

Supplementary Materials for
**Protecting and connecting landscapes stabilizes populations of the
Endangered savannah elephant**

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The PDF file includes:

Supplementary Text
Figs. S1 to S14
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References

Other Supplementary Material for this manuscript includes the following:

Tables S1 to S10

Supplemental Materials

Here we provide the background information for the nine clusters of protected areas. Their designations only serve as a reference and does not imply the most important protected area. For each cluster, we provide a brief description of where it is situated in southern Africa, the number of cores, buffers and insular elephant populations, the total area (km²), the total number of elephants (based on all the latest survey estimates in our time series) and the weighted average population growth rates. We briefly described the main landscape features, topography, rainfall, dominant vegetation, and where relevant the presence of fences and the provision of surface water for elephants. We also indicated if the populations were exposed to disturbances such as poaching, or management interventions (such as translocation, contraception). The figures (cartograms) and tables give details for each administrative unit included in each cluster (i.e. IUCN status, size [km²], the number of elephants returned by the latest survey estimates in our time series, survey areas [km²], density, the mean population size based on all the estimates from 1995 to 2020, and the population growth rate). The figure legends and table headers are the same for each cluster, and we only provide full details of these with the first (Etosha) cluster.

Etosha Cluster

The Etosha cluster consists of the Etosha National Park (NP) as the core elephant population and the North West Namibia region as the buffer population (Fig. S1, Table S1). This cluster is situated in the most arid parts of the distributional range of elephants in southern Africa (1, 38). The region is known for a relatively steep rainfall gradient of about 50 mm of rain per year along the Skeleton Coast in the west to about 450 mm of rain per year in the eastern parts of Etosha NP (83). Etosha NP received 394 ± 52 mm rainfall per year (84). The cluster (82,492 km²) supports 4,627 elephants and grew at 4.78 percent per year.

Mopane (*Colophospermum mopane*) tree savanna and mixed broadleaved woodlands, grasslands and shrubland are the dominant vegetation types (85, 86). In North West Namibia, elephants remain close to the Hoanib and Hoarisub Rivers, the two main drainage lines in the region (38). Etosha NP has no rivers and a few natural springs around the Etosha Pan – a prominent landscape feature in the park (87). Providing surface water for animals started in the 1960s, and the park has 63 artificial and perennial water sources (88). Etosha NP was fenced in 1973 (87), but elephants continues to move between Etosha NP and North West region (38, 84, 89). Apart from mortalities due to small-scale and sporadic anthrax outbreaks during the end of some dry seasons (90, 91), elephants here have not been exposed to poaching or management interventions since 1995 (68).

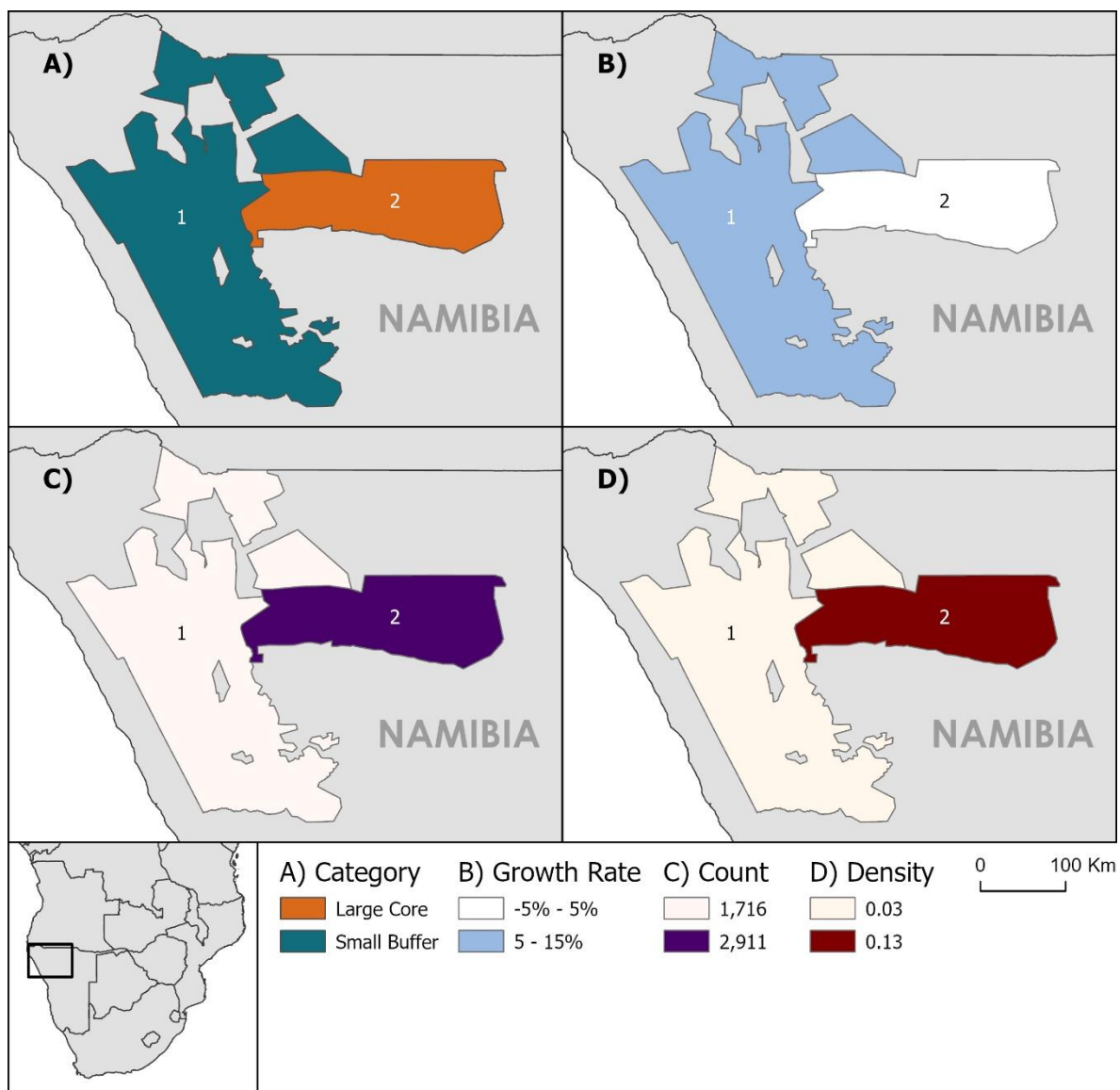


Figure S1. Cartograms illustrating A) the protected area landscape, B) population growth, C) the number of elephants, and D) elephant density (ind/km²) for populations assigned to the Etosha cluster. Core protected areas are primary protected areas with an IUCN status of I-IV adjoined by one or more buffer areas (secondary protected areas with an IUCN status of V-VI or NA adjoined by core or other buffer protected areas). Large populations have > 1,000 and small populations < 1,000 elephants (based on the average across all the survey estimates). Insular protected areas had an IUCN status of I-VI or NA and were not bordered by other protected areas or were isolated by fences. Protected areas delineations were sourced from the World Database on Protected Areas (WDPA) (www.protectedplanet.com).

Table S1. Summary information of elephant populations assigned to the Etosha cluster. “No.” indicate the position on the cartogram in Fig. S1, “IUCN Status” refer to the protected area category as classified by IUCN and along with “Size (km²)” were extracted from the World Database on Protected Area (WPDA) (www.protectedplanet.net), “Year” is the year of the latest population estimate in our time series with “Estimate (± 95% CL)” the number of elephants and “Survey area (km²)” the area covered during the latest survey, “Density (per km²)” is the number of elephants per km² of each administrative unit, “Mean (±SD) population size” is the mean number of elephants for the “Time-period” for which “n” number of population estimates were extracted, “Growth rate (± SE)” was the population growth based on the density-independent diffusion approximation model (54, 77). Dashes indicate missing information.

(See Excel file)

* NP = National Park

IUCN protected area management categories classify protected areas according to their management objectives, where: Ia – Strict Nature Reserve; Ib – Wilderness Area; II – National Park; III – Natural Monument or Feature; IV – Habitat/Species Management Area; V – Protected Landscape/Seascape; VI – Protected area with sustainable use of natural resources; NA – Not Assigned, Not Applicable or Not Reported (see www.iucn.org/theme/protected-areas for more details).

Chobe Cluster

The Chobe cluster is the largest cluster of protected areas in southern Africa, making up most of the Kavango-Zambezi Transfrontier Conservation Area (KAZA TFCA). The cluster spans five countries: Angola, Botswana, Namibia, Zambia and Zimbabwe (Fig. S2). It includes 21 protected areas (eight core, 12 buffer, and one insular population) and covers 135,548 km² that supported 183,168 elephants (Table S2). The overall weighted average population growth rate was 2.71 percent per year.

The major river systems consist of the Kavango River that drains into the Okavango Delta. The Boteti River flows from the Delta into the Makgagakadi basin/pans (described as a paleolake environment (92, 93)). The Kwando River flows into the Linyanti Swamps linking it with the Chobe River, which then flows into the Zambezi River. The landscape in the hinterland, away from the major rivers, has a generally flat topography (94).

Rainfall for this arid region is erratic (35-45 % CV). It increase from about 540 mm in Khaudum National Park (NP) (84) at the western end of the cluster to about 600 mm in Hwange NP at the eastern end (66). Kalahari sand is the dominant soil type nutrient-poor (94) with occasional nutrient-rich deposits such as the Mubabe Depression and pans in the Central Kalahari (95). The vegetation in Chobe NP varies between floodplain grass and riparian woodland close to the major rivers and drainage lines (96, 97). Away from the floodplains, the vegetation is dominated by a mixture of tree species such as *Baikiaea plurijuga*, *Burkea africana*, *Combretum* spp., and *Terminalia sericea* (96) and in the hinterland by a mixture of mopane (*Colophospermum mopane*) and *Acacia*-dominated woodlands (98). Hwange NP consists of an heterogenous dystrophic wooded savanna (about two-thirds of the park) covered by *B. plurijuga* woodlands, a mixed bushland dominated by *Combretum* spp, *T. sericea*, and a few *Acacia* spp. (99). In the northern parts of Hwange NP, clayey soils are covered by Mopane (*C. mopane*) with patches of open grasslands (66).

The primary protected areas in the Chobe cluster are not fenced but across northern Botswana, a series of veterinary fences divides the land and isolate the Seronga area from the surrounding landscape (36, 38). An international fence alongside parts of the border between Namibia and Botswana forms a hard boundary and effectively cuts-off the elephant populations in Khaudum NP and Nyae Nyae Conservancy from those in northern Botswana (38, 84).

Khaudum NP has 12 artificial waterholes (100), and 23 artificial waterholes have been placed across northern Botswana, including Chobe NP (Mike Chase, *pers. comm.*). Hwange NP in Zimbabwe has 67 artificial waterholes, mainly in the northern and north-eastern sections of the park (66). Poaching elephants for ivory has recently been reported in south-east Angola, the Zambezi region in Namibia, in five regions across northern Botswana (59, 101, 102), and in Hwange NP in 2013 when more than a 100 elephants were poisoned (103).

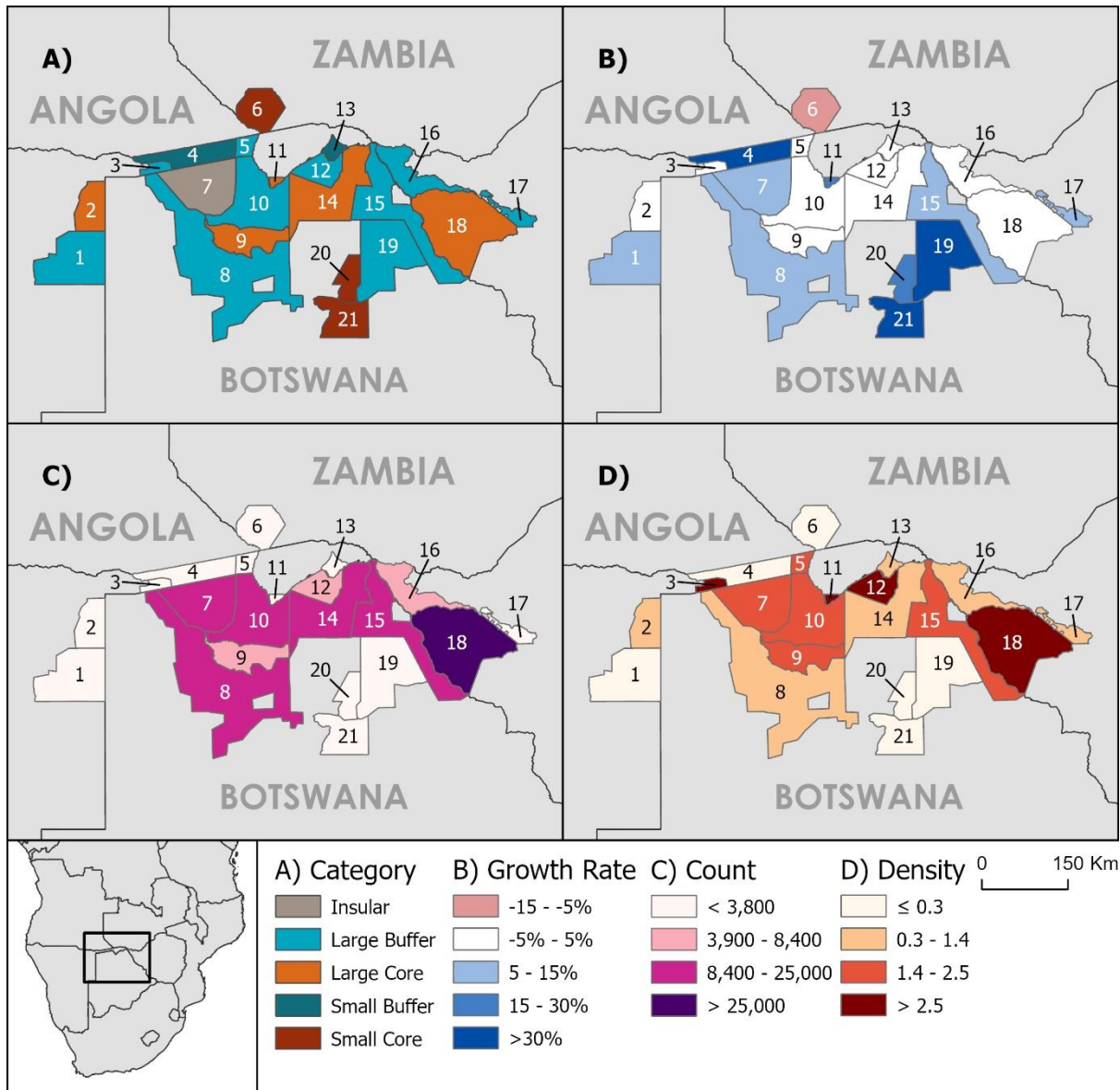


Figure S2. Cartograms illustrating A) the protected area landscape, B) population growth, C) the number of elephants, and D) elephant density (ind/km²) for populations assigned to the Chobe cluster. Protected areas delineations were sourced from the World Database on Protected Areas (WDPA) (www.protectedplanet.com).

Table S2. Summary information of elephant populations assigned to the Chobe cluster.

(See Excel file)

* NP = National Park, GR = Game Reserve, FA = Forested Area

^a Bwabwata NP consists of three areas: Bwabwata Multiple Use Area, Buffalo/Mahango Conservation Core Area and Kwando Conservation Core Area (104). We report each area independently.

^b Survey area increased from 9,313 km² in 2010 to 20,601 km² in 2018.

^c Includes Sikumi and Ngamo Forest Areas.

^d Includes Panda-Masue Forested Area, Zambezi National Park, Kazuma Pan and Matetsi Safari Area.

Kafue Cluster

The Kafue cluster is situated in central-west Zambia and consists of Kafue National Park (NP) as the core population surrounded by nine Game Management Areas (buffers) (Fig. S3, Table S3). No insular elephant populations are associated with this cluster. With Kafue NP not fenced, elephants can move between the park and the adjacent buffers (38). The Kafue cluster covers 56,314 km² and supported 6,166 elephants and grew at 3.83 percent per year.

Mean yearly rainfall range from 600 mm to 1,200 mm (105). The Kafue River is the area's primary drainage system. Lake Itzhi-Tezhi (a hydro-electrical power supply dam) in the Kafue River serves as the primary water source for the central and southern regions of Kafue NP (106). There are no other artificial waterholes in the park. Open grasslands and *Brachystegia/Julbernardia* (Miombo) woodlands are the dominant vegetation in the northern parts of Kafue NP, and *Colophospermum mopane* (mopane) woodlands are dominant in the southern parts (106).

The GMAs adjoining Kafue NP had about 175,000 people living there and practising subsistence farming (CSO 2003). Poaching of elephants occurred in western Zambia (50,53,107), which included elephants in the Kafue cluster. Recent attempts to improve game-scout patrols in Kafue NP may have reduced poaching (105, 108).

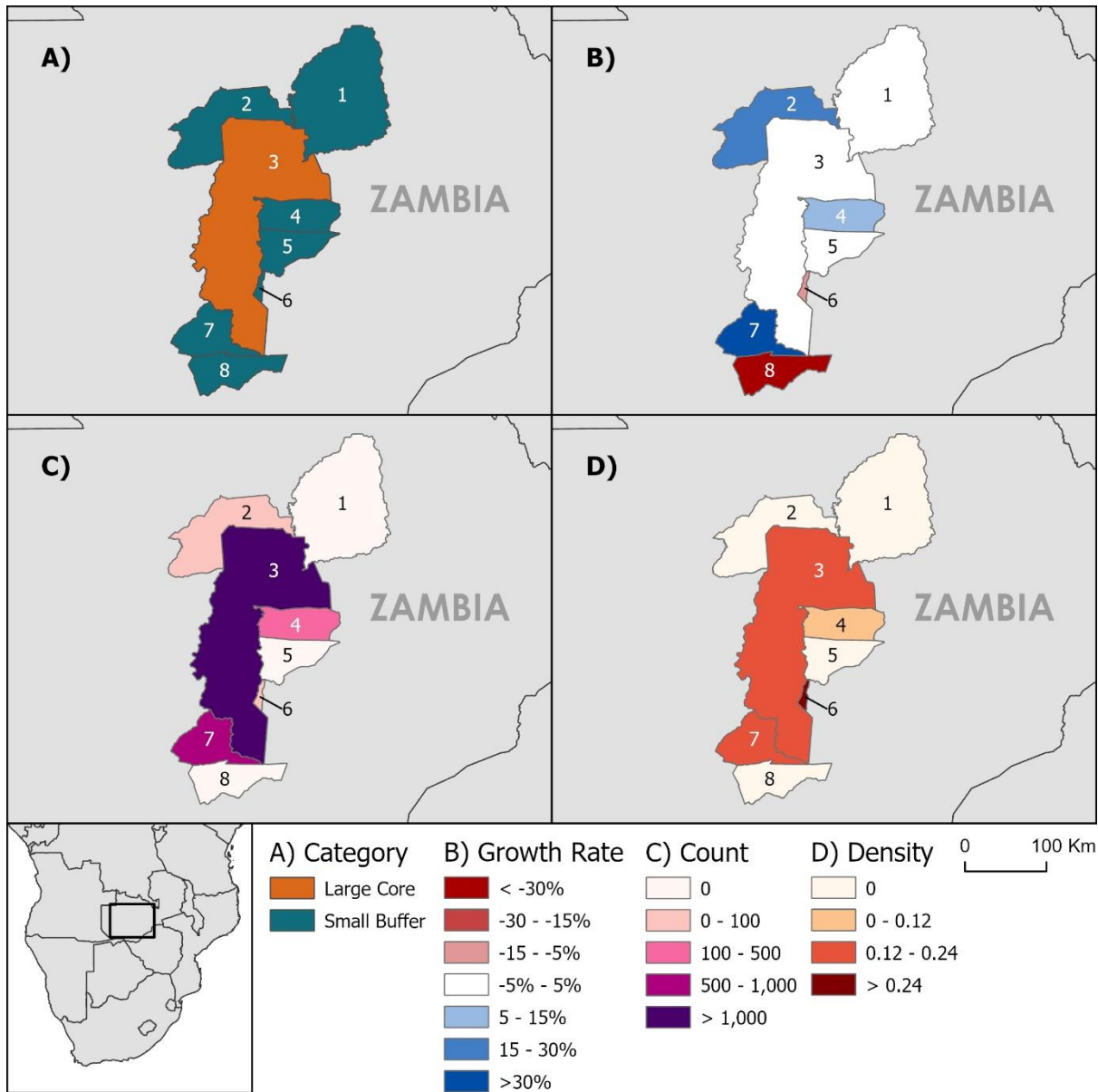


Figure S3. Cartograms illustrating A) the protected area landscape, B) population growth, C) the number of elephants, and D) elephant density (ind/km²) for populations assigned to the Kafue cluster. Protected areas delineations were sourced from the World Database on Protected Areas (WDPA) (www.protectedplanet.com).

Table S3. Summary information of elephant populations assigned to the Kafue cluster.

(See Excel file)

* GMA = Game Management Area, NP = National Park

Zambezi Cluster

The Zambezi cluster spans across Zambia, Zimbabwe and Mozambique and is situated alongside the Zambezi River that is the international border between Zimbabwe and Zambia. The four core protected areas include Chizarira National Park (NP), Matusadona NP and Mana Pools NP (in Zimbabwe) and Lower Zambezi NP in Zambia (Fig. S4, Table S4). Magoé NP in Mozambique was established in 2013 (1) and for this assessment forms part of the Magoé District and designated as a buffer. Mavuradonha Wilderness Area (in Zimbabwe) harbours an insular elephant population, and the remaining 12 administrative units (Safari Areas, Game Management Areas) are classified buffer populations. The Zambezi cluster covers 38,279 km² and supports an estimated 17,537 elephants with an overall weighted average population growth rate of -5.03 percent per year.

The Zambezi Valley received between 700 to 800 mm of rain per year in a single rainy season from November to March (109). The Sebungwe region (Chizarira NP, Matusadona NP and the buffer areas that surrounded them) is situated south of Lake Kariba (in the Zambezi River) and has an undulating topography between 700-800m above sea level (109). The landscape downstream of the lake consists of a floodplain adjacent to the Zambezi River, the valley floor, and the Zambezi escarpment at the southern end of the Zambezi valley (110).

The vegetation consists of *Brachystegia* and *Julbernardia* spp. (Miombo) woodlands, Mopane (*Colophospermum mopane*) woodlands, a mixed *Terminalia/Combretum* woodlands, and Jesse (local colloquial name) thicket, *Faidherbia albida* woodlands along the floodplains with grassland areas dominated by *Setaria* spp. (110-113). There are no artificial waterholes and no fences surrounding the protected areas.

Poaching in the Sebungwe region (of which Chizarira NP formed part) increased >16-fold from 1988 to 2006 (114). In Mana Pools NP and the surrounding Safari Areas (Hurungwe, Charara, Sapi, Chewore, and Dande), the elephant population declined by ~40% from 2001 to 2014 due to poaching (115).

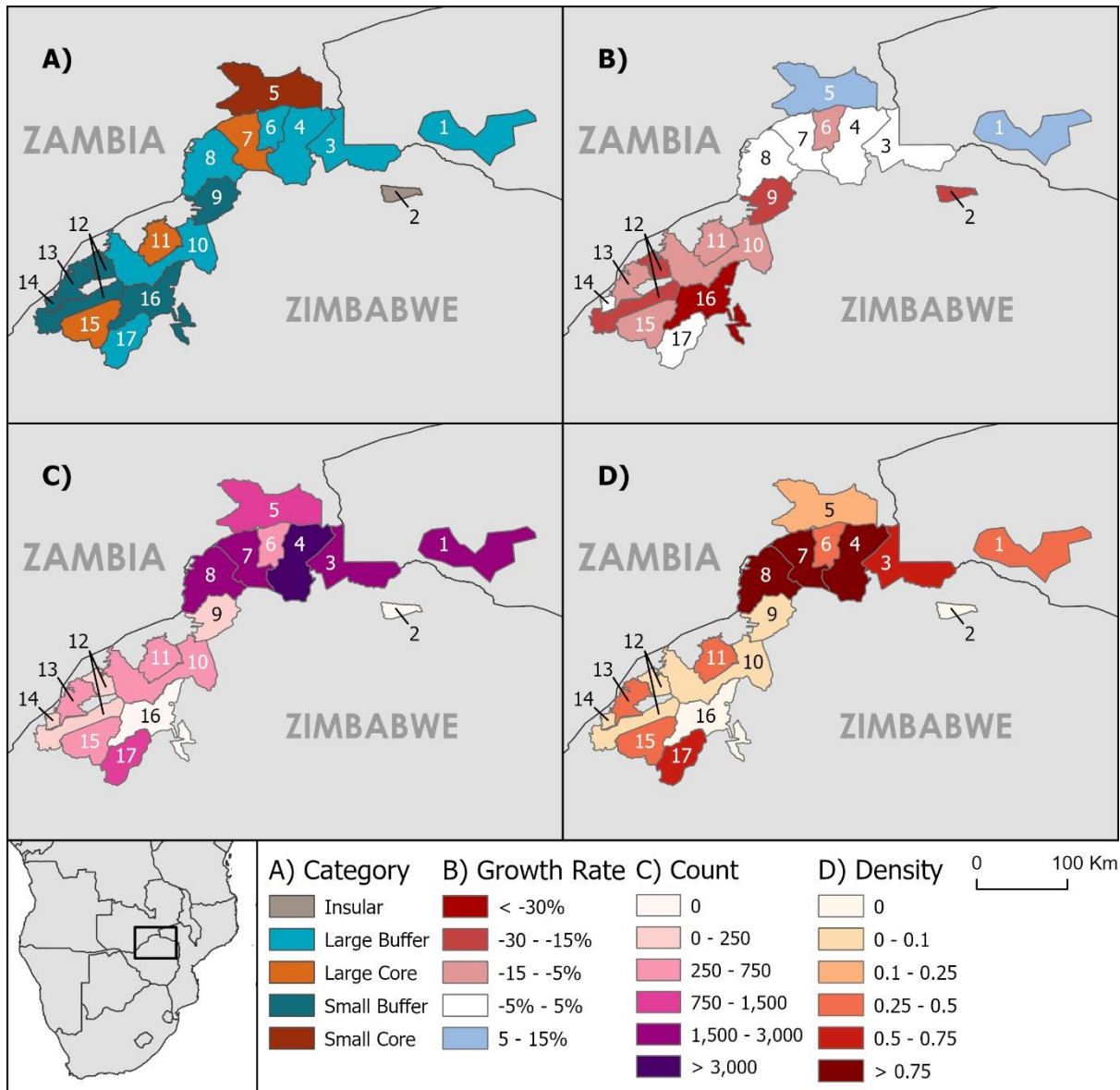


Figure S4. Cartograms illustrating A) the protected area landscape, B) population growth, C) the number of elephants, and D) elephant density (ind/km²) for populations assigned to the Zambezi cluster. Protected areas delineations were sourced from the World Database on Protected Areas (WDPA) (www.protectedplanet.com).

Table S4. Summary information of elephant populations assigned to the Zambezi cluster.

(See Excel file)

* WA = Wilderness Area, SA = Safari Area, NP = National Park, CL = Communal Land

^a Includes the Magoe area south of Cahora Bassa and the southern Tete Province further east (*1*)

^b Dande includes Dande Safari Area and surrounding areas (Chapoto, Kanyurira, Chisungu and Kadze)

Luangwa Cluster

The Luangwa cluster in northeast Zambia stretches across the eastern border of Zambia into Malawi. In Zambia, the North Luangwa National Park (NP), South Luangwa NP and Luambe NP form the cluster's core and the nine Game Management Areas the buffers (Fig. S5, Table S5). We designated Lukusuzi NP as a buffer as no elephants have been recorded in the park since 1994 (1, 116, 117). The park is also known for encroachment by people and mining activities (55, 118). Kasungu NP in Malawi is an insular elephant population. The Luangwa cluster covers 56,024 km² and supports an estimated 10,894 elephants with an overall weighted averaged population growth rate of -6.61 percent per year.

Most of this cluster is situated within the Luangwa Valley, a ~200 km wide channel at the southern end of the Great Rift Valley (119). The Luangwa River flows through the valley for about 700 km and along the western slopes, the Muchinga Escarpment rises to an elevation of 1,500 m (118). The dominant vegetation type in the valley region (450 – 650 m in elevation) is mopane (*Colophospermum mopane*) and *Combretum* woodlands and grasslands (120). Miombo (mainly *Brachystegia* spp.) woodlands is the dominant vegetation on the adjacent slopes and plateau (118). Average yearly rainfall is 800 mm (119). On the Malawi side, similar environmental conditions prevails, with an average yearly rainfall of 780 mm in Kasungu NP (121). Kasungu NP is situated on the Kasungu Plateau at 1,000 m – 1,500 m and the vegetation again is dominated by Miombo woodlands. Three main rivers flow through Kasungu NP (121).

The elephants in the Luangwa cluster did not escape the wave of continent-wide poaching onslaught from about 2007 to 2012 (2, 63, 122). Poaching elephants was particularly rife in North Luangwa and South Luangwa NPs (50, 51) and in Kasungu NP (56, 121).

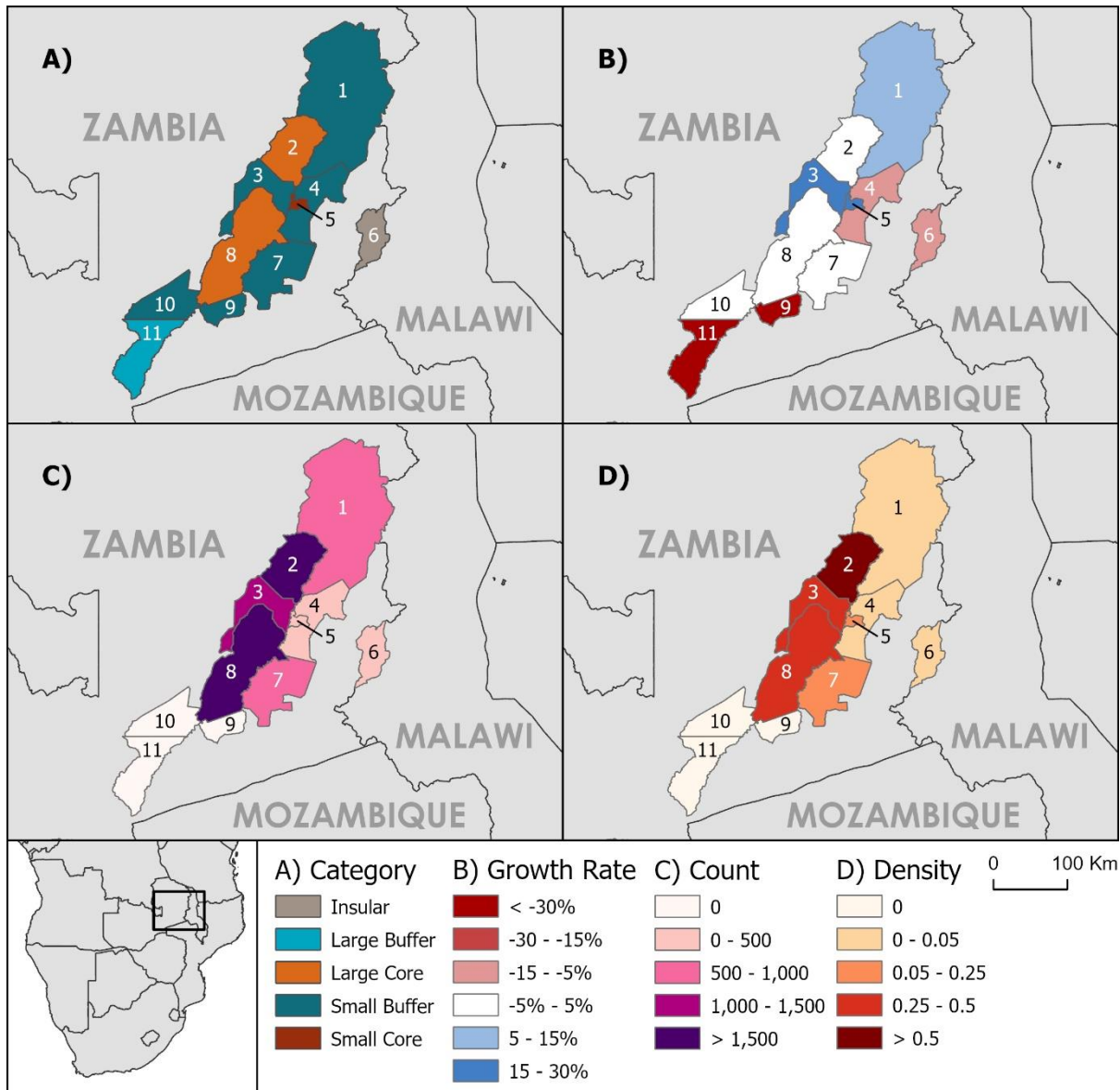


Figure S5. Cartograms illustrating A) the protected area landscape, B) population growth, C) the number of elephants, and D) elephant density (ind/km²) for populations assigned to the Luangwa cluster. Protected areas delineations were sourced from the World Database on Protected Areas (WDPA) (www.protectedplanet.com).

Table S5. Summary information of elephant populations assigned to the Luangwa cluster.

(See Excel file)

* GMA = Game Management Area, NP = National Park, GR = Game Reserve

Niassa Cluster

The Niassa cluster is also referred to as the Ruvuma landscape (52), and include the elephant populations in Selous Game Reserve (GR) and Mikumi National Park (NP) as core populations, and Kilombero Game Control Area (GCA) and the surrounding areas as buffers in southern Tanzania (Fig. S6, Table S6). In northern Mozambique, the Niassa (Ecosystem) Reserve, Chipanje Chetu, Quirimbas NP and the surrounding areas are buffer populations (Fig. S6, Table S6). The Selous GR is 48,000 km² and the elephant populations in the larger Selous-Mikumi Ecosystem are connected with those in the Niassa Ecosystem via the Selous-Niassa (Wildlife Protection) Corridor (52). The Quirimbas-Niassa Corridor connect the elephant populations in the Niassa Reserve (42,400 km²) and surrounding areas with those in the Quirimbas NP (7,500 km²). Collectively the Niassa cluster cover 106,268 km² (the second largest cluster in southern Africa) but only support an estimated 18,048 elephants with an overall weighted average population growth rate of -8.60 percent per year.

The region is tropical and has an east-west gradient in rainfall (52). The eastern parts of the cluster received about 800 mm of rain per year. In the western regions, at a higher altitude of 1,400 m above sea level, the region received about 1,500 mm of rain per year.

The Niassa cluster comprises plains, valleys, an undulating topography and granite inselberg mountains (123, 124). The main rivers are the Lugenda River, a main tributary of the Ruvuma River (that forms the international border between Tanzania and Mozambique), and the Rufiji River in Selous GR (52, 123). The landscape is mainly covered by Miombo woodland (*Brachystegia* and *Julbernardia* spp.) with scattered bushland, savanna, and wooded grasslands among the miombo woodlands (52, 123, 125).

Unlike in the Tanzanian protected area, people live in the Niassa Reserve (in three towns and >40 villages) and practise crop production and shifting agriculture (124). About 95,000 people live in Quirimbas NP (126). Poaching was particularly severe for elephants in Selous GR, Niassa Ecosystem, Quirimbas NP and their surrounding areas (50, 52, 53, 107, 123, 124, 126).

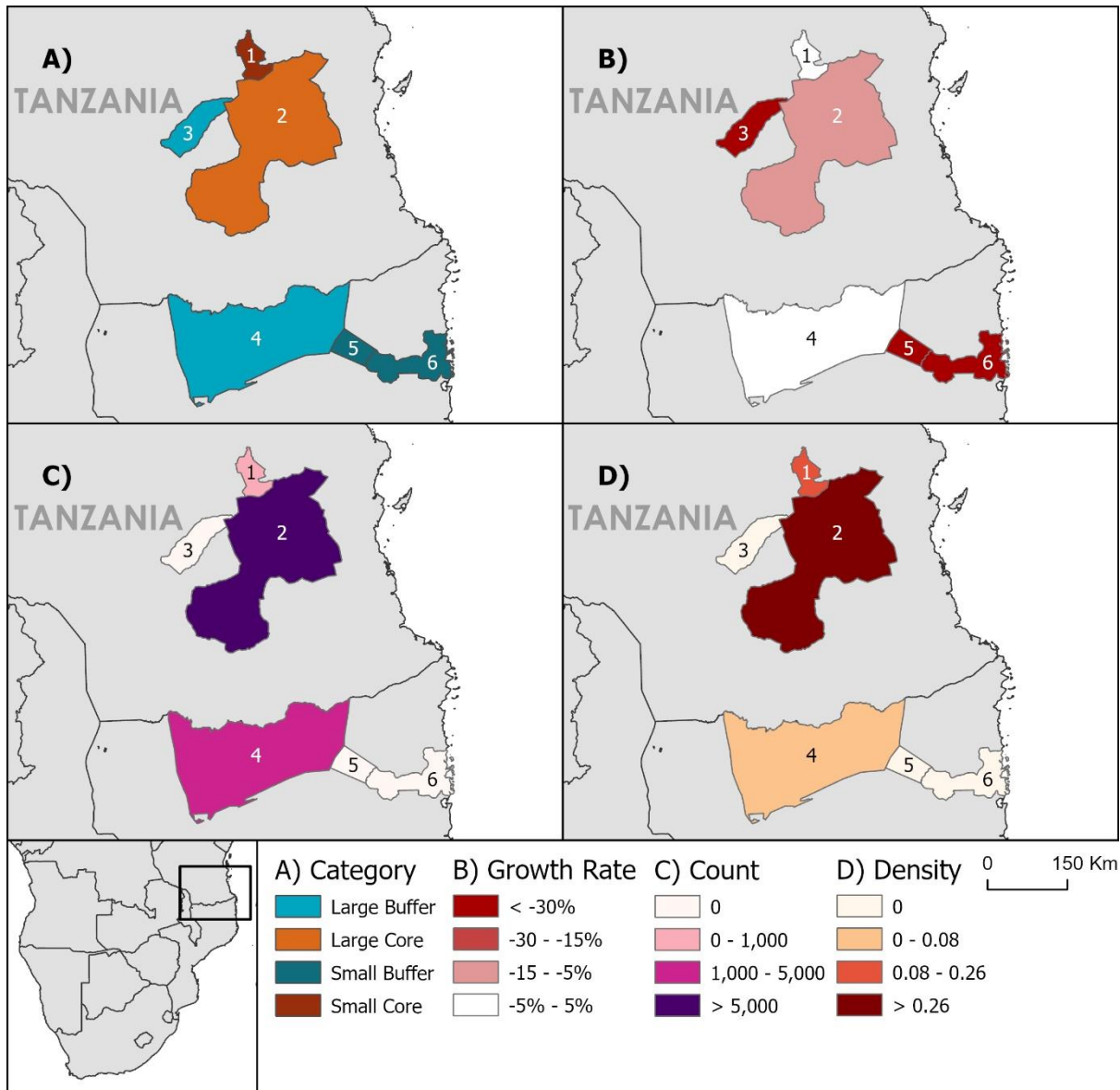


Figure S6. Cartograms illustrating A) the protected area landscape, B) population growth, C) the number of elephants, and D) elephant density (ind/km²) for populations assigned to the Niassa cluster. Protected areas delineations were sourced from the World Database on Protected Areas (WDPA) (www.protectedplanet.com).

Table S6. Summary information of elephant populations assigned to the Niassa cluster.

(See Excel file)

* NP = National Park, GR = Game Reserve, GCA = Game Controlled Area

^a No protected area delineation from WDPA

Mapungubwe Cluster

The Mapungubwe cluster is the smallest of the nine clusters in our study and is centered around the confluence of the Limpopo and Shashe Rivers (127). Both rivers form international boundaries between Zimbabwe, Botswana and South Africa, and the protected areas here is part of the Greater Mapungubwe Transfrontier Conservation Area (GMTCA) (128). The Northern Tuli Game Reserve (GR) in Botswana and Mapungubwe National Park (NP) in South Africa are the core elephant populations (Fig. S7, Table S7). The Venetia Limpopo Nature Reserve (NR) is an insular population. The buffer populations consist of elephants in the Tuli Safari Area (SA), Sentinal Ranch and Nottingham Estate in Zimbabwe, the Tuli Block in Botswana and Vhembe Game Reserve (GR) in South Africa. Land use and ownership of the relatively small parcels are diverse (129). The cluster collectively covers 3,317 km² that support an estimated 1,554 elephants and grew at 4.22 percent per year.

The rainfall varies from 350 to 400 mm per year, and the region experiences severe droughts that may last up to three years (130). The vegetation is dominated by Mopane trees (*Colophospermum mopane*), *Acacia* / *Faidherbia* riparian woodland along the rivers, and mixed broadleaf trees consisting of *C. mopane* / *Terminalia* spp. and *Albizia* / *Combretaceae* (131, 132).

Some fences between the protected areas are removed to form the GMTFCA, allowing elephants to colonize Mapungubwe NP (128). There are some electrified fences that may restrict elephant movement, such as along the western boundary of the Northern Tuli GR, the northern boundary of the Tuli Block and along the Limpopo River on the South African side, apart from the 'Vhembe gap' at the confluence of the Shashe and Limpopo Rivers (129). The Northern Tuli GR and Mapungubwe NP has several permanent artificial waterpoints (one every 3-5 km) that provide water year-round for elephants (132, 133).

Venetia Limpopo NR harbours a newly established population with elephants brought in from Kruger NP and Gonarezhou NP starting in 1991 to 1994 (131). Trophy hunting of elephants still occurs in buffer populations of the Tuli Circle, Tuli Block, Sentinal Ranch and Nottingham Estate, and the private estates surrounding Vhembe GR in South Africa (133).

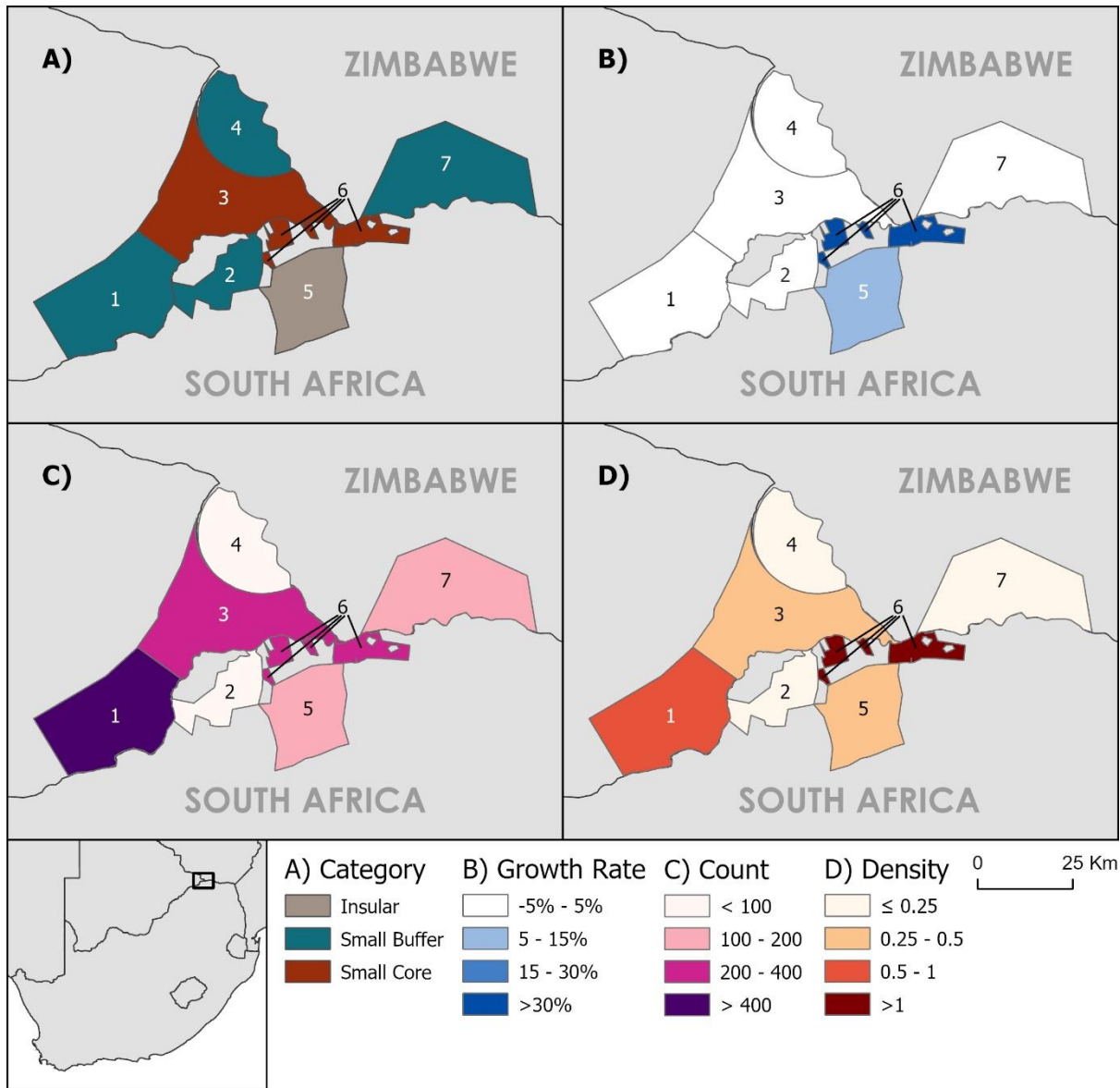


Figure S7. Cartograms illustrating A) the protected area landscape, B) population growth, C) the number of elephants, and D) elephant density (ind/km²) for populations assigned to the Mapungubwe cluster. Protected areas delineations were sourced from the World Database on Protected Areas (WDPA) (www.protectedplanet.com).

Table S7. Summary information of elephant populations assigned to the Mapungubwe cluster.

(See Excel file)

* GR = Game Reserve, SA = Safari Area, NR = Nature Reserve, NP = National Park

Limpopo Cluster

The Limpopo cluster spans South Africa, Zimbabwe, and Mozambique. It forms part of the Greater Limpopo Transfrontier Conservation Area (GLTFCA) (134), which was at first known as the Great Limpopo Transfrontier Park (GLTP) (135). The Limpopo cluster consist of 19 protected areas (nine core, nine buffers and one insular population, Fig S8, Table S8) cover 41,307 km², and supports an estimated 38,392 elephants and grew at 4.88 percent per year.

The region experiences a sub-tropical climate (136). Yearly rainfall in Gonarezhou National Park (NP) was 501 ± 35 (SE) mm from 1972 to 2010 (136), and in Kruger NP rainfall varied from 450 mm rain per year in the north to 750 mm in the south (137). Similarly, the Limpopo NP had a rainfall gradient from 360 mm in the northern parts to over 500 mm of rain per year in the south (135).

The Limpopo cluster is situated in the 'Lowveld' of southern Africa at 350-500 m above sea level (138, 139). Gonarezhou NP has three main rivers including the Save, Runde and Mwenezi Rivers (140). Six perennial rivers flow through Kruger NP in an east-west direction (134), with three of them, the Limpopo, Shingwedzi and Olifants, also flowing through Limpopo NP (135). The vegetation in Gonarezhou NP, Limpopo NP and northern parts of Kruger NP is dominated by Mopane (*Colophospermum mopane*) and tree species of the *Combretaceae* family in the southern parts of Kruger NP (*Combretum* spp. & *Terminalia* spp.) (135-137, 140).

Management in Kruger NP started constructing boreholes and earth dams during the 1930s, reaching a maximum of 340 artificial water points and 50 dams and weirs across the park in the early 1990s (142). About two-thirds of these boreholes and catchment dams have been closed since 1994 (141). In the Private Game Reserves (PGRs) to the west of Kruger NP, i.e., in Klaserie PGR, water points were spaced about 2 km apart, which at the height of providing water for animals in Kruger NP was >10 km apart (142). The fences between Kruger NP and the PGR to the west were removed in the mid-1990s (143) and in 2001 between Kruger and Limpopo NPs (134, 144).

The Limpopo NP was established in 2001 (135), and at the time, about 27,000 people lived in the park (145). The number of people has since increased to about 30,000 living in some 50 villages along with about 7,000 heads of cattle (135). Following the land reform policies in Zimbabwe in 2000, people and their livestock occupy the northern regions of Gonarezhou NP (146).

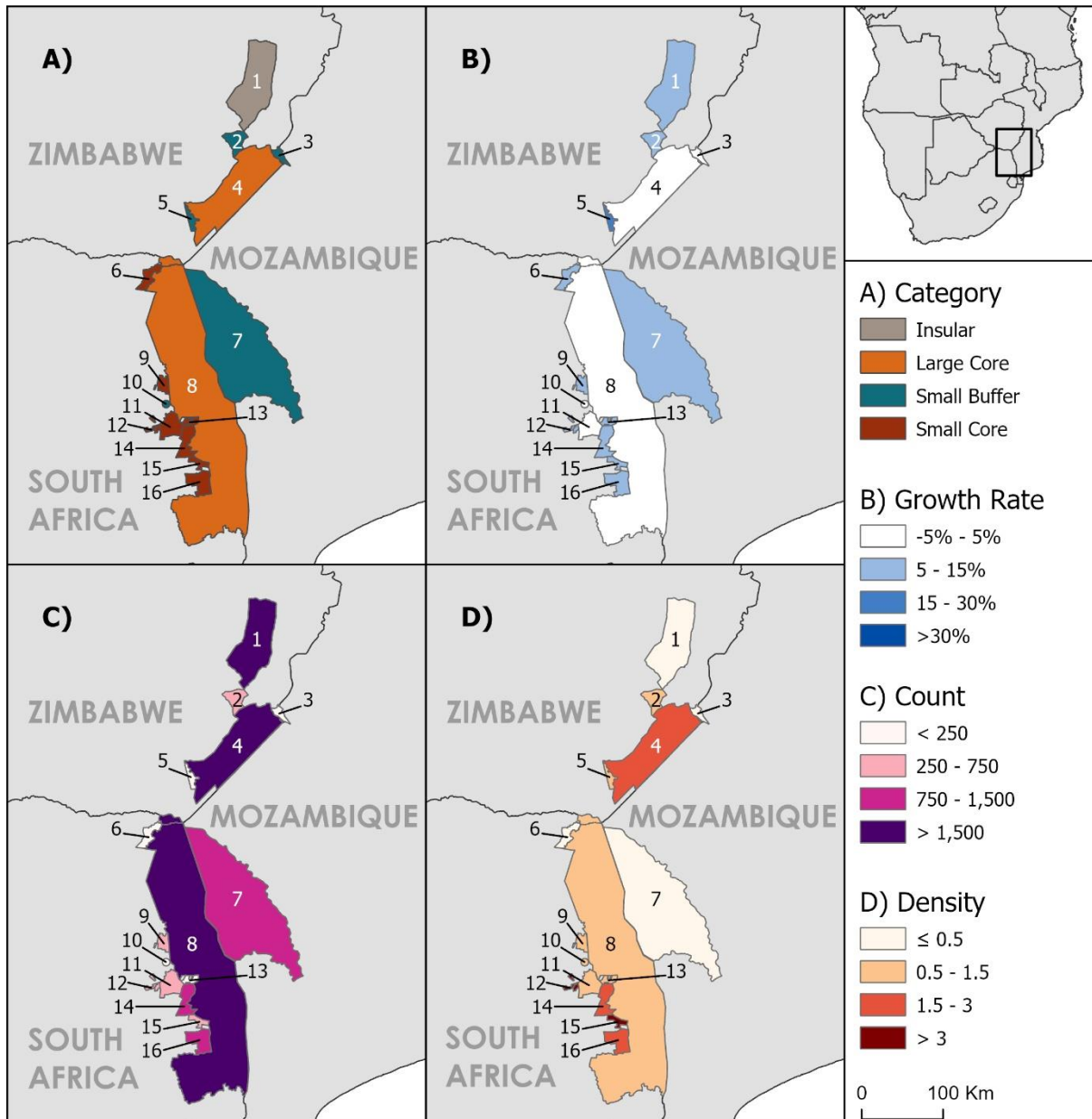


Figure S8. Cartograms illustrating A) the protected area landscape, B) population growth, C) the number of elephants, and D) elephant density (ind/km²) for populations assigned to the Limpopo cluster. Protected areas delineations were sourced from the World Database on Protected Areas (WDPA) (www.protectedplanet.com).

Table S8. Summary information of elephant populations assigned to the Limpopo cluster.

(See Excel file)

* WR = Wildlife Reserve, NP = National Park, SA = Safari Area, NR = Nature Reserve, Co. = Company, PGR = Private Nature Reserve, GR = Game Reserve

^a Limpopo National Park was established in 2001 and designated a buffer population

Maputo Cluster

The Maputo cluster is situated in the north-east corner of the KwaZulu-Natal Province in South Africa and extends into the southern region of Mozambique to include the Maputo Special Reserve (SR) and Futi Corridor. Maputo SR forms the cluster's core and is connected to the Futi Corridor as the buffer (Fig. S9, Table S9). The seven elephant populations in South Africa are insular. The Maputo cluster covers 4,542 km² and supports an estimated 1,823 elephants that grew at 5.58 percent per year.

The Maputo cluster forms part of the Maputaland Centre of (Plant) Endemism (147) and Maputo-Pondoland-Albany biodiversity hotspot (148, 149). This region has diverse and complex floristic, climatological and geological features and is recognized for its endemic species (149). iSimangaliso Wetland Park (WP) is also declared a World Heritage Site (149). The landscape is characterized by an east-west gradient (formed by north-south land features, i.e., coastline, rivers, mountains) from the Indian Ocean coastline in the east to the Lebombo Mountains in the west (150). The parks differ in that they are situated along this gradient, for instance, Maputo SR (151) and iSimangaliso WP along the Indian Ocean, the Futi Corridor, Tembe Elephant Park (EP) and Phinda Private Game Reserve (PGR) on coastal undulating paleo-dunes, uMkhuze Game Reserve (GR) on the eastern and Pongola GR on the western foot hills of the Lebombo Mountains. Ithala GR and Hluhluwe-iMfolozi Park are situated further west of the Lebombo Mountain range, with Hluhluwe-iMfolozi Park reaching an altitude of 540 m above sea level (152) and Ithala GR reaching 1,550 m (153).

Several river systems flow through the various parks, i.e., the Pongola River through Ithala GR, into the Jozini Dam alongside Pongola NR (154). From here, the river is the Jozini River (on the South African side) (155) and known as Rio de Maputo (Maputo River) in Mozambique. The Muzi swamps in (and around) Tembe EP flows north into the Futi River towards Maputo SR (156). The main rivers in Hluhluwe-iMfolozi Park are the Hluhluwe, Black- and White Umfolozi Rivers (157) and the Mkhuze River from Mkhuze GR flow into Lake St Lucia in iSimangaliso WP (158).

The Maputo cluster is tropical to subtropical (148, 155). Maputo SR receives between 600 mm to 1,000 mm of rain per year with hot, rainy summers (October to March) and colder, drier winters (April to September) (151). There exists several rainfall gradients on the South African side of Maputaland with about 670 mm per year in the north to 1,000 mm per year in the southern regions (155). In Tembe EP, the mean (\pm SD) annual rainfall is 748 \pm 388 mm per year (159). In Hluhluwe-iMfolozi Park, rainfall varies from about 600 mm in the south to 1,000 mm in the north (160) and Ithala GR receives about 791 mm of rain annually (153).

Plant diversity in the Maputo cluster is high (147) and mainly associated with Sand Forests (156, 161) and the Maputaland Wooded Grasslands dominated by geoxylic suffrutices spp. (162, 163). Sand Forests are a very dense and dry semi-deciduous to deciduous forest type (147) and occurred in Maputo SR, Tembe EP and Phinda PGR (151, 159, 164). The remaining vegetation consist of mangroves, coastal dune forests, riverine and swamp forests, reedbeds, and grass plains. The vegetation in Hluhluwe-iMfolozi Park, Pongola- and Ithala GRs is predominantly *Acacia* savanna with patches of forests and thickets (153, 154, 160).

The South African parks in the Maputo cluster (apart from Tembe EP) contain newly established elephant populations (165). These elephants came from the culling program in Kruger NP (all young elephants introduced were <10 years old) and from 1995 to 2001 consisted of family groups (165-167). These elephant populations are intensely managed and populations are controlled through the application of contraception and through translocation (167-170).

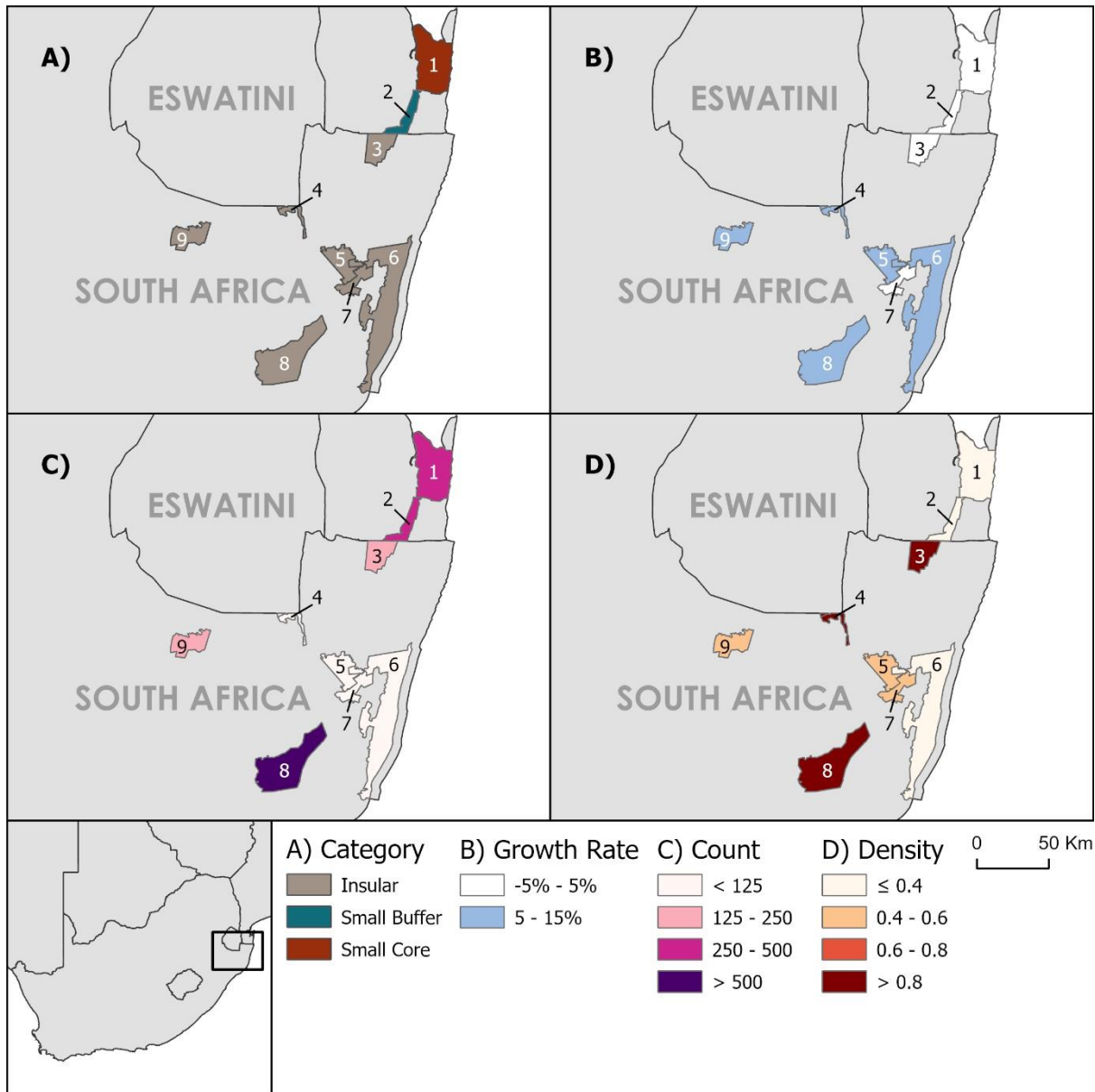


Figure S9. Cartograms illustrating A) the protected area landscape, B) population growth, C) the number of elephants, and D) elephant density (ind/km²) for populations assigned to the Maputo cluster. Protected areas delineations were sourced from the World Database on Protected Areas (WDPA) (www.protectedplanet.com).

Table S9. Summary information of elephant populations assigned to the Maputo cluster.

(See Excel file)

* SR = Special Reserve, EP = Elephant Park, GR = Game Reserve, PGR = Private Game Reserve, WP = Wetland Park

^a Includes the Futi Corridor (see No. 2 in Figure S9)

No Cluster affiliation

The Addo Elephant National Park (NP), Pilanesberg and Madikwe Provincial Reserves (PR) are situated in South Africa and the Liwonde NP in Malawi. These protected areas are all insular elephant populations and are fenced off from their surrounding landscapes (Table S10). Addo Elephant NP (the Main Camp section, 267 km²) is part of the Maputaland-Pondoland-Albany biodiversity hotspot (149, 171). Pilanesberg (534 km²) and Madikwe (750 km²) PRs have newly established elephant populations with the introduction of elephants preceding our study (172, 173). In Pilanesberg (proclaimed in 1979), elephants were introduced from 1979 to 1993 (172, 174). Madikwe PR was proclaimed in 1991, and elephants were introduced in 1992 and 1993 (173).

Addo Elephant NP and Madikwe PR has a semi-arid climate, with Addo Elephant NP receiving 399 ± 125 (SD) rain per year (77) and Madikwe PR about 520 mm rain per year (175). Yearly rainfall in Pilanesberg PR was about 630 mm per year (176), with Liwonde NP (with a sub-tropical climate) receiving from 700 mm to 1,400 mm per year (177). Low-growing shrubs (178), secondary grasslands (179) and remnants of cultivated fields dominate Addo's vegetation. In Pilanesberg PR, the vegetation is broadleaf/*Acacia* thickets and grasslands (176). In Liwonde NP the dominant vegetation (~70%) is a dry deciduous woodland and consists of mopane (*Colophospermum mopane*) (180) with the remainder consisting of grassland on the floodplains adjacent to the Shire River, and mixed woodland and riverine thickets (177). In Madikwe PR, the current vegetation still shows signs of bush encroachment (due to fire suppression and intense grazing by domestic livestock before the park was established) on red clay loam soils (181).

Addo Elephant NP (the Main Camp section) increased from 102 km² (in 1995) to 267 km² (in 2015) (77), and in 2018 the Mangochi Forest was included in Liwonde NP to increase it to 860 km². Liwonde NP is situated alongside the Shire River (180), and Pilanesberg PR has one major river with several tributaries and streams (176). Addo Elephant NP has 16 artificial waterholes (77). Similar to Madikwe PR with about 50 artificial waterholes (173), Addo Elephant NP has no rivers within the respective park boundaries.

The parks in South Africa are well protected, with no reports of elephants being illegally killed, but populations are managed intensely (165, 182). Elephants were exposed to translocation to reduce numbers (77) or immunocontraception applied to stem population growth (169, 182). From 2006 to 2017, about 500 elephants were removed (translocated) from Liwonde NP to repopulate other protected areas in Malawi. In Pilanesberg, a catastrophic fire in 2005 killed about 18% of the elephant population (176). Elephants in Liwonde NP had been exposed to poaching, human-elephant conflict, and encroachment by people (settlements and cultivation) (57, 180).

Table S10. Summary information of elephant populations in Addo Elephant National Park, Pilanesberg Provincial Reserve, Madikwe Provincial Reserve and Liwonde National Park.

(See Excel file)

* NP = National Park, PR = Provincial Reserve

Summary Growth Rates By Category

Here we provide the growth rates ($r \pm SE$) for each population included in the five categories (insular, small and large cores, and small and large buffers) along with the cluster to which it belongs, the number of estimates and the period over which the surveys took place, and the statistics of each estimated growth (F , degrees of freedom, and the p -value). The figures provide the yearly population estimates (and 95% CL) for each elephant population in each category.

Table S11. Growth rates for 16 insular elephant populations. Growth rates (“ $r \pm SE$ ”) were calculated using the density-independent diffusion approximation model (54, 77). “Time-period” gives the start and end year for which “ n ” number of estimates were extracted. “ p ” values in bold indicate the slope (growth rate) to be statistically significant different from zero ($p < 0.05$). Others refer to the four populations with no cluster affiliation.

Cluster	Population	Time period (n)	$r \pm SE$	F	df	p
Chobe	Seronga Area	1996-2018 (12)	0.063 ± 0.117	0.293	1, 10	0.600
Luangwa	Kasungu National Park	1995-2014 (3)	-0.120 ± 0.075	2.580	1, 1	0.354
Zambezi	Mavuradonha Wilderness Area	1997-2014 (3)	-0.282 ± 0.143	3.910	1, 1	0.298
Mapungubwe	Venetia Limpopo Nature Reserve	1995-2011 (6)	0.053 ± 0.024	4.710	1, 4	0.096
Limpopo	Savé Valley Conservancy	2001-2014 (5)	0.084 ± 0.134	0.387	1, 3	0.578
Maputo	Hluhluwe-iMfolozi Park	1995-2016 (14)	0.076 ± 0.017	20.80	1, 12	0.001
Maputo	iSimagaliso Wetland Park	2001-2016 (5)	0.097 ± 0.033	8.420	1, 3	0.062
Maputo	Ithala Game Reserve	1997-2016 (5)	0.071 ± 0.016	19.80	1, 3	0.021
Maputo	Phinda Private Game Reserve	2001-2020 (15)	0.014 ± 0.028	0.228	1, 13	0.641
Maputo	Pongola Game Reserve	1997-2016 (9)	0.085 ± 0.034	6.350	1, 7	0.040
Maputo	Tembe Elephant Park	1995-2019 (16)	0.042 ± 0.086	0.235	1, 14	0.635
Maputo	uMkhuze Game Reserve	1997-2016 (4)	0.083 ± 0.026	10.40	1, 2	0.084
Other	Addo Elephant National Park	1995-2020 (21)	0.034 ± 0.029	1.430	1, 19	0.247
Other	Liwonde National Park	1995-2014 (3)	0.033 ± 0.012	7.774	1, 1	0.219
Other	Madikwe Provincial Reserve	1995-2020 (21)	0.072 ± 0.026	7.340	1, 19	0.014
Other	Pilanesberg Provincial Reserve	1996-2020 (18)	0.064 ± 0.035	3.290	1, 16	0.089

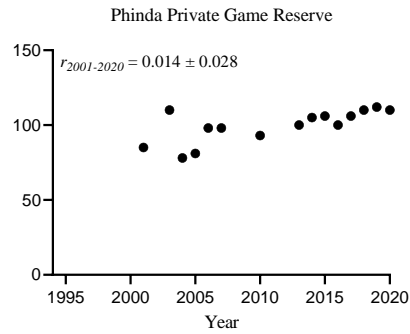
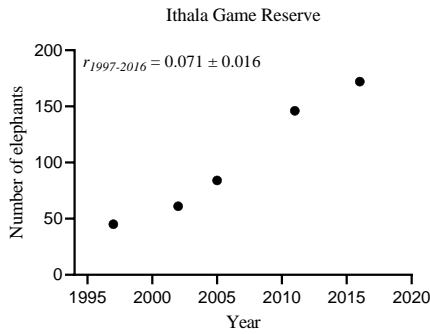
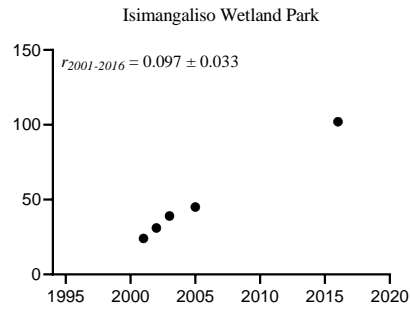
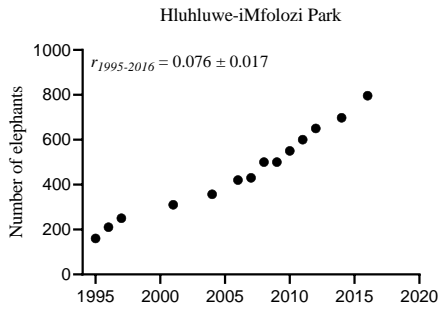
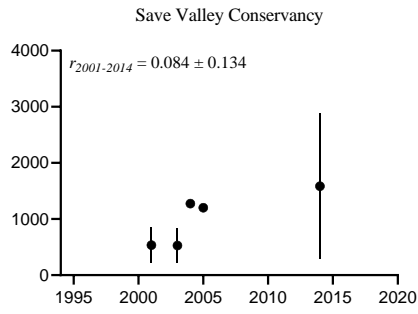
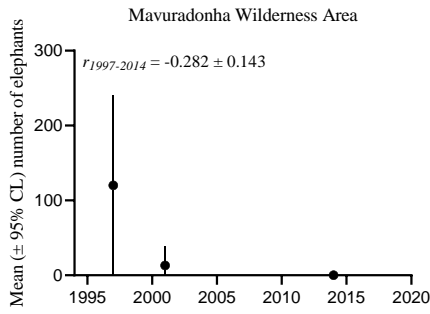
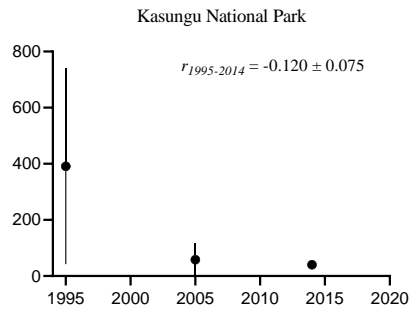
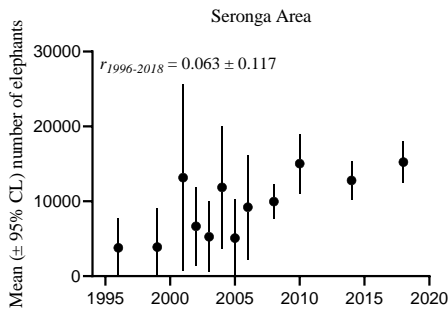


Figure S10. The mean (\pm 95% CL) number of elephants for 16 insular populations extracted from 1995 to 2020. The growth rates ($r \pm$ SE) were calculated using the density-independent diffusion approximation model (54, 77). The Y-axes were not standardized.

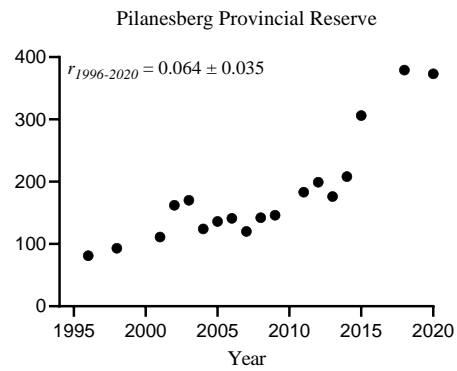
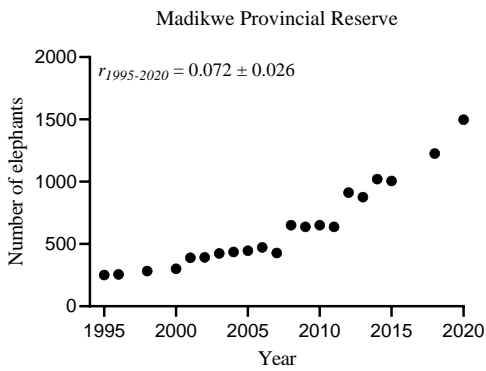
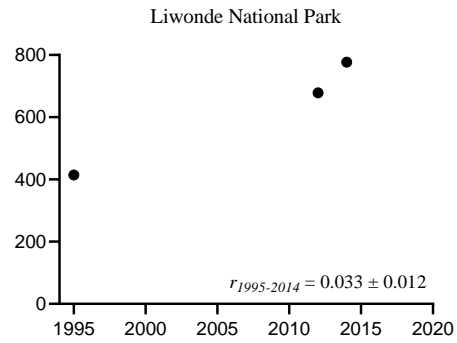
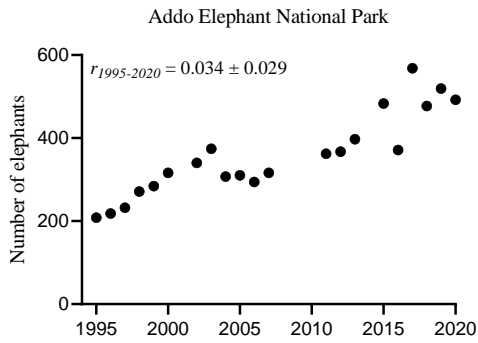
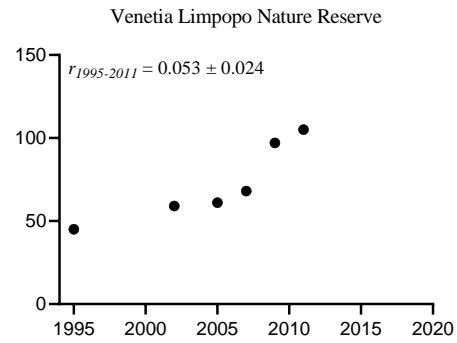
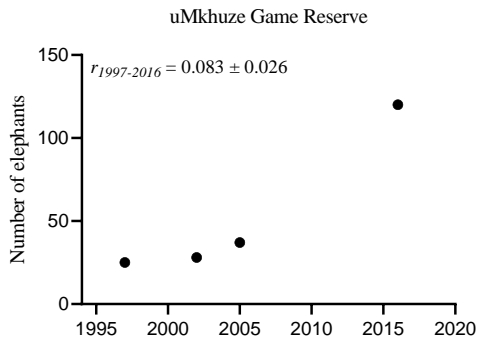
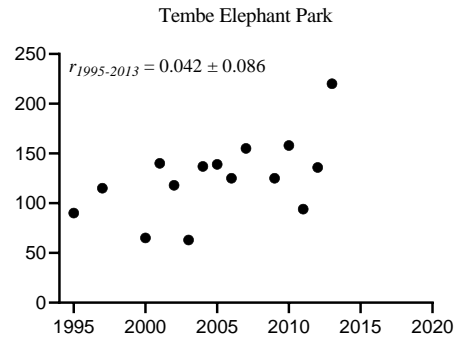
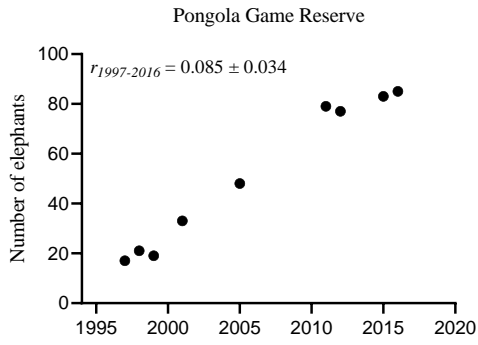


Figure S10 continues.

Table S12. Growth rates for 17 elephant populations in small core areas. Growth rates (“ $r \pm SE$ ”) were calculated using the density-independent diffusion approximation model (54, 77). “Time-period” gives the start and end year for which “ n ” number of estimates were extracted. “ p ” values in bold indicate the slope (growth rate) to be statistically significant different from zero ($p < 0.05$).

Cluster	Population	Time period (n)	$r \pm SE$	F	df	p
Chobe	Makgadikgadi National Park	1996-2018 (9)	0.331 \pm 0.230	2.080	1, 7	0.192
Chobe	Nxai Pan National Park	1996-2018 (10)	0.284 \pm 0.637	0.199	1, 8	0.668
Chobe	Sioma Ngwezi National Park	1996-2015 (6)	-0.087 \pm 0.232	0.141	1, 4	0.727
Zambezi	Lower Zambezi National Park	1996-2015 (3)	0.076 \pm 0.144	0.273	1, 1	0.693
Luangwa	Luambe National Park	1996-2014 (4)	0.223 \pm 0.370	0.363	1, 2	0.608
Niassa	Mikumi National Park	2002-2018 (4)	-0.020 \pm 0.182	0.013	1, 2	0.921
Mapungubwe	Mapungubwe National Park	2000-2014 (8)	0.417 \pm 0.333	1.570	1, 6	0.257
Mapungubwe	Northern Tuli Game Reserve	1995-2014 (12)	-0.006 \pm 0.102	0.003	1, 10	0.958
Limpopo	Balule Private Game Reserve	2002-2015 (14)	0.147 \pm 0.126	1.350	1, 12	0.268
Limpopo	Klaserie Private Game Reserve	1996-2019 (17)	0.027 \pm 0.071	0.148	1, 15	0.706
Limpopo	Letaba Provincial Nature Reserve	1997-2019 (3)	0.076 \pm 0.440	0.030	1, 1	0.891
Limpopo	Makuya Nature Reserve	1997-2019 (9)	0.105 \pm 0.130	0.660	1, 7	0.443
Limpopo	Manyeleti Game Reserve	1997-2019 (6)	0.133 \pm 0.061	4.740	1, 4	0.095
Limpopo	Sabi Sands Game Reserve	1996-2012 (10)	0.110 \pm 0.071	2.430	1, 8	0.157
Limpopo	Timbavati Private Game Reserve	1996-2019 (17)	0.054 \pm 0.061	0.765	1, 15	0.396
Limpopo	Umbabat Private Game Reserve	1996-2019 (16)	0.080 \pm 0.183	0.194	1, 14	0.666
Maputo	Maputo Special Reserve	1995-2019 (14)	0.011 \pm 0.085	0.015	1, 12	0.904

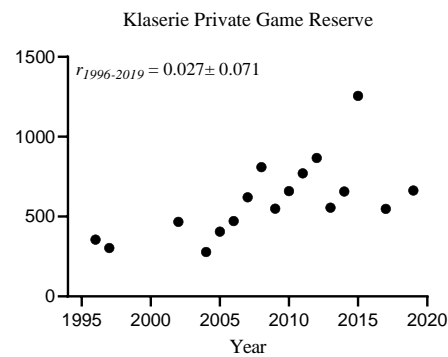
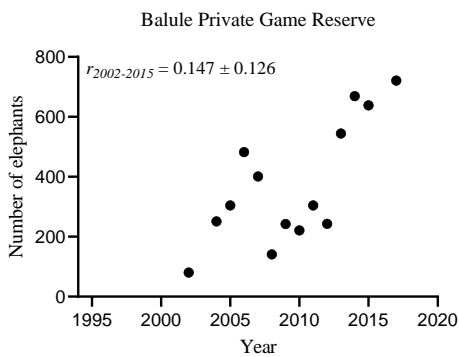
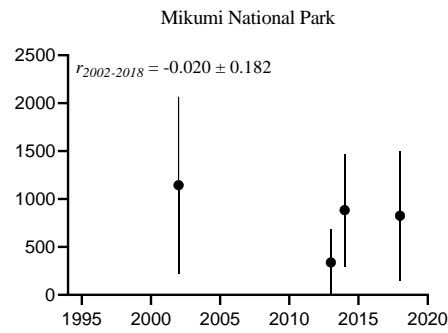
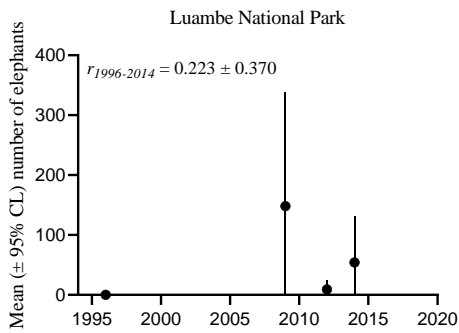
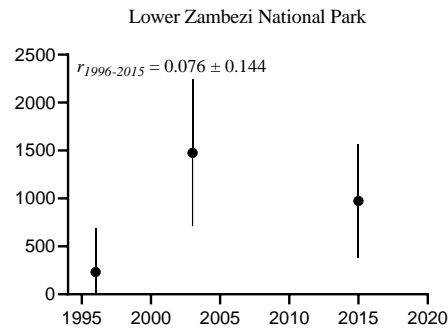
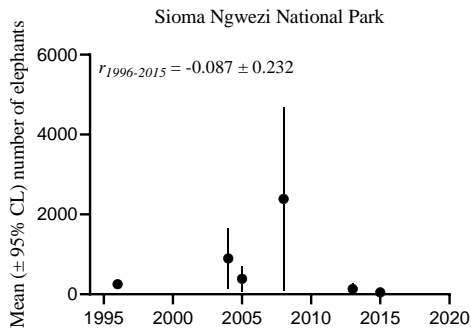
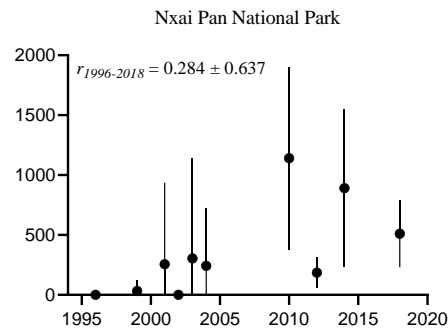
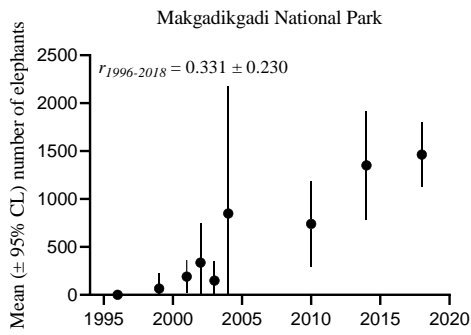


Figure S11. The mean (\pm 95% CL) number of elephants for 17 populations in small core areas extracted from 1995 to 2020. The growth rates ($r \pm$ SE) were calculated using the density-independent diffusion approximation model (54, 77). The Y-axes were not standardized.

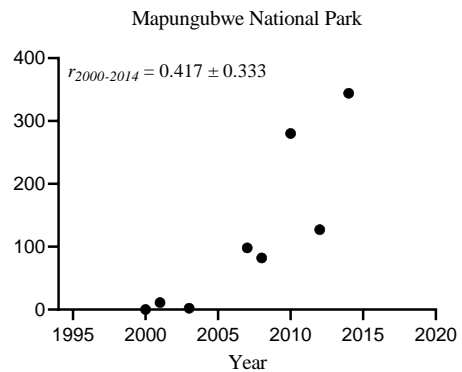
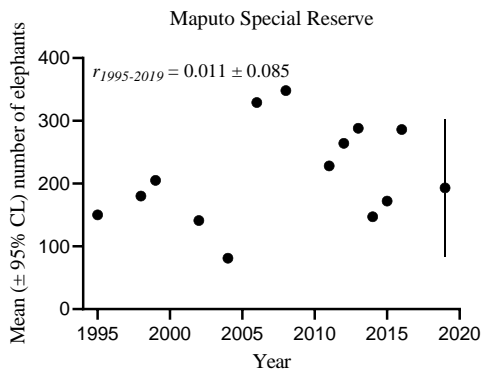
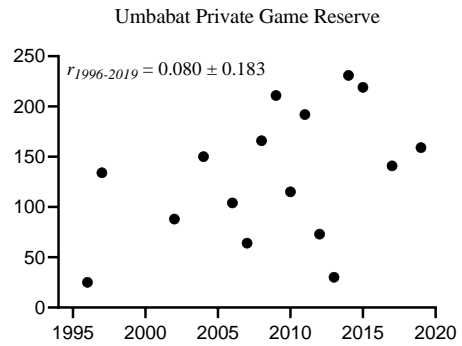
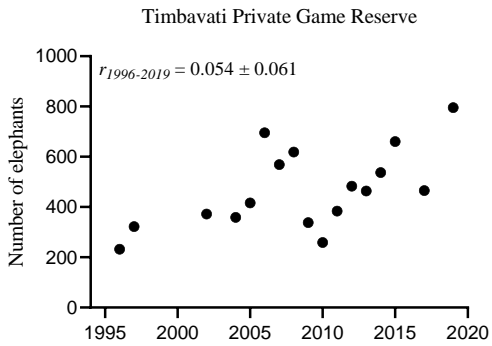
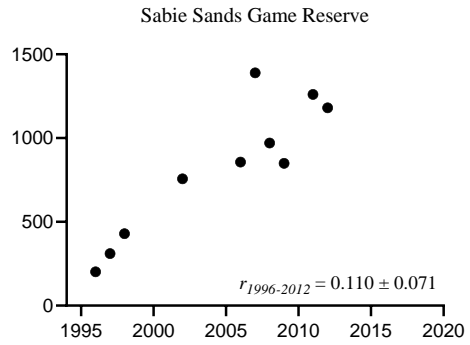
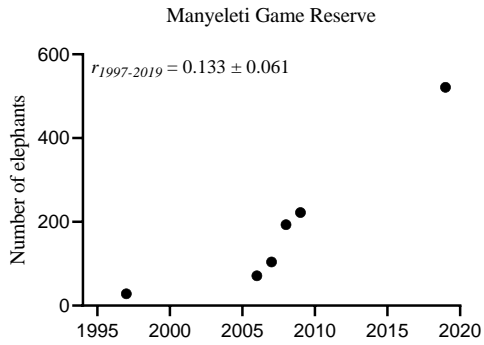
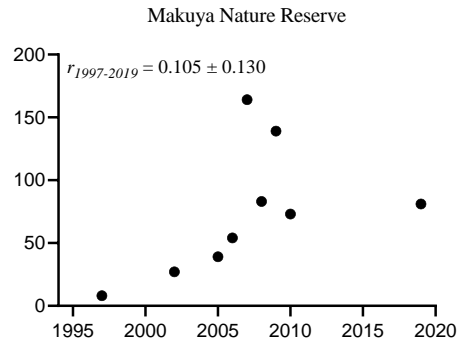
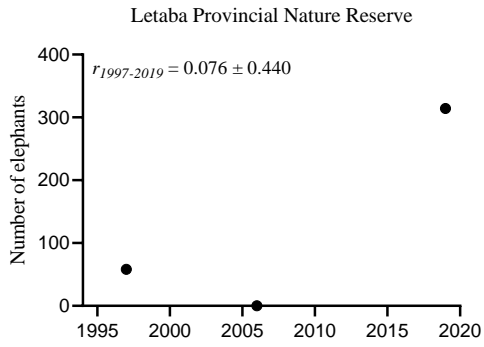


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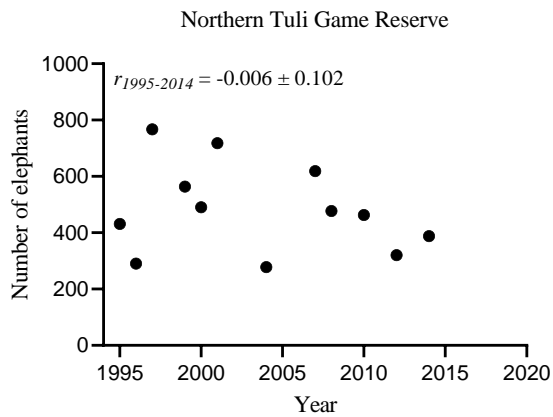


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Table S13. Growth rates for 15 elephant populations in large core areas. Growth rates (“ $r \pm SE$ ”) were calculated using the density-independent diffusion approximation model (54, 77). “Time-period” gives the start and end year for which “ n ” number of estimates were extracted. “ p ” values in bold indicate the slope (growth rate) to be statistically significant different from zero ($p < 0.05$).

Cluster	Population	Time period (n)	$r \pm SE$	F	df	p
Etosha	Etosha National Park	1995-2015 (7)	0.045 ± 0.036	1.541	1, 5	0.270
Chobe	Nkasa Rupara National Park	2005-2009 (3)	0.209 ± 0.437	0.229	1, 1	0.716
Chobe	Chobe National Park	1996-2018 (10)	-0.023 ± 0.032	0.509	1, 8	0.496
Chobe	Hwange National Park	1995-2014 (8)	0.036 ± 0.031	1.340	1, 6	0.291
Chobe	Khaudum National Park	1998-2015 (5)	0.031 ± 0.027	1.340	1, 3	0.331
Chobe	Moremi Game Reserve	1996-2018 (10)	0.004 ± 0.077	0.002	1, 8	0.964
Kafue	Kafue National Park	1995-2015 (10)	0.011 ± 0.087	0.016	1, 8	0.901
Zambezi	Chizarira National Park	1997-2014 (4)	-0.093 ± 0.072	1.660	1, 2	0.327
Zambezi	Mana Pools National Park	2001-2014 (3)	-0.017 ± 0.038	0.194	1, 1	0.736
Zambezi	Matusadona National Park	1997-2014 (4)	-0.070 ± 0.047	2.250	1, 2	0.272
Luangwa	North Luangwa National Park	1996-2015 (9)	0.023 ± 0.092	0.061	1, 7	0.812
Luangwa	South Luangwa National Park	1996-2015 (8)	-0.046 ± 0.049	0.895	1, 6	0.381
Niassa	Selous Game Reserve	1998-2018 (5)	-0.063 ± 0.041	2.310	1, 3	0.226
Limpopo	Gonarezhou National Park	1995-2018 (10)	0.040 ± 0.019	4.660	1, 8	0.063
Limpopo	Kruger National Park	1995-2017 (18)	0.041 ± 0.013	10.30	1, 16	0.005

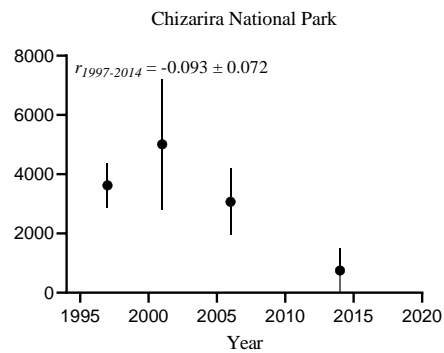
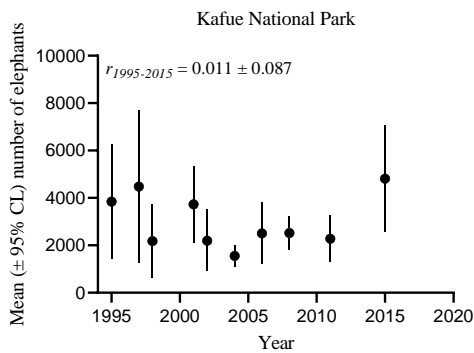
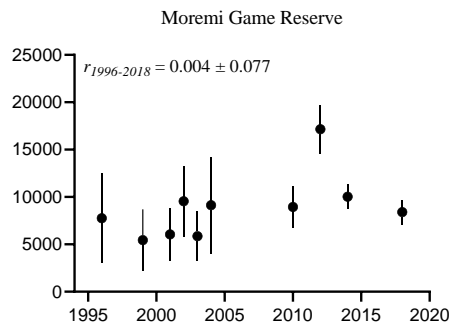
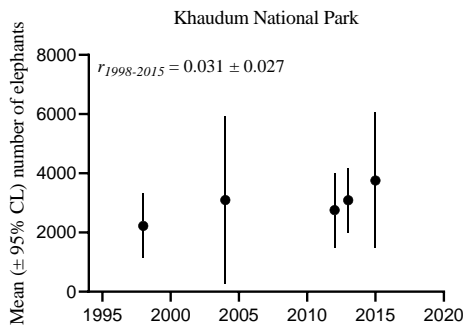
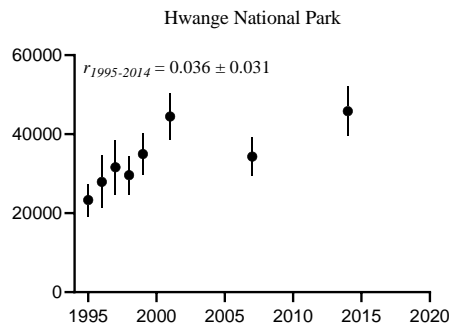
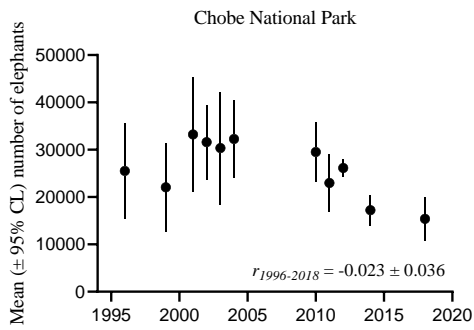
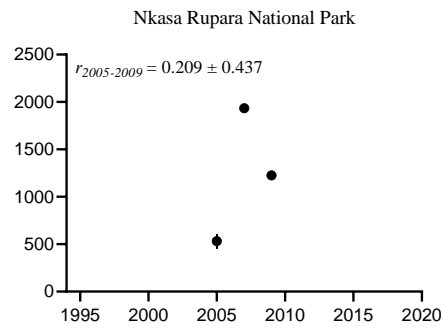
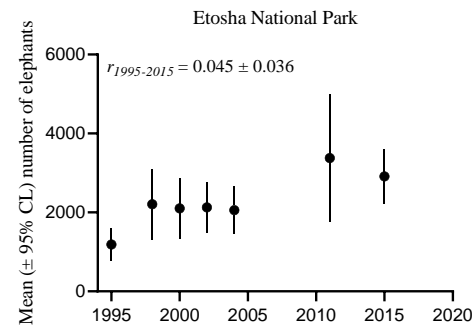


Figure S12. The mean (\pm 95% CL) number of elephants for 15 populations in large core areas extracted from 1995 to 2020. The growth rates ($r \pm$ SE) were calculated using the density-independent diffusion approximation model (54, 77). The Y-axes were not standardized.

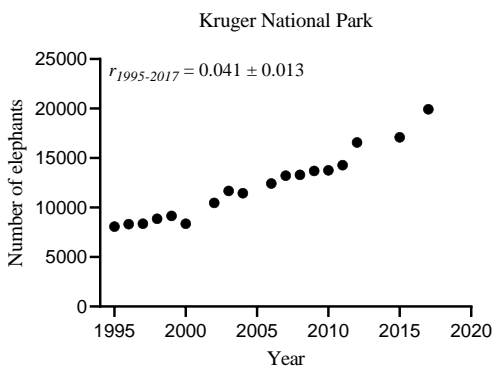
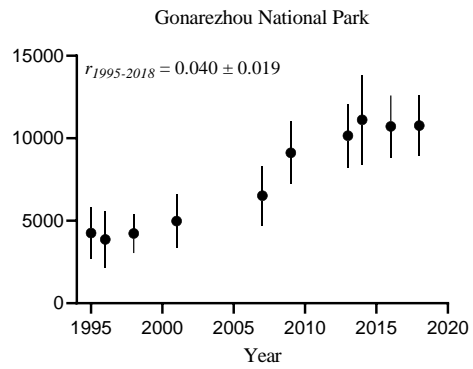
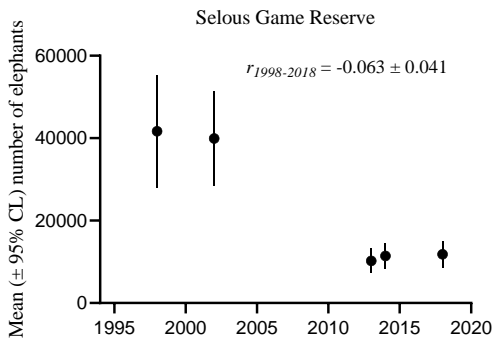
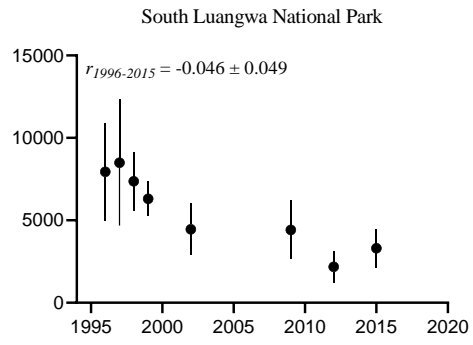
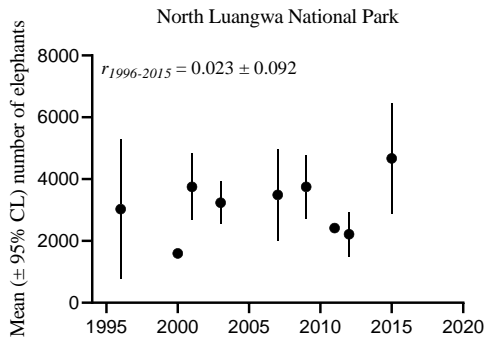
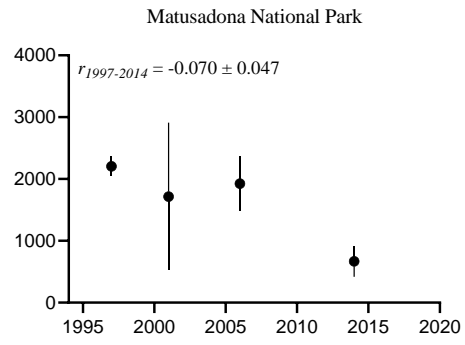
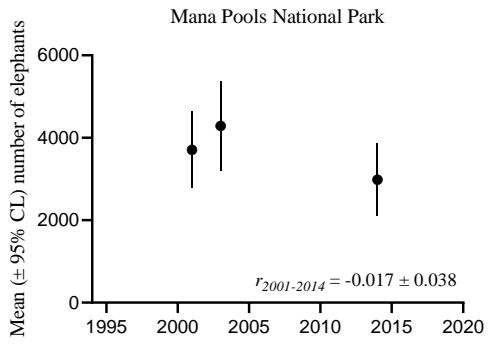


Figure S12 continues.

Table S14. Growth rates for 33 elephant populations in small buffer areas. Growth rates (“ $r \pm SE$ ”) were calculated using the density-independent diffusion approximation model (54, 77). “Time-period” gives the start and end year for which “ n ” number of estimates were extracted. “ p ” values in bold indicate the slope (growth rate) to be statistically significant different from zero ($p < 0.05$).

Cluster	Population	Time period (n)	$r \pm SE$	F	df	p
Etosha	North West Namibia	1995-2016 (6)	0.058 ± 0.098	0.348	1, 4	0.587
Chobe	Salambala/Impalila	2004-2019 (4)	-0.025 ± 0.135	0.135	1, 2	0.870
Chobe	Bwabwata National Park	1998-2015 (5)	0.337 ± 0.293	1.320	1, 3	0.333
Kafue	Nkala Game Management Area	2004-2011 (4)	-0.131 ± 0.083	2.490	1, 2	0.255
Kafue	Kasonso-Busanga Game Management Area	1997-2011 (5)	0.227 ± 0.766	0.088	1, 3	0.786
Kafue	Lunga-Lushwishi Game Management Area	1996-2011 (4)	0.000 ± 0.515	0.000	1, 2	0.999
Kafue	Mulobezi Game Management Area	1997-2011 (6)	0.480 ± 0.287	2.800	1, 4	0.169
Kafue	Mumbwa Game Management Area	1997-2011 (6)	0.087 ± 0.626	0.019	1, 4	0.896
Kafue	Namwala Game Management Area	1997-2011 (3)	0.000 ± 0.693	0.000	1, 1	1.000
Kafue	Sichifula Game Management Area	1997-2011 (5)	-0.423 ± 0.616	0.476	1, 3	0.541
Zambezi	Sijarira Forest	1997-2014 (4)	-0.048 ± 0.291	0.027	1, 2	0.885
Zambezi	Binga Communal Land	1997-2014 (4)	-0.155 ± 0.033	21.50	1, 2	0.044
Zambezi	Charara Safari Area	2001-2014 (3)	-0.215 ± 0.331	0.422	1, 1	0.633
Zambezi	Chete Safari Area	1997-2014 (4)	-0.090 ± 0.045	4.090	1, 2	0.180
Zambezi	North Gokwe Communal Land	1997-2014 (4)	-0.398 ± 0.186	4.570	1, 2	0.166
Luangwa	Sandwe Game Management Area	1996-2012 (3)	-0.419 ± 0.201	4.330	1, 1	0.285
Luangwa	Chisomo Game Management Area	1996-2009 (3)	0.000 ± 0.887	0.000	1, 1	1.000
Luangwa	Lumimba Game Management Area	1996-2012 (4)	-0.149 ± 0.260	0.329	1, 2	0.624
Luangwa	Lupande Game Management Area	1996-2012 (5)	-0.032 ± 0.066	0.234	1, 3	0.661
Luangwa	Munyamadzi Game Reserve	1996-2012 (3)	0.165 ± 0.273	0.365	1, 1	0.654
Luangwa	Musalungu Game Management Area	1996-2012 (5)	0.062 ± 0.085	0.533	1, 3	0.518
Niassa	Niassa-Quirimbas Corridor	2011-2018 (3)	-0.779 ± 0.754	1.070	1, 1	0.490
Niassa	Quirimbas National Park	2011-2018 (3)	-0.903 ± 0.631	2.050	1, 1	0.388
Niassa	Selous-Masasi Corridor	2000-2018 (4)	0.000 ± 0.478	0.000	1, 2	1.000
Mapungubwe	Sentinal Ranch & Nottingham Estate	2000-2014 (6)	-0.007 ± 0.128	0.003	1, 4	0.959
Mapungubwe	Tuli Safari Area	2000-2014 (8)	0.001 ± 0.571	0.000	1, 6	0.998
Mapungubwe	Tuli Block	2000-2014 (8)	0.017 ± 0.160	0.012	1, 6	0.918
Mapungubwe	Vhembe Game Reserve	2000-2014 (8)	-0.029 ± 0.470	0.004	1, 6	0.953
Limpopo	Mahenye	1996-2018 (7)	-0.015 ± 0.346	0.002	1, 5	0.968
Limpopo	Malapati Safari Area	2001-2018 (6)	0.208 ± 0.438	0.224	1, 4	0.660

Cluster	Population	Time period (n)	$r \pm SE$	F	df	p
Limpopo	Malilangwe Wildlife Reserve	1999-2013 (6)	0.064 ± 0.049	1.690	1, 4	0.264
Limpopo	Palaborwa Mining Company	1996-2017 (10)	-0.038 ± 0.125	0.090	1, 8	0.772
Limpopo	Limpopo National Park	2006-2014 (3)	0.068 ± 0.052	1.720	1, 1	0.415

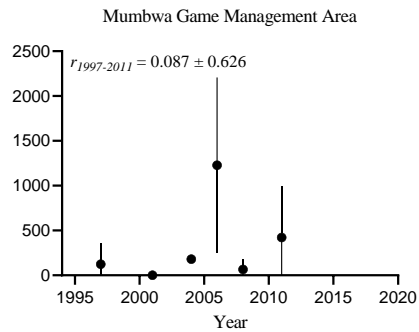
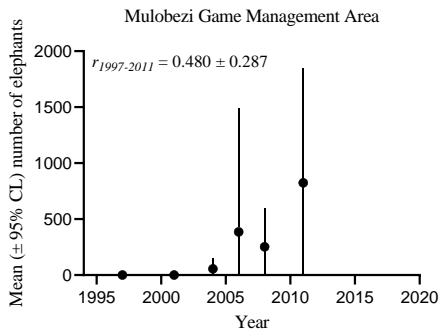
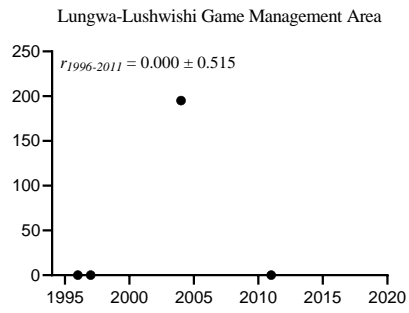
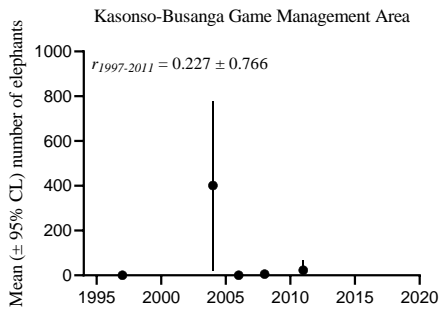
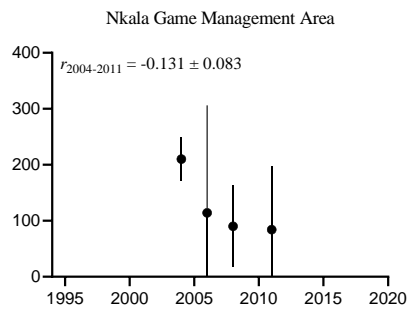
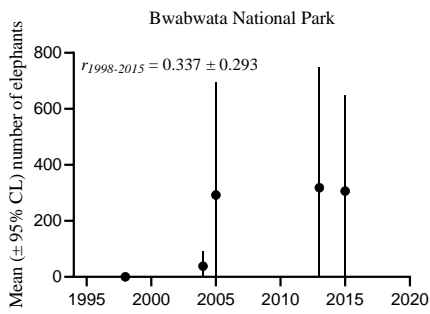
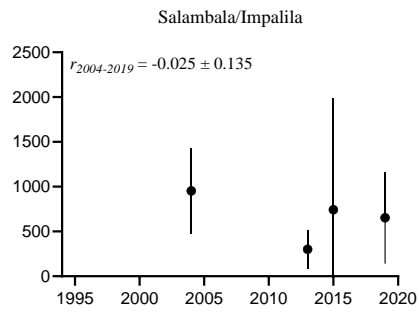
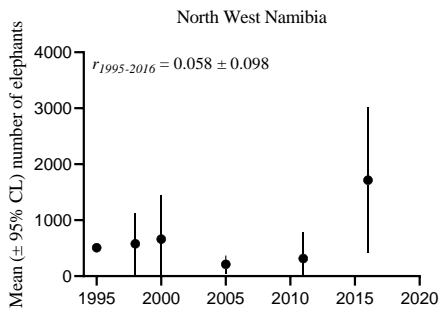


Figure S13. The mean (\pm 95% CL) number of elephants for 33 populations in small buffer areas extracted from 1995 to 2020. The growth rates ($r \pm$ SE) were calculated using the density-independent diffusion approximation model (54, 77). The Y-axes were not standardized.

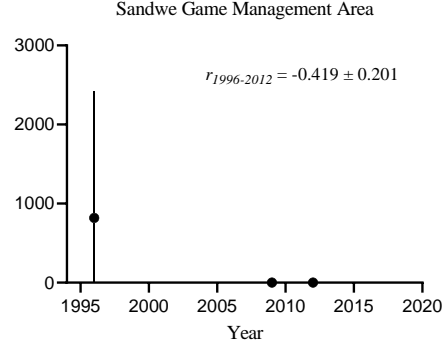
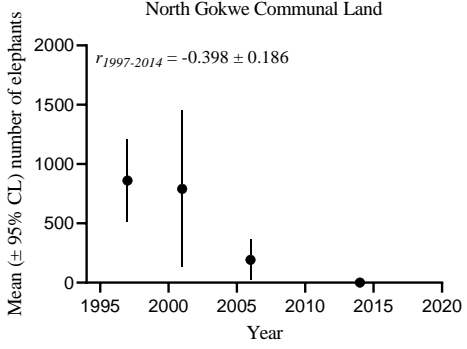
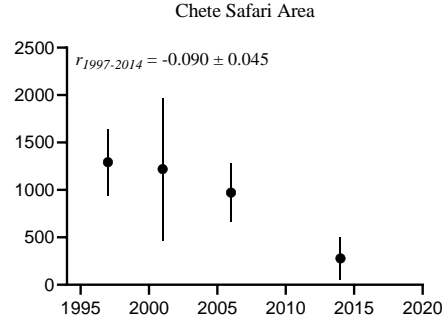
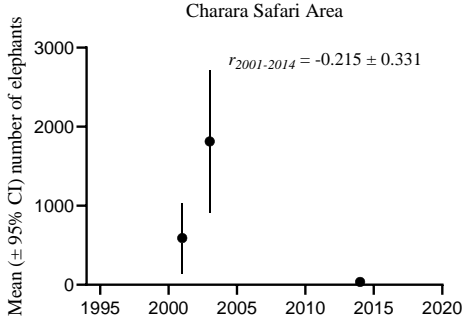
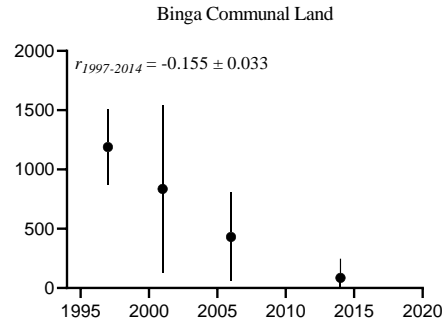
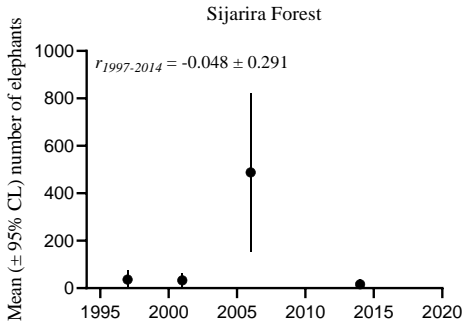
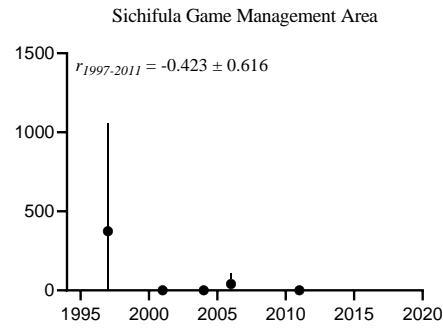
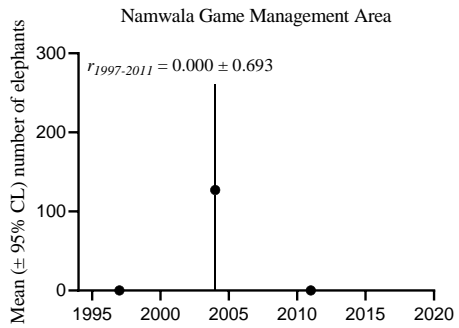


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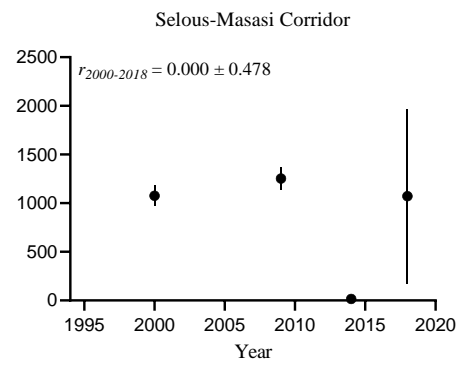
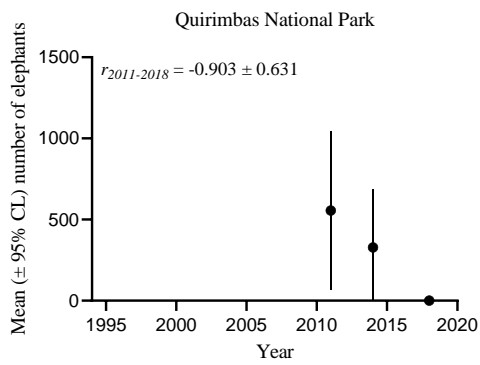
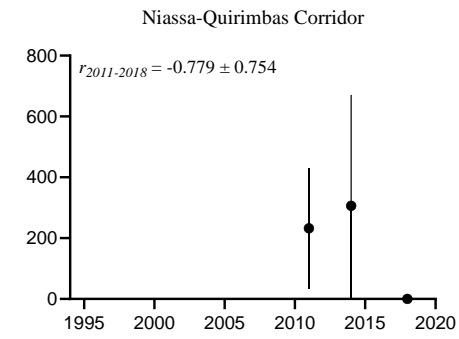
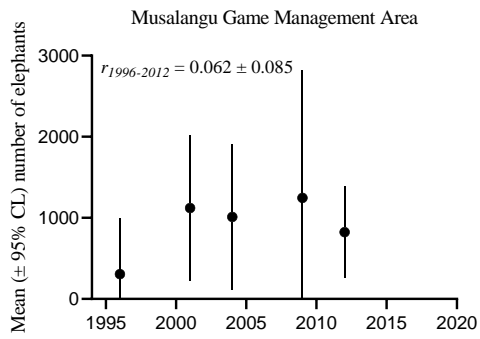
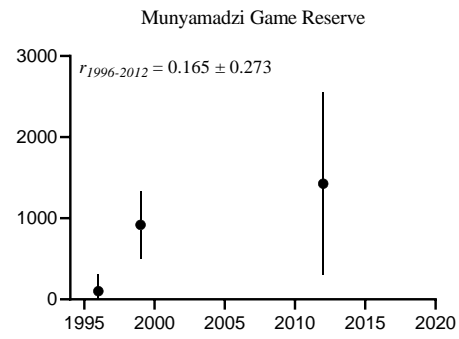
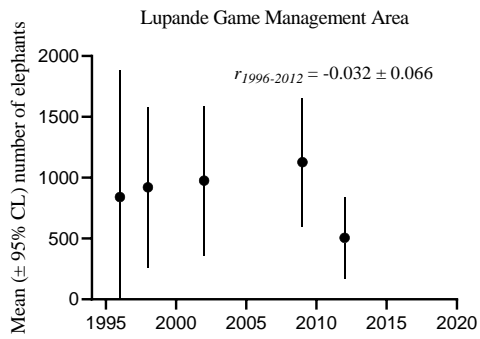
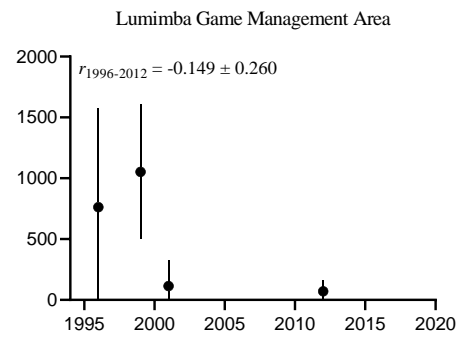
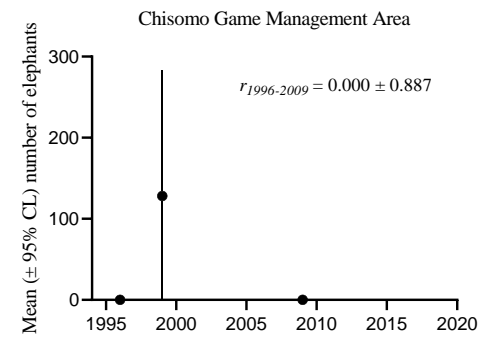


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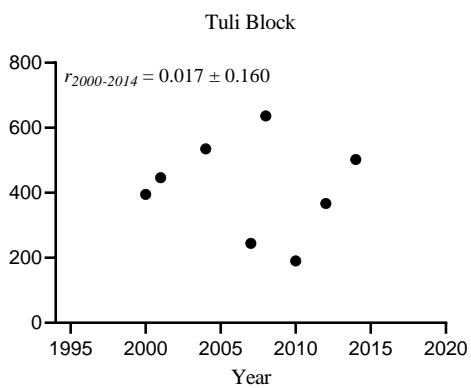
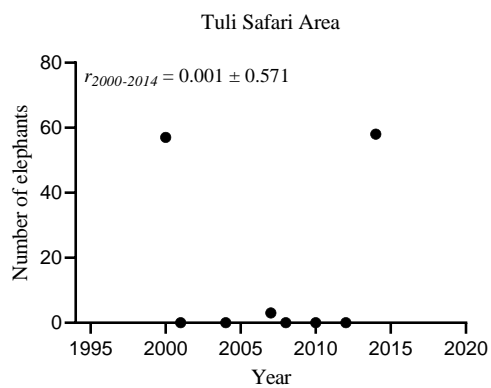
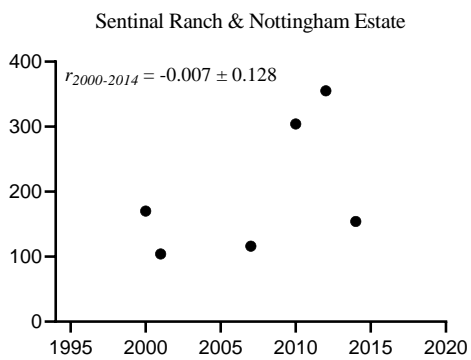
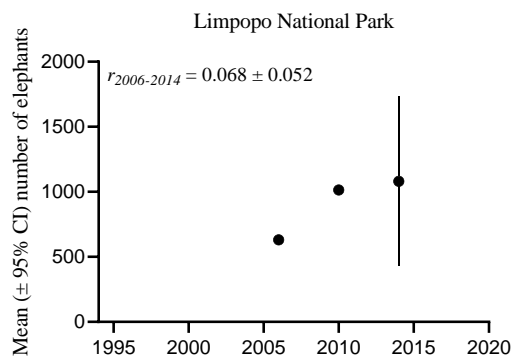
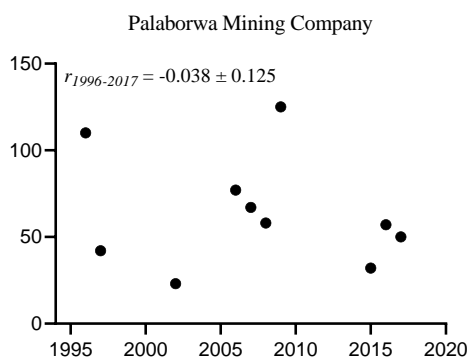
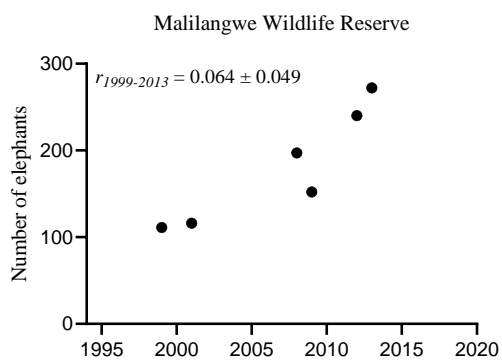
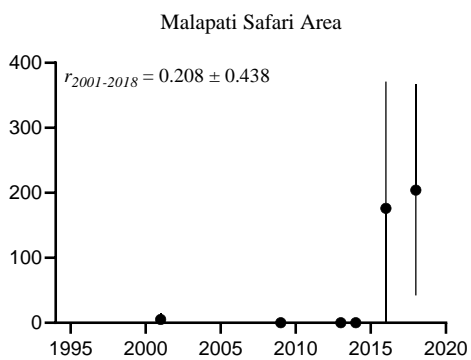
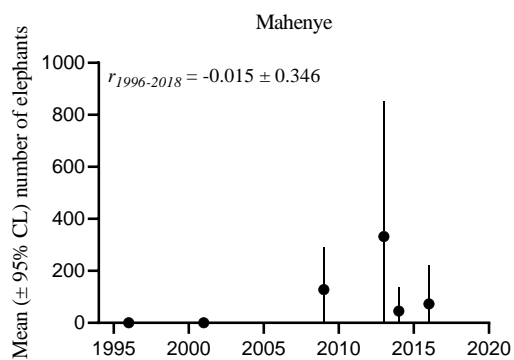


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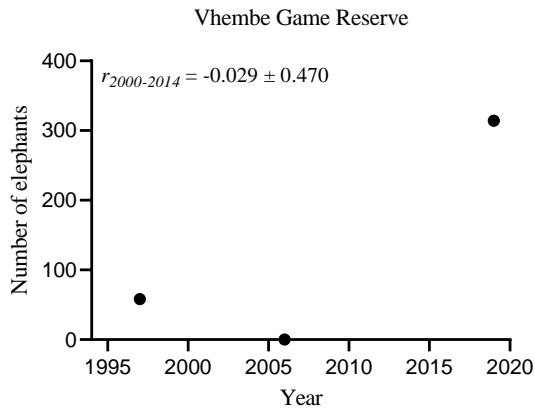


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Table S15. Growth rates for 22 elephant populations in large buffer areas. Growth rates (“ $r \pm SE$ ”) were calculated using the density-independent diffusion approximation model (54, 77). “Time-period” gives the start and end year for which “ n ” number of estimates were extracted. “ p ” values in bold indicate the slope (growth rate) to be statistically significant different from zero ($p < 0.05$).

Cluster	Population	Time period (n)	$r \pm SE$	F	df	p
Chobe	Buffalo/Mahango Core	2004-2015 (4)	0.030 ± 0.158	0.037	1, 2	0.865
Chobe	Central District	1996-2018 (9)	0.331 ± 0.376	0.775	1, 7	0.408
Chobe	Chobe District East	1996-2018 (9)	0.085 ± 0.150	0.321	1, 7	0.589
Chobe	Chobe District North	1996-2018 (10)	-0.019 ± 0.172	0.012	1, 8	0.914
Chobe	Kwando Core	2004-2015 (4)	0.005 ± 0.075	0.004	1, 2	0.955
Chobe	Matabeleland Forested Area	1996-2014 (5)	0.067 ± 0.331	0.257	1, 3	0.647
Chobe	Matetsi Complex	1996-2014 (5)	-0.004 ± 0.077	0.003	1, 3	0.959
Chobe	Ngamiland District North	1996-2018 (9)	-0.004 ± 0.027	0.022	1, 7	0.888
Chobe	Ngamiland District West	2010-2018 (3)	0.061 ± 0.067	0.831	1, 1	0.529
Chobe	Nyae Naye Conservancy	1998-2015 (5)	0.083 ± 0.201	0.170	1, 3	0.708
Zambezi	Chewore Safari Area	2001-2014 (4)	-0.043 ± 0.057	0.565	1, 2	0.531
Zambezi	Chirisa Safari Area	1997-2014 (4)	-0.027 ± 0.139	0.036	1, 2	0.866
Zambezi	Dande	1995-2014 (4)	-0.005 ± 0.042	0.016	1, 2	0.911
Zambezi	Hurungwe Safari Area	2001-2014 (3)	-0.025 ± 0.061	0.173	1, 1	0.749
Zambezi	Kariba Communal Land	1997-2014 (4)	-0.101 ± 0.118	0.736	1, 2	0.481
Zambezi	Sapi Safari Area	2001-2014 (3)	-0.095 ± 0.061	2.440	1, 1	0.362
Zambezi	Magoe District	1995-2014 (5)	0.131 ± 0.098	1.810	1, 3	0.271
Luangwa	West Petauke Game Management Area	1996-2009 (3)	-0.600 ± 0.146	16.80	1, 1	0.152
Niassa	Kilombero Game Controlled Area	2002-2018 (4)	-0.546 ± 0.260	4.400	1, 2	0.171
Niassa	Niassa adjacent	2009-2018 (3)	-0.182 ± 0.001	28400	1, 1	0.004
Niassa	Niassa Ecosystem	1997-2018 (9)	-0.033 ± 0.066	0.250	1, 7	0.633
Niassa	Selous-Niassa Corridor	2000-2018 (5)	-0.079 ± 0.108	0.530	1, 3	0.519

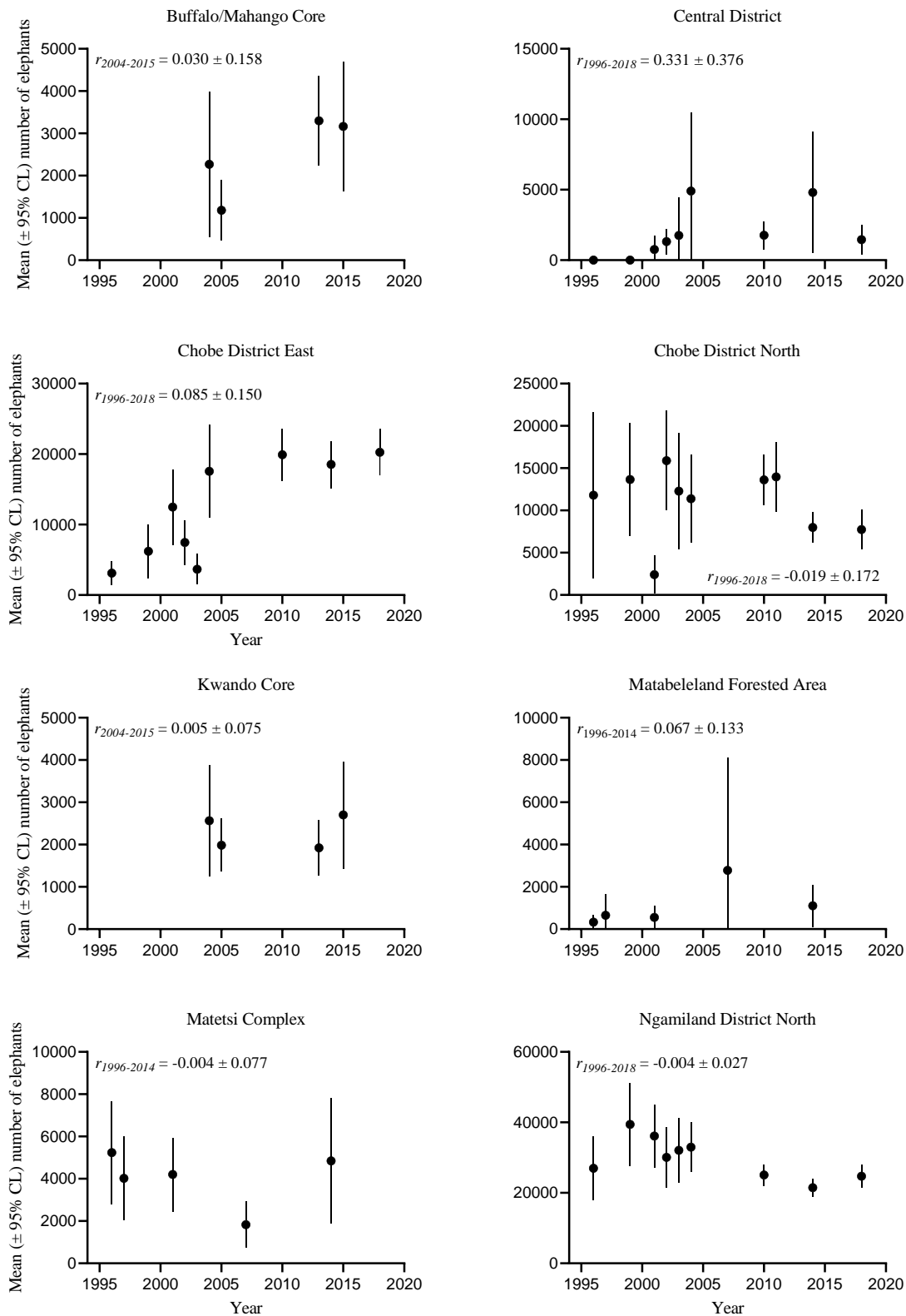


Figure S14. The mean (\pm 95% CL) number of elephants for 22 populations in large buffer areas extracted from 1995 to 2020. The growth rates ($r \pm SE$) were calculated using the density-independent diffusion approximation model (54, 77). The Y-axes were not standardized.

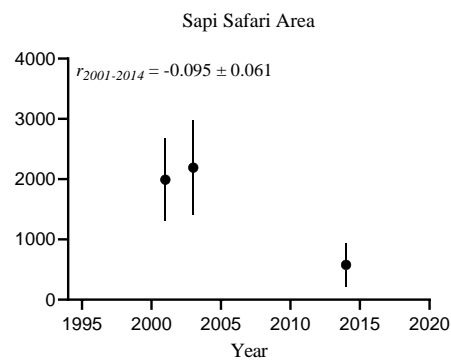
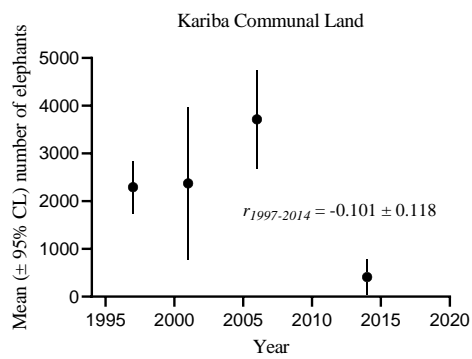
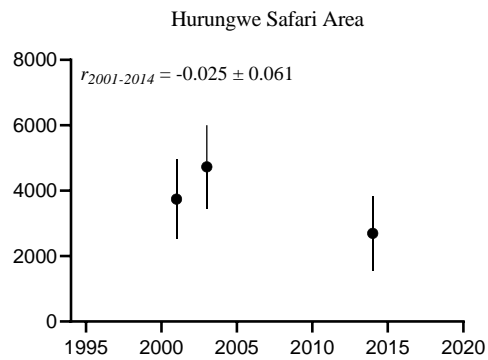
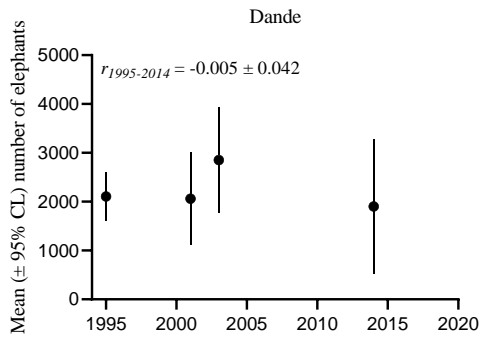
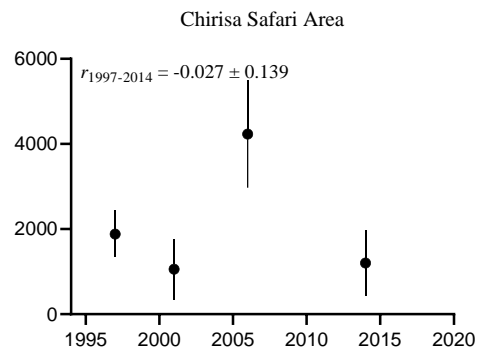
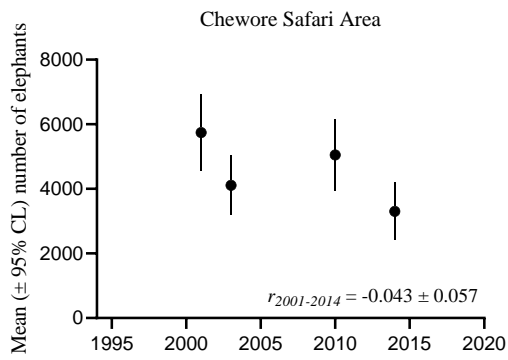
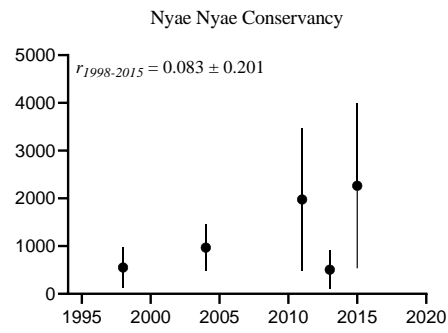
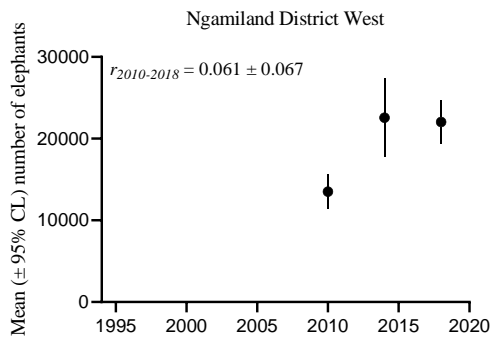


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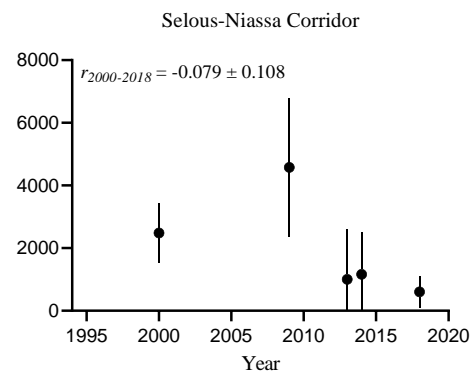
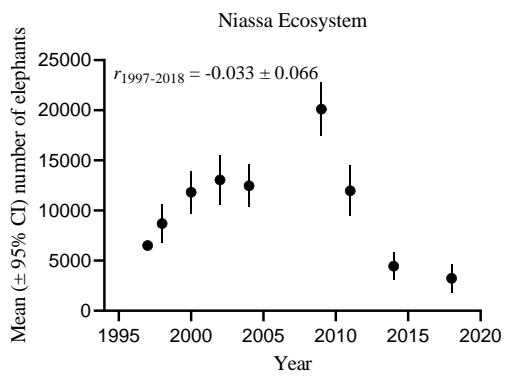
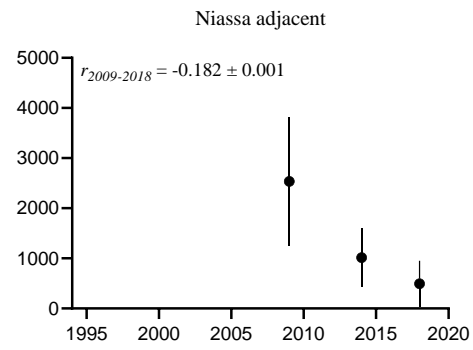
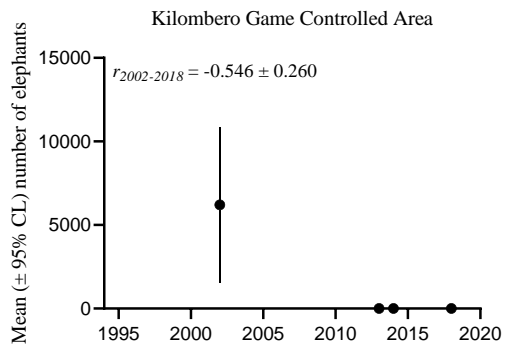
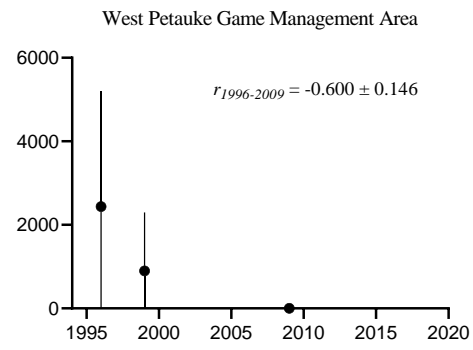
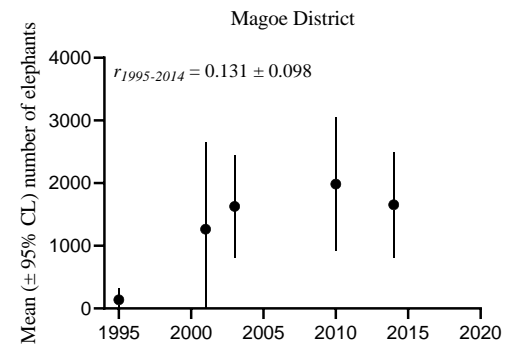


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