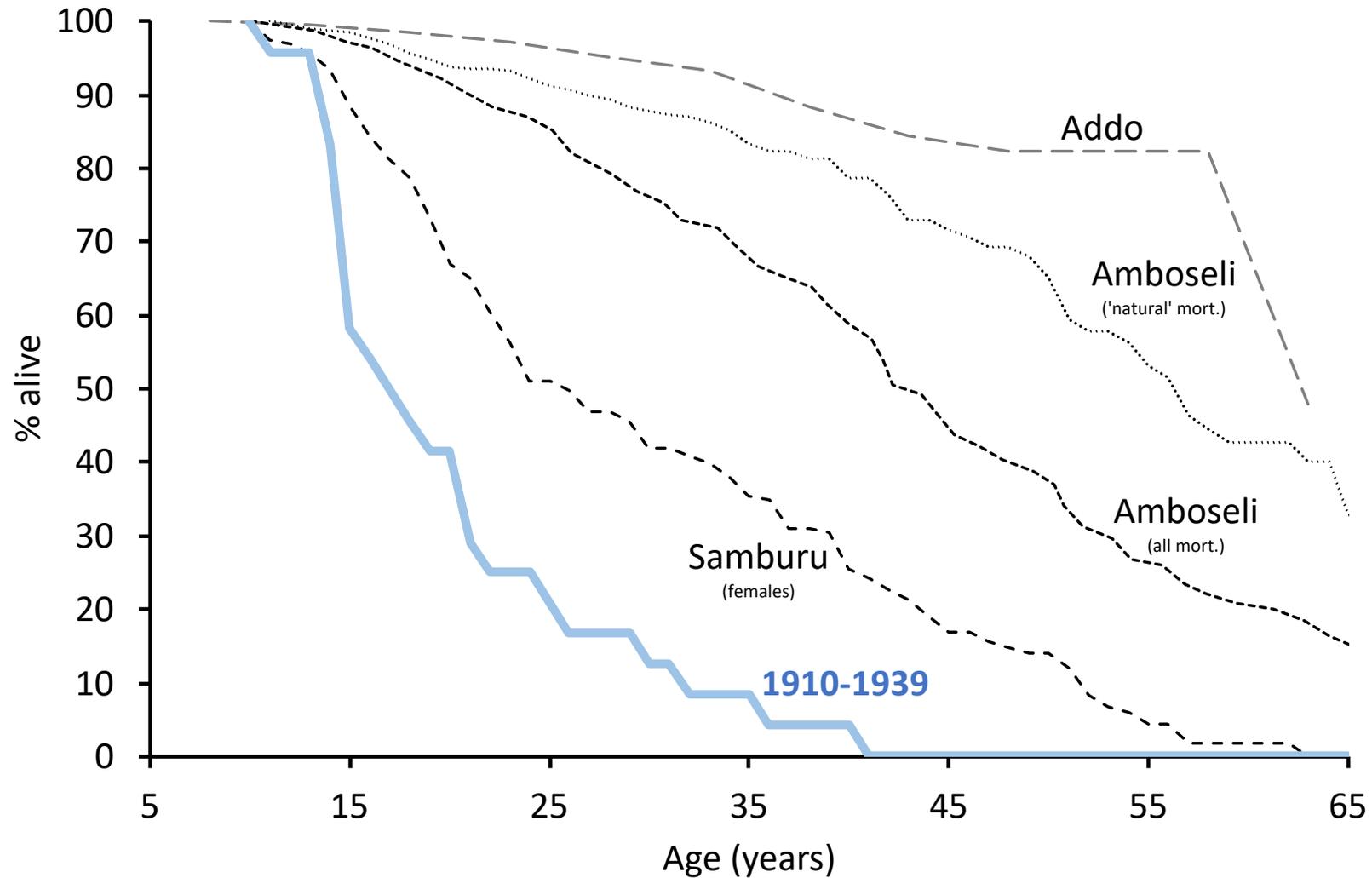


# Adult survivorship – African elephants (N.Am. & EU)



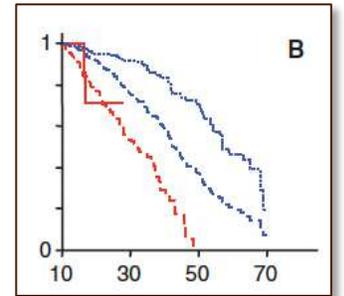
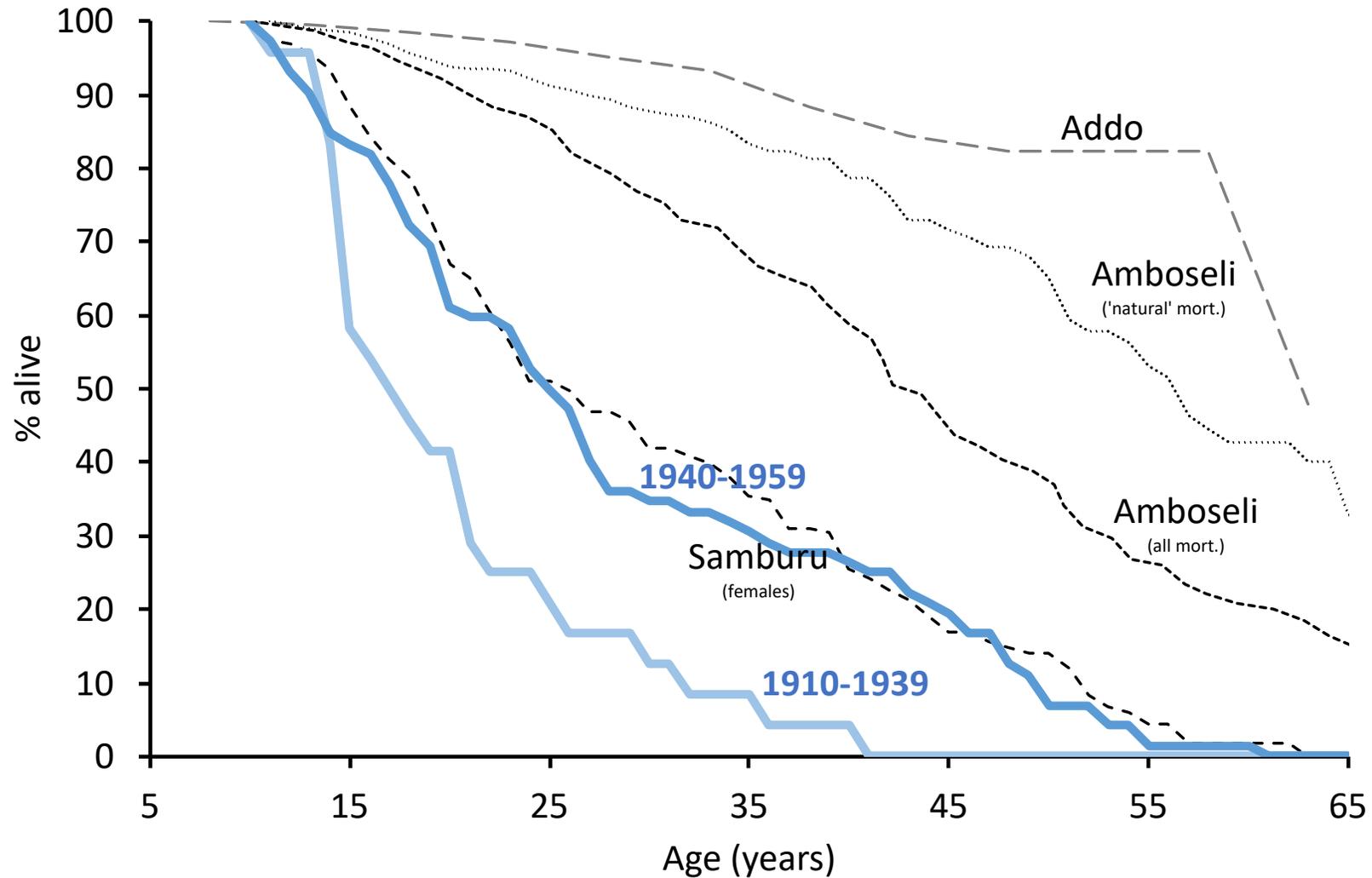


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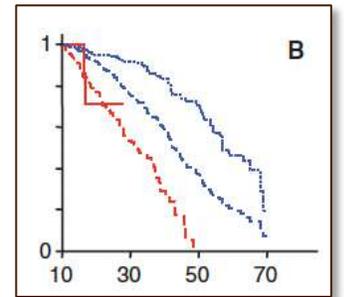
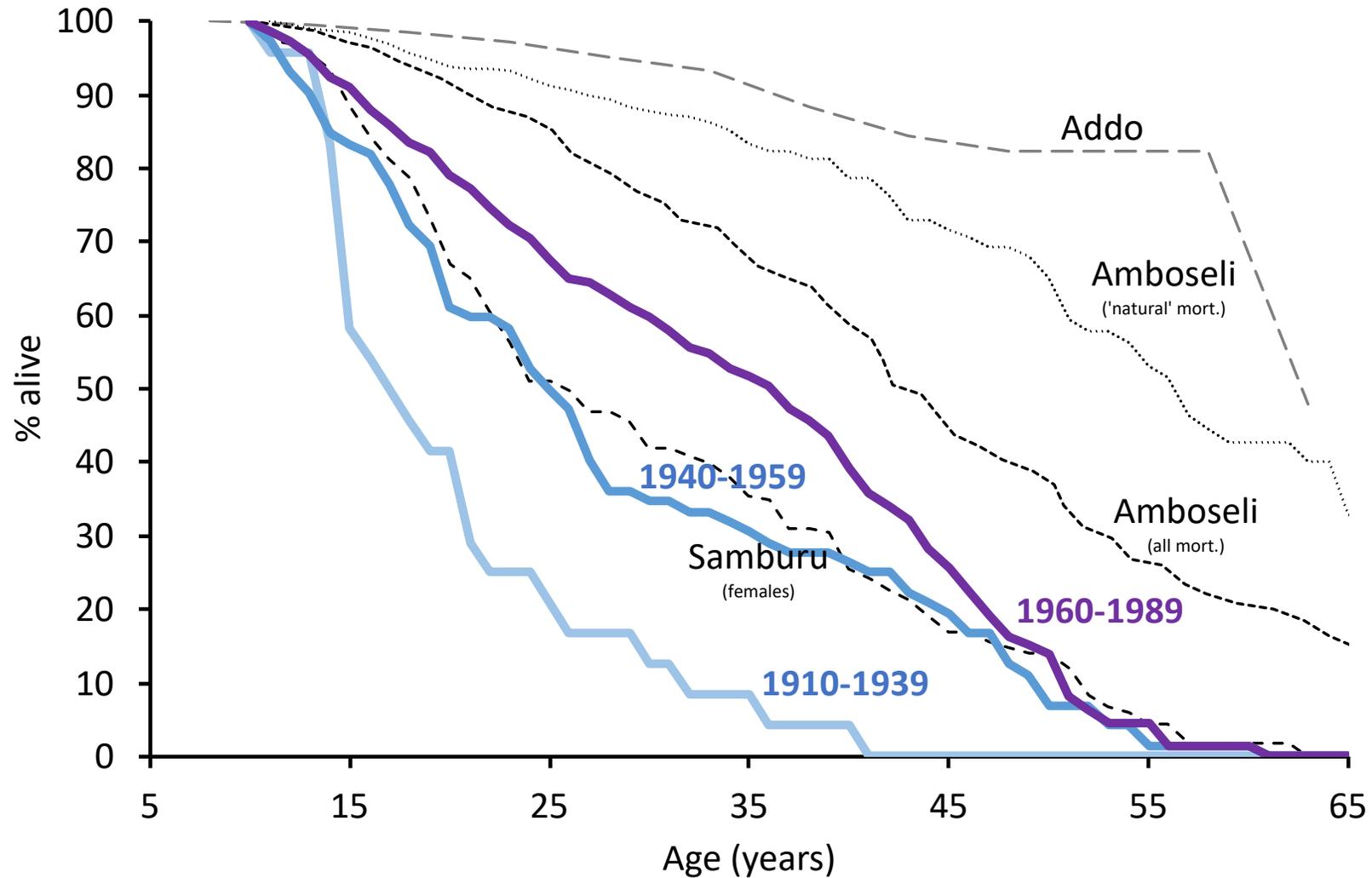


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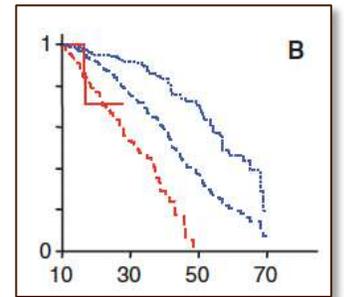
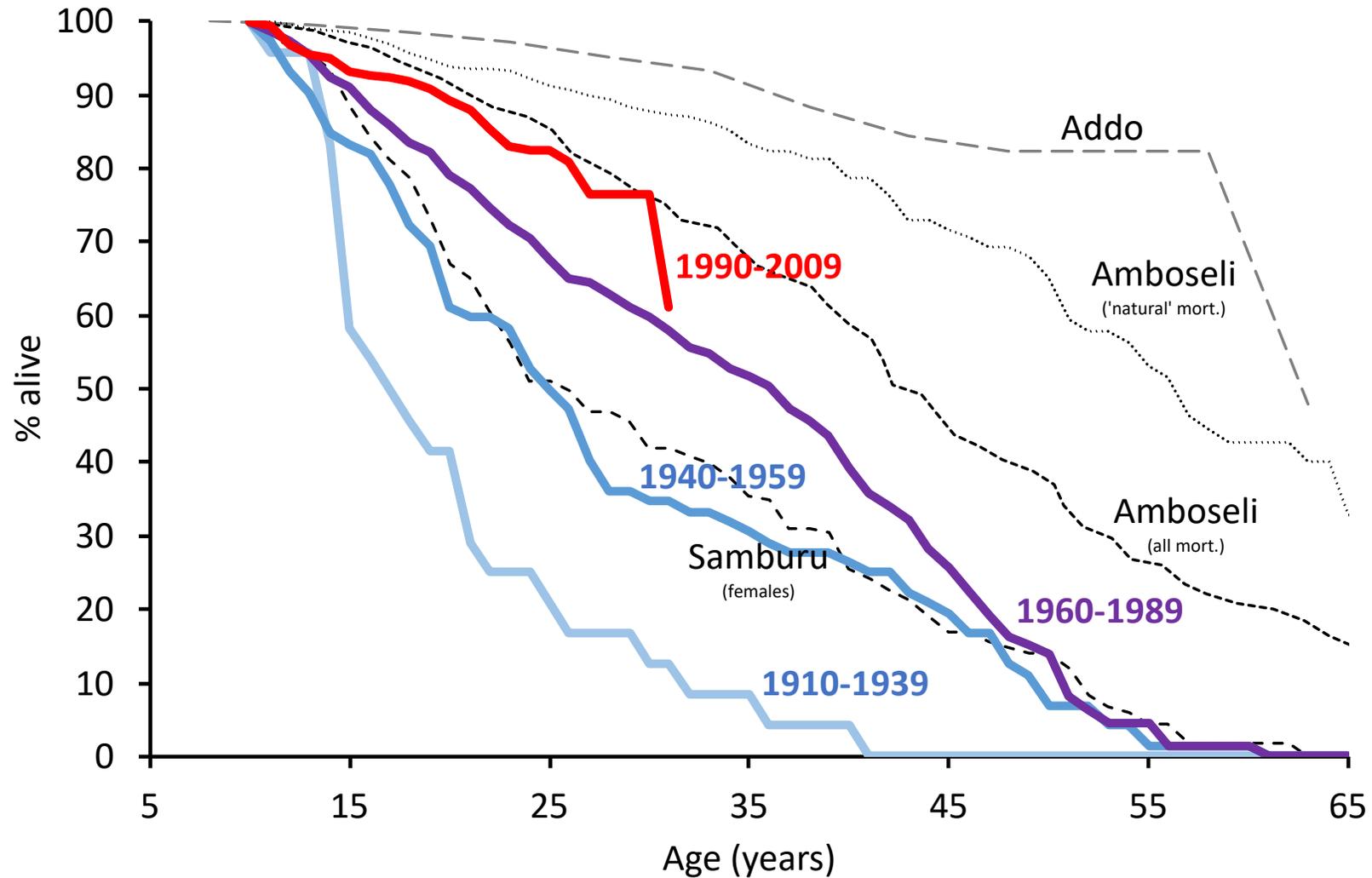


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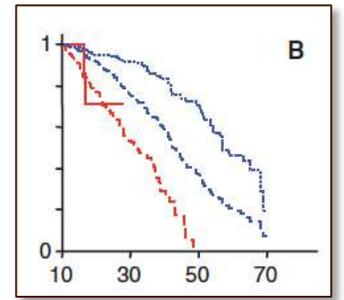
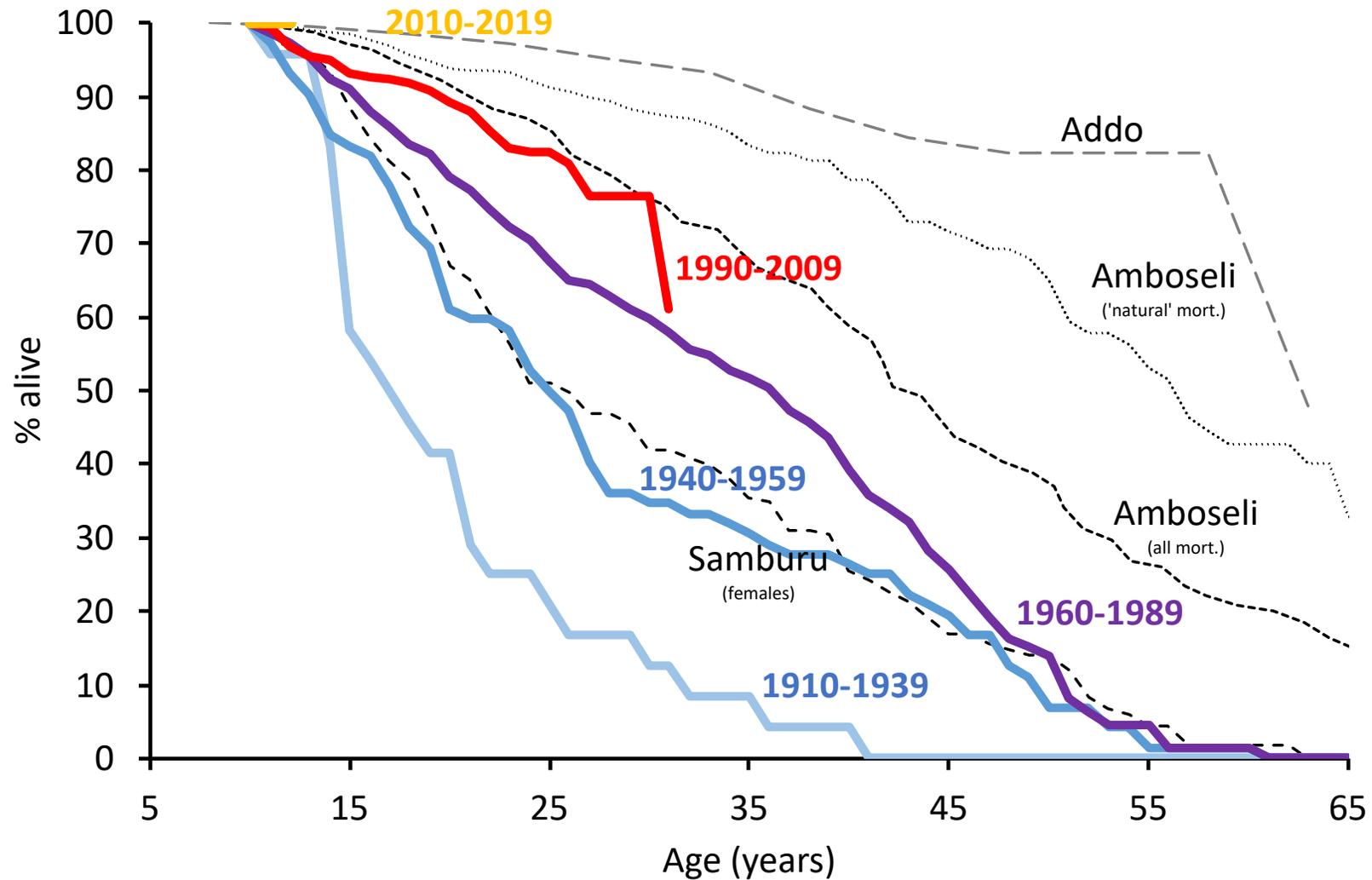


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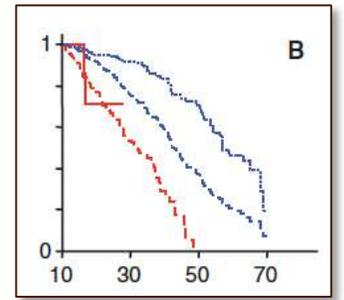
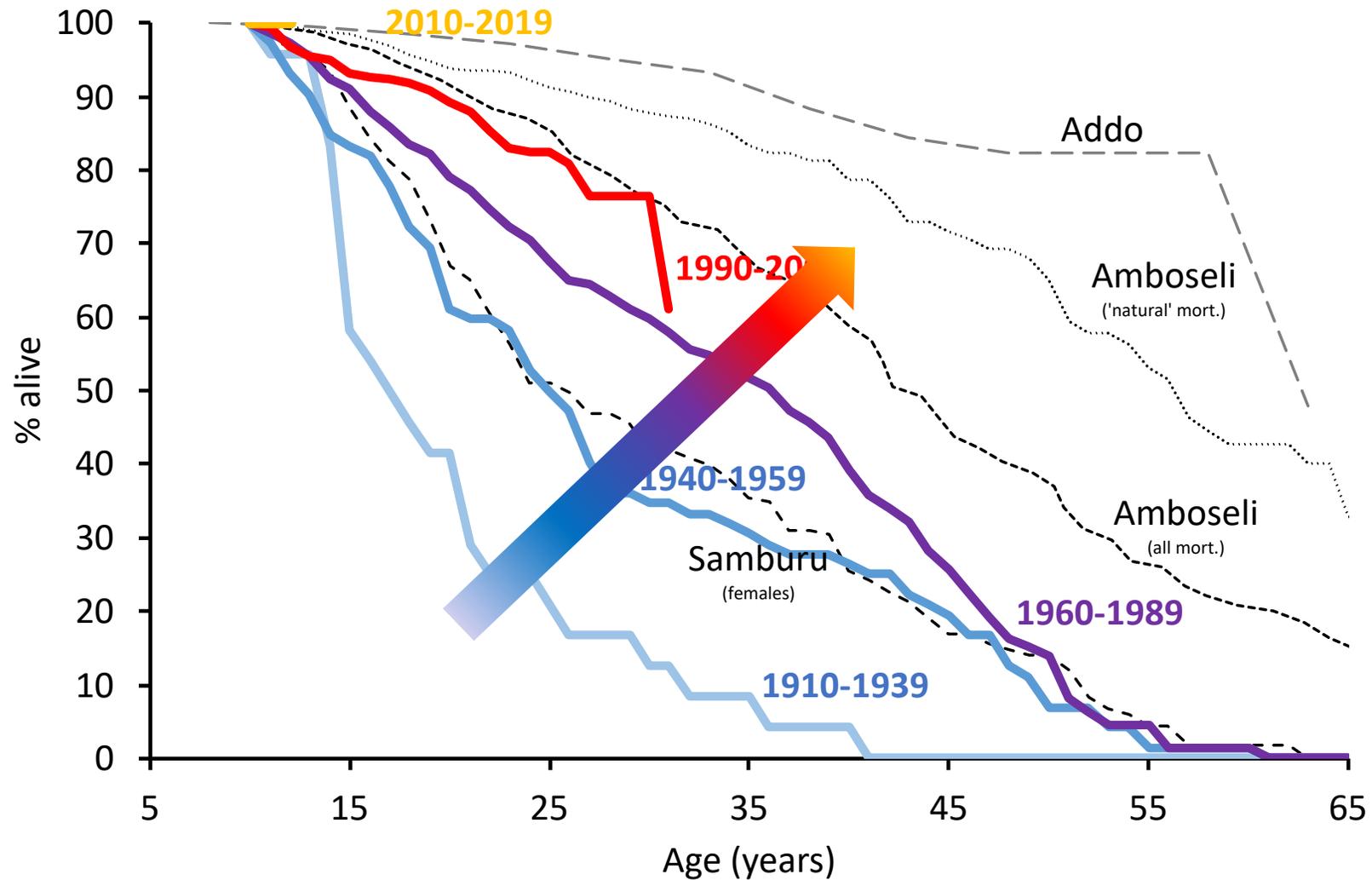


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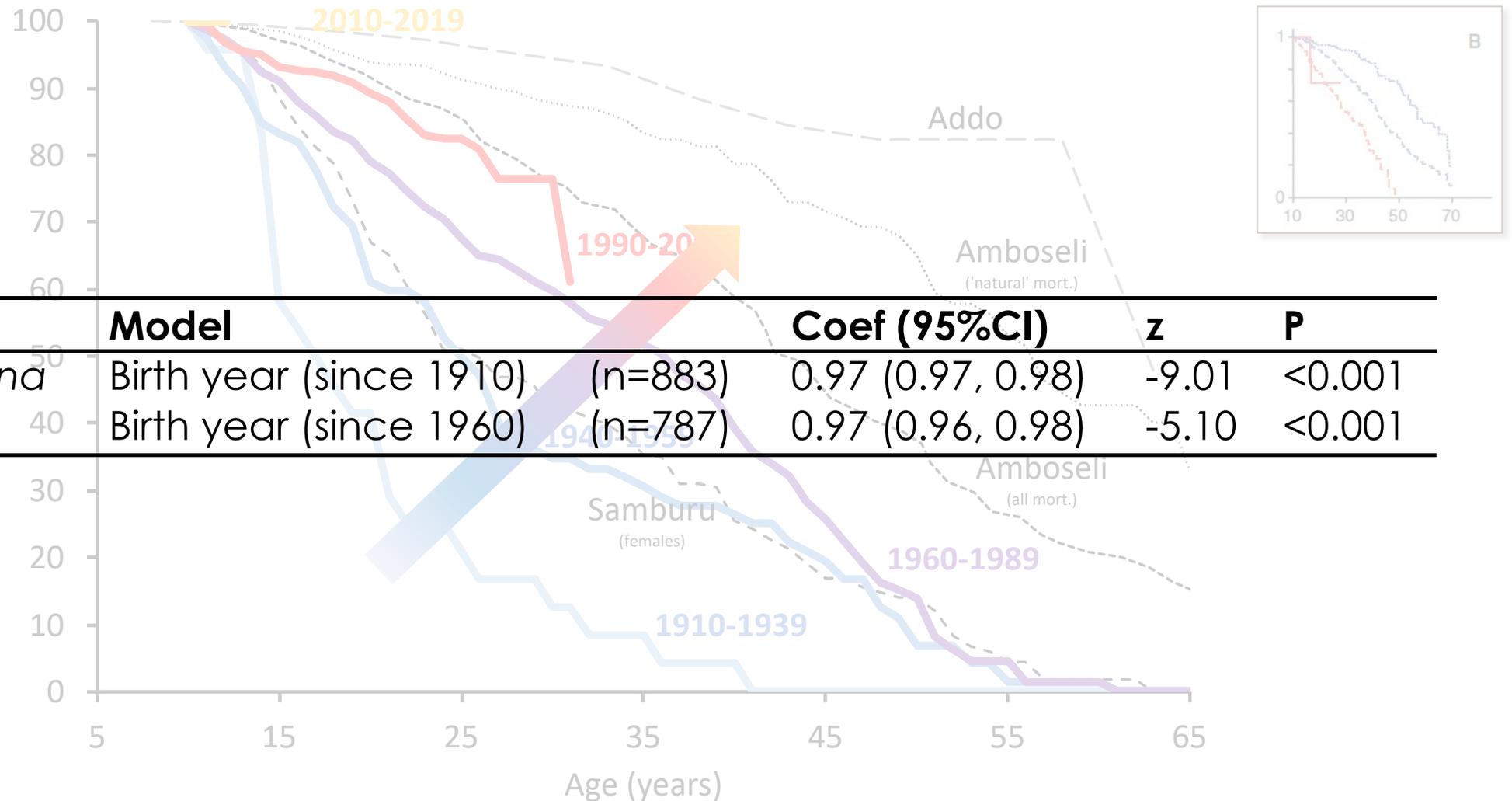


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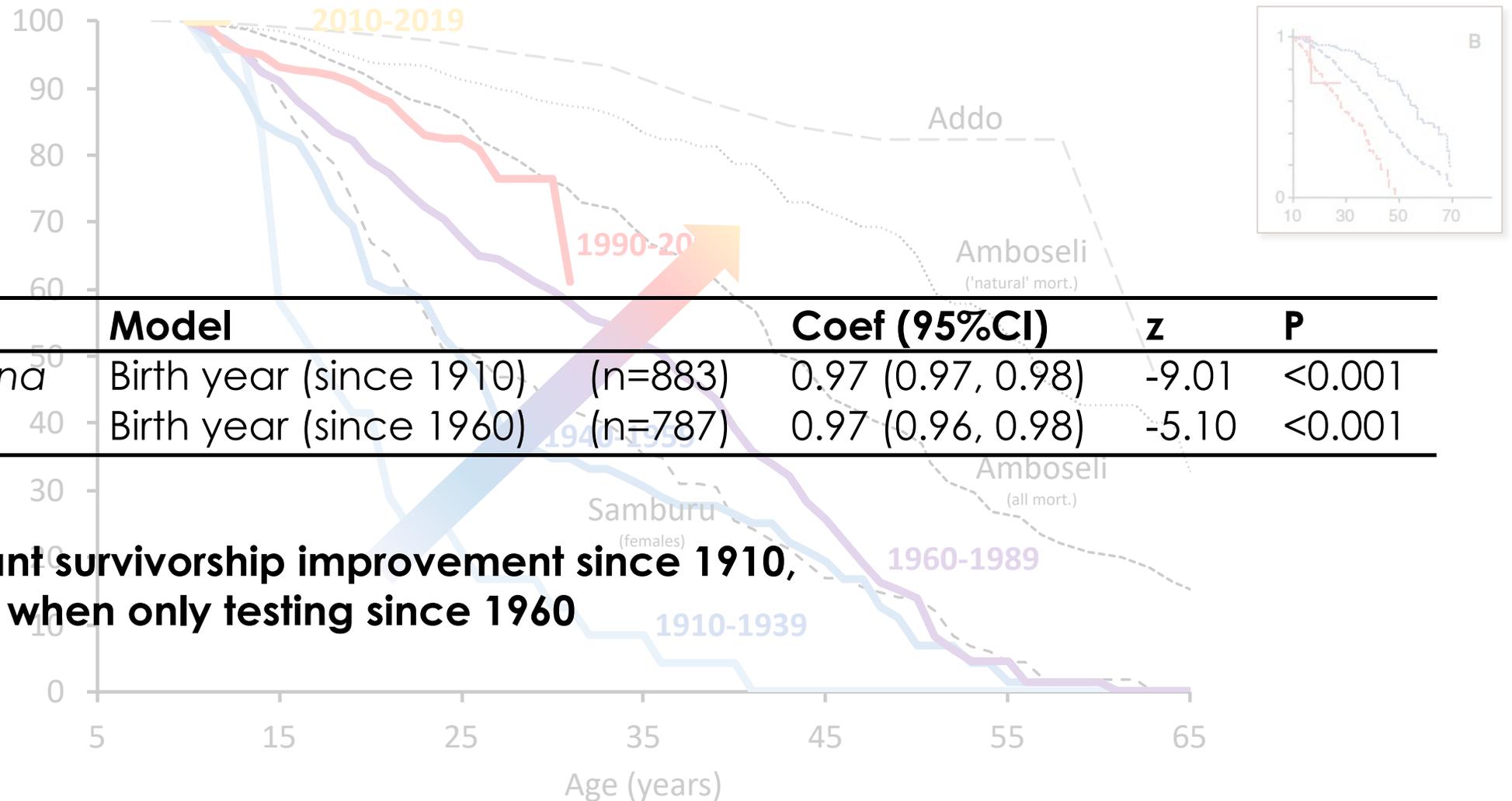
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Species	Model	Coef (95%CI)	z	P
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	Birth year (since 1960) (n=787)	0.97 (0.96, 0.98)	-5.10	<0.001



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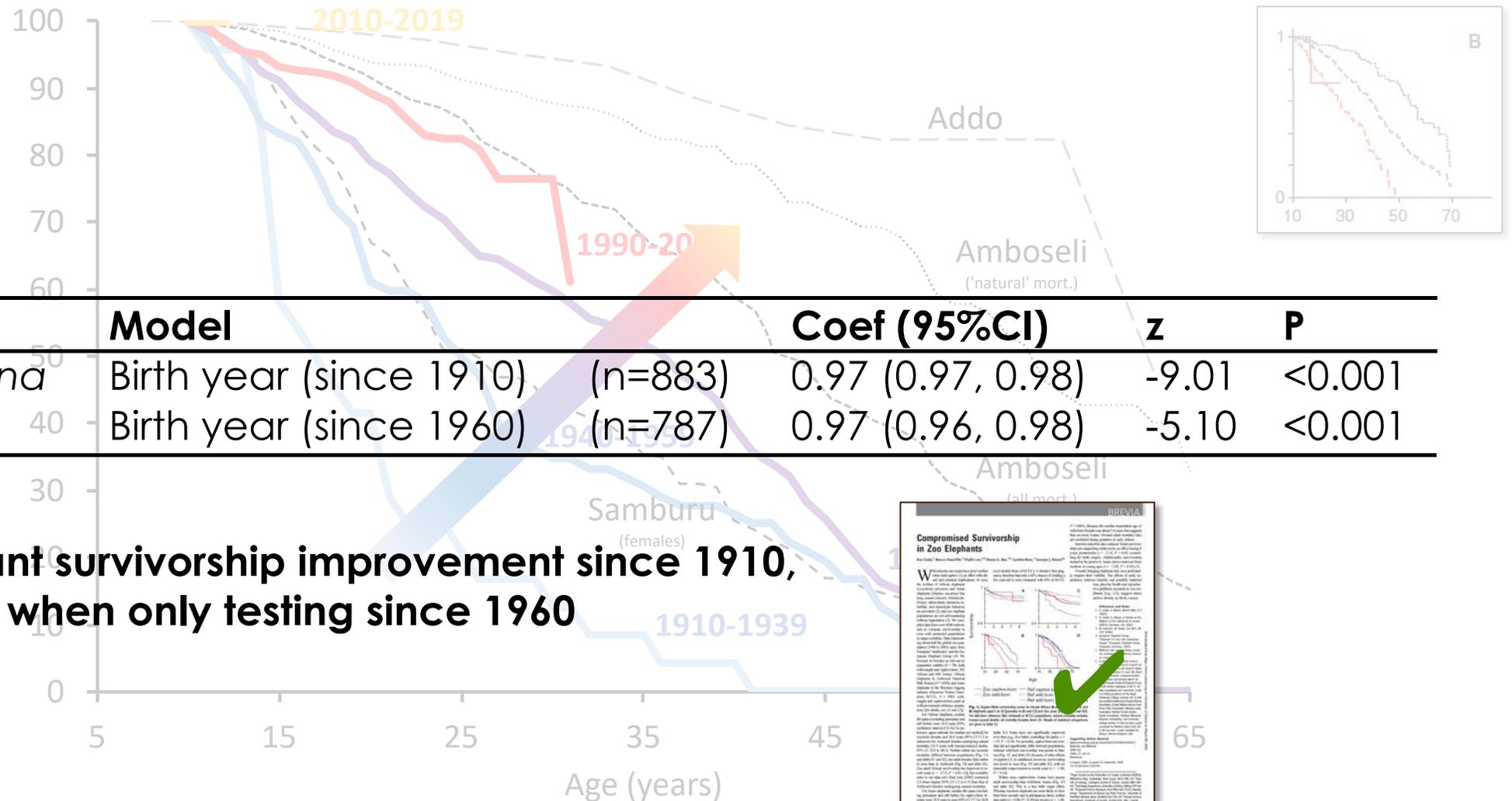


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**Significant survivorship improvement since 1910, but also when only testing since 1960**

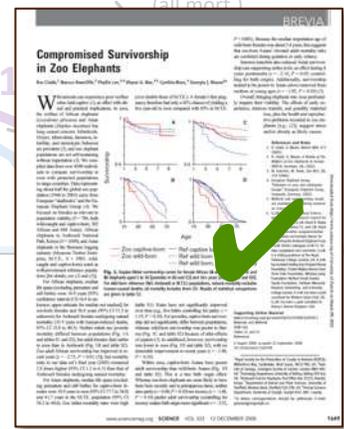


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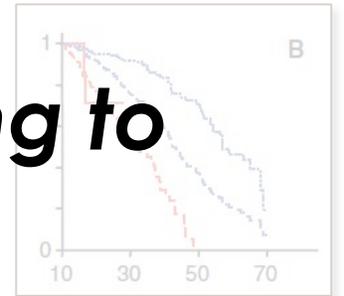




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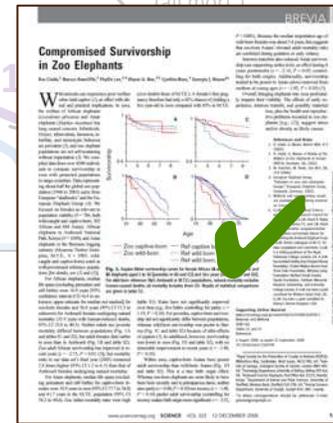
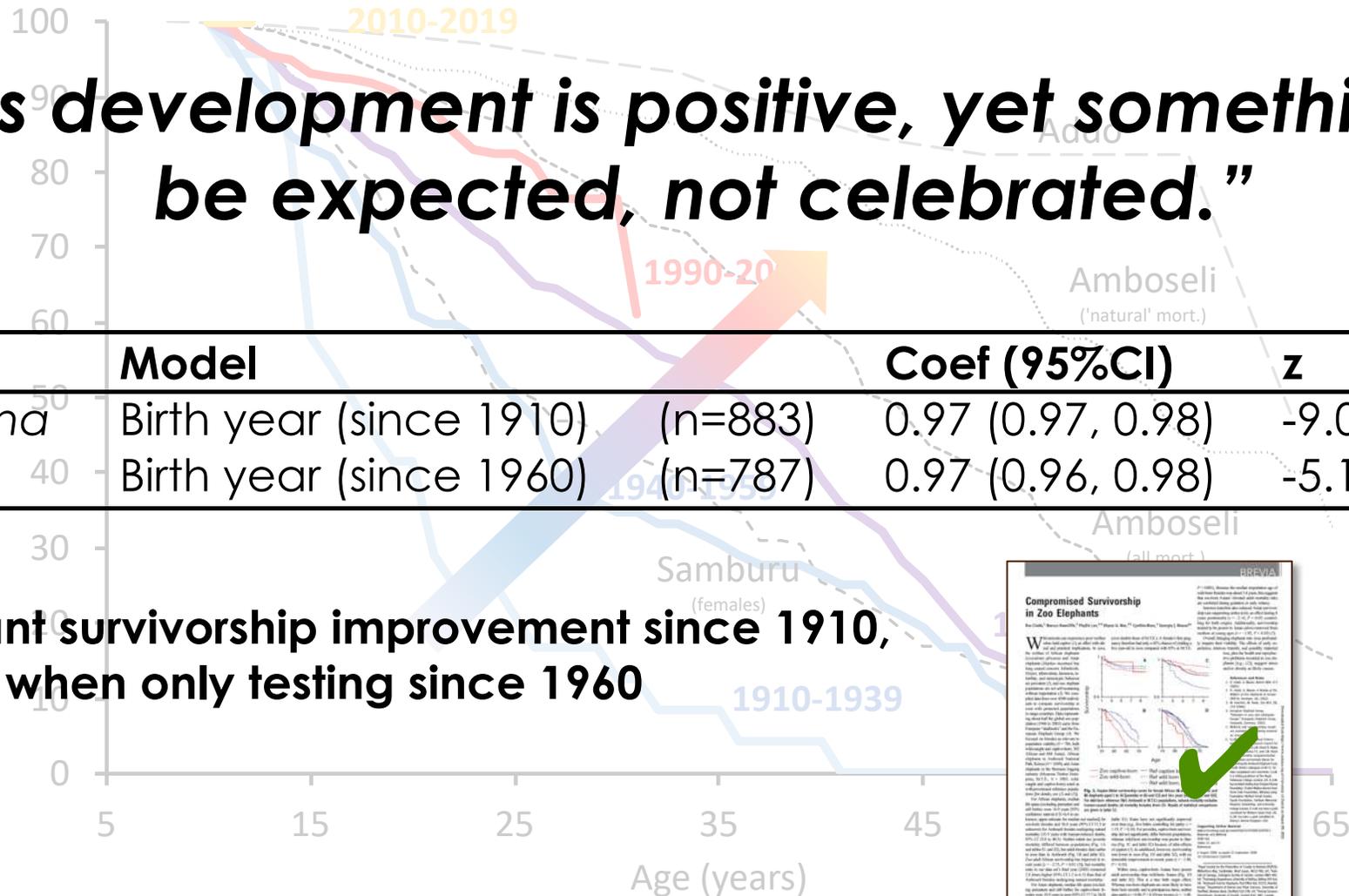


**“This development is positive, yet something to be expected, not celebrated.”**



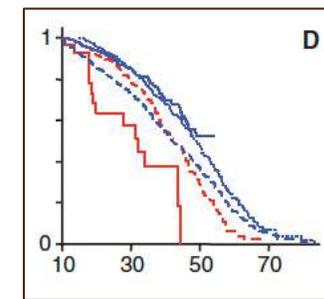
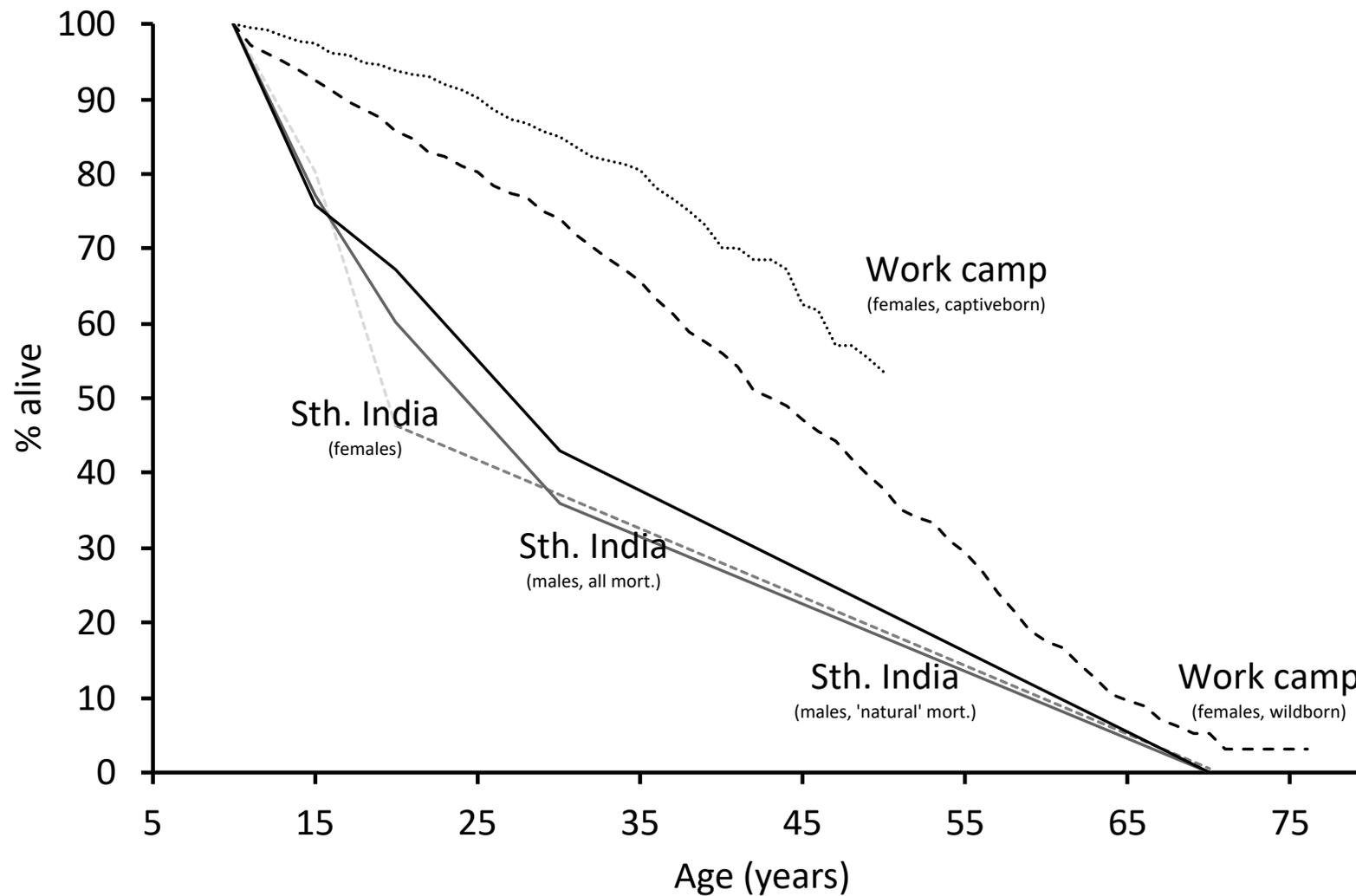
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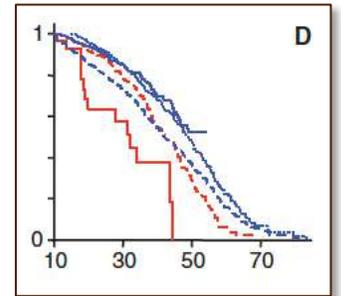
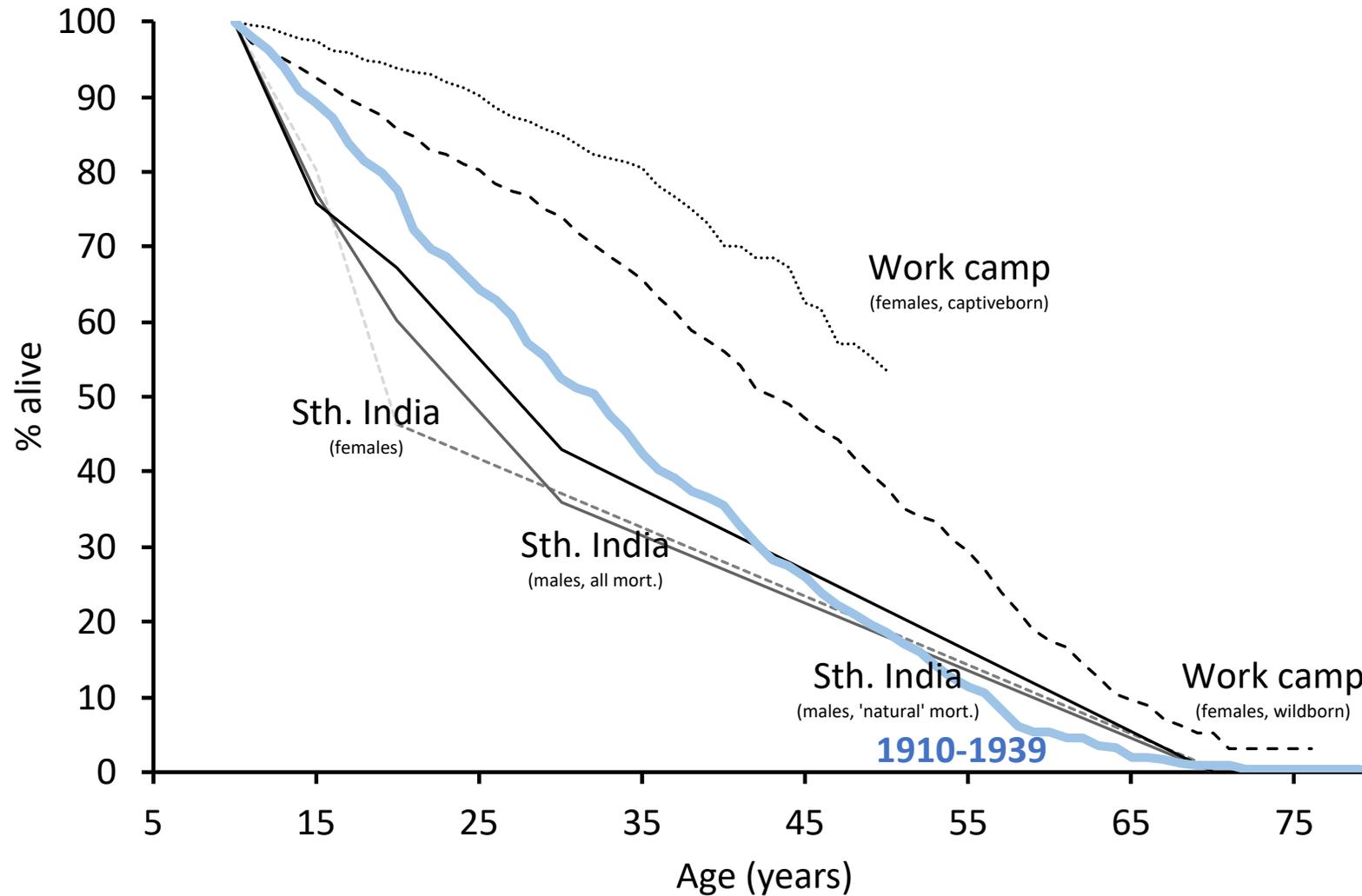


# Adult survivorship – Asian elephants (N.Am. & EU)



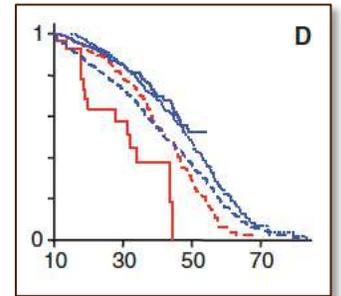
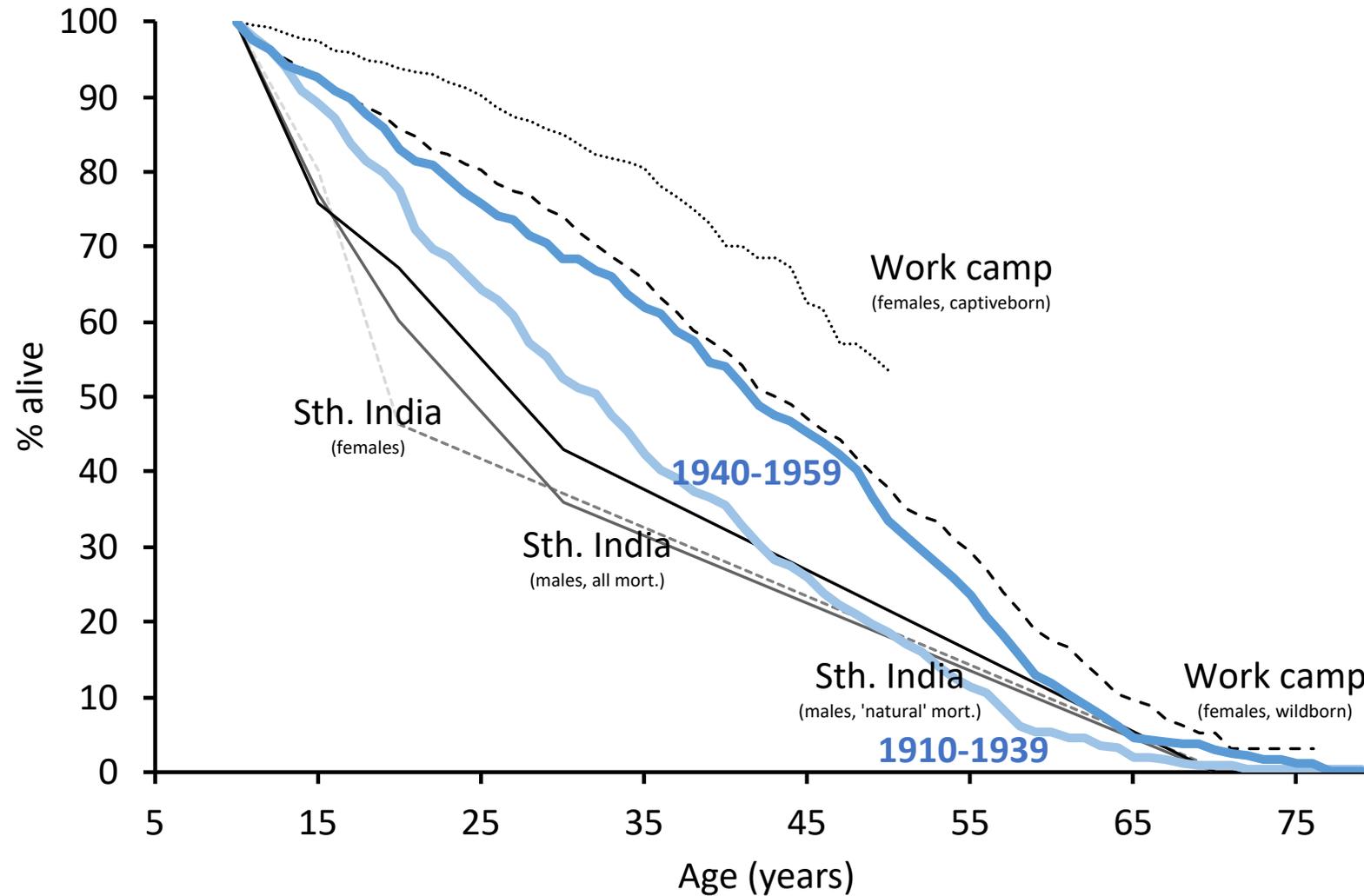


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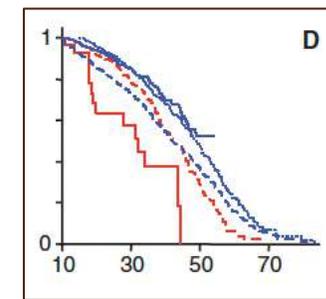
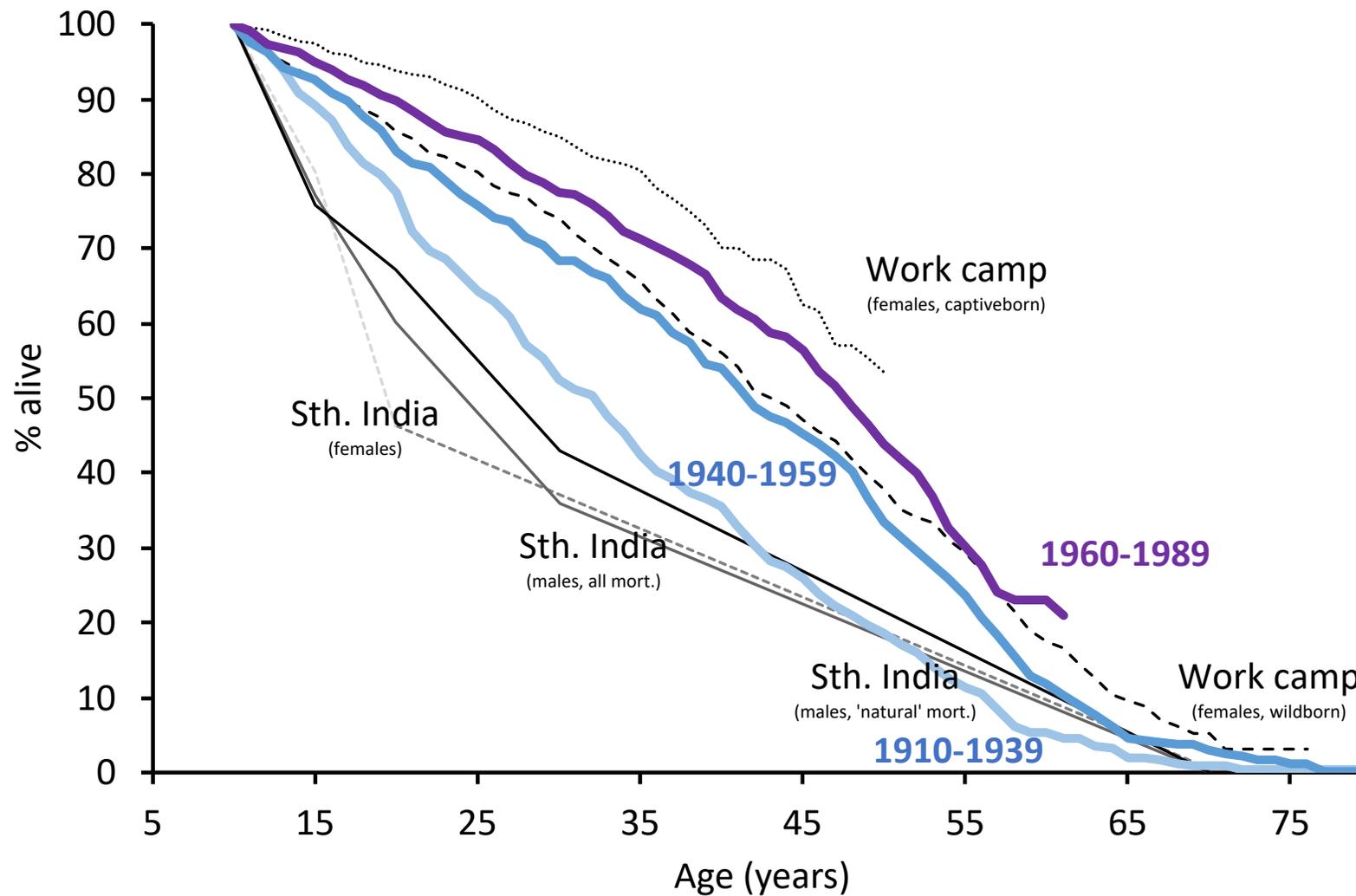


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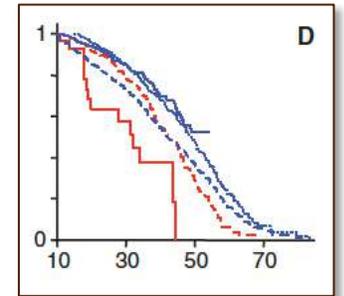
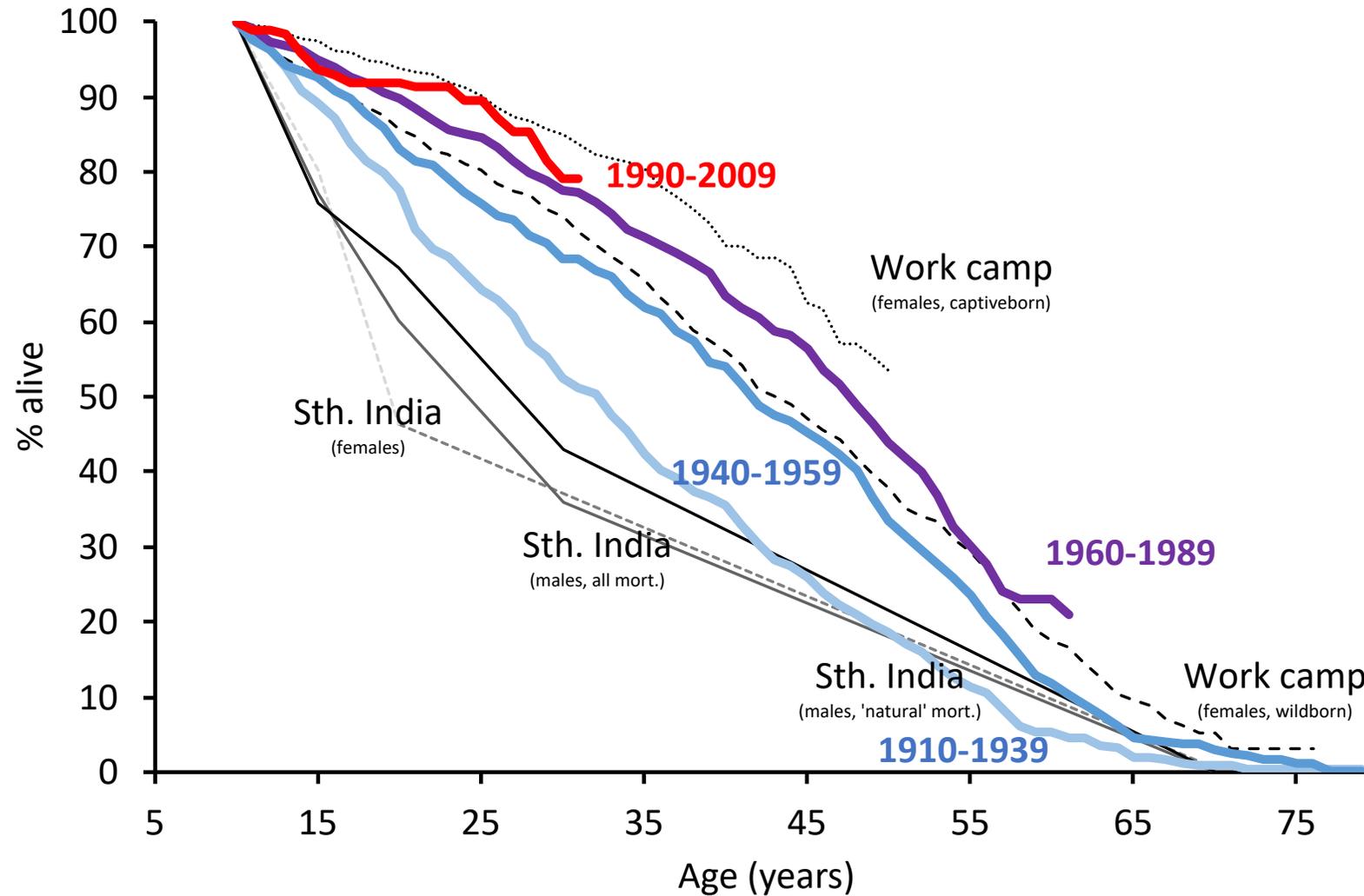


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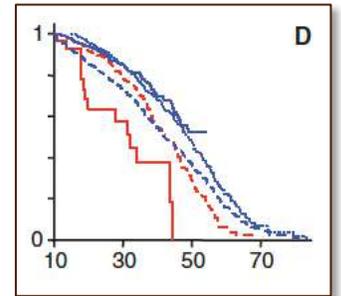
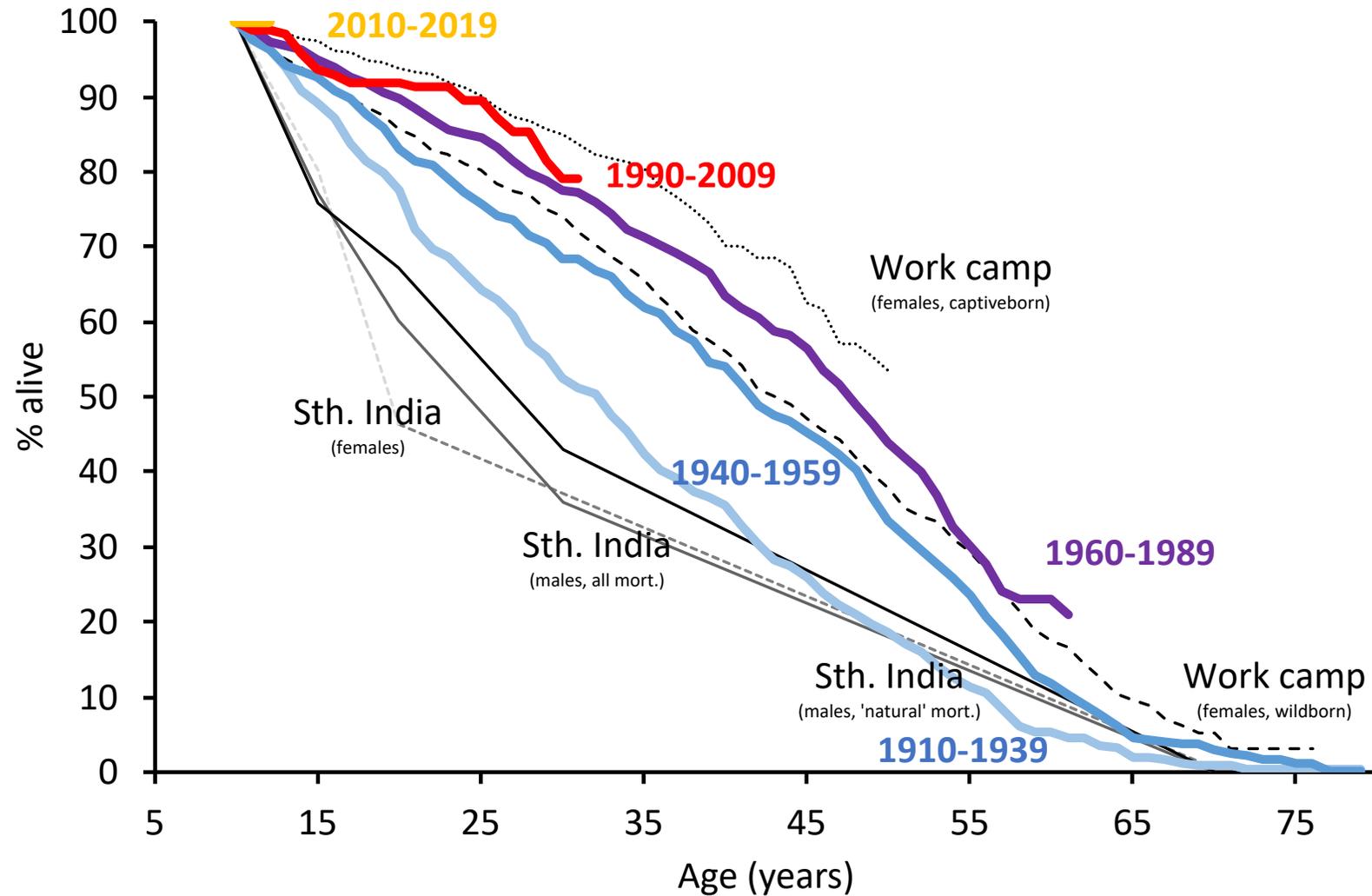


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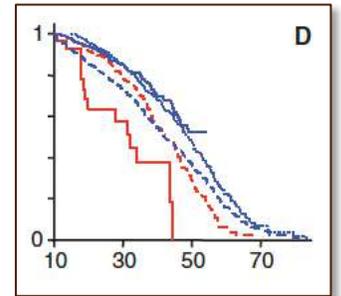
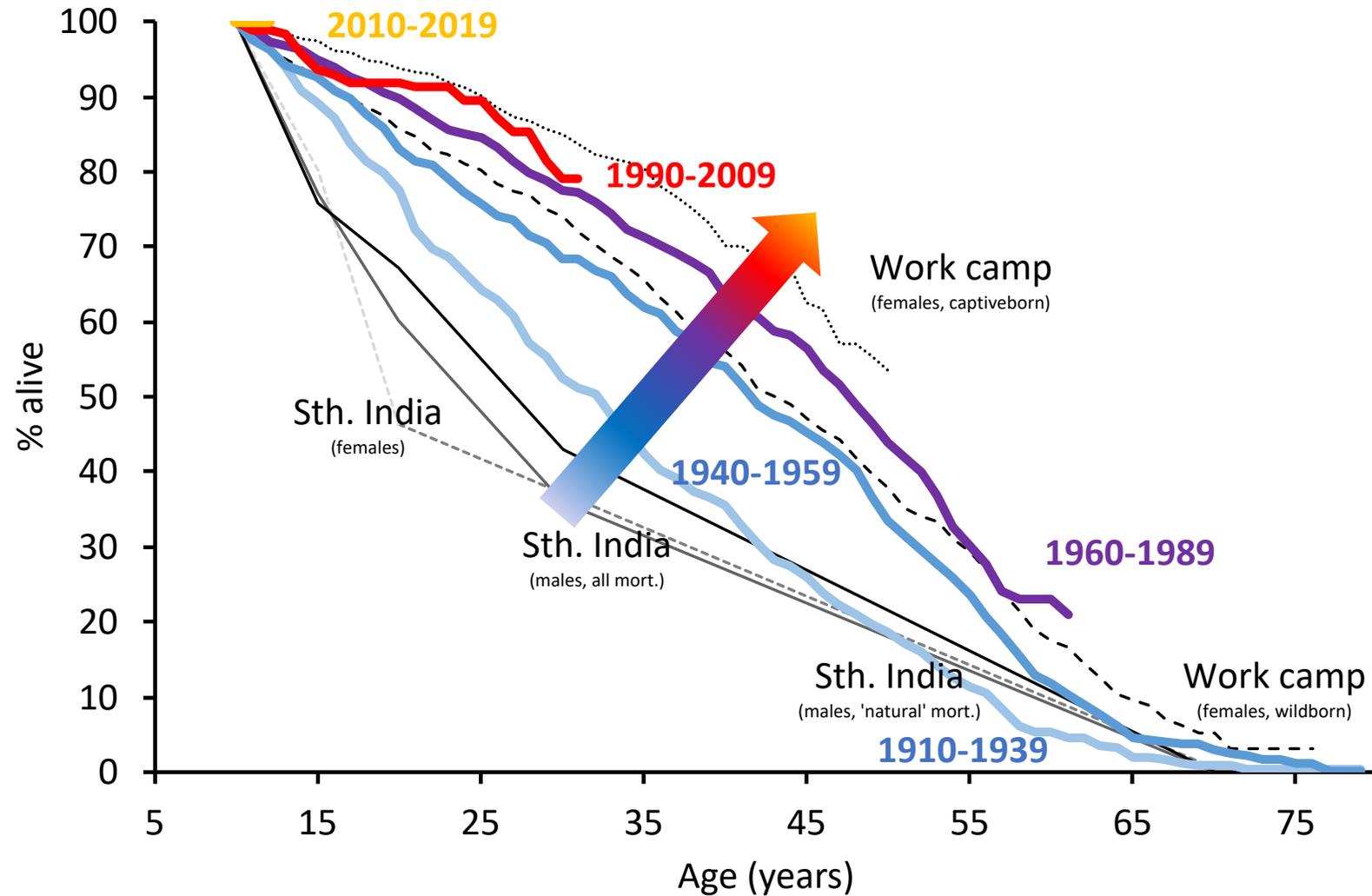


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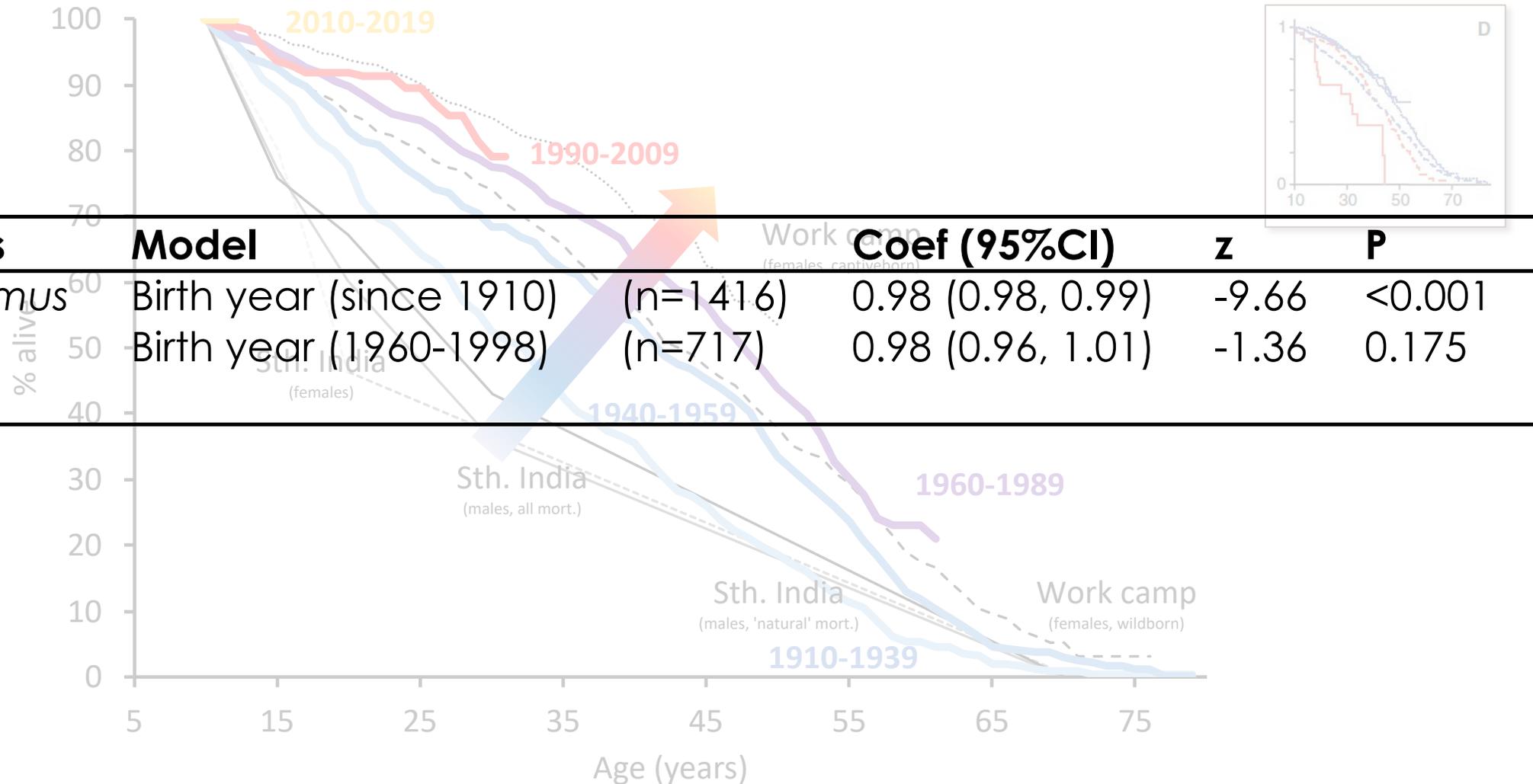


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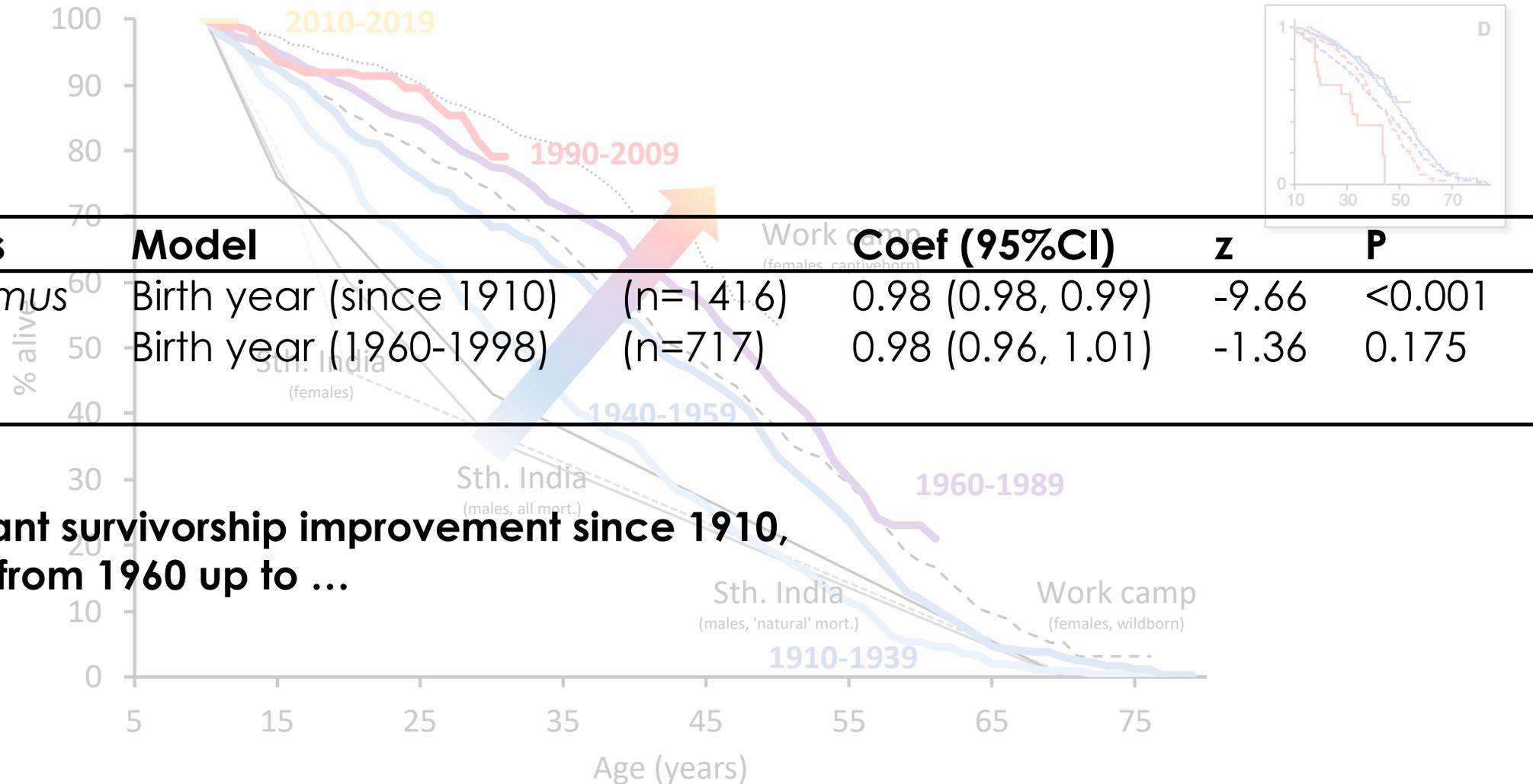
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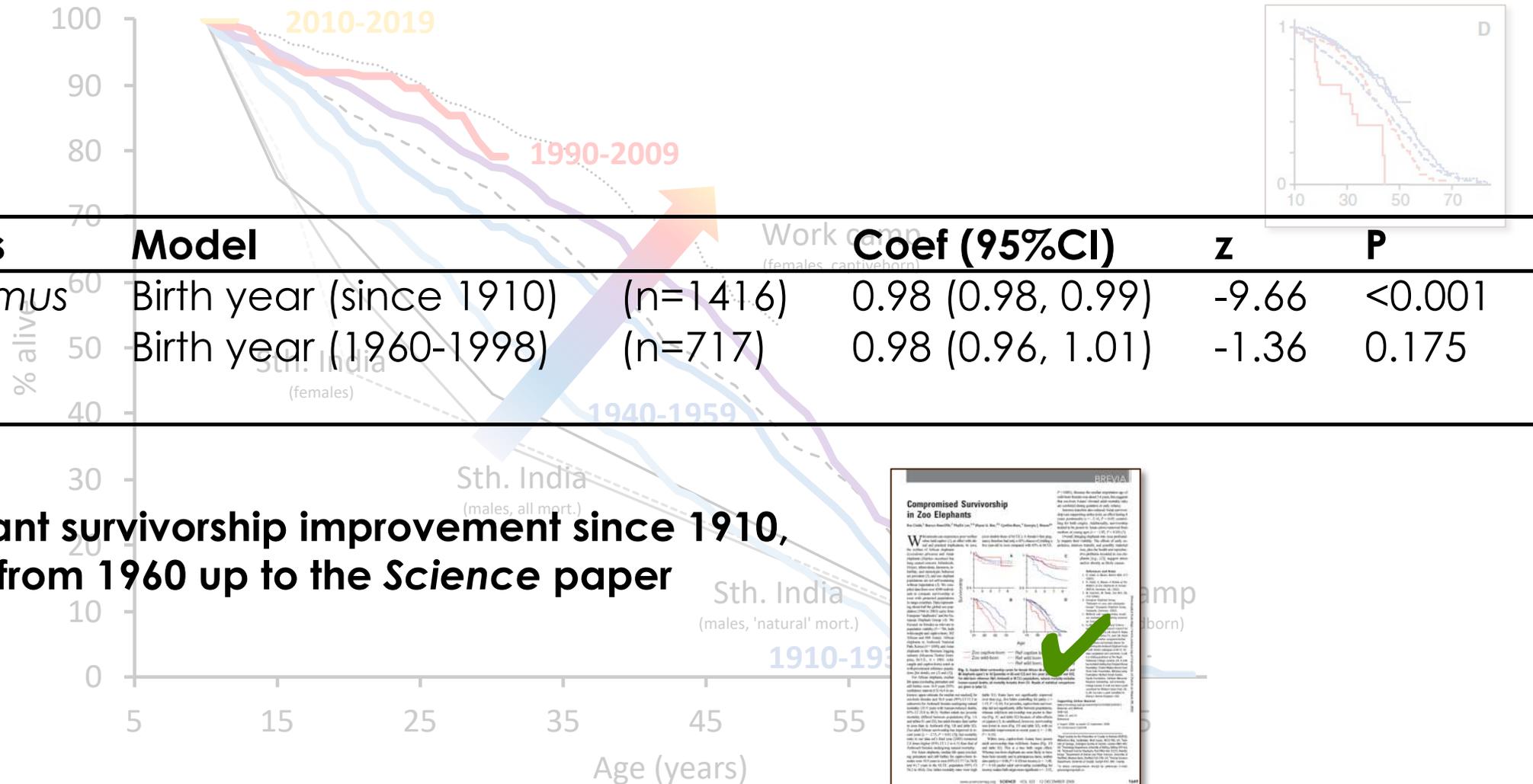


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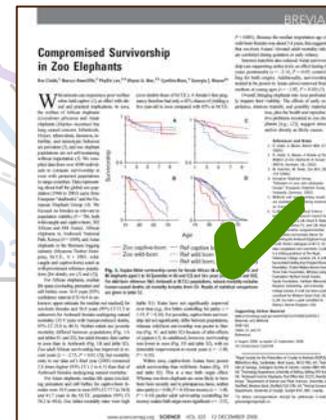


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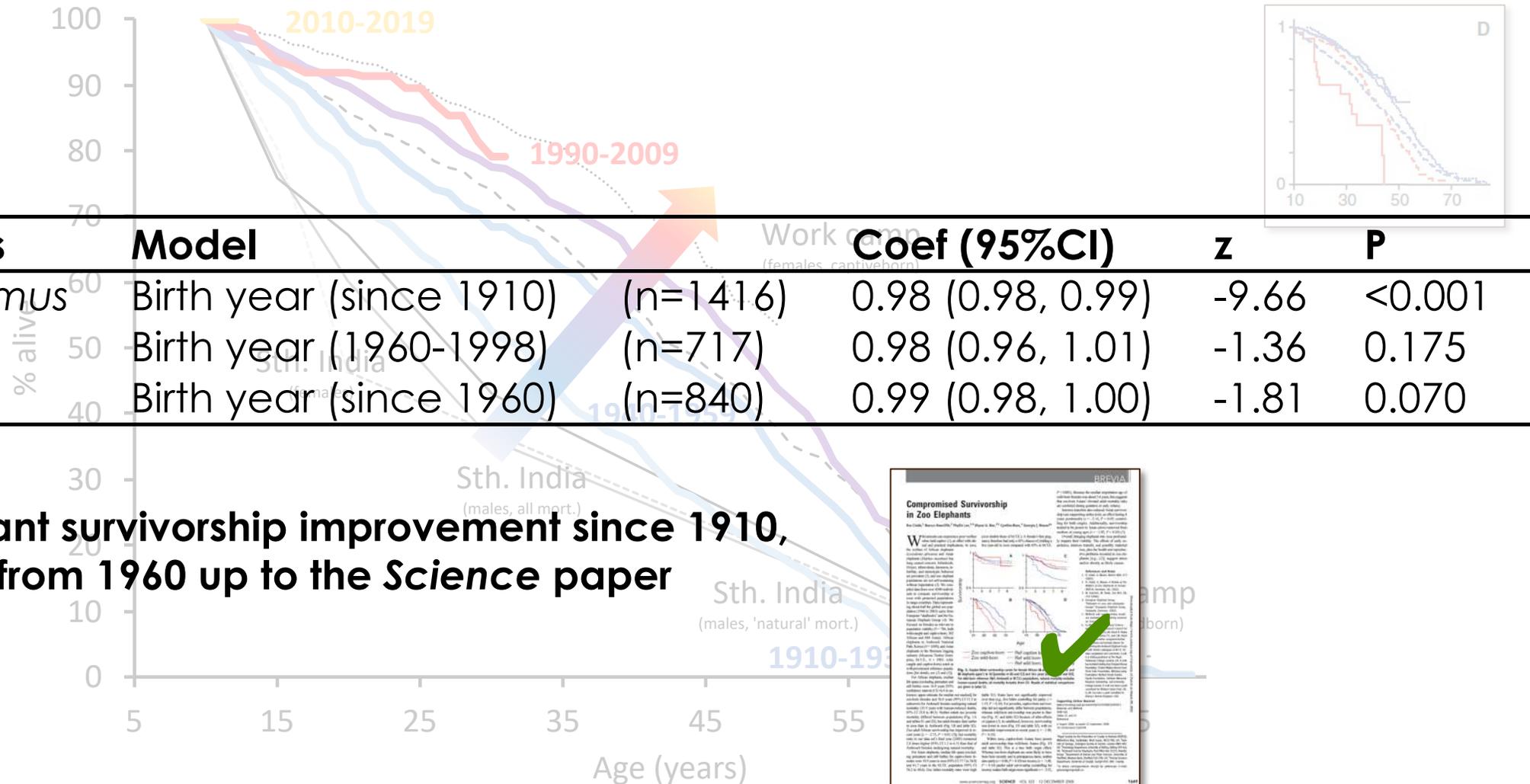
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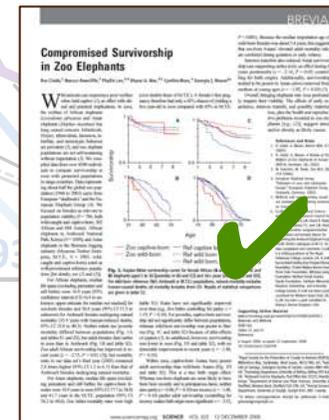




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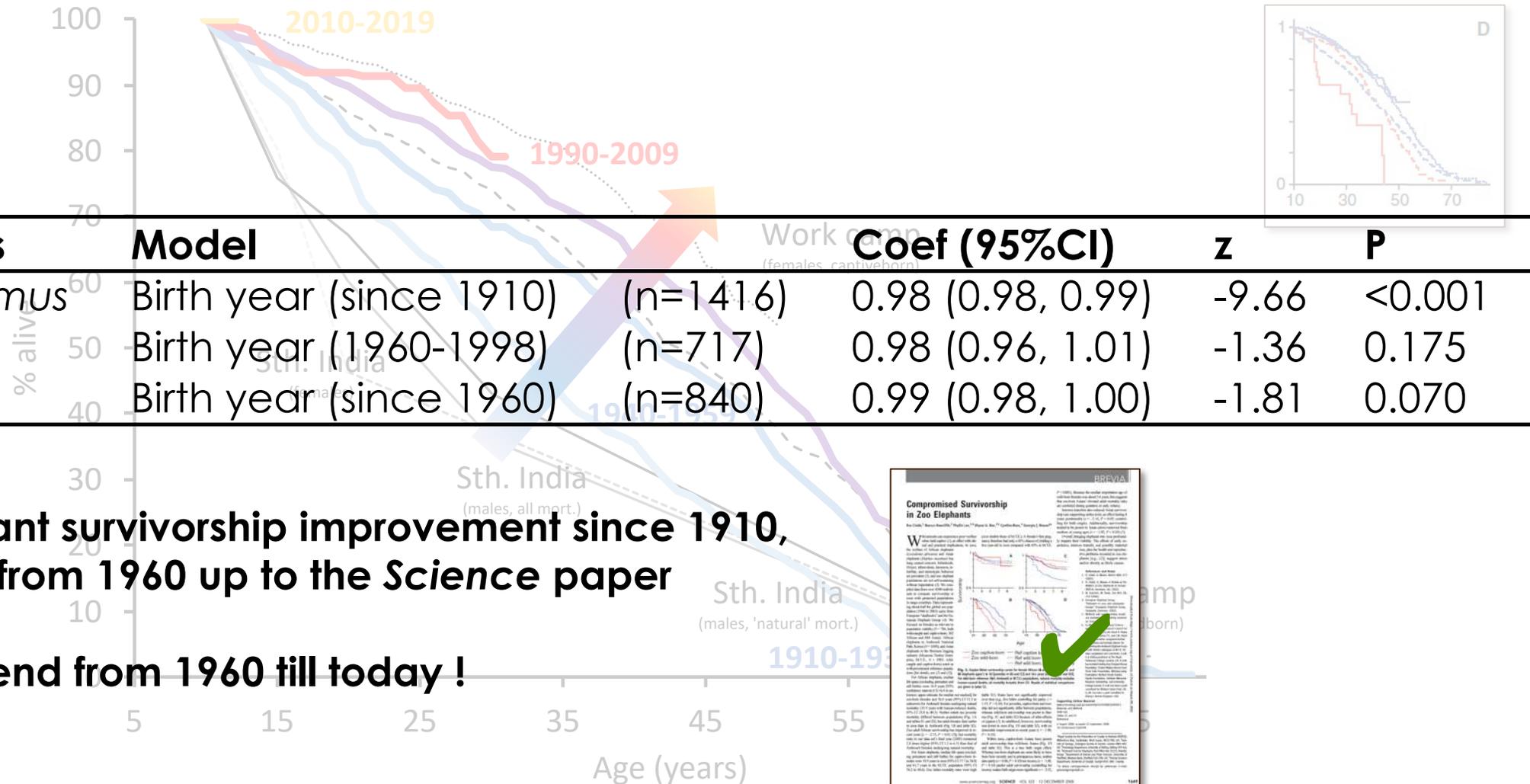


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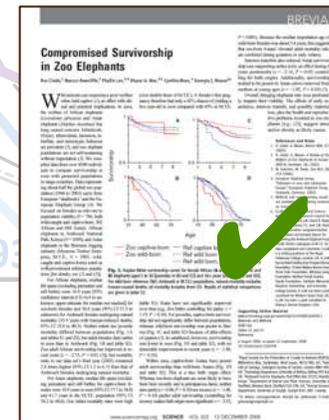
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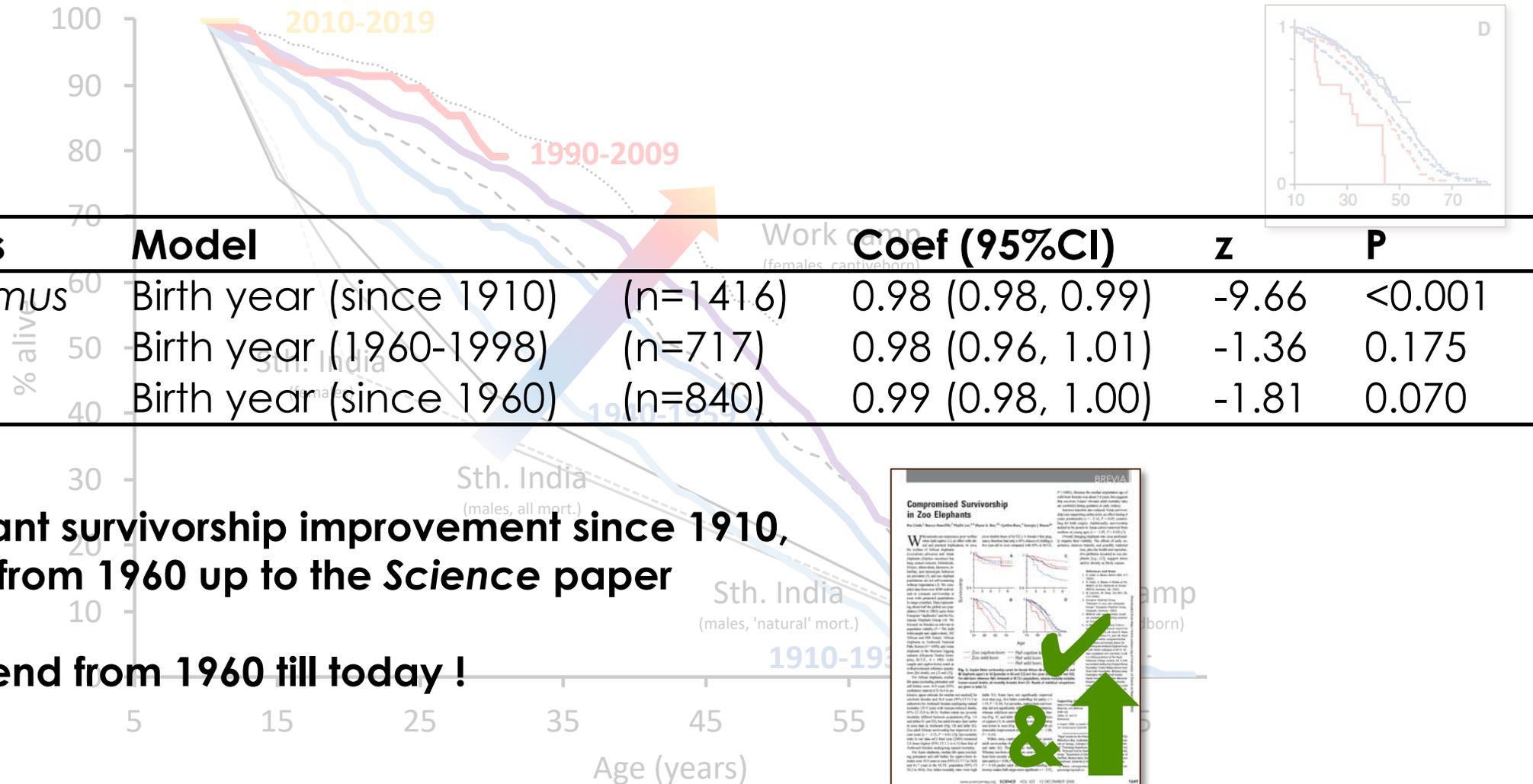
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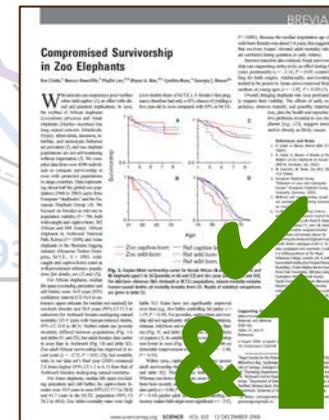


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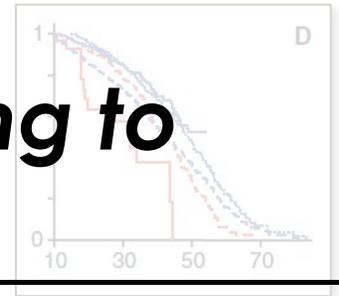




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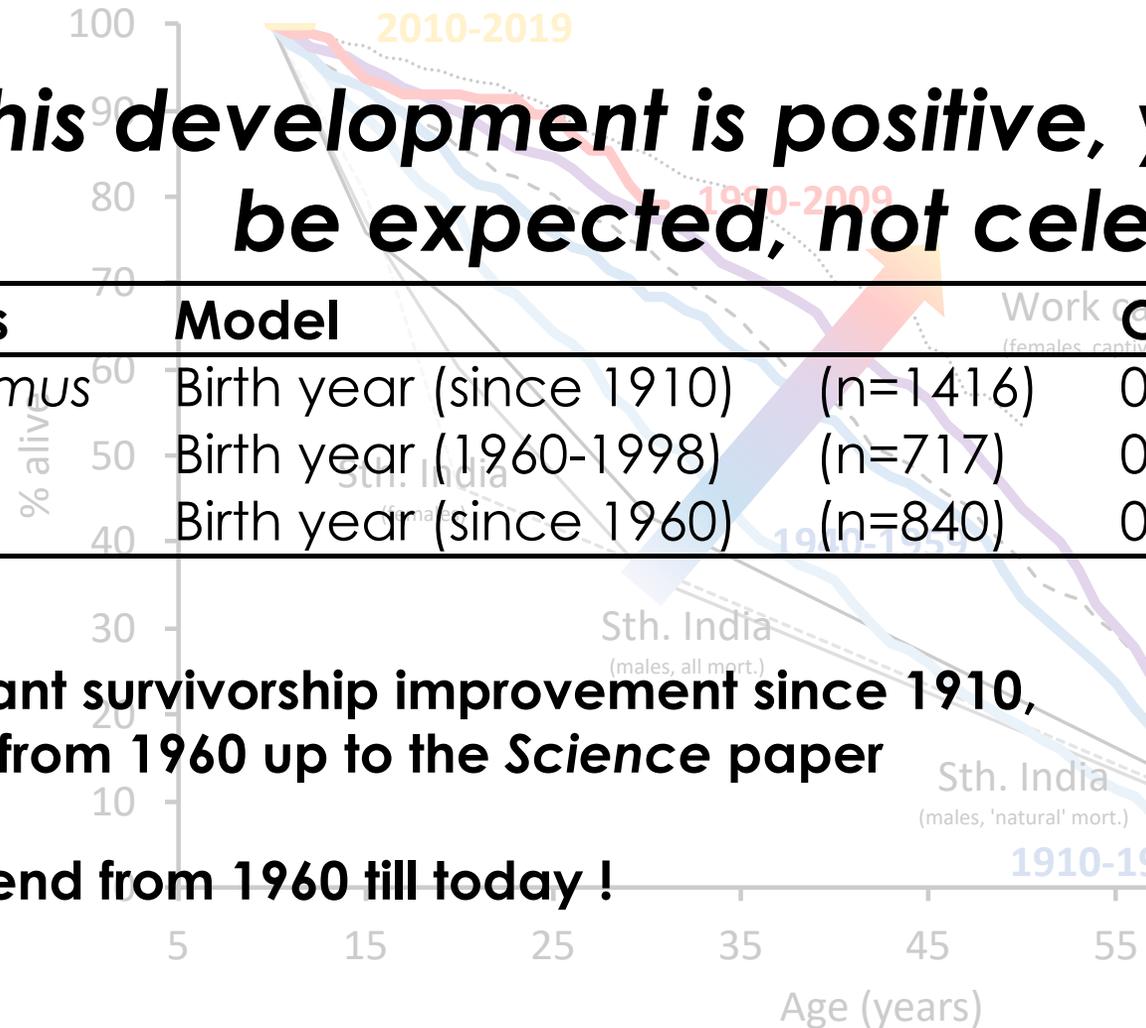
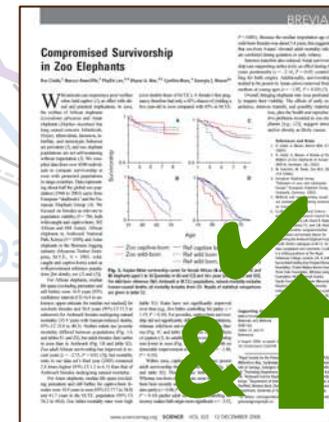
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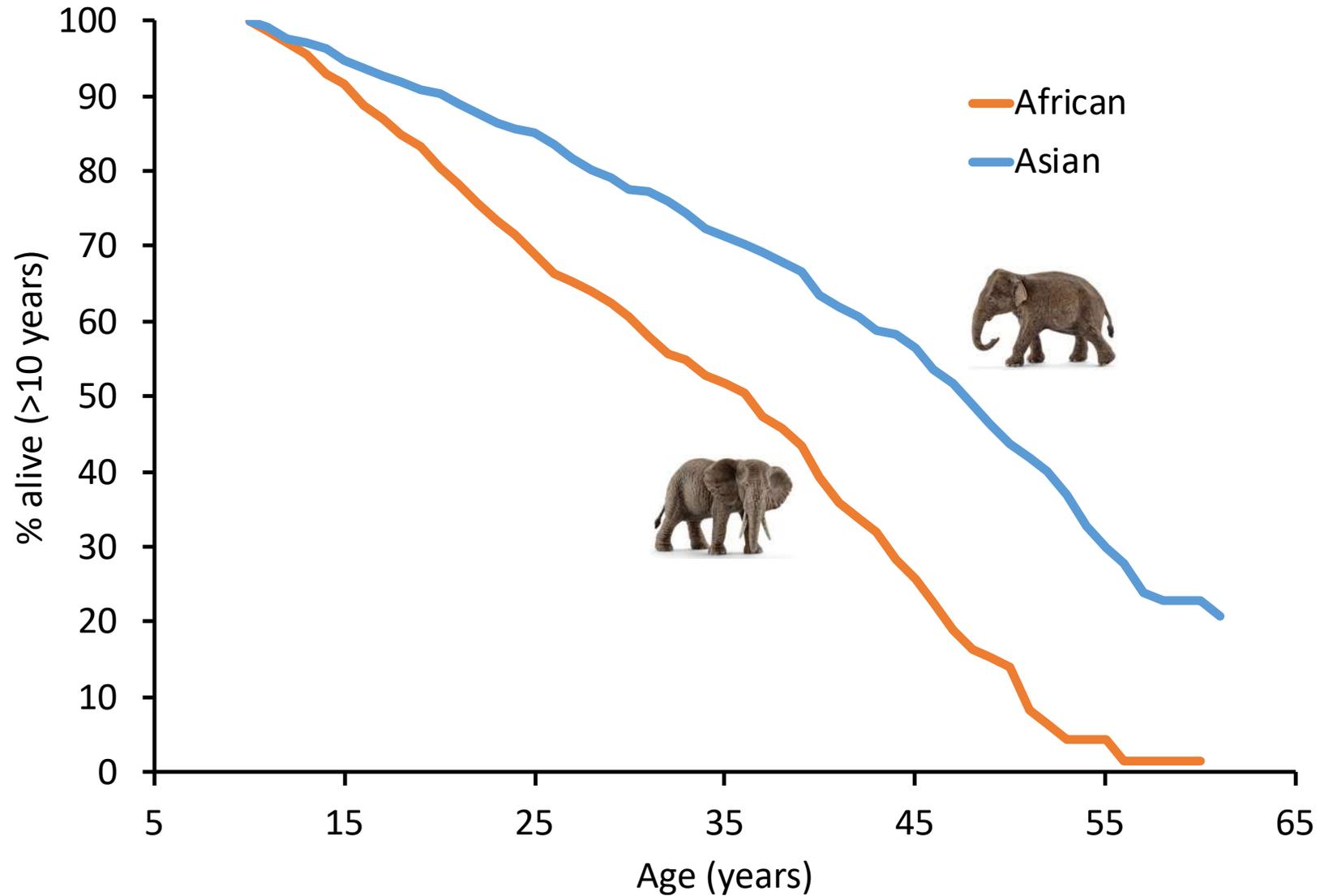
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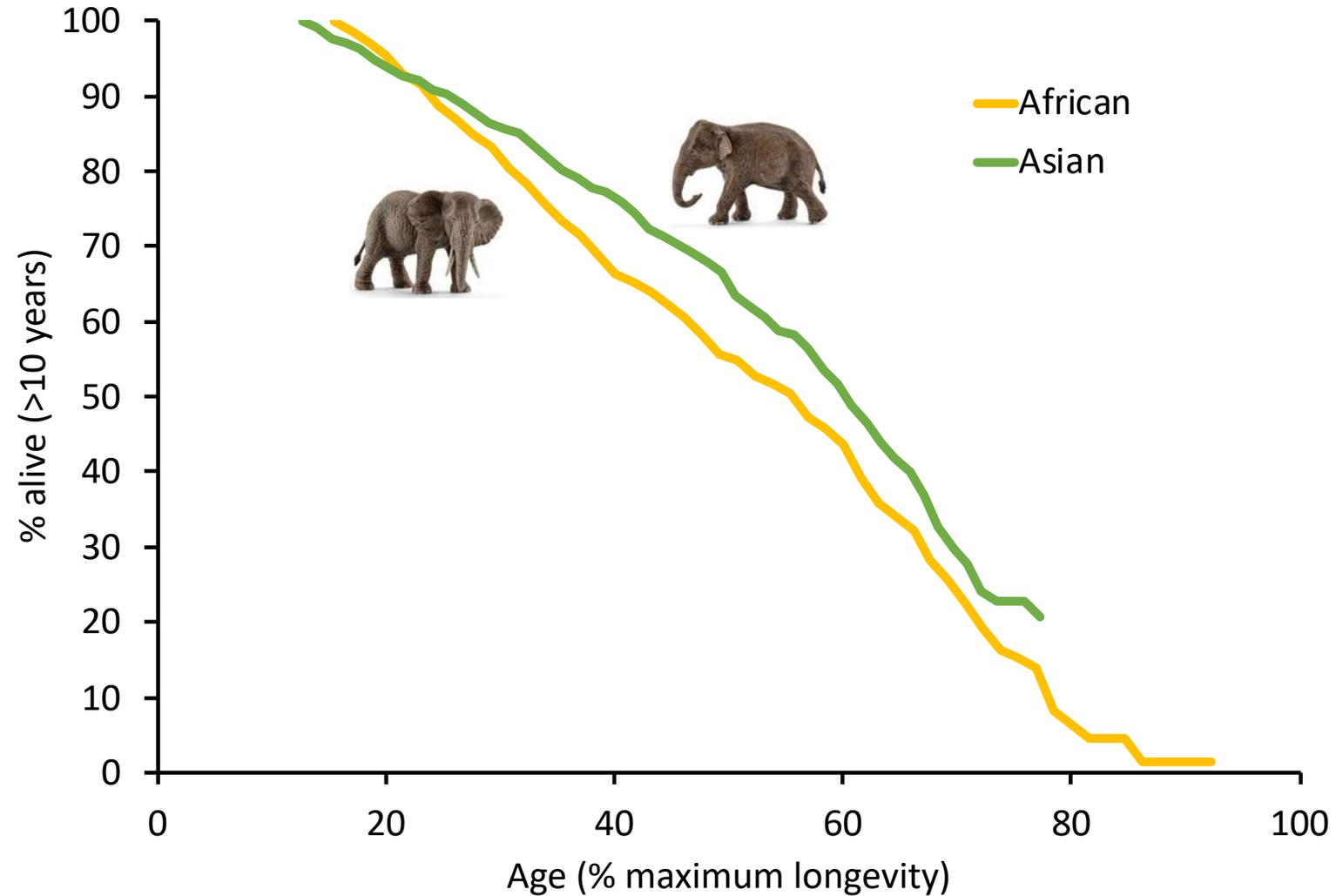


# Adult survivorship – species comparison (N.Am. & EU, since 1960)



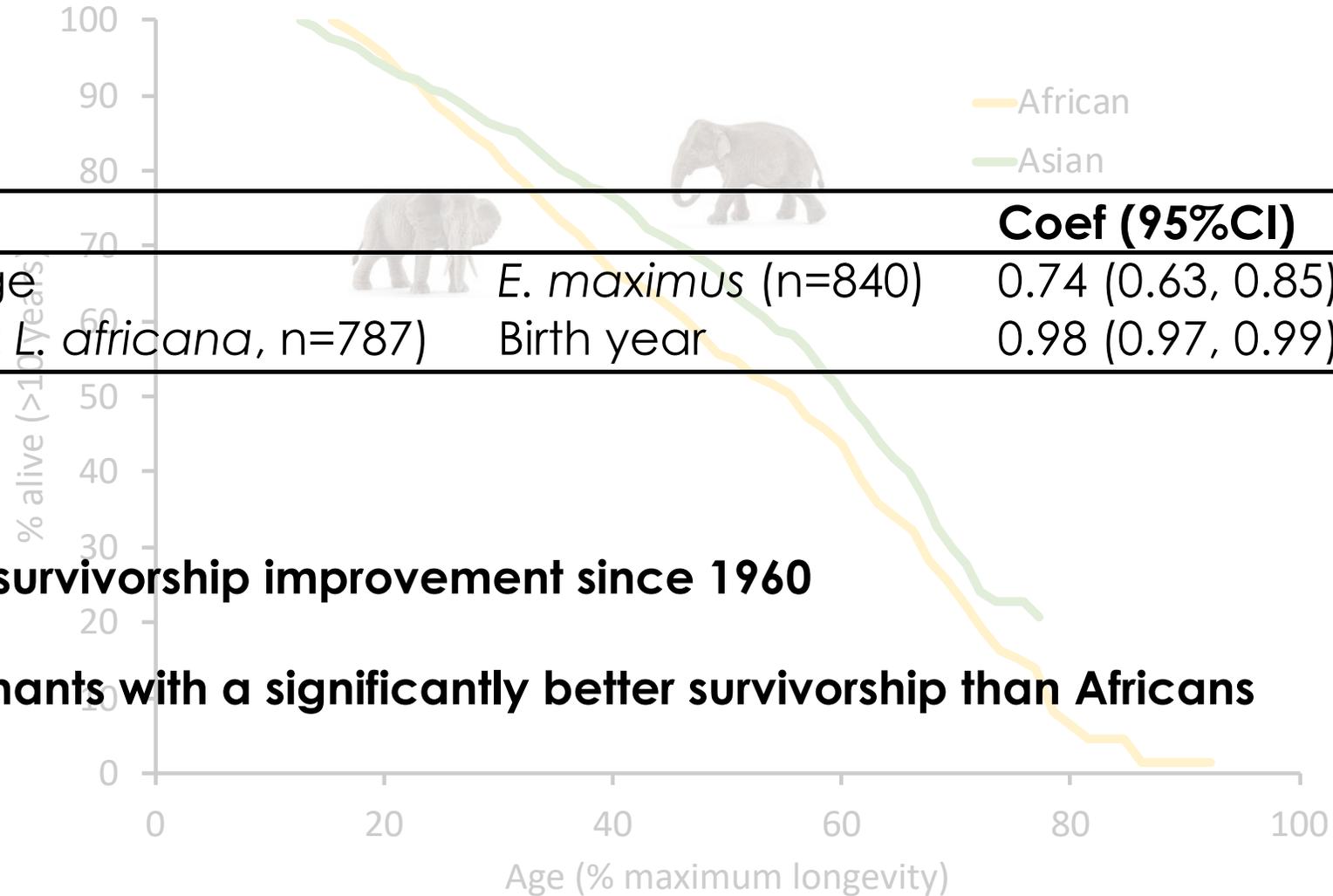


# Adult survivorship – species comparison (N.Am. & EU, since 1960)





# Adult survivorship – species comparison (N.Am. & EU, since 1960)



Model		Coef (95%CI)	z	P
Relative age	<i>E. maximus</i> (n=840)	0.74 (0.63, 0.85)	-4.05	<0.001
(reference: <i>L. africana</i> , n=787)	Birth year	0.98 (0.97, 0.99)	-5.02	<0.001

**Significant survivorship improvement since 1960**

**Asian elephants with a significantly better survivorship than Africans**



# Summary and Recommendations



# Summary and Recommendations

**Compromised Survivorship in Zoo Elephants**

**W**hether captive elephants are healthier and live longer than their wild counterparts is a matter of debate. In a new study, researchers from the University of Edinburgh and the University of Stirling compared the survival of 100 zoo elephants with that of 100 wild elephants. The study found that zoo elephants have a significantly higher survival rate than wild elephants, particularly in the first 10 years of life. This finding suggests that captive environments may provide better care and protection for elephants, but it also raises questions about the quality of life and natural behaviors of these animals in captivity.

**Fig. 5. Kaplan-Meier survivorship curve for female African elephants. The solid line represents zoo elephants and the dashed line represents wild elephants. The x-axis is age in years (0-100) and the y-axis is survival probability (0-1). Zoo elephants show significantly higher survival rates than wild elephants, especially in the first 10 years of life.**

**Key Findings:**

- Zoo elephants have a significantly higher survival rate than wild elephants.
- The difference is most pronounced in the first 10 years of life.
- Wild elephants have a significantly higher mortality rate in the first 10 years of life.

**Conclusion:** Captive environments may provide better care and protection for elephants, but it also raises questions about the quality of life and natural behaviors of these animals in captivity.

Don't question the data ...



# Summary and Recommendations

**Compromised Survivorship in Zoo Elephants**

**W**hether in the wild or in captivity, elephants face a variety of threats to their survival. In the wild, they are often killed by poachers for their ivory. In captivity, they are often kept in small, confined spaces and may suffer from health problems due to poor nutrition and lack of exercise. A study published in *Science* in 2015 found that zoo elephants have a significantly lower life expectancy than their wild counterparts. The study analyzed data from 1970 to 2010 and found that the average life expectancy of a zoo elephant is 17.7 years, compared to 24.3 years for a wild elephant. This finding is particularly concerning because it suggests that the conditions in which zoo elephants are kept are not conducive to their long-term health and survival.

**Fig. 5. Kaplan-Meier survivorship curves for female African elephants.** The solid line represents elephants born in the wild, and the dashed line represents elephants born in captivity. The y-axis is survival probability, and the x-axis is age in years. The wild-born curve shows a higher survival probability over time, with a median survival age of 24.3 years. The captive-born curve shows a lower survival probability, with a median survival age of 17.7 years.

Don't question the data ...  
 ... question the method of 'life expectancy' calculation.

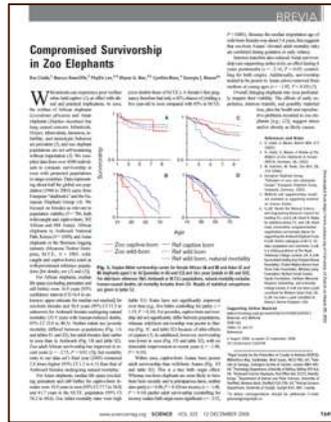
**Calculating 'average' or 'median lifespan'**

“Average” or “median” lifespan can only be compared on equal conditions – either similar cohorts, or only using the retrospective extrapolation.

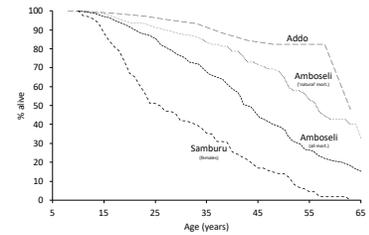
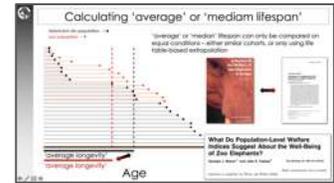
**What Do Population-Level Metrics Indicate About the Well-Being of Zoo Elephants?**



# Summary and Recommendations

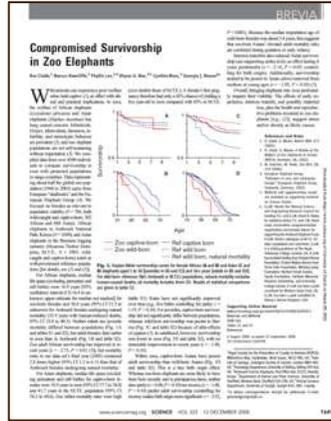


Don't question the data ...  
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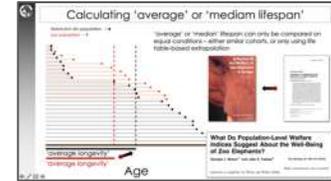


# Summary and Recommendations

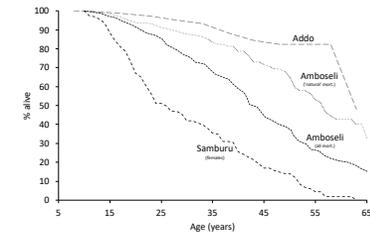
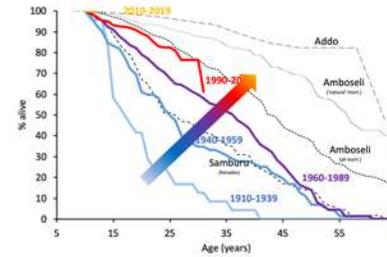


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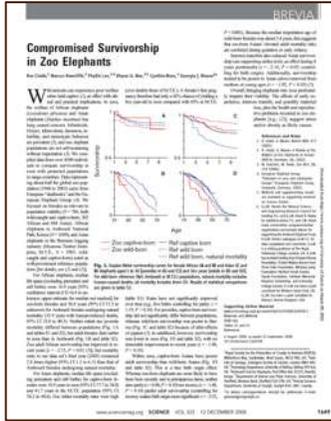


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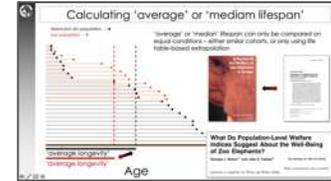


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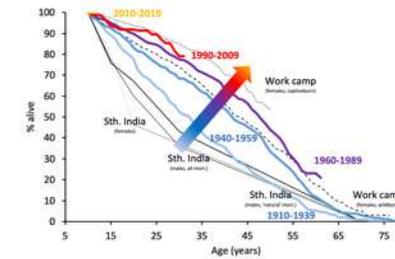
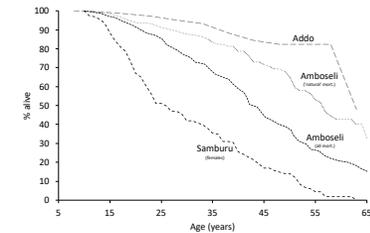
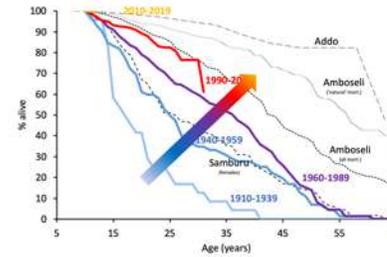


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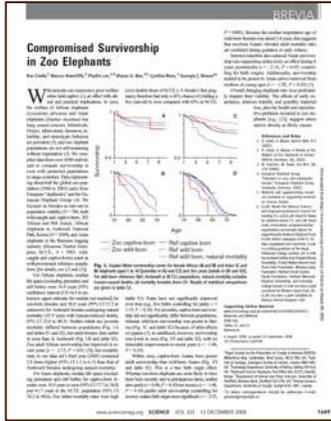


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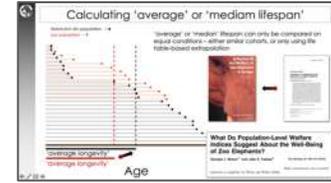




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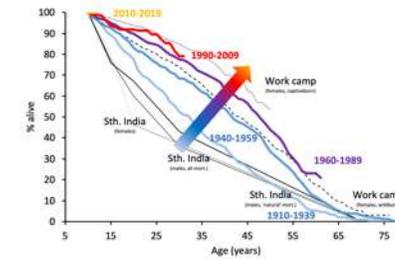
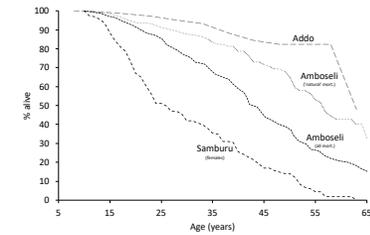
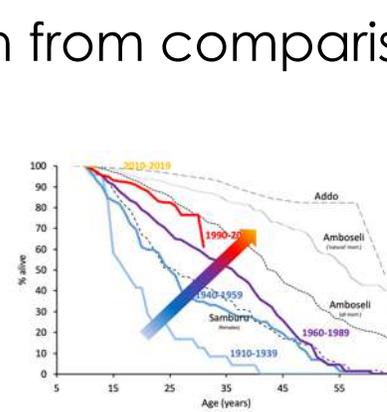


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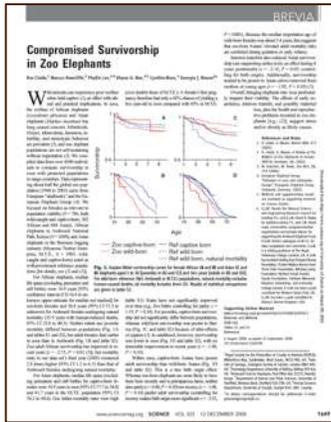
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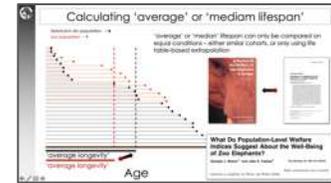
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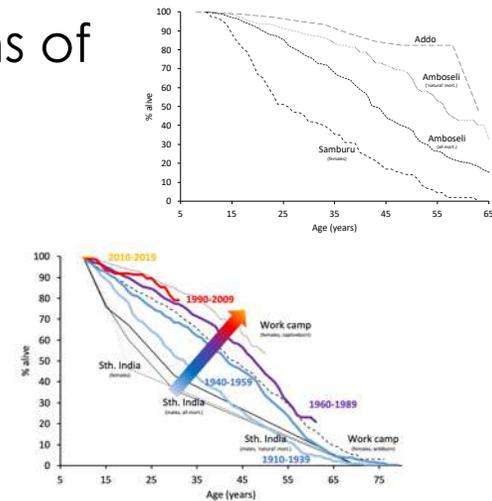
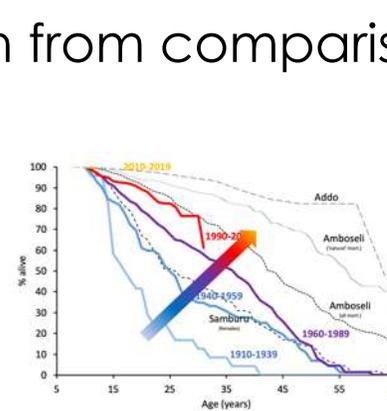


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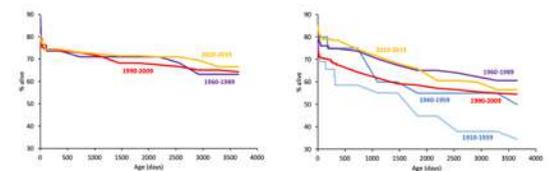
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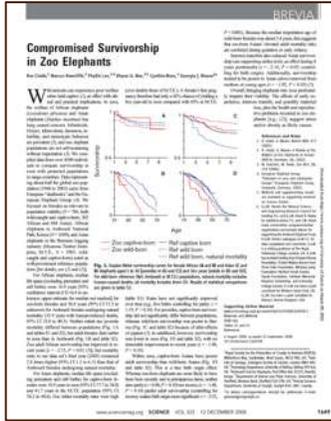
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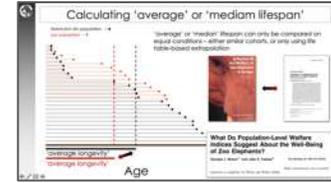


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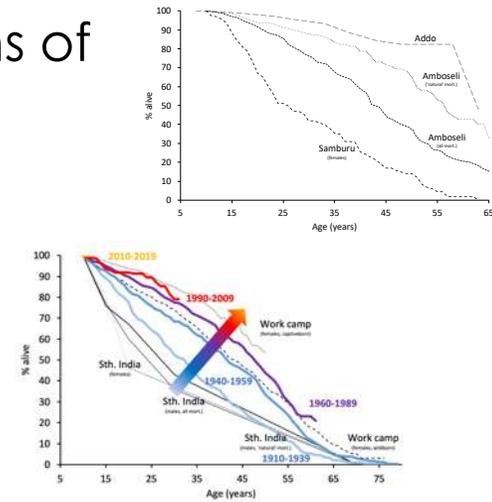
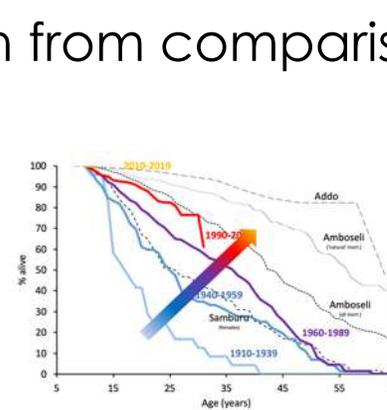


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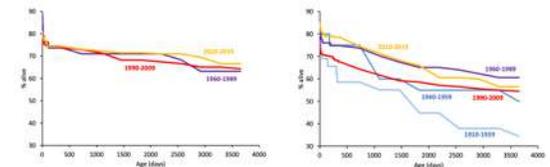
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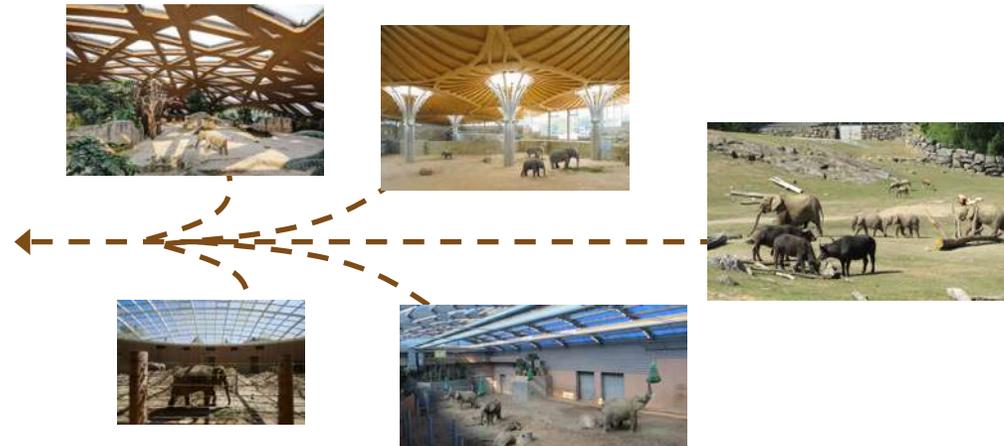
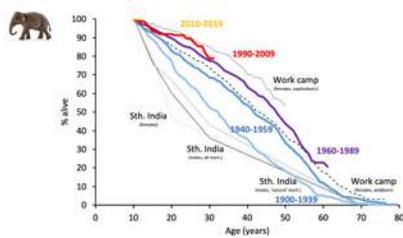
Survivorship monitoring must continue, and there should be no regression.





# Outlook

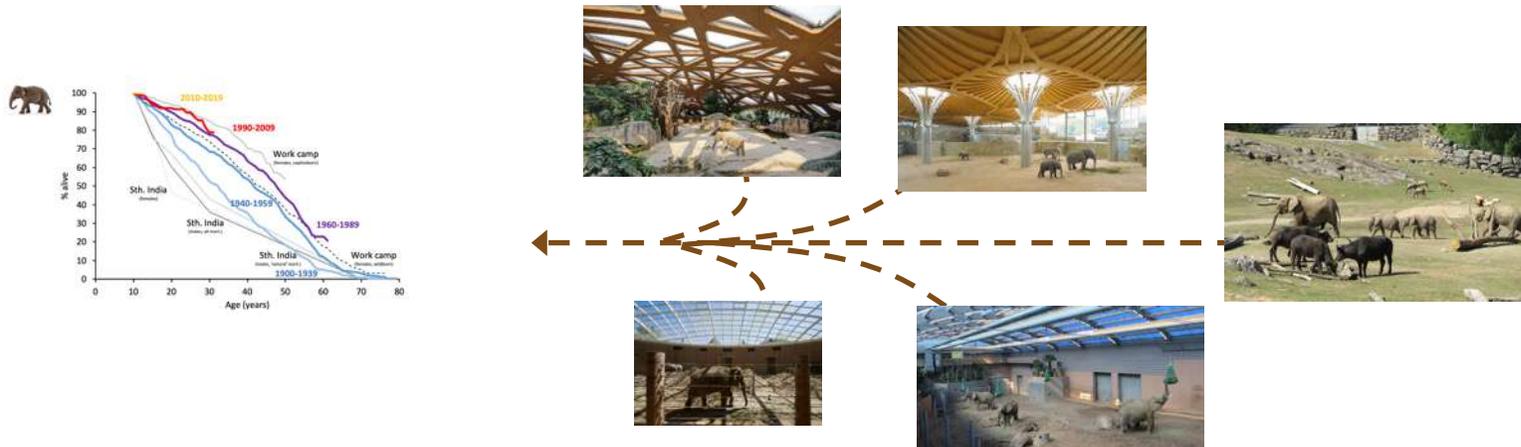
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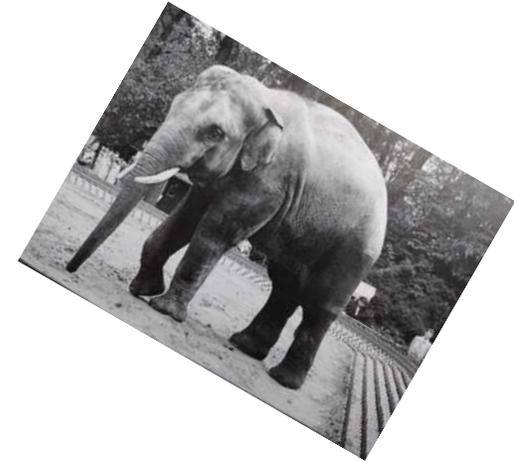
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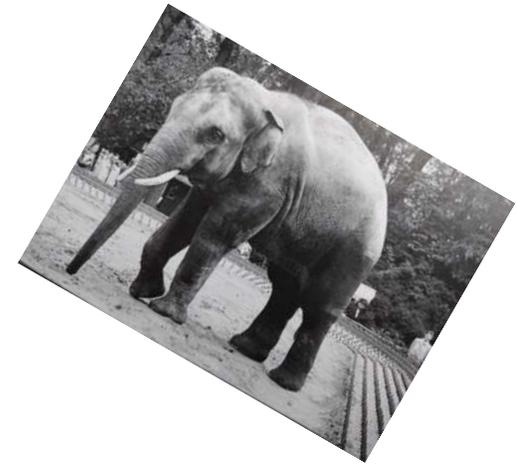
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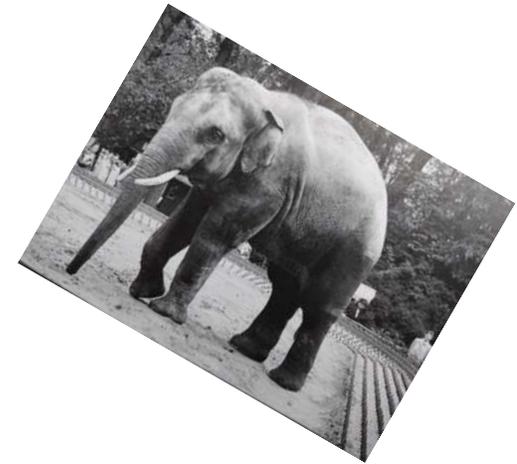
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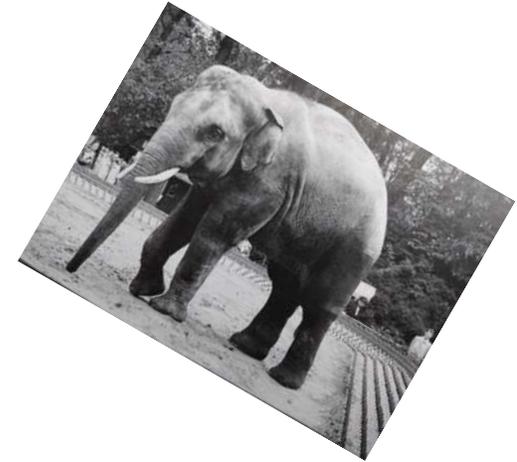
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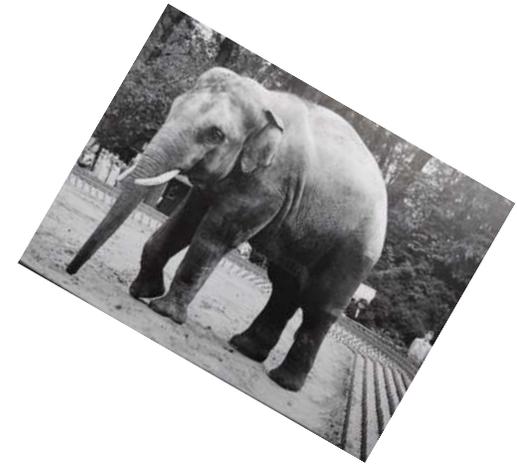
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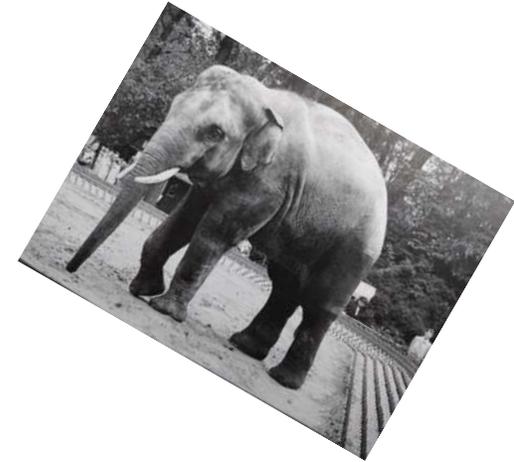
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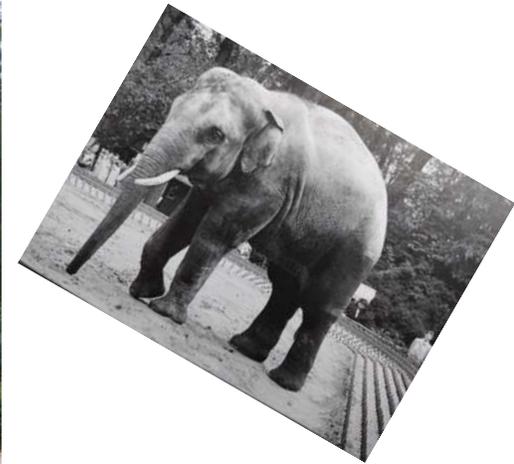
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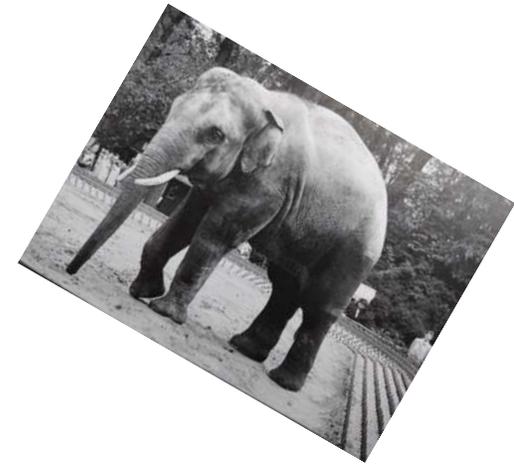
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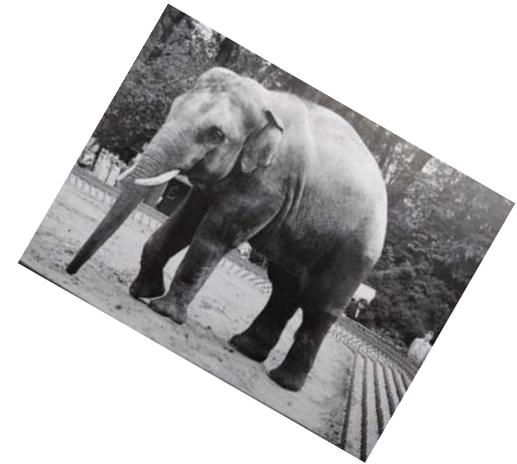
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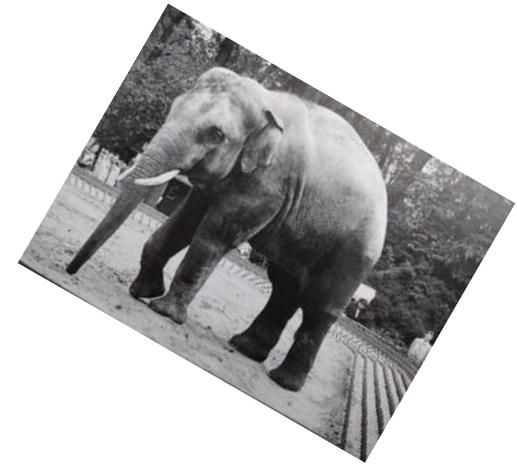
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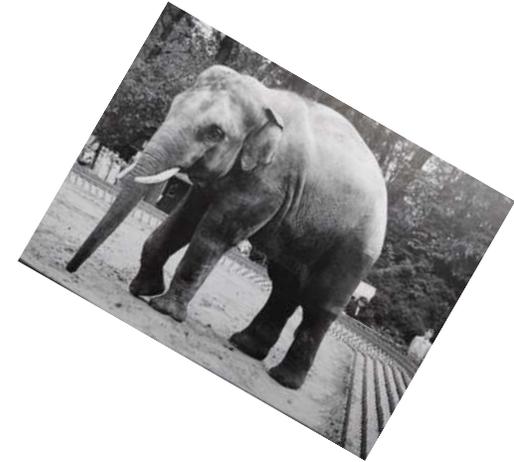
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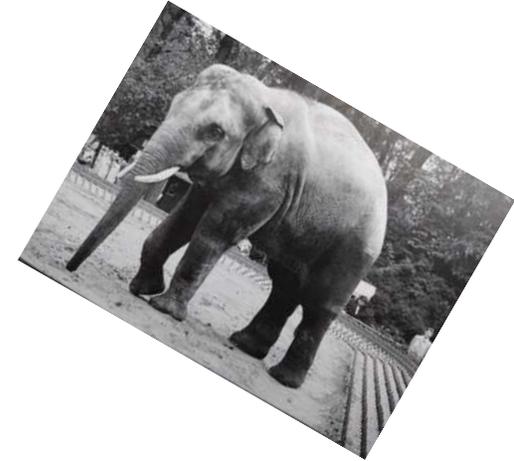
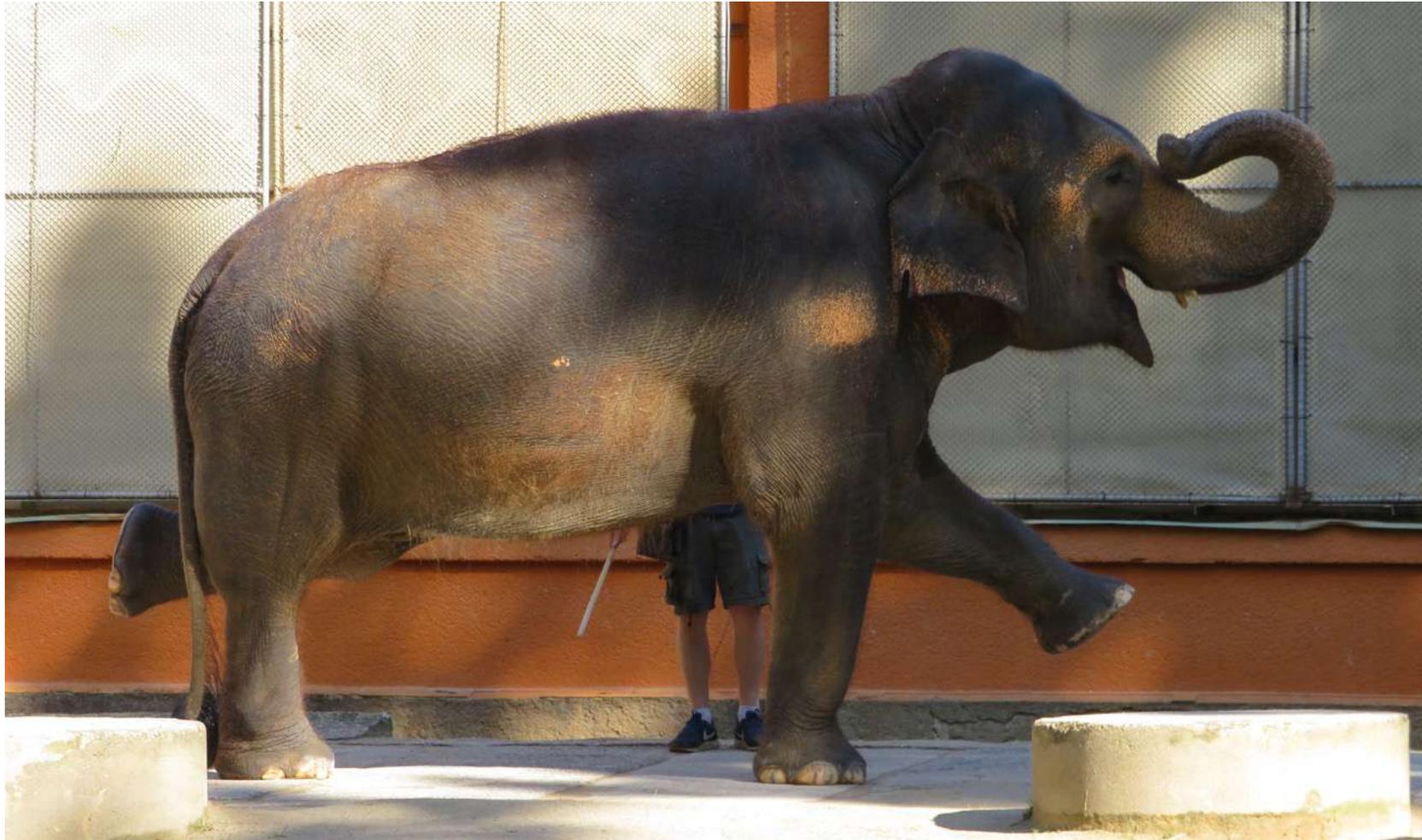
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Demographic data are the result of many **individual actions** but cannot recommend individual actions – only inform large-scale decisions.

***“This development is positive, yet something to be expected, not celebrated.”***

***And this development needs to be continued to ensure a further improvement in our management & care of elephants.***



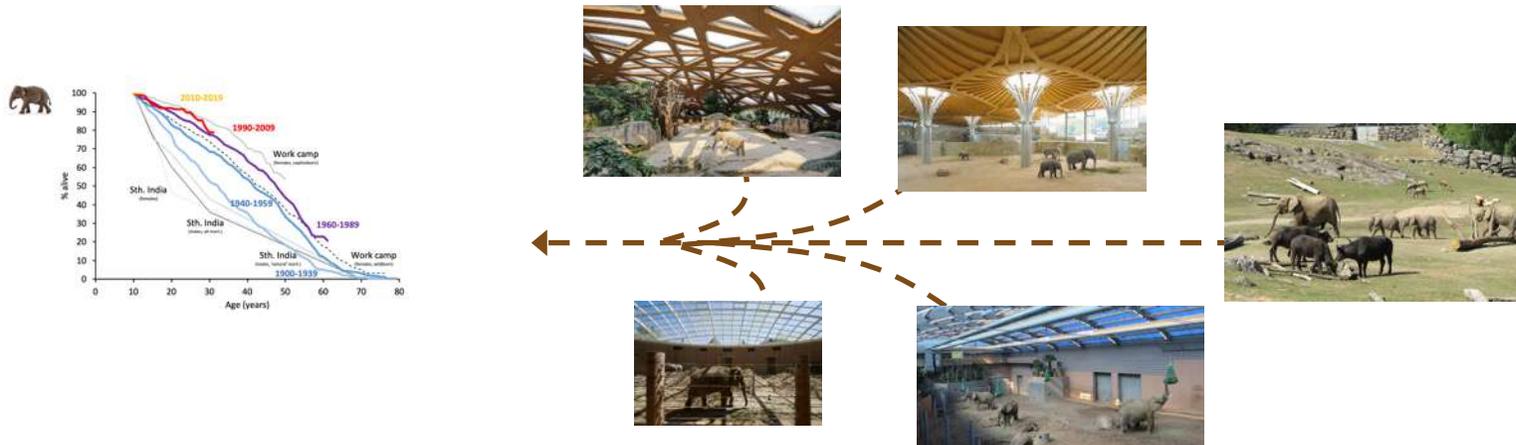
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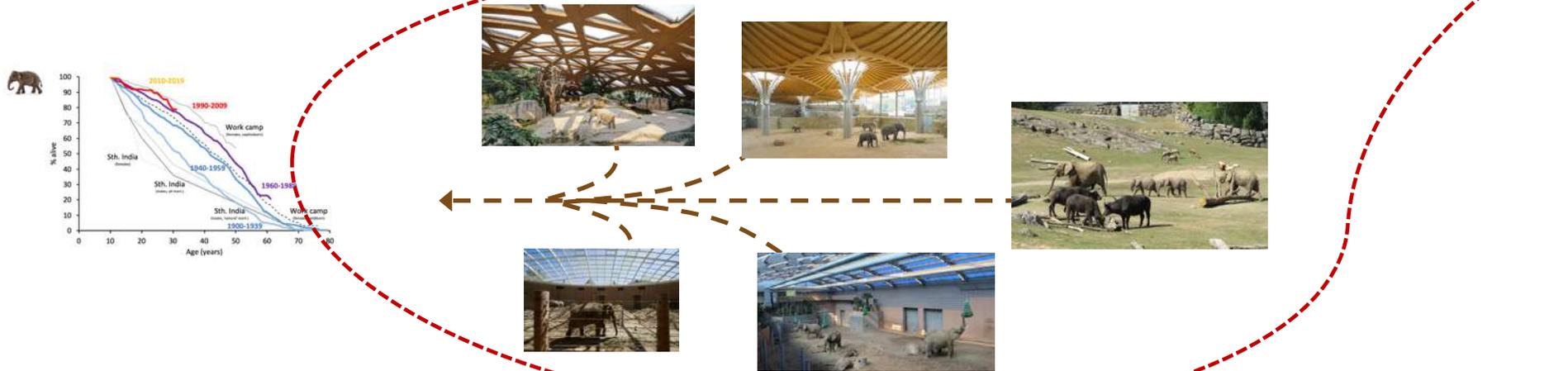
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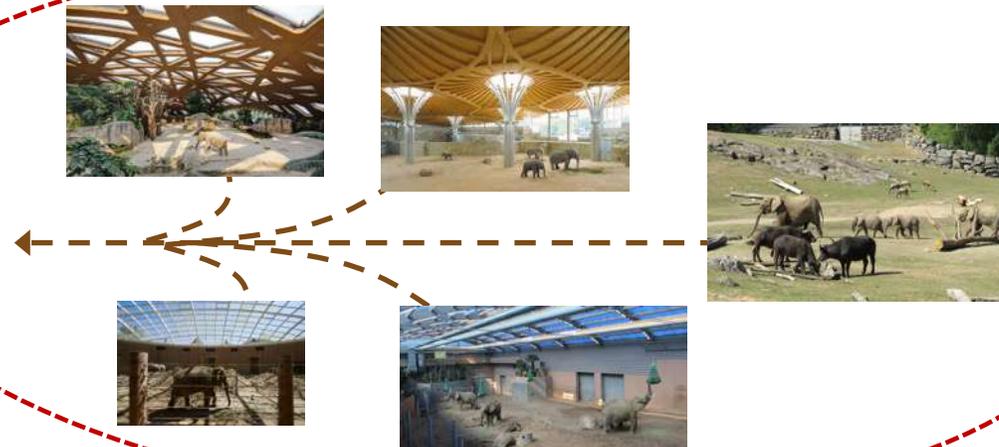
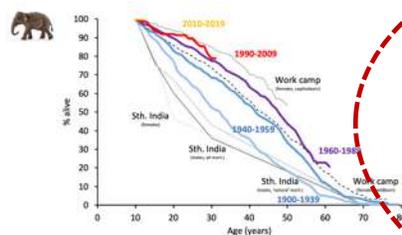
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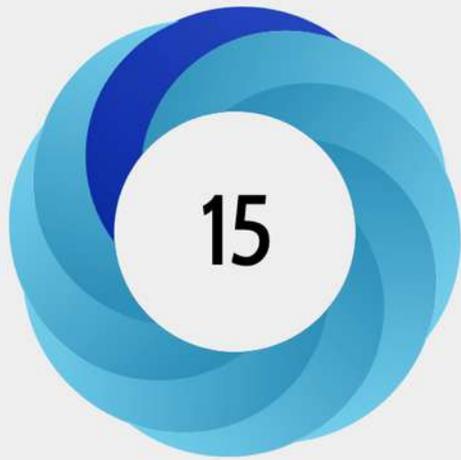




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Demographic data are the result of many individual actions but cannot recommend individual actions – only inform large-scale decisions. To understand demographic changes, we need to know what is happening in the total of facilities ... by surveying the facilities. Ideally, on a regular basis (5-10 years). **Doing 'just another husbandry and health survey' is a good idea!**





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<b>Published in</b>	Zoo Biology, September 2022
<b>DOI</b>	10.1002/zoo.21733 <a href="#">↗</a>
<b>Pubmed ID</b>	36074074 <a href="#">↗</a>
<b>Authors</b>	Lara Scherer, Laurie Bingaman Lackey, Marcus Clauss, Katrin Gries, David Hagan, Arne Lawrenz... <a href="#">[show]</a>

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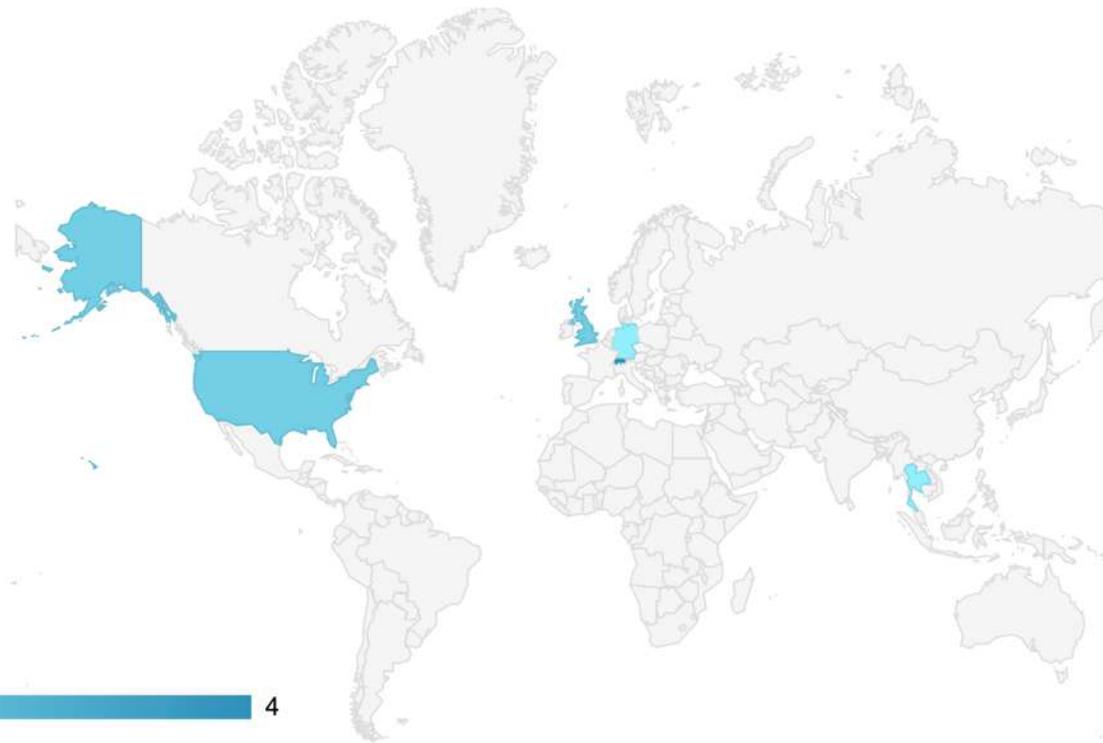
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Geographical breakdown

Demographic breakdown

Received 21 May 2022 | Revised 25 August 2022 | Accepted 26 August 2022  
DOI: 10.1002/zoo.21733

**TECHNICAL REPORT** **ZOO BIOLOGY** WILEY

**The historical development of zoo elephant survivorship**

Lara Scherer<sup>1</sup> | Laurie Bingaman Lackey<sup>2</sup> | Marcus Clauss<sup>1</sup> | Katrin Gries<sup>2</sup> | David Hagan<sup>4</sup> | Arne Lawrenz<sup>2</sup> | Daniels W. H. Müller<sup>2</sup> | Marco Roller<sup>2</sup> | Christian Schiffmann<sup>2</sup> | Ann-Kathrin Oerke<sup>2</sup>

**Abstract**  
In the discussion about zoo elephant husbandry, the report of Clark et al. (2008, Science 322: 1649) that zoo elephants had a 'compromised survivorship' compared to certain non-zoo populations is a grave argument, and was possibly one of the triggers of a large variety of investigations into zoo elephant welfare, and changes in zoo elephant management. A side observation of that report was that whereas survivorship in African elephants (*Loxodonta africana*) improved since 1945, this was not the case in Asian elephants (*Elephas maximus*). We used historical data based on the Species360 database to revisit this aspect, including recent developments since 2008. Assessing the North American and European populations from 1910 until today, there were significant improvements of adult (15+) survival in both species. For the period from 1950 until today, survivorship improvement was significant for African elephants and close to a significant improvement in Asian elephants. Asian elephants generally had a higher survivorship than Africans. Juvenile 1-10 years survivorship did not change significantly since 1945 and was higher in African elephants, most likely due to the effect of elephant keepers versus on Asian elephants. Current zoo elephant survivorship is higher than some, and lower than some other non-zoo populations. We discuss that in our view, the shape of the survivorship curve, and its change over time, are more relevant than comparisons with specific populations. Zoo elephant survivorship should be monitored continuously, and the expectation of a continuous trend towards improvement should be met.

**KEYWORDS**  
husbandry, mortality, *Proboscidea*, progress, survival

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Zoo Biology, 2022, 1-11. [wileyonlinelibrary.com/journal/zoo](#) | 1



*thank you for your attention*

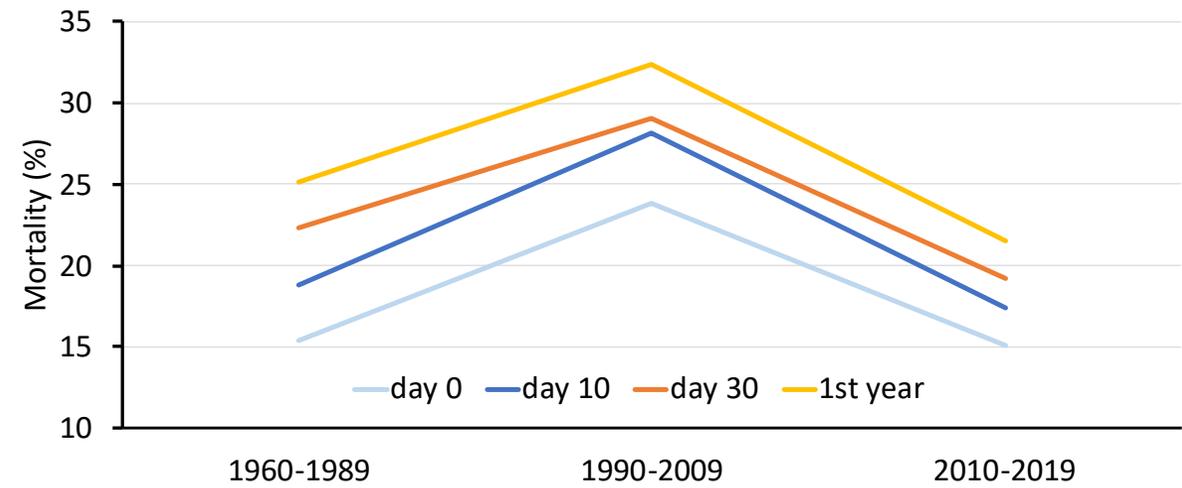
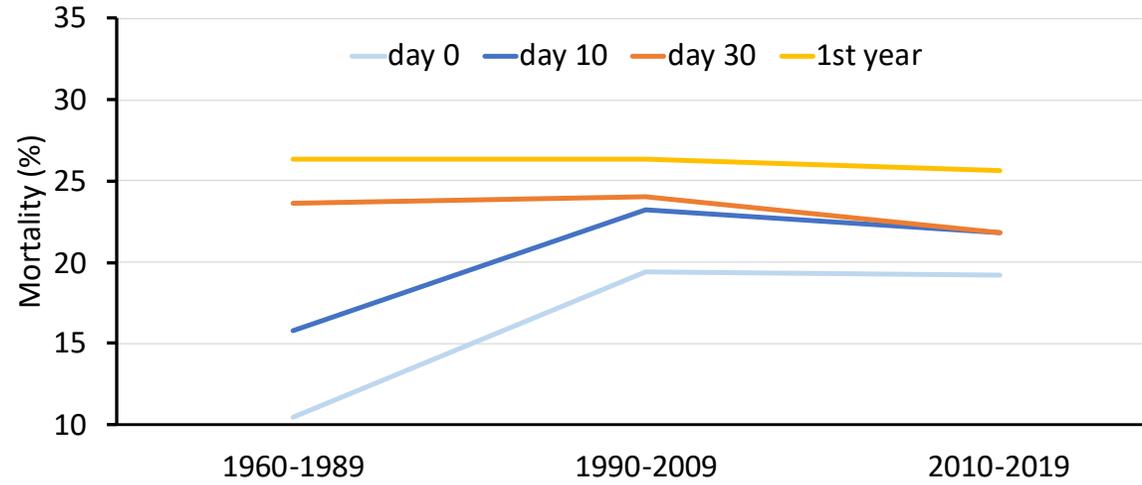
Species360 Research Data Agreement # 2019-Q3-RR3

there is no funding to report

*conflict of interest: all co-authors work for zoological gardens, or are linked to the zoo community*

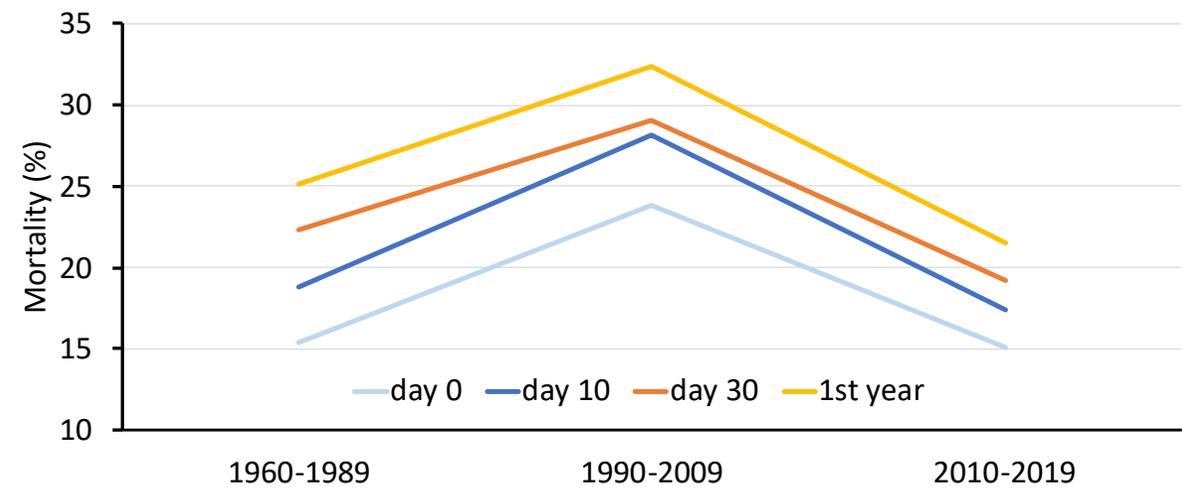
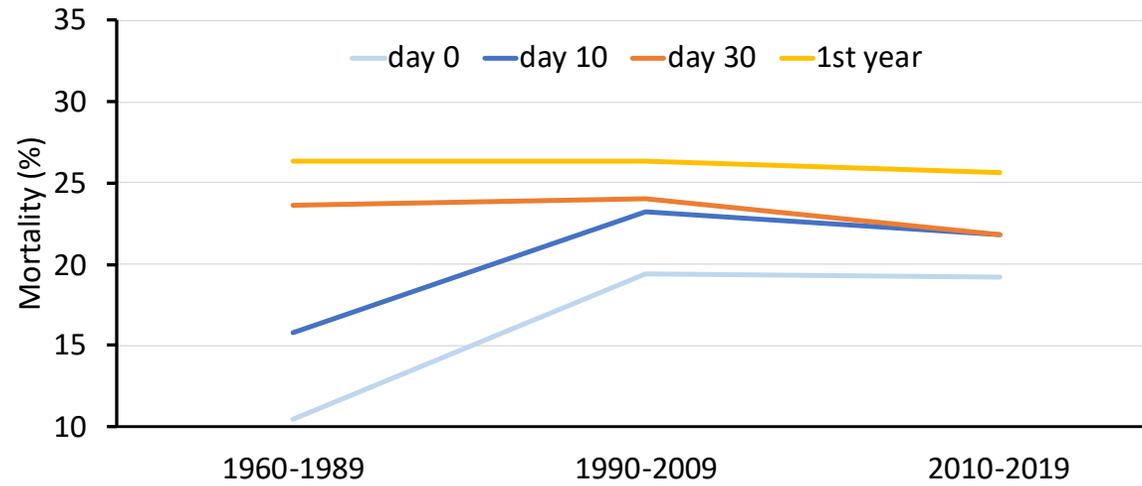


# Juvenile mortality (zooborn only)





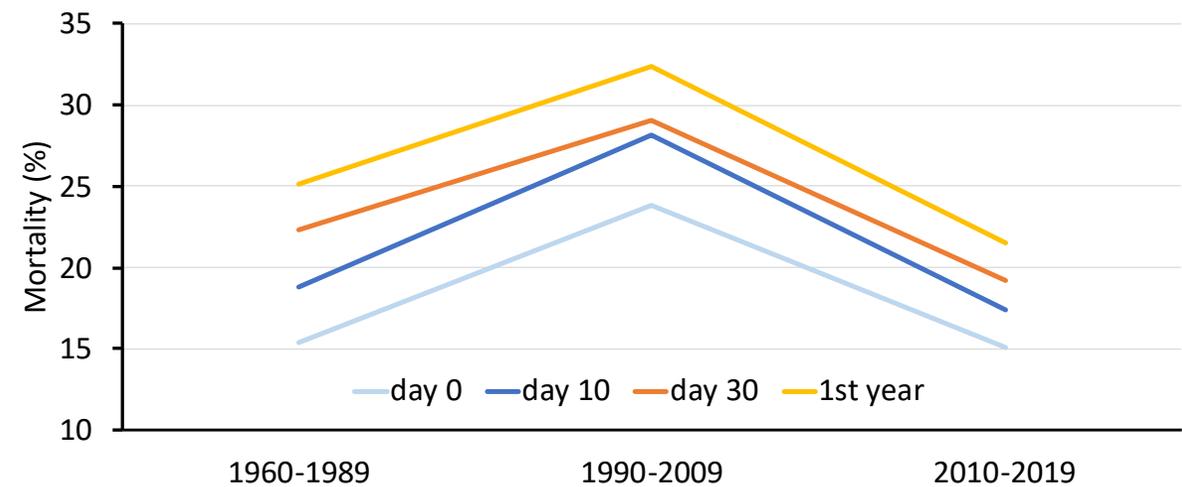
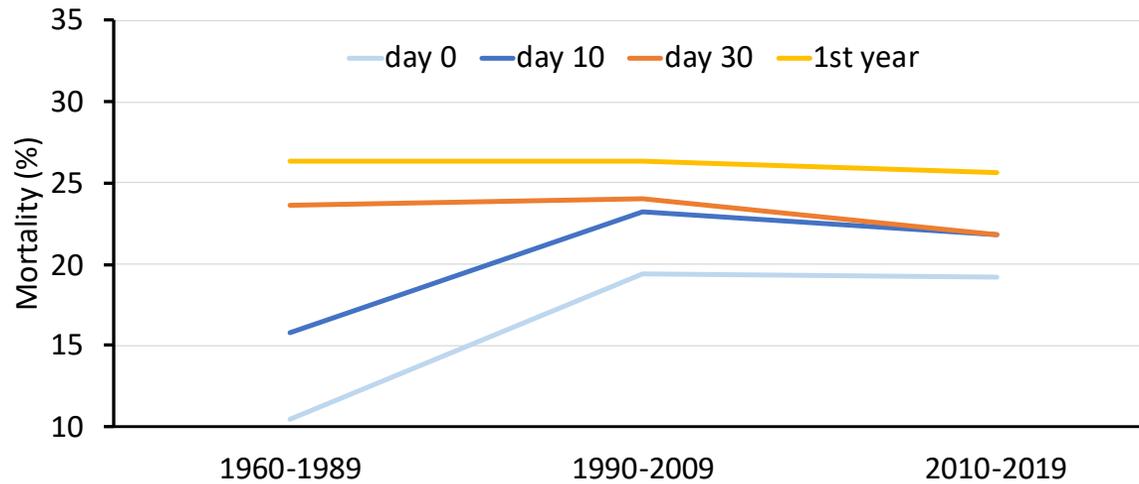
# Juvenile mortality (zooborn only)



Are comparisons with *in situ* reliable – in terms of day0 mortality reporting ?



# Juvenile mortality (zooborn only)



Are comparisons with *in situ* reliable – in terms of day0 mortality reporting ?

‘Natural’ births in zoos – establishment of experienced matriline.