RESEARCH ARTICLE

A 20-year review of the status and distribution of African wild dogs (*Lycaon pictus*) in South Africa

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South Africa is one of only seven countries with a viable population of African wild dogs (*Lycaon pictus*). The national population in 2017 was 372 adults and yearlings and comprised three subpopulations: 1) Kruger National Park (Kruger), 2) an intensively managed metapopulation established through reintroductions into isolated, fenced reserves, and 3) a free-roaming population that occurs naturally outside protected areas. We assessed the long-term (four wild dog generations, ~20 years) trends in population size and growth rate within each of these three subpopulations. We found that Kruger supports a substantial population, which has declined over time. The metapopulation is the only subpopulation that has increased significantly over time (both in population size and number of packs), likely due to intensive conservation efforts and the reintroduction of wild dogs into 15 additional reserves since 1998. The free-roaming subpopulation has remained small but stable, even though the number of packs has declined due to anthropogenic threats. The overall national population has remained stable even though the number of packs has increased. Kruger has consistently supported the highest proportion of the national population over the last two decades. However, the contribution of the metapopulation has increased significantly over time. It is clear that despite differences in survey effort among the three subpopulations, South Africa has a small (~500) but stable population of wild dogs, with the metapopulation contribution becoming increasingly important. The circumstances in the country necessitate, and demonstrate the benefit of, intensive, adaptive management for the national population of wild dogs. While this assessment provides baseline information for the three subpopulations, wild dog conservation in South Africa would benefit greatly from equal survey effort and standardized methods to accurately assess long-term population trends.

Keywords: conservation, data collection, managed metapopulation, reintroduction.

INTRODUCTION

The African wild dog (*Lycaon pictus*) is globally listed as Endangered, with the latest available data suggesting a population of about 6600 individuals, including ~1400 mature individuals in 39 subpopulations (Woodroffe & Sillero-Zubiri, 2012). Their range and distribution are fragmented (Fanshawe, Ginsberg, Sillero-Zubiri & Woodroffe, 1997) and wild dogs now occur in only 14 of the 39 countries they historically inhabited, with viable populations (consisting of more than eight packs) in just seven countries (Lindsey & Davies-Mostert, 2009; Woodroffe & Sillero-Zubiri, 2012). It is estimated that wild dog range has contracted by 93% (Ripple & Wolf, 2017). Primary anthropogenic threats to the species include loss of prey and habitat, direct persecution, such as conflict killing, (Woodroffe, Lindsey, Romanach, Stein & Ole Ranah, 2005), indirect persecution, such as snaring and road kills, and in some instances, utilization of body parts for traditional medicine (Everatt, Kokes & Lopez Pereira, 2019).

South Africa is one of the seven countries that contains a viable population of wild dogs (Mills, *et al.*, 1998). The national population comprises three distinct subpopulations, the first of which

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occurs in the Kruger National Park (hereafter Kruger). This population is the stronghold for wild dogs in South Africa, where the species is largely unmanaged and is well monitored *via* long-term surveys based on photographic returns from tourists (Maddock, 1989; Maddock & Mills, 1994). The second subpopulation is the managed metapopulation (hereafter 'metapopulation'), which occurs across several small (≤1000 km^2), fenced, and geographically isolated reserves. The metapopulation (Mills *et al.*, 1998) was established through reintroductions, to establish a second viable population of wild dogs in South Africa outside Kruger. Periodic translocation of individuals among the different reserves aims to mimic natural dispersal and colonization, and promotes gene flow (Davies-Mostert, Mills & Macdonald, 2009, 2015). The metapopulation approach allows for the utilization of habitat fragments that would otherwise be too small for successful wild dog conservation (Woodroffe & Ginsberg, 2001). Wild dogs were first reintroduced into Hluhluwe-iMfolozi Park (KwaZulu-Natal province – KZN) in 1980, and subsequently into 15 other reserves around the country (WAG-SA meeting minutes). Generally, all packs in the metapopulation are intensively monitored. The third subpopulation comprises free-roaming packs (defined as those which are unmanaged and wide-ranging) that occur naturally outside the managed metapopulation reserves and Kruger, in the northern and northeastern parts of the country (Lindsey, du Toit & Mills, 2004). These wild dogs reside on and traverse private and communal land, where livestock or wildlife ranching are the primary economic activities, and with low human population densities close to source populations (Lindsey *et al.*, 2004). The dynamics of free-roaming wild dogs are poorly understood due to their low density, elusive nature, wide-ranging nature, and constraints around access by researchers to land due to private land tenure. There is therefore a lack of robust data regarding this subpopulation, but it is suspected to be vulnerable to persecution from landowners (Thorn, Green, Dalerum, Bateman & Scott, 2012).

Several partial assessments of the South African wild dog population have been conducted, including five photographic censuses in Kruger (Maddock, 1989; Maddock & Mills, 1994; Wilkinson, 1995; Davies, 2000; Kemp & Mills, 2005; Marnewick, Ferreira, Grange, Watermeyer, Maputla *et al.*, 2014; Knutson, 2015); ongoing documentation of the metapopulation (WAG-SA meeting minutes; Davies-Mostert *et al.*, 2009; Gusset, Ryan, Hofmeyer *et al.*, 2008); and an assessment of the status of the species outside protected areas during the late 1990s and early 2000s (WAG-SA meeting minutes; Lindsey *et al.*, 2004).

As almost 64% of terrestrial large carnivores are threatened with extinction and 80% are declining in number (Wolf & Ripple, 2018), baseline knowledge on the status and trends of populations is key for effective conservation. Therefore, an understanding of a rapidly declining population can inform governments and relevant land managers to guide urgent conservation effort to halt further decline and avoid extirpation or extinction. This knowledge can also contribute to regional and national species assessments.

In this study, we consolidate documentation of the entire South African wild dog population, and we present updated population estimates and growth rates from all three subpopulations between 1998 and 2017. Due to the different sampling techniques and efforts available for population data, we aim to present descriptions of the population rather than providing detailed comparisons and analysis. We predicted (1) a relatively stable population in Kruger due to the size of the protected area allowing for natural population dynamics, (2) an increasing metapopulation due to extensive reintroduction efforts over the last 20 years, (3) a declining free-roaming population due to extensive changes in land-use practises in South Africa that have rendered large areas unsuitable for free-roaming packs due to human–wildlife conflict, and (4) a stable national population with shifting relative contributions of each subpopulation over time.

METHODS

We classified data into four periods reflecting the generation length of wild dogs (five years; Woodroffe & Sillero-Zubiri, 2012; Davies-Mostert *et al.*, 2016): 1998–2002, 2003–2007, 2008–2012 and 2013–2017. We defined annual population size as the sum of adults and yearlings midway through the breeding cycles (*i.e.* at the first available estimate for the year, closest to 1 January (*cf.* Maddock & Mills, 1994). We defined a pack as a group containing at least one adult male and adult female. Each subpopulation had varying methods and intensities of data collection (Table 1), but we ensured comparability of data by providing population size and number of packs for

Table 1. Summary and description of the data and methods used for each wild dog subpopulation.

Subpopulation	Description	References
Kruger National Park	• Photographic census every 4–5 years (2000, 2005, 2009, 2014) • Regular monitoring between 2010 and 2018	Maddock, 1989, Maddock & Mills, 1994, Wilkinson, 1995, Davies, 2000, Kemp & Mills, 2005, Marnewick *et al.,* 2014
Metapopulation	• Total count of individuals through intensive daily monitoring • All packs radio-collared	WAG-SA minutes, Mills *et al*., 1998, Davies-Mostert *et al*., 2015
Free-roaming	• Opportunistic reports to WAG-SA members • Some individuals collared during study years	Lindsey *et al.,* 2004

January/February each year at the WAG-SA meeting. This represented a population estimate midway through the normal breeding cycle for wild dogs (Maddock & Mills, 1994) and has been used for population descriptions previously (Davies-Mostert *et al*., 2015). Although we do not provide analyses on mortality data due to large inter-population discrepancies in survey methods (Table 1), we have included the confirmed cases of mortality for each subpopulation in Supplementary Table S1.

Kruger subpopulation

Photographic surveys of wild dogs were conducted in Kruger in 1995, 2000, 2005, 2009 and 2014 (*cf.* Maddock & Mills, 1994). We used these surveys to provide a minimum count of individuals based on the identification of unique coat patterns (Maddock & Mills, 1994). Thus, population estimates were available for census years. For years between censuses, we used linear regression to infer the population size. It is important to note that by using this method we are assuming that the populations changed linearly between population estimates. Regular monitoring was conducted by a researcher from the Endangered Wildlife Trust (EWT) between 2010 and 2018 and for those years we are able to present individual counts as packs and their individuals were known.

Managed metapopulation

All packs in the metapopulation are radio-collared and intensively monitored, with monitoring teams aiming for at least monthly pack estimates. This effort over 20 years has provided not only population size estimates and number of packs but also individual life history data from approximately three months of age until death. As managed metapopulation reserves were intensively monitored and few individuals naturally immigrated into each subpopulation, counts for known packs in each reserve are likely to be the absolute count for that reserve. We used data from WAG-SA meeting minutes that were provided by reserve management and researchers to WAG-SA.

Free-roaming subpopulation

We adopted methods used by Lindsey *et al*. (2004), which demonstrated that the collection and analysis of *ad hoc* sighting data represents a useful approach for estimating the distribution of wild dogs and providing conservative estimates of population size over large areas. This enabled us to delineate sightings among different free-roaming packs. We consolidated sightings data between January 1998 and December 2017 from several sources:

a) Direct correspondence with provincial wildlife authorities (1998–2017);
b) Interviews with ranchers from three focal areas where published records mention wild dog activity (conducted during 2000–2002, Lindsey *et al*., 2004) (Limpopo Valley, n = 28; Central Lowveld, n = 149; and KZN, n = 37);
c) *Ad hoc* sightings reported to WAG-SA members and recorded in WAG-SA minutes (between 1998 and 2017);
d) A pool of expert respondents (*e.g.* field guides, researchers, landowners, key respondents from the surveys in ‘b’ above) was identified and contacted regularly to provide information on sightings of wild dogs outside protected areas (between 1998 and 2017);
e) Field researchers also provided additional

sightings data from the Waterberg region of South Africa (a known hotspot of wild dog activity, Lindsey *et al.*, 2004) and northwestern KZN (2006 – current) (WAG-SA). The researcher in charge of each project collected sightings through a process of networking with local stakeholders; and

f) In 2013 and 2014, posters of wild dogs were put up in towns in the Waterberg area (*e.g.* Vaalwater, Thabazimbi, Lephalale) to raise awareness of free-roaming packs and to encourage the public to report sightings (EWT unpubl. data).

Due to the wide-ranging behaviour of wild dogs and active stakeholder networks in key parts of the country, we are confident that if any packs were resident in an area for any length of time that we would have received reports of their presence. Additionally, long-distance dispersing groups of wild dogs stand a high chance of being reported at some stage during their movements outside protected areas (Davies-Mostert *et al.*, 2012).

We identified areas of high reporting frequencies of free-roaming dogs using frequency of occurrence over the four periods (for the purpose of this assessment we will refer to these areas as 'core areas'). We illustrated core areas as those quarter degree squares (QDS) that had sightings in each of the four periods (1998–2002, 2003–2007, 2008–2012 and 2013–2017). Peripheral areas, reported less frequently, were illustrated as only having sightings in that QDS square in two or fewer of the periods.

Data handling and statistical analyses

We calculated annual population growth rate (*i.e.* instantaneous population growth) as $\ln(n_{t+1}/n_t)$ which was the natural logarithm of the change in population size (n) from one year (t) to the next ($t + 1$) (Turchin, 1990).

We used linear regressions to test how population size, number of packs, and annual population growth rate changed over time for all three subpopulations from 1998 to 2017. For the managed metapopulation only, we also used linear regressions to test the effect of year on (1) the number of reserves and (2) area size. As there were no reliable records for the number of packs in Kruger between census sample studies, we could not assess the effect of year on pack size in this case.

We used a Shapiro-Wilks test to test for normality and determine if the annual population growth rates were different between the three subpopulations. The data were found to be normal (W = 0.965, P = 0.09), thus a one-way ANOVA was completed to determine if there were differences in the growth rate between the three subpopulations.

Mean and standard deviations are presented throughout, and we performed all statistical analyses and compiled all figures in RStudio, desktop version 1.1.456 for Windows using functions in the packages *dunn.test* (Dinno, 2016), *rcompanion* (Mangiafico, 2019) and *ggplot2* (R Team, 2015).

RESULTS

Kruger subpopulation

The mean annual population size in Kruger was 163 ± 34 adults and yearlings (range: 115–262; Fig. 1), and the population size has declined over time ($F_{(1,18)} = 4.99$, $P = 0.04$, $R^2 = 0.21$; Fig. 1). Although the population growth rate decreased by a mean of 3% per annum, (±0.21%, range: 0.36–0.56), this was not a significant interannual decrease ($F_{(1,17)} = 0.52$, $P = 0.48$, $R^2 = 0.03$) and as such the subpopulation has remained relatively stable over time.

Metapopulation

The mean annual metapopulation size was 108 ± 41.08 adults and yearlings (range: 37–160; Fig. 1), and the population has increased over time ($F_{(1,18)}$ = 22.42, P < 0.001, R^2 = 0.56). The mean annual number of packs in the metapopulation was 12 ± 6 (range: 1–20) and this increased over time ($F_{(1,18)}$ = 202.8, P < 0.001, R^2 = 0.92). The mean annual growth rate of the metapopulation was 6% (±0.24%, range: –0.46–0.47) but this remained stable over time as we found no significant interannual increase ($F_{(1,17)}$ = 0.17, P = 0.69, R^2 = 0.01).

The mean annual number of reserves comprising the metapopulation was 7 ± 3.13 (range: 2–14), and this increased over time ($F_{(1,18)} = 82.69$, P < 0.001, R^2 = 0.82; Table 2). Consequently, the mean area encompassed by metapopulation reserves increased over time (from 1516 to 5385 km^2; $\bar{x} = 3753 \pm 1200$ km^2 ($F_{(1,18)} = 47.56$, $P <$ 0.0001, R^2 = 0.73; Table 2).

Free-roaming subpopulation

The mean annual free-roaming population size was 79 ± 18 adults and yearlings (range: 46–104; Fig. 1) across five provinces (Fig. 2a–d), but the size of this subpopulation was constant over time

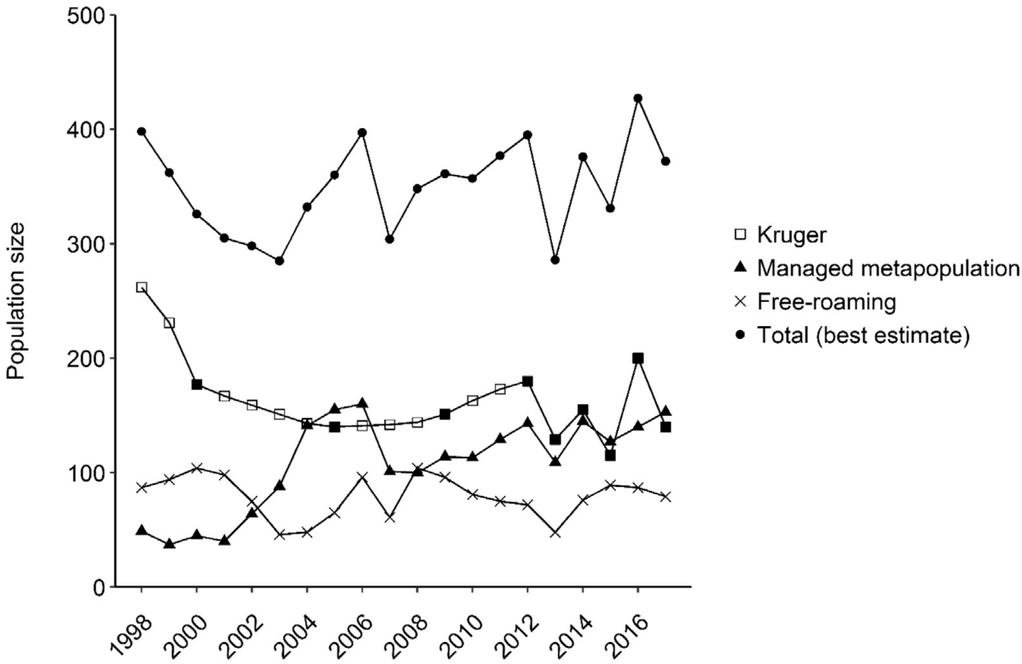


Fig. 1. Wild dog population size amongst the three subpopulations in South Africa during 1998–2017. (Note: For the Kruger population, the black squares represent the census/monitoring years while the white squares represent the periods where estimates were used).

($F_{(1,18)}$ = 0.31, P = 0.58, R^2 = –0.04). However, the number of free-roaming packs decreased over time ($F_{(1,18)}$ = 11.56, P = 0.00, R^2 = 0.39). The mean annual population growth rate declined at 1% per annum (±0.29 range: –0.49–0.53) but this remained stable over time as we found no significant interannual decrease ($F_{(1,17)}$ = 0.05, P = 0.83, R^2 = 0.00).

Sightings of free-roaming wild dogs outside protected areas still occur in the Limpopo province (especially around Marakele National Park; even though an introduced pack of wild dogs was removed in 2007). Since the removal of wild dogs from the De Beers Venetia Limpopo Nature Reserve in 2010 (northern Limpopo), the frequency of reported sightings of the species in that area has declined. The 'core areas' for wild dogs (based on occurrence; Fig. 3) occur predominantly in Limpopo; specifically, in the Waterberg, along the Zimbabwe/South Africa border, and between Mpumalanga and Limpopo (near the Kruger).

National population

The mean annual national population size of wild dogs was 350 ± 40.52 (range: 285–427; Fig. 1) with the highest count recorded in January 2016 with an estimated 427 adults and yearlings (Fig. 1). The mean annual population size was stable over the study period ($F_{(1,18)}$ = 1.74, P = 0.20, R^2 = 0.04) even though the number of packs increased over time ($F_{(1,18)}$ = 37.99, P < 0.0001, R^2 = 0.68). The contributions of Kruger and the metapopulation towards the national population changed over time. Kruger consistently contributed the greatest proportion of the national population ($\bar{x}$ = 46.75% ± 8.51, range: 34.7–65.8%), although this contribution decreased over time ($F_{(1,18)}$ = 19.72, P < 0.001, R^2 = 0.50). The metapopulation contributed the second highest proportion towards the national population ($\bar{x}$ = 30.6% ± 10.7; range: 10.2–43.1%), and this contribution increased significantly over time ($F_{(1,18)}$ = 18.85, P < 0.00, R^2 = 0.48). The free-roaming population consistently contributed the smallest proportion to the national population ($\bar{x}$ = 22.64% ± 5.10; range: 14.5–32.1%) and this contribution did not change over time ($F_{(1,18)}$ = 1.653, P = 0.22, R^2 = 0.03).

The mean annual national population growth rate was 0.00 ± 0.16 (range: –0.32–0.27) and was stable over time ($F_{(1,17)}$ = 0.24, P = 0.63, R^2 = –0.04). Moreover, we found no significant differences in annual population growth rates among the three subpopulations ($F_{(2,54)}$ = 0.49, P = 0.70).

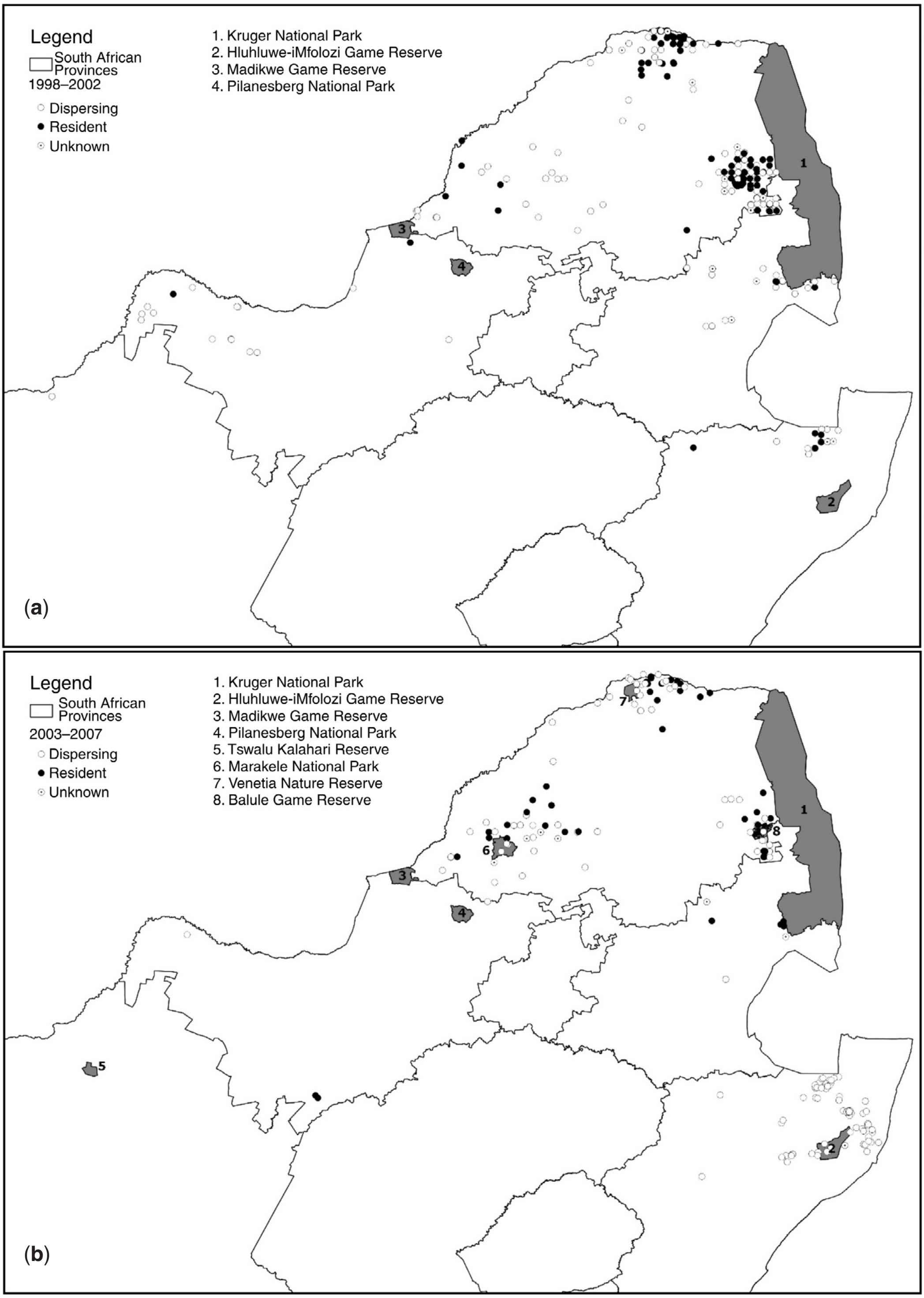
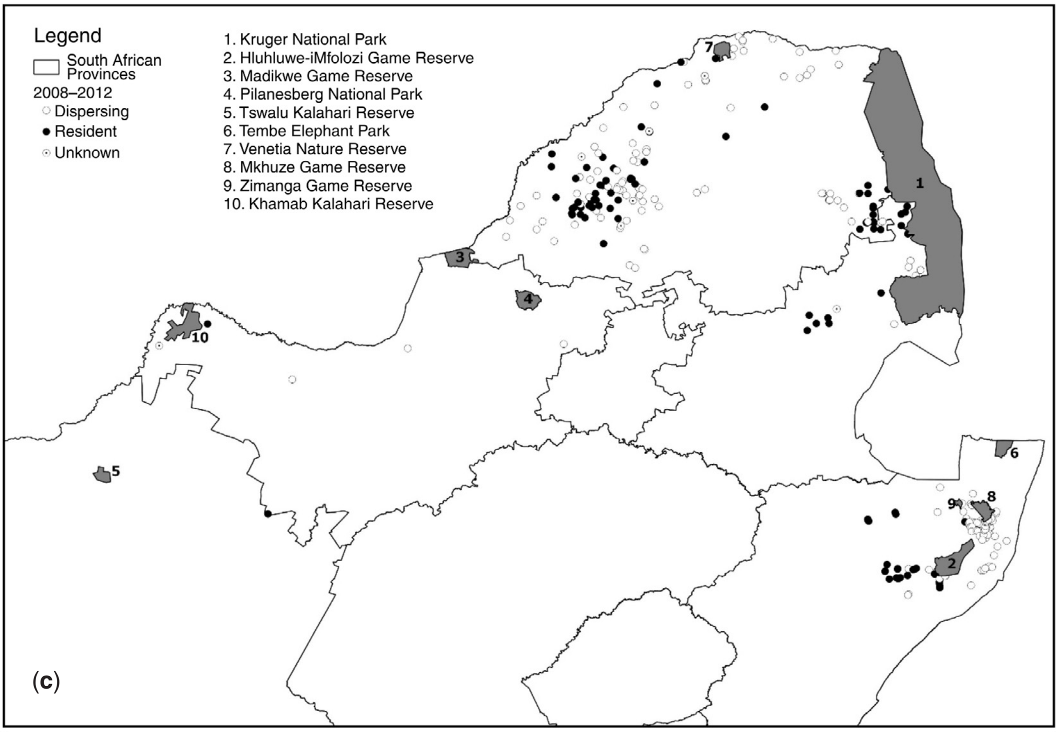


Fig. 2. The distribution of free-roaming wild dogs in South Africa during four time periods: **a**, 1998–2002; **b**, 2003–2007; **c**, 2008–2012; **d**, 2013–2017. Numbers refer to national parks, state-run game reserves, private game reserves and one community-run game reserve within the managed metapopulation. (Continued on p. 14.)



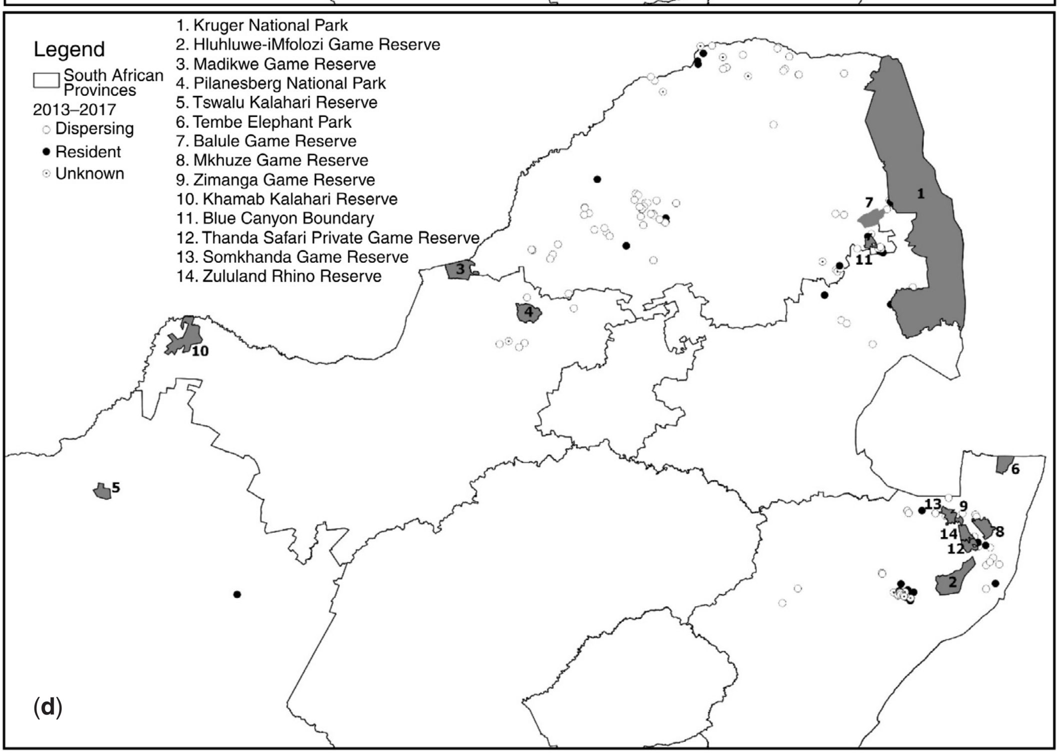


Fig. 2 (continued).

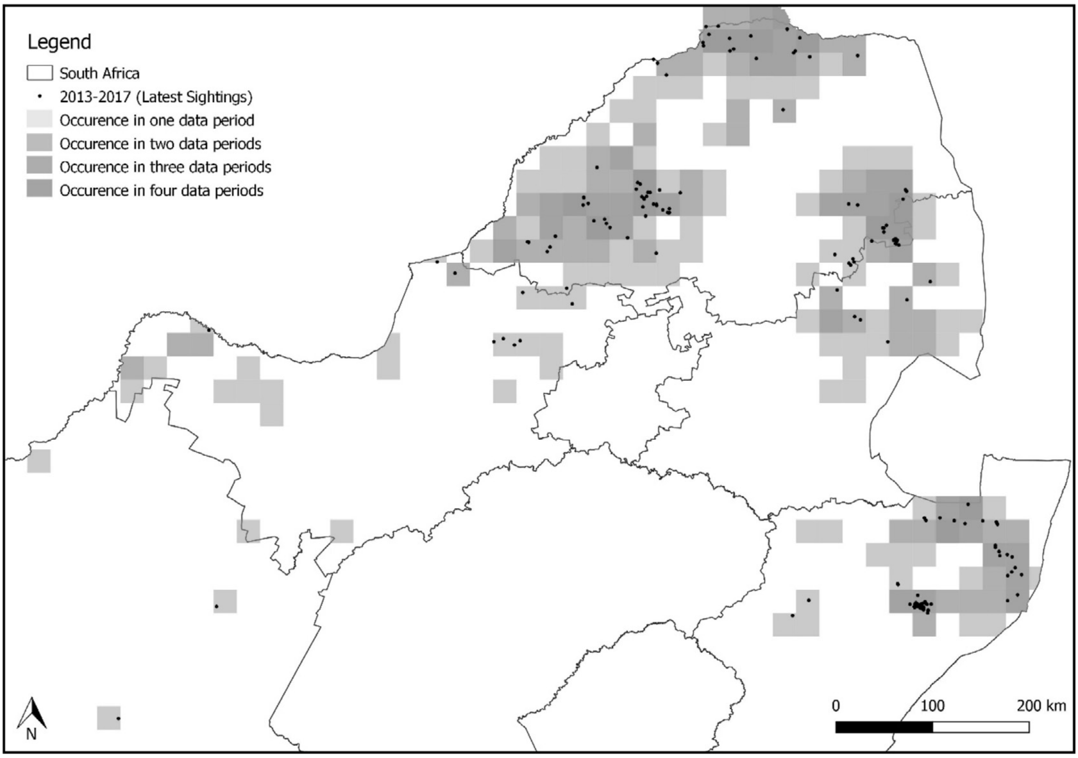


Fig. 3. The core areas of free-roaming wild dogs in South Africa and latest sightings (between 2011 and 2014).

DISCUSSION

Wild dog numbers in South Africa fluctuated between 1998 and 2017 but overall the national population was stable. South Africa's population of wild dogs remains modest, with fewer than 500 adults and yearlings. The 2016 population size of 427 adults and yearlings was the highest count recorded in the past two decades and this was driven primarily by the expanding metapopulation. The mean annual national population size of wild dogs (adults and yearlings) was 350 which was stable over time. Each subpopulation makes a critical contribution to the national total, particularly the metapopulation and Kruger. It is evident that without the development and expansion of metapopulation, and all the intensive and costly management that this involves (Lindsey *et al.*, 2005b), the South African national population would be significantly smaller and more vulnerable. For example, Kruger experienced a significant decrease from 450 individuals in 1995 to 132 in 2009, but because the metapopulation provided a demographic buffer for the national population, this decline was not as severe at a national scale. Recent genetic evidence from South Africa suggests that translocations between all three subpopulations greatly lower the risk of loss of local adaptation and unique lineages (Tensen, Van Vuuren, du Plessis *et al.*, 2019). Thus, the Kruger, metapopulation and free-roaming subpopulations should be considered linked for the purposes of conservation management.

Kruger is a large, natural system and contains a wild dog population of global demographic, conservation and genetic significance (Creel *et al.*, 2004; Tensen, Groom, van Belkom *et al.*, 2016). Kruger has maintained a stable, though slightly decreasing population, for the last 20 years, with an average population size of 163. However, the population decrease of 3% p.a. we found was larger than previously reported for Kruger, where Creel *et al.* (2004) reported a 0.3% decreasing growth rate. This highlights how the relatively stable period reported up to 2004 (Creel *et al.*, 2004) has declined slightly up to 2017. This could be due to a sharp decline in the population as reported in 2009. Consequently, intense full-time and consistent monitoring of the Kruger subpopulation was initiated in 2010, which has allowed for more accurate data and knowledge of individual pack sizes and demographics that attempted to assess reasons for consistent decline between 1998 and 2009. This decline was not significant, and recent interannual increases in the population size suggest that the Kruger population may be resilient to demographic stochasticity (though the population remains vulnerable to those effects, Creel *et al.*, 2004). Long-term datasets like the one collected from Kruger highlight large demographic variation that shorter datasets are unable to show. Growth rates in Kruger are tending towards systematic decline (*i.e.* rates below 0%) where further shifts in reproduction or survival can push the population closer towards further decline. Thus, despite the likely resilience of Kruger to demographic stochasticity as reported previously (Creel *et al.*, 2004), management actions to assist Kruger's population need to be seriously considered.

The only subpopulation to increase significantly over time has been the managed metapopulation, with an average annual population size of 107. This is the direct result of intensive management strategies adopted by WAG-SA and multiple stakeholders. The initial target population size of nine packs (Mills *et al.*, 1998) in the managed metapopulation was achieved by 2002 (Lindsey *et al.*, 2005a). Since then, the population peaked at 160 adults and yearlings in 2006. However, further expansion of the metapopulation is constrained by the number of suitable reserves willing to participate. The metapopulation footprint has increased significantly from two wild dog metapopulation reserves in 1998 (1516 km^2) to 14 (5385 km^2) in 2017. This demonstrates that relatively small and isolated patches of land can have large national benefits to an endangered species if they are fenced and if metapopulation management is applied (Lindsey, Masterson, Beck *et al.*, 2012). Combining metapopulation approaches with adequate fencing, expertise in wild dog management, and sufficient funding for translocations, should provide invaluable lessons for the conservation of similarly threatened carnivores (Davies-Mostert *et al.*, 2009).

With extensive range contraction for all large carnivore globally (Wolf & Ripple, 2017), a managed metapopulation paradigm could help buffer these populations and even increase them to ensure the maintenance of carnivores as critical elements of healthy ecosystems. Essentially, our data highlight the success of the managed metapopulation approach for wild dogs in growing their numbers and range, and we suggest that a similar approach may work for other large carnivores in South Africa (such as lions *Panthera leo*; Miller, Bissett, Burger, Courtenay, Dickerson *et al.*, 2013; Miller, Harper, Bloomer, *et al.*, 2015), and for other species elsewhere in Africa (if sufficient funding, long-term commitment, and management expertise are available) (Miller *et al.*, 2013). As the metapopulation is intensively monitored, population and mortality data are more readily reported; this is aided by the fact that most reserves (excluding Hluhluwe-iMfolozi) have 1–3 packs which makes recording demographics considerably easier. Further, regular WAG-SA meetings have ensured that reserve data are captured and collaboration at a national level occurs. This has been successful for national demographics (this study) and from ensuring healthy levels of heterozygosity (Tensen *et al.*, 2019). When contrasting the population growth rate to previous records for the metapopulation, our study shows that the growth rate has declined from 8% p.a. (Davies-Mostert *et al.*, 2015) to 6% p.a. (this study). This growth rate is only marginally higher than that of the largest subpopulation within the metapopulation, Hluhluwe-iMfolozi Park, which had a 1% growth rate during a low population size period (Somers *et al.*, 2008) but which increased to 5% growth since 2004 (Marneweck, 2019). Likely due to large interannual fluctuations in the population size of the smaller subpopulations, the metapopulation has increased the total growth rate for the metapopulation. As Hluhluwe-iMfolozi Park has held wild dogs the longest and has the largest population within the metapopulation, the annual growth of this population has greatly assisted the metapopulation's persistence.

The distribution of free-roaming wild dogs in South Africa does not appear to have changed significantly over the last 20 years and remains limited primarily to wildlife ranches in savanna regions, close to source populations, with low human densities (Lindsey *et al.*, 2009b). Currently, the free-roaming wild dogs occur predominantly in the Waterberg region of the Limpopo province and the northeastern areas of the KZN. Even though the current primary land use in most of the areas inhabited by free-roaming wild dogs is largely unsuitable (very small and intensively fenced and electrified areas, with very low tolerance of wild dogs due to intensive breeding of wildlife for trophy hunting and sale), wild dogs have persisted.

The low densities, large dispersal distances (Davies-Mostert *et al.*, 2012) and reliance on natural prey rather than domestic prey have likely assisted this population to go largely unnoticed and hence avoid persecution. We also cannot rule out that these areas (Waterberg and northeastern KZN) might act as sinks for source populations from southern Zimbabwe and southern Botswana and from KZN metapopulation reserves, respectively. Long-term individual monitoring and cross-border collaboration between conservation agencies can help with individual identification and detection of movements to assess the degree of connectivity and transfer between South Africa's free-roaming and those in Botswana and Zimbabwe (Davies-Mostert *et al.*, 2012).

South Africa has a stable wild dog population that is evident by the national population growth rate on zero. This population is relatively well protected and collectively can be considered a stronghold for wild dogs in Africa. Comparing this estimate to the other large, protected and documented populations in Africa, northern Botswana also has a stable population (0% annual growth) and Selous has a growing population (3.8% growth) (Creel *et al.*, 2004). Results from other non-protected populations in Africa, however, show widespread declines (Woodroffe & Sillero-Zubiri, 2012). These data highlight that the relatively small but stable population in South Africa is vitally important in maintaining a viable and genetically diverse population in Africa. However, as the growth rate is on zero, any shifts in reproduction and survival within each subpopulation could drive the national population towards more systematic decline. Thus, the consideration towards linking the subpopulations in South Africa should be given real attention for buffering any demographic stochasticity that could cause reductions in the viability of South Africa's national population of wild dogs.

One of the challenges in species management and conservation is obtaining accurate, robust and comparable data that allows for valuable analysis. To improve conservation of wild dogs, we acknowledge that standardized methods for data collection and monitoring are needed. Although standard and robust methodologies are required to make reliable comparisons across the subpopulations, we were able to make general inferences about the populations within South Africa. However, standardized methods are required to accurately assess long-term population trends. Methodologies that have currently been developed and utilized are based on the populations, researcher presence and available funding.

Our paper demonstrates that a range of methods can be used to describe comparisons across subpopulations, but one must be cognisant of the limitations. For instance, we understand that there are greater uncertainties around the free-roaming population numbers due to detection biases and this uncertainty decreases with the Kruger population. Due to intensive monitoring of the metapopulation reserves, we are confident that the uncertainly levels around these population numbers are far less. Irrespective of the method of data collection, ongoing monitoring of endangered species is essential for adaptive management which responds to changing conditions, and to provide a basis for conservation prioritization.

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H.T. Davies-Mostert

A 20-year review of the status and distribution of African wild dogs (*Lycaon pictus*) in South Africa

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Table S1: Confirmed wild dog mortalities and their causes observed between 1998 and 2017 in South Africa's three subpopulations : the free-roaming population, managed metapopulation and the Kruger National Park subpopulation.

Population	Natural	Anthro-pogenic	Disease	Unknown	Other	Total
Free-roaming	5	102	5	2	3	117
Managed metapopulation	91	71	127	112	36	437
Kruger	16	14	12	3	0	45
Total (South Africa)	**112**	**187**	**144**	**117**	**39**	**599**

Table S2: The WAG-SA Reporting Form that is submitted quarterly for each WAG meeting to present wild dog population structure and events in individual reserves.

WAG-SA Reporting Form	
Report date:	
Property name:	
Report prepared by:	

Population Structure										
Pack name	**Adults**			**Yearlings**			**Pups**			**Total**
	M	F	U	M	F	U	M	F	U	
Total										

Demographic Events		
Type	Details	Date
Introductions / Removals		
Mortality		
Disappearances		
Dispersals		
Births		
Pack formations		
Other		

Additional Notes