Chapter 3

Evaluating historical estimates of population size for the elephants of Maputaland

Introduction[2]

The elephant population of Maputaland has a recent history of fragmentation. Since 1989 part of the population has been fenced into the Tembe Elephant Park that adjoins the southern boundary of Mozambique. The unfenced fragment of the population, however, continues to roam freely across southern Mozambique's Maputo Elephant Reserve and the Futi Corridor (an area either side of the Futi River). Here they occasionally associate closely with humans but continue to be legally protected (Soto, Munthali & Breen 2001). Maputaland is earmarked for the development of a transfrontier conservation area that will reunite the elephant and other wildlife populations occurring in the region (Wynberg 2002). Maputaland supports an exceptionally high number of species (van Wyk 1994) and elephants, as surrogates for the conservation of regional biota (see Caro & O'Doherty 1998; Simberloff 1998), may well affect the success of the development of a cross border conservation initiative in Maputaland. An understanding of historical events driving trends in the abundance of elephants may benefit future initiatives to conserve and manage the reunited population as a single unit.

The status of the elephant population of Maputaland has never been accurately assessed and surveys have been infrequent and unsystematic (see Tello 1973; Hall-

[2] Chapter 3 has been drafted as an independent publication and much of the information provided here therefore repeats that in Chapter 1.

Martin 1980; Ward 1986; Matthews 1994, 2000; de Boer *et al*. 2000). Many of these earlier estimates (e.g. Thompson 1978; Hall-Martin 1980; Klingelhoeffer 1987; Matthews 2000) are little more than 'educated' guesses. In spite of this these are some of the only data that can be used to evaluate past and future trends in population numbers.

Large numbers of elephants must have been present in recent times as Smithers & Tello (1976) reported that over 500 were killed between the Maputo River and the Swaziland border in the 1940s as a crop protection measure. Large scale hunting for ivory was conducted in Maputaland from the 1850s (Baldwin 1863; Leslie 1875) and in northern Natal elephants were largely hunted out by the turn of the century (Bruton & Cooper 1980).

Smithers and Tello (1976) regarded the elephant population as increasing after the closure of professional meat and ivory hunting in the early 1960s. By then the Maputaland population was separated from the Gaza populations, which were then continuous with those of the Kruger National Park. They reported elephant as 'abundant' in the Maputo Elephant Reserve during the early 1970s.

With the onset of civil war in Mozambique attempts to count elephant populations in Mozambique ceased and uncontrolled hunting became common (Hatton, Couto & Ogelthorpe 2001). The perception of large scale hunting of elephants in southern Mozambique influenced the fragmentation of the Maputaland elephant population as conservation authorities sought to protect elephants in Tembe Elephant Park (Hall-Martin 1988; Ostrosky 1989). Conflict in Mozambique also led to humans moving out of southern Mozambique (Ogelthorpe 1997; Hatton *et al*. 2001).

Attempts to census the elephants living in the Tembe Elephant Park (TEP) were more frequent but the difficulties of aerial surveying elephants in such a thickly vegetated habitat (Caro 1999; Walsh & White 1999; Whitehouse, Hall-Martin & Knight 2001; Jachmann 2002) led to inconclusive population estimates. Here I use estimates of population size derived from a total count, using non-overlapping transects (by helicopter) for the Maputo Elephant Reserve (MER) and the Futi Corridor (Ntumi 2002) and ground surveys using sight-resight models (see Chapter 4) to interpret earlier estimates based on realistic population growth rates.

Methods

Earlier estimates of population size

I extracted estimates of population size from the papers and reports of Hall-Martin (1986), Ward (1986, 1987, 1988, 1989, 1990), Klingelhoeffer (1987), Ostrosky (1988 *pers. comm.* Matthews[3]), Matthews (1992, 1993, 1994, 2000) and Ntumi (2002). Of the earlier estimates few are based on properly structured surveys, or are based on methods described by de Boer *et al*. (2000), Matthews (2000) and Ntumi (2002). For the Maputo Elephant Reserve, only six estimates of population size were attempted between 1970 and 1999 (Tello 1973; Klingelhoeffer 1987; de Boer *et al*. 2000; Ntumi 2002; Matthews *pers comm.*[1]).

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Population growth rates

I extracted population estimates from published and unpublished reports. These estimates were transformed to natural logarithms ($\log_e$) and used to derive intrinsic rates of population change using linear regression analysis (see Caughley 1977).

Modeling of population size

I determined minimum possible population sizes for the fragments and for the combined population and used a spreadsheet (Excel 2000) model to derive population sizes. The minimum number of animals alive at the time of the last estimate (1999 for southern Mozambique, 2002 for Tembe Elephant Park) were used to estimate past population sizes using the equation:

$$N_0 = \frac{N_t}{e^{rt}} \qquad (1)$$

where N_t = the known population size and r = intrinsic of rate increase (Caughley 1977). The population growth rates (r) used ranged from 7%, the maximum modeled for closed elephant populations (Calef 1988), to 3%, within the lower rates reported from east Africa (Douglas-Hamilton 1972; Moss 2001). An intermediate rate of 5% was used as reported for elephants in the region (Kruger National Park; Whyte, van Aarde & Pimm 1998, and Zimbabwe; Craig 1989), similar to the 5.23% reported by Whitehouse & Hall-Martin (2000) for Addo Elephant National Park. Although I used 7% as the maximum growth rate other studies (Craig 1989; Whyte *et al*. 1998; Whitehouse & Hall-Martin 2000) suggest that a more realistic maximum population growth rate is close to 5.5%, higher than the 4% suggested as close to the maximum by Hanks & McIntosh (1973).

To model the Maputaland population as a single entity I added the 1999 population estimate for southern Mozambique to the 2000 estimate for TEP. My

estimates of population size are based on minimum observed population size for MER (Ntumi 2002) and a sight-resight model for TEP (as described in Chapter 4).

Results

Earlier estimates of population size

The earliest published estimate of the size of the elephant population of the Maputo Elephant Reserve (Tello 1973) yielded 350 elephants (Table 3.1). In 1970 Tello (1973) identified 280 elephants and estimated that the population in Mozambican Maputaland did not exceed 350 elephants. For 1972 Tello estimated that 269 elephants occurred in the Maputo Elephant Reserve (cited as *pers. comm.* in Klingelhoeffer 1987).

The elephant population of the Maputo Elephant Reserve apparently declined from 269 in 1972 to 80 in 1979 (K.N. Tinley, *pers. comm.* in Klingelhoeffer 1987) with displaced animals moving into the Maputo flood plain, the Futi floodplain and into South Africa. Klingelhoeffer estimated the population of 'northern Tongaland' to fluctuate between 50 and 150 elephants at the time of his research (1979 to 1981) before the Tembe Elephant Park was established (Klingelhoeffer 1987). An estimate of 150 elephants for southern Mozambique for 1995 given to the Mozambique authorities in a 1995 report by Ostrosky & Matthews (W.S. Matthews, *pers. comm.*[4]), seems to be a guess rather than based on an actual survey.

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Table 3.1. Summary of population estimates for southern Mozambique and Tembe Elephant Park based on information extracted from published and unpublished papers and reports.

Year	Population size	Survey method	Source
Southern Mozambique			
1970	350	Ground survey	Tello 1973
1972	269		Klingelhoeffer 1987
1979	80	Educated guess	Klingelhoeffer 1987
1995	150	Educated guess	W.S. Matthews*
1998	180	Unstructured helicopter count	De Boer *et. al.* 2000
1999	205	Helicopter Transects	Ntumi 2002
Tembe Elephant Park			
1947	40	Guess	Lugg 1970
1971	16	Educated guess	Ostrosky 1988*
1973	25	Educated guess	Anon. 1978*
1974	40	Educated guess/Fixed Wing	Thompson 1978
1976	30	Educated guess/Helicopter	Hall-Martin 1980
1980	60	Fixed Wing /Aerial photo	Hall-Martin 1986
1981	75	Educated guess	Klingelhoeffer 1987
1984	39	Count-Helicopter	Ward 1986
1985	32	Count-Helicopter	Ward 1986
1986	35	Helicopter transects	Ward 1986
1987	41	Helicopter transects	Ward 1987
1988	56	Helicopter transects	Ward 1988
1988	104	ID Photo kits	Ostrosky 1988*
1989	54	Helicopter transects	Ward 1989
1990	48	Helicopter transects	Ward 1990
1992	85	Helicopter transects	Matthews1992
1993	54	Helicopter transects	Matthews1993
1994	71	Helicopter transects	Matthews1994
1996	106	ID Photo kits	W.S. Matthews*
2000	74	Helicopter transects	Matthews 2000
2000	130	Educated guess	Matthews 2000
2002	167	ID Photo kits	Present study
2002	179	Recapture models	Present study

**Pers. comm*., W.S. Matthews, Regional Ecologist, Tembe Elephant Park, PB.356, Kwangwanase KwaZulu-Natal.

An unstructured helicopter survey conducted over two days in October 1998, while collars were fitted to elephants, yielded a minimum number alive estimate of 180 animals (de Boer *et al*. 2000). While not intended as a complete survey it covered the Futi floodplain and the Maputo Elephant Reserve in southern Mozambique. An attempt at a total count, using non-overlapping transects, flown with a helicopter and conducted over five days during October 1999, covered an area of 1270km^2 and yielded a minimum number alive estimate of 205 elephants (Ntumi 2002).

Twenty one estimates of population size have been made for elephants in the TEP between 1947 and 2000 (Table 3.1). KwaZulu Nature Conservation officers reported 17 of these in internal reports. Four estimates were supplied by the regional ecologist (W.S. Matthews, *pers. comm.*[5]).

The 1947 estimate is questionable as it is based on a descriptive statement that 'about' 40 elephants came into the area at night 'having travelled a great distance' (Lugg 1970), based on the recollections of a magistrate in Ingwavuma District in the late 1940s. The timing of this estimate coincides with an elephant extermination programme in adjacent areas of southern Mozambique (Smithers & Tello 1976).

For the Tembe Elephant Park the first 'educated guesses' are based on ground surveys and are given for 1971 and 1973. Between 1974 and 2000, 14 aerial transect surveys were conducted, two by fixed wing aircraft and 12 by helicopter. Prior to the 2002 estimate (Chapter 4), two estimates were based on the identification of known animals. Two further estimates were based on educated guesses (Table 3.1). Aerial surveys used transect sampling based on the method of Norton-Griffiths (1978), but were not standardized and did not yield estimates of their accuracy or precision. Waterhole counts, where water points are flown-over at mid-day when elephants are thought to concentrate at them, were used in an attempt to support the transect counts.

My estimates for 2002 are based on sight-resight models and yielded a population size of 179 (compared to 167 individual elephants identified as a 'known to be alive' estimate during the sight-resight research programme) for Tembe Elephant Park, with a 95% confidence interval for the Park of between 136 and 233 elephants (see Chapter 4).

[5] Mr W. S. Matthews, Regional Ecologist, Tembe Elephant Park, PB.356, Kwangwanase, KwaZulu-Natal.

Trends in population size and growth rates

The estimates of the size of the elephant population of southern Mozambique declined from 350 to 80 animals between 1970 and 1979. Since then estimates have increased to 205 in 1999 (Table 3.1). The data for the Tembe Elephant Park suggests a relatively small population in the 1970s and early 1980s that, thereafter, increased to the present level (Table 3.1).

A linear regression analysis on transformed ($\log_e$) population estimates of the southern Mozambique elephant population yielded an annual rate of decline of 1.2% per year[6] ($y = 28.42–0.012x$, $r^2=0.09$, $F_{1,4}=0.41$, $P=0.56$) between 1970 and 1999. A similar analysis for the Tembe Elephant Park's population suggests an increase from 1971 to 2002 of 5.6% per year ($y = 0.056x-106.8$, $r^2= 0.71$, $F_{1,20} = 49.76$, $P<0.001$).

From 1970 to 1979, the last population estimate for southern Mozambique before fragmentation, estimates of population size for southern Mozambique declined by 16.6% per year ($y = –0.1664x–333.7$, $r^2=1.0$, $F_{1,1} = 487.9$ $P< 0.05$) and from 1979 to 1999 increased at 4.4% per year ($y= 0.044x–83.31$, $r^2=0.98$, $F_{1,2}=106.4$, $P< 0.05$).

[6] This value and all later estimates of intrinsic population growth rate should be treated with caution since they are based on population estimates of unknown accuracy and precision.

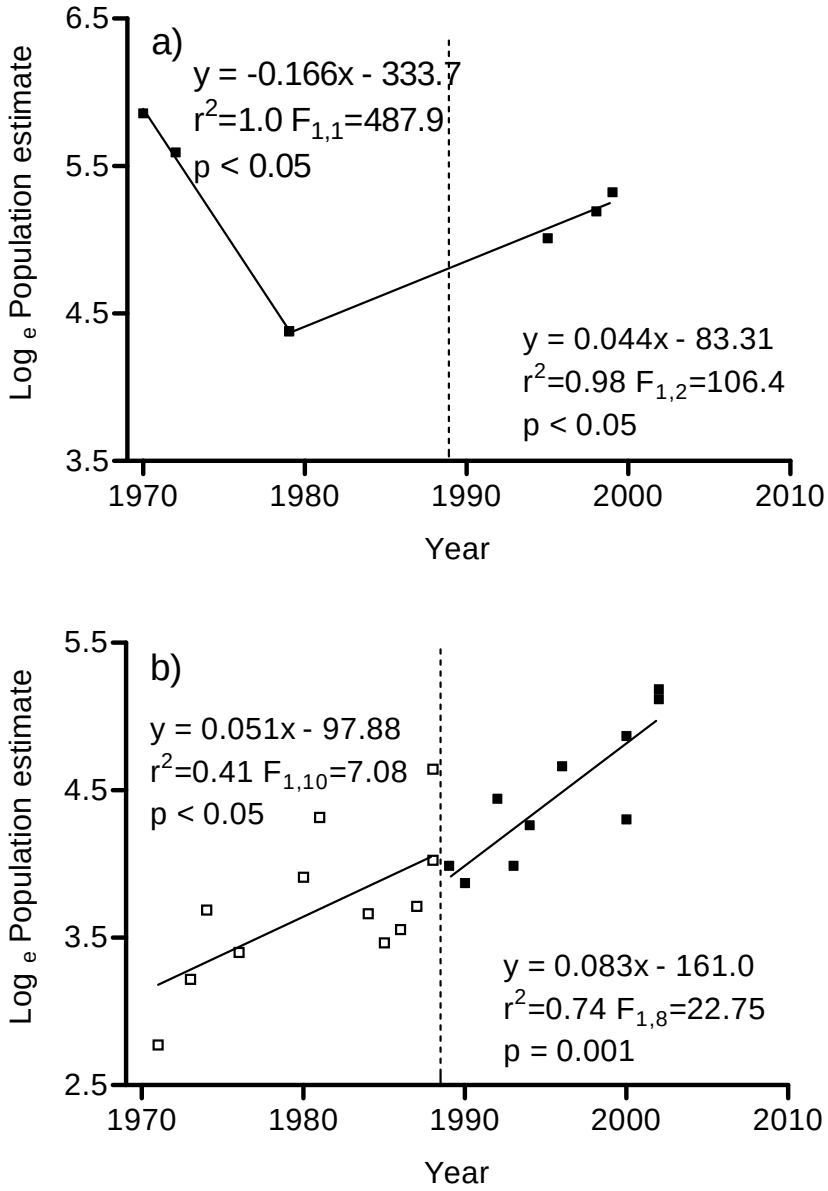

Figure 3.1. Population growth rates for (a) southern Mozambique and (b) Tembe Elephant Park calculated from linear regression analysis of $\log_e$ transformed population size estimates. For the southern Mozambique population estimates are indicated by shaded squares. The left hand slope shows population decline between 1970 and 1979 of approximately 16.6 % per year and the right slope shows population increase from 1979 to 1999 of 4.4% per year. For the Tembe Elephant Park, open squares indicate population estimates up to 1988; shaded squares indicate population estimates from 1989. The curve on the left of the graph shows population increase between 1971 and 1988 of 5.1% year and the curve on the right shows population increase from 1989 to 2002 of approximately 8.3% per year. The stippled vertical line indicates fragmentation of the population.

The southern Mozambique population may, therefore, have been increasing at the time the Maputaland population was fragmented through the fencing of the Tembe Elephant Park.

The annual rate of population increase for the TEP between 1971 and 1988 was 5.1% (y = 0.05127x–97.88, r^2=0.41, $F_{1,10}$=7.08, P< 0.05) and after fencing apparently increased to 8.3% per year (y = 0.08293x–161.0, r^2= 0.74, $F_{1,8}$= 22.75, P= 0.001) (Fig. 3.1b).

Retrospective modeling of population size

Retrospective extrapolation for the southern Mozambican elephant population starting from a minimum population size of 205, with rates of change ranging from 3% to 7% per year suggests that earlier estimates dramatically under-estimated population size. My extrapolations suggest that at a maximum potential growth rate of 7% the population would have been >190 in 1998, >150 in 1995 and numbered a minimum of 100 animals when separated from the South African fragment in 1989 (Table 3.2).

The minimum possible population size in 1979 would have exceeded the 50 animals proposed. At a growth rate of 5% the population would have numbered 195 animals in 1998, 168 in 1995, 124 when fenced from South Africa and 75 animals in 1979 (Table 3.2). At a growth rate of 4.4%, as predicted by linear regression of the post-1979 estimates, the predicted population sizes were 196 for 1998, 172 for 1995 and 132 in 1989 when fenced from South Africa (Table 3.2). At a growth rate of 3% population size would have been 199 animals in 1998, 182 in 1995 and 152 when fenced from South Africa with a minimum population size in 1979 of 113 animals (Table 3.2).

Table 3.2. Population sizes extrapolated from the most recent minimum estimates (in bold) for the elephant population fragments of Maputaland. The minimum estimates are 205 elephants for southern Mozambique, 179 elephants for Tembe Elephant Park and 339 elephants for the combined population in 1999. Growth rates (r) were from lower range estimates (3%), intermediate (5%) and maximum (7%) published for elephants, and estimates of growth from linear regression analysis. Estimates for years prior to those in bold were extrapolated from the most recent estimates. Population estimates for years after those in bold are based on extrapolations of varying intrinsic population growth rates. The population has been fragmented since a fence was completed around Tembe Elephant Park in 1989.

Area	**Year**					
Southern Mozambique	2002	1999	1998	1995	1989	1979
Estimate	NA	**205**	180	150	NA	80
r=0,044*	234	**205**	196	172	132	85
r=0.03	224	**205**	199	182	152	113
r=0.05	238	**205**	195	168	124	75
r=0.07	253	**205**	191	155	102	51
Tembe Elephant Park						
Estimate	**167**	74[A]	106[B]	71[C]	54	60
r= 0.083 & 0.051*	**167**	131	120	93	57	34
r=0.03	**167**	153	148	135	113	33
r=0.05	**167**	144	137	118	87	53
r=0.07	**167**	135	126	102	67	84
Maputaland						
Estimate	NA	**279[D]**	NA	256[E]	NA	140[F]
r=0.03	371	**339**	329	301	251	186
r=0.05	394	**339**	322	278	206	125
r=0.07	418	**339**	316	256	168	84

* based on a linear regression analyses of $\log_e$ transformed estimates

[A] data for 2000, [B] data for 1996, [C] data for 1994, [D] TEP 2000 estimate plus MER 1999 estimate, [E] TEP 1996 estimate plus MER 1995 estimate, [F] TEP 1980 estimate plus MER 1979 estimate

For the TEP retrospective extrapolation suggests that population estimates after the fencing have consistently under-estimated the true population size for elephants. For earlier estimates to be valid the elephant population in the TEP would have to have attained a growth rate in excess of the biological maximum for the species given by Calef (1988). Extrapolation shows that at potential growth rate of 7% the population would have been 130 in 1999 and >100 in 1996. The population would have numbered a minimum of 67 animals when separated from the southern Mozambique population in 1989 (Table 3.2). A population growth rate of 5% predicts that there were more than 140 animals in 1999, nearly 120 in 1996 and 87 when fenced into South Africa (Table 3.2). At a rate of population increase of 3% the population would have numbered more than 150 animals in 1999, 135 in 1995 and more than 110 when fenced into South Africa in 1989 (Table 3.2).

For the combined population of Maputaland the minimum population size of 339 animals in 1999 suggests that at Calef's (1988) maximum growth rate of 7% the population would have been >310 in 1998, >250 in 1995 and numbered a minimum of 168 animals in 1989 (Table 3.2). The minimum possible population size in 1979 would have been 84 should the population have been growing at 7% per year. The consequences of lower rates of increase are illustrated in Table 3.2. My extrapolation suggests that the Maputaland elephant population comprised of between 371 and 418 elephants in 2002 (Table 3.2).

Discussion

Problems have been identified when comparing historical estimates to determine trends, as counting methods change (Eltringham 1977; Dublin & Douglas-Hamilton 1987; Hall-Martin 1992; St. C. Gibson, Craig & Masogo 1998; Rookmaaker 2002). Furthermore, estimates of population size and trend detection tend to increase as methods improve (Laws 1969a; Barnes 2002). The biases in aerial counts are different year on year, as environmental conditions differ even when time of year is controlled for (Redfern *et al*. 2002). Bias in censuses can also mask large changes in population sizes from year to year (Redfern *et al*. 2002).

Eltringham (1977) identified problems in determining population trends from aerial surveys even when relatively large numbers of surveys were available. Census data with unknown bias should not, therefore, be used to determine management actions (van Jaarsveld, Nicholls & Knight 1999; Redfern *et al*. 2002).

Despite the difficulty of interpreting population trends from historical data, this type of data has been used in an attempt to predict population persistence (van Jaarsveld *et al*. 1999) and promote elephant population control measures or range expansion (Hall-Martin 1992). St. C. Gibson *et al*. (1998) dismiss population estimates from non-standardised methods as 'not useful in analysis of trends' and emphasised the importance of standardised surveys for predicting trends. Historical estimates from non-standardised methodologies are often, however, all that is available (Rookmaaker 2002).

Different aerial methods were used to enumerate the elephant population of Tsavo (Laws 1969a), and the difficulty in interpreting such data is further highlighted by Ottichilo's assertion that, for Tsavo between 1967 and 1970, there were 'probably more than 35 000 elephants present' because the population estimate was 35 000 in

1974, following 6 000 elephant deaths recorded during the 1970-1971 drought (Ottichilo 1986).

For the Serengeti-Mara region long term population estimates from 1958 to 1977 show an increasing elephant population until 1965 followed by a long period of population stability, then increase in elephants in the Masai Mara Game Reserve and a significant decline in the Serengeti National Park (Dublin & Douglas-Hamilton 1987). In their study Dublin & Douglas-Hamilton (1987) only calculate population change between the means of 1965-1977 estimates and a 1984 estimate. They concluded that the Mara population increased by 19% between 1977 & 1984, and the Serengeti population experienced a 52% decline during the same period, and that elephants moved from the Serengeti to the Mara (Dublin & Douglas-Hamilton 1987).

For the Kasungu National Park, Malawi, Bhima, Howard & Nyanyale (2003) analysed trends in elephant numbers from historical data collected between 1969 and 1998 using different methods. They did not interpret population change other than stating that the population declined between the 1970s and 1998 (Bhima *et al*. 2003).

These studies highlight that even where survey data has been collected relatively frequently the determination of trend, and even population size, is often crude but frequently the only information available (Rookmaaker 2002). I faced a similar situation determining population trend for Maputaland where until recently information on the size of the Maputaland elephant population, and on the factors influencing it, has been either lacking or inadequate. From my analysis it appears that many earlier estimates were little more than guesses, or derived from aerial counts conducted under poor surveying conditions. These estimates would have been of little value to managers especially considering that past under-estimates inflated future growth rates. Incorrect estimates could solicit overreactions from managers

responsible for controlling the consequences elephants may have for enclosed parks (Cumming *et al*. 1997; Trollope *et al*. 1998; van Aarde, Whyte & Pimm 1999; Whyte *et al*. 1999; Matthews *et al*. 2001).

It appears that the elephants of southern Mozambique may not have been as threatened as was feared some 10 to 15 years ago (Klingelhoeffer 1987; Hall-Martin 1988; Ostrosky 1989; World Bank 1996). Based on the maximum rate of change at least 100 elephants remained in Mozambique when the fence was constructed during 1989. The population must therefore have exceeded the 1979 estimate of Klingelhoeffer (1987) and the 1995 estimate of 150 of W.S. Matthews (*pers. comm.* [7]), especially if poaching was as high as has been suggested (Hall-Martin 1988; Ostrosky 1989).

My extrapolations also suggest that estimates for the TEP were constantly lower than that implied by realistic maximum intrinsic growth rates of 5.5%. The apparent steep population decline from shortly before Mozambican independence in 1975, to the onset of civil war in 1980 and on into the mid-1980s is probably due to an overly pessimistic population estimate by Klingelhoeffer (1987).

People abandoned former elephant range during the war years (Ogelthorpe 1997; Soto *et al*. 2001) and their numbers within the MER declined from 10 000 before the war to fewer than 1 000 in the mid-1990s (Ogelthorpe 1997; Fairall & van Aarde 2004b). By the mid-1990s only 5 000 to 8 000 people remained between the Maputo River and the coast (World Bank 1996). The human population in the area may have freed elephants from competition for landscapes with people and domestic animals (Parker & Graham 1989a). The elephant population living here may even have started to recover during the civil conflict.

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For the TEP aerial surveys have constantly under-estimated true population size. At best the available data may have given an indication of changes in population size but the wide confidence limits would have masked real growth trends. This would have rendered the censuses cost inefficient and of limited value to conservation management. The underestimation of population size from recent aerial surveys seems to be due to the undercounting of breeding herd members. This applies especially to those animals that concentrate in the north-east of the Park where vegetation is dense and where canopy cover is high.

Before the international border was fenced annual population trends were almost certainly influenced by the migration of elephants in and out of Tembe Elephant Park (Klingelhoeffer 1987; Ostrosky 1987, 1989; Hall-Martin 1988). Their movement into the Park may have increased due to persecution in southern Mozambique (Ostrosky 1987). Aerial surveys consistently yield fewer than 100 elephants for the Tembe Elephant Park (Ward 1989, 1990; Matthews 1992, 1993, 1994, 2000), the three registration counts based on ID profiles, however, all produced estimates >100 (Matthews *pers. comm.*[8]; see Table 3.1). I conclude that most historical estimates were considerably lower than that reflected by the trend I derived from realistic values of intrinsic population growth.

At present the densities of elephants in Tembe Elephant Park (0.56 km^2) exceed that for southern Mozambique (0.14 km^2) and the Maputo Elephant Reserve (0.26 km^2). The restoration of former elephant range through a transfrontier conservation initiative in the region would most probably reinstate the historical roaming patterns of these elephants.

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