TRANSBOUNDARY SPECIES PROJECT

# ROAN, SABLE AND TSESSEBE

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SPECIES REPORT FOR ROAN, SABLE AND TSESSEBE

IN SUPPORT OF

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by Reay H.N. Smithers

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# PREFACE

I have not given a list of acronyms at the start of this report because I have tried to avoid using them in the text and, where one is used, the meaning is given together with the acronym. This draft has not benefitted by having another person review it and is therefore likely to contain numerous typing errors, omissions and spelling mistakes. I seem to be deficient in noticing my own errors. Hopefully, any such mistakes can be corrected in a second draft.

I had hoped that this report would be shorter than the background study on buffalo which I completed in November last year, but it is much the same length. It is long partly because a large amount of background information is available on roan, sable and tsessebe and much of it is relevant to the subject in hand. There are more diagrams and less text in this report and a larger amount of detail has been consigned to the appendices. It is long also because some extremely interesting concepts and hypotheses have arisen in the course of the work and these have needed to be examined thoroughly.

I would like to thank all those people who gave so kindly of their time and valuable experience to this project. In particular, I thank Chris Brown of the Namibia Nature Foundation, who provided me with a large number of references in the literature on roan, sable and tsessebe, John Mendelsohn who assembled rainfall data for on a number of sites in northern Namibia and Peter Erb who gave me all of his working notes and recent data on the three species. I thank also Chris Weaver of the WWF LIFE programme, and Ben Beytell and Pauline Lindeque of the Ministry of Environment and Tourism who spared considerable time to discuss the subject matter. I am unused to receiving such a high level of assistance on consulting work and thank Barbara Paterson as the project co-ordinator for her support. I thank Kevin Dunham, Fay Robertson and David Cumming all of whom assisted me with key documents. Finally, I would like to thank Debbie Gibson and Colin Craig for accommodating me in Windhoek, making a large amount of aerial survey data available and spending much time in discussion of the study.

# 1. BIOLOGICAL INFORMATION

## a. Taxonomy

The current state of the taxonomy of the entire order Artiodactyla (even-toed ungulates) is in some disarray. New suborders and superfamilies have been created, and there seems to be some uncertainty whether Tsessebe still belong in the genus Damaliscus. For the purposes of this study, the classification of the three species used by the Antelope Specialist Group of the IUCN Species Survival Commission (ASG 1998) has been adopted –

Roan antelope – *Hippotragus equinus* (Desmarest 1804)

Sable antelope – *Hippotragus niger* (Harris 1838), subspecies *H.n. niger*

Tsessebe – *Damaliscus lunatus* (Burchell 1824), subspecies *D.l. lunatus*

The taxonomic relationship of the three species within the antelope family **Bovidae** as given by Smithers (1983) is shown in **Fig.1** on the following page. The species shown in red font are those for which Background Studies have been carried out under the Transboundary Species Project of the Ministry of Environment and Tourism.

Smithers (1983) notes that Ansell (1972) lists six subspecies of roan for the African continent, including a subspecies *H. e. cottoni* occurring in northern Botswana, the Caprivi and extending into Angola and southern Zaire. However, in the latest classification of the Antelope Specialist Group there is no mention of this subspecies and it seems there is no longer a valid basis for recognising any subspecies of roan antelope.

Apart from the Giant sable in Angola (*H. niger variani*), it seems that the taxonomic status of the other subspecies of sable (*H. n. roosevelti* which occurs in coastal Kenya and northern Tanzania, and *H. n. kirkii* found in the Selous Game Reserve) are under question at the moment.

Ansell (1972) lists 7 subspecies of *Damaliscus lunatus* but the Antelope Specialist Group has reduced this number to 5 subspecies: *D. l. lunatus* – Tsessebe in southern Africa; *D. l. korrigum* – Korrigum, in northern Benin, Nigeria and Cameroun; *D. l. tiang* – Tiang, occurring eastwards from Chad across southern Sudan to Ethiopia and northern Kenya; *D. l. topi* – Coastal Topi from East Africa and *D. l. jimela* – the Topi in western Tanzania extending into south-western Kenya and Uganda.

The maps showing the continental distribution of the three species (**Figs. 2, 3 & 4**) are shown on the three pages following the taxonomic diagram.

**FAMILY : BOVIDAE – ANTELOPE**

- Subfamily : Alcelaphinae – Wildebeest, hartebeest, bontebok, blesbok, tsessebe
  - Tribe : Connochaetini – Black Wildebeest, Blue Wildebeest
  - Tribe : Alcelaphini – Hartebeest, Bontebok, Blesbok & Tsessebe
    - Genus: *Alcelaphus* – Lichtenstein's Hartebeest, Red Hartebeest
    - Genus: *Damaliscus* – Bontebok, Blesbok, Tsessebe
      - Species : *Damaliscus dorcas* – Bontebok, Blesbok
      - Species : *Damaliscus lunatus* – Tsessebe, Topi, Tiang and Korrigum — 5 subspecies
        - **Subspecies: *D. l. lunatus* – Tsessebe** — only subspecies in southern Africa
- Subfamily : Cephalophinae – Duikers
- Subfamily : Antilopinae – Springbok, klipspringer, dik-dik, oribi, steenbok, grysbok, suni
- Subfamily : Aepycerotinae – Impala
- Subfamily : Pelinae – Grey rhebok
- Subfamily : Hippotraginae – Roan, sable, gemsbok
  - Genus: *Hippotragus* – Roan, sable
    - **Species : *Hippotragus equinus* – Roan** — no subspecies
    - Species : *Hippotragus niger* – Sable — possibly 4 subspecies
      - **Subspecies: *H. n. niger* – Sable** — only subspecies in southern Africa
  - Genus: *Oryx* – Oryx — 3 species
    - Species : *Oryx gazella* – Gemsbok — Only species in southern Africa, no subspecies
- Subfamily : Bovinae – Buffalo, kudu, sitatunga, nyala, bushbuck, eland
  - Tribe : Bovini – Buffalo
    - Genus: *Syncerus* – Buffalo
      - Species : *Syncerus caffer* – Buffalo — 4 subspecies
        - **Subspecies: *S. c. caffer* – Southern savanna buffalo** — Only subspecies in southern Africa
  - Tribe : Tragelaphini – Kudu, sitatunga, nyala, bushbuck, eland
- Subfamily : Reduncinae – Reedbuck, waterbuck, lechwe, puku

**Figure 1**: Taxonomy of the Antelope Family (*Bovidae*) based on Smithers (1983)

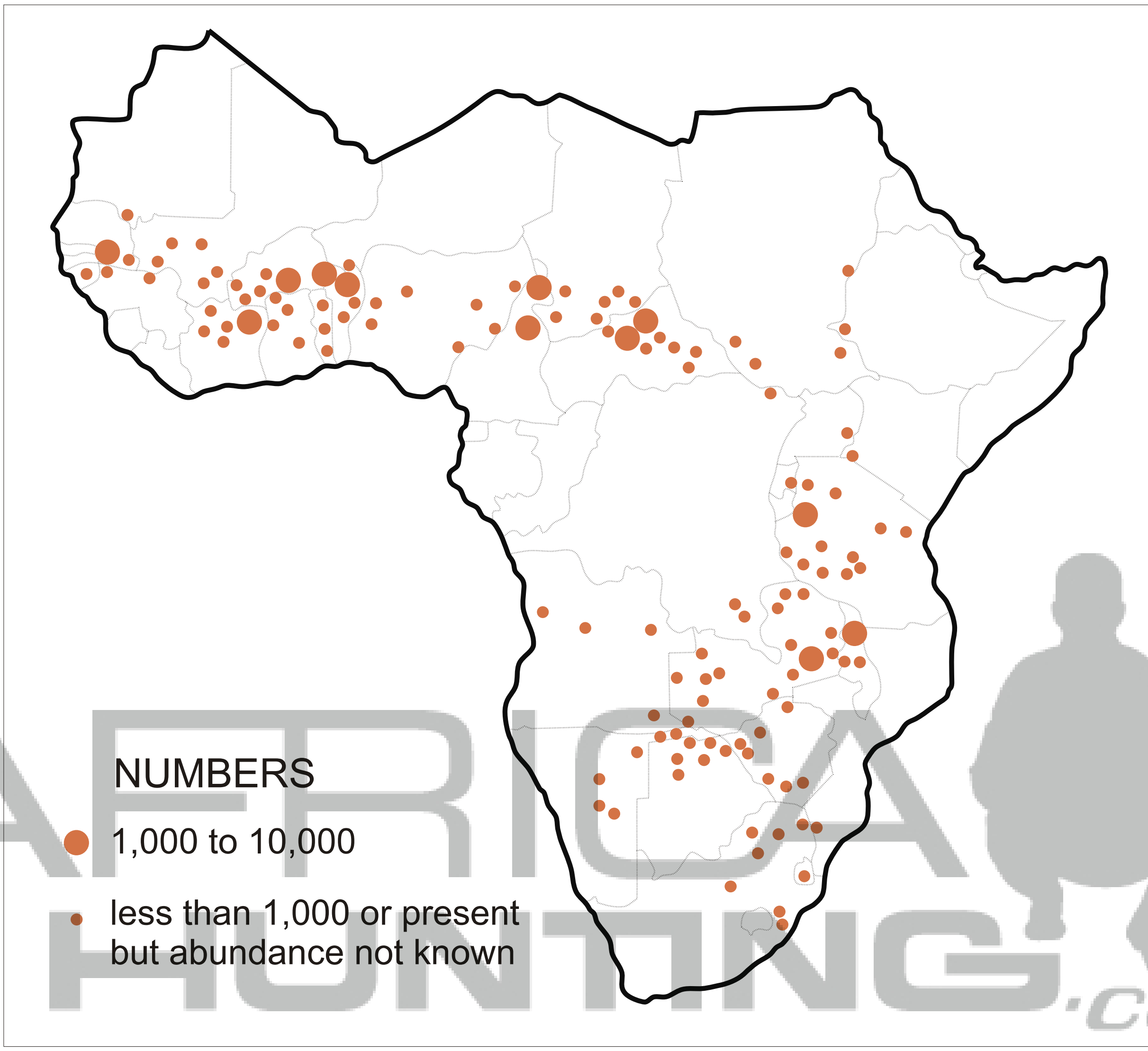


**Figure 2**: The Distribution of Roan Antelope in Africa. *Source: ASG (1998)*

### b. Physical description

Roan are a large antelope, second only in size to eland. Adult males have a shoulder height of about 1.4 metres and weigh slightly under 300kg. Females are slightly smaller and lighter. Both sexes carry horns which rise from the head in a uniform backward curve and are ridged. The longest pair of horns on record (99 cm) are from a trophy taken in the Tokwe Valley, Zimbabwe (Best and Best, 1977). The females' horns are smaller than the males.

The body coat is greyish brown with touches of rufous colouring which varies amongst individuals. The legs are darker brown than the remainder of the body and the animal possesses a noticeable mane. The most distinctive features are the facial markings which resemble a black balaclava mask with elongated white 'cut-outs' around the eyes. The ears are unusually long with dark brown tufts on the tips.

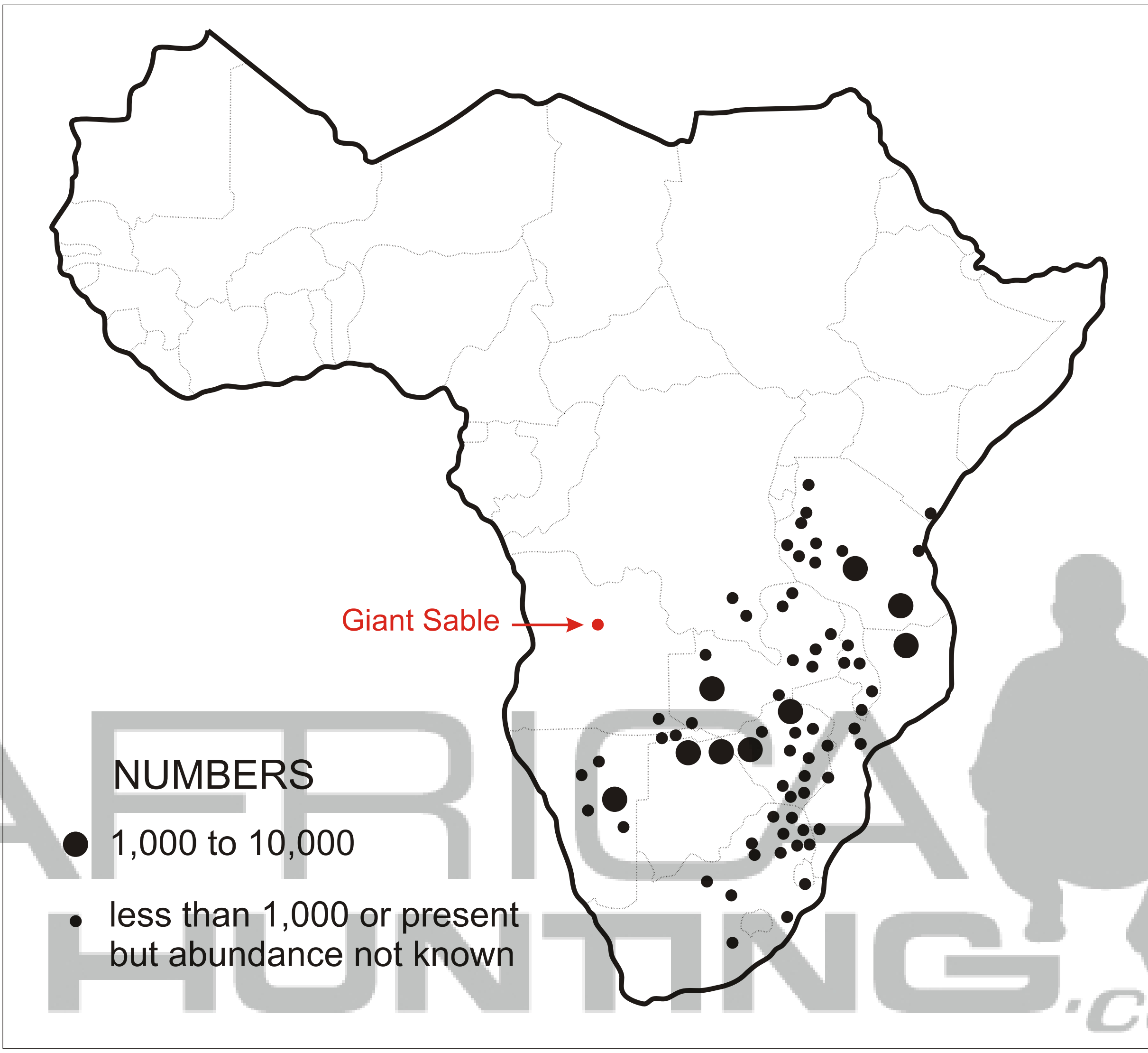


**Figure 3**. The Distribution of Sable Antelope in Africa. *Source: ASG (1998)*

Sable are slightly smaller than roan, with adult males standing under 1.4 metres at the shoulder and weighing about 230kg. There is a distinct dimorphism: older males have shiny black coats whilst females are dark brown. Subadults and juveniles of both sexes tend to be a lighter shade of brown. All have white bellies with the colour extending inside the rear legs and up to the base of the tail. The face is marked longitudinally with white stripes extending from each eye towards the muzzle.

Both sexes carry horns but the fully developed male horns are far larger than those of the females. The horns sweep back from the head in a characteristic curve, with the largest trophies from the southern African region being just over 50 inches.

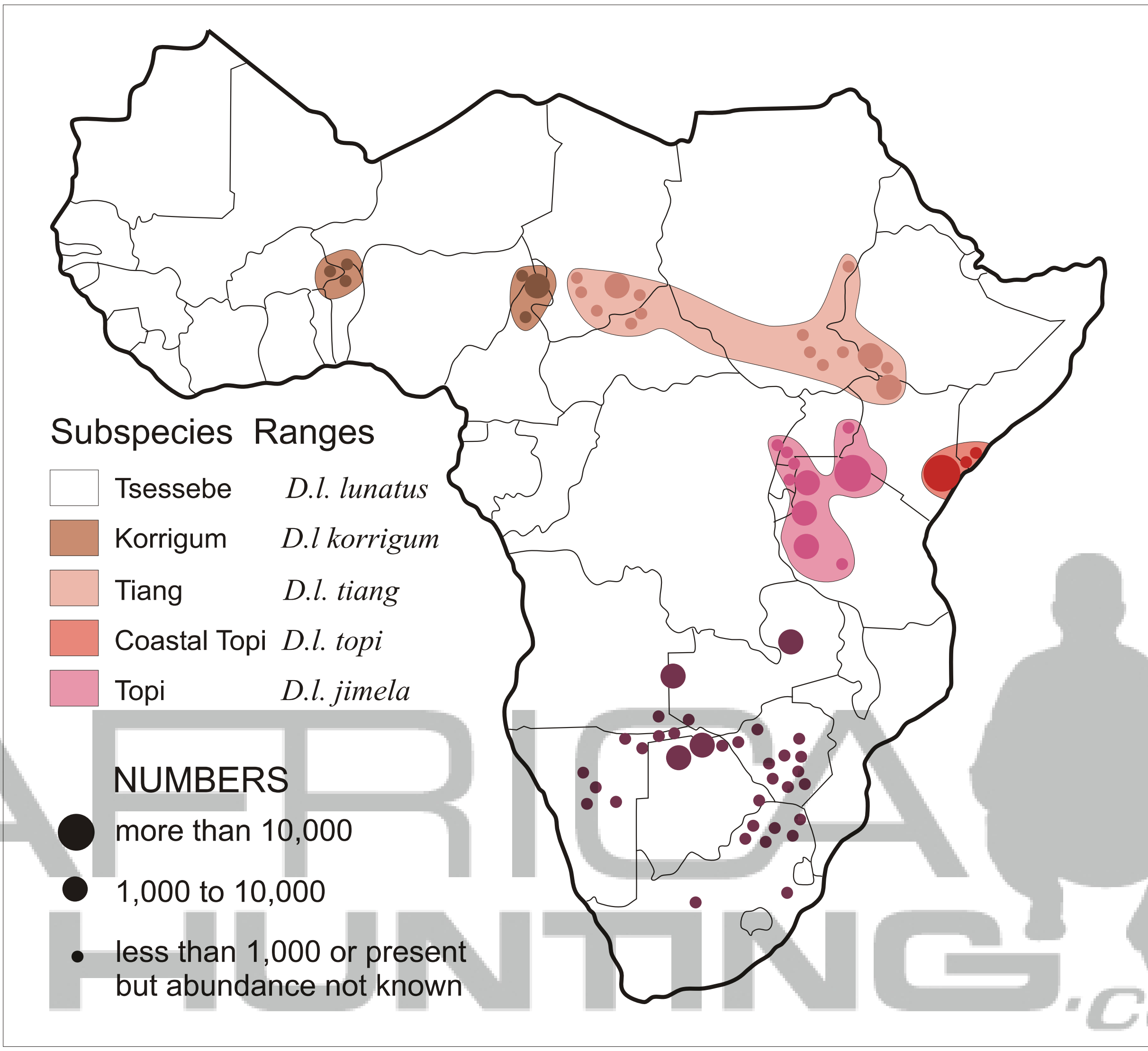




**Figure 4**: Distribution of tsessebe and other subspecies of the species *Damaliscus lunatus* in Africa.
Source: ASG(1998a)

Tsessebe are smaller than sable, with adult males standing about 1.2 metres at the shoulder and weighing about 140kg. The average female body weight is slightly less than 130kg. The general colour of the body is dark reddish-brown with a purplish sheen. The upper part of the head and muzzle is almost black. The colouration of the flanks and withers are darker than the remainder of the body giving the appearance of a 'watermark' from mid-body downwards. There is some yellowish colouring on the base of the tail, the back of the ears, the insides of the hind legs and on the abdomen. Tsessebe have a characteristic body shape which slopes downwards towards to the rump.

Both sexes possess horns which rise close together in the centre of the head and bend outwards and upwards in a uniform curve. A record trophy of 47cm (Best and Best, 1977) was taken in northern Botswana.

### c. Habitat

Pienaar (1974) examined the range of physiognomic habitat types occupied by the different large mammal species in Africa. Coetsee (1980) re-ordered Pienaar's original table of vegetation types and clustered the various mammal species to show similarities of habitat occupation. At the broadest level, Coetsee categorised habitats into three main types: dense woody vegetation, non-desert open vegetation, and subdesert and desert vegetation. Roan, sable and tsessebe are found only in the second category. Coetsee noted specifically the close similarity between roan and tsessebe in their range of selected habitats.

I have revisited Pienaar's original classification and present the tables on the following page (**Table 1**) which show the 'niches' occupied by roan, sable and tsessebe. The niche for each species is essentially three-dimensional: the first axis (the columns in the matrix below) shows the occurrence of the species along a moisture gradient, the second axis (the rows in the matrix below) shows the degree of openness of the habitat, ranging from deserts to closed forests, and the third axis is an altitudinal gradient from lowland tropical to temperate montane conditions (the dual columns under the broad heading "Mesic" in each table). The content of the tables is represented pictorially in **Fig. 5** on the next page.

All three species occur only in the middle range of moisture conditions (mesic) – they are not found in very dry or in high rainfall areas. This is significant for attempts to conserve them in Namibia – the majority of the country falls below the lower limit of acceptable precipitation. Both roan and tsessebe are found across a wide altitudinal range – they occur from tropical lowlands to temperate montane conditions (e.g. the Nyika plateau in Malawi). Sable, however, are not found in the in the cool high altitude areas. All three species have a strong preference for open and fairly well treed savannas, although roan and tsessebe tend to avoid closed canopy woodlands. Roan is the only one of three species found in rocky outcrops and sable does not occur in swamp/grassland habitats.

I have summarised and compared the key findings on the habitat requirements of roan, sable and tsessebe in **Table 2** (page 9) which has been compiled from studies carried out by Dörgeloh (1998), Dunham and Robertson (2001), Erb (1993), Grobler (1974), Harrington (*et al* 1999), Joubert (1976a), Joubert and Bronkhorst (1977), Pienaar (1963), Smithers (1983), Wilson (1975) and Wilson and Hirst (1977).

A list of grass species eaten by roan, sable and tsessebe (**Table 3**, page 10) has been compiled from detailed feeding studies undertaken by Erb (1993), Grobler (1974, 1981b), Huntly (1972), Joubert (1976), Perrin and Taolo (1999), Wilson (1975) and Wilson and Hirst (1977). Because most of the studies have been done in restricted localities, the list is unlikely to be comprehensive. It nevertheless shows that there are a number of grass species common to the diet of all three antelope species. At the genus level, which is probably a more useful indicator of shared preferences on a regional scale, seven grass genuses are common to all three antelope species.

Both roan and sable browse to a limited extent in the dry season – sable less so than roan. Wilson (1975) noted that roan in northern Transvaal remained in better body condition than sable because of being able to switch to browsing in critical periods. A list of woody species eaten by roan and sable (**Table 4**, page 11) has been compiled from the studies of Erb (1993), Grobler (1974), Joubert (1976), and Wilson (1969).

## Table 1. Habitat Niches occupied by Roan, Sable and Tsessebe

| **ROAN** | DRY | MESIC | | WET |
|---|---|---|---|---|
| | | TEMPERATE | TROPICAL | |
| ROCKY OUTCROP | | | 1 | |
| GRASSLAND/SWAMPLAND | | 2 | 2 | |
| SHRUB SAVANNA | | 1 | 2 | |
| OPEN TREE SAVANNA | | | 2 | |
| TREE SAVANNA | | 2 | 2 | |
| WOODLAND | | | 1 | |
| THICKET | | | | |
| FOREST | | | | |

| **SABLE** | DRY | MESIC | | WET |
|---|---|---|---|---|
| | | TEMPERATE | TROPICAL | |
| ROCKY OUTCROP | | | | |
| GRASSLAND/SWAMPLAND | | | | |
| SHRUB SAVANNA | | | 1 | |
| OPEN TREE SAVANNA | | | 2 | |
| TREE SAVANNA | | | 2 | |
| WOODLAND | | | 2 | |
| THICKET | | | | |
| FOREST | | | | |

| **TSESSEBE** | DRY | MESIC | | WET |
|---|---|---|---|---|
| | | TEMPERATE | TROPICAL | |
| ROCKY OUTCROP | | | | |
| GRASSLAND/SWAMPLAND | | 2 | 2 | |
| SHRUB SAVANNA | | 2 | 2 | |
| OPEN TREE SAVANNA | | | 2 | |
| TREE SAVANNA | | 1 | 2 | |
| WOODLAND | | | 1 | |
| THICKET | | | | |
| FOREST | | | | |

In the cells of each matrix, the number '1' indicates that the species has been recorded in the particular habitat and the number '2' indicates a strong preference for the habitat type.

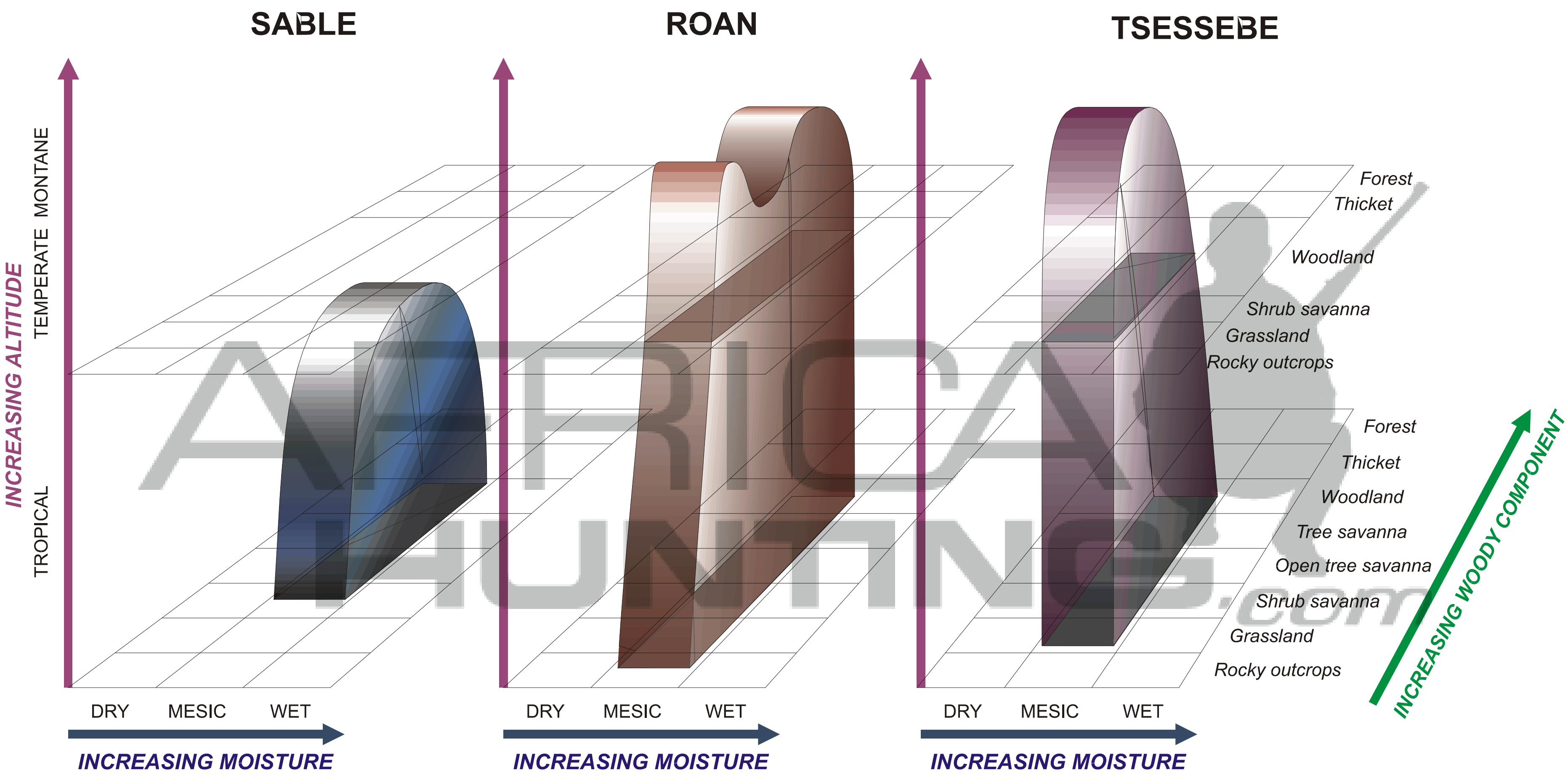


**Figure 5**. Habitat Niches of Roan, Sable and Tsessebe

## Table 2. Habitat requirements of Roan, Sable and Tsessebe

<table>
<tr><th>Roan</th><th>Sable</th><th>Tsessebe</th></tr>
<tr><td colspan="3">All are predominantly grazers</td></tr>
<tr><td colspan="2">Include a small amount of browse in their dry season diet</td><td>Not known to browse</td></tr>
<tr><td colspan="3">All are water dependent</td></tr>
<tr><td>Usually found within 5km of water.</td><td>Usually found within 3km of water.</td><td>Usually found within 1km of water.</td></tr>
<tr><td colspan="3">All occur primarily in savanna woodlands</td></tr>
<tr><td>Prefer lightly wooded savanna with open areas of medium to tall grasses. Tolerant of low bush growth up to 1.5m provided it is open and patchy. Well adapted to grass heights up to 1.5m.</td><td>Dependent on cover. Prefer open woodlands adjacent to vleis or grassland with medium to high stands of grass.</td><td>Optimum habitats are open stands of healthy grasslands with easily accessible shelter in form of trees or shrubs either as an ecotone or as scattered islands in the grassland.</td></tr>
<tr><td>Avoid closed canopy woodland and thick closed stands of bush 1.5-4m high. Avoid short grass areas.</td><td>Avoid dense woodland and short grasslands especially when overused by other species.</td><td>Avoid habitats where plant height exceeds 2 metres.</td></tr>
<tr><td>Spend little time on burns even when a green flush occurs – prefer taller grass stands.</td><td>Not particularly attracted to burns.</td><td>Prefer burnt to unburnt areas. Readily concentrate on burned areas when a green flush appears.</td></tr>
<tr><td colspan="3">All are highly selective feeders<br>– characterised by narrow muzzles with which they can select particular clusters of leaves from grass swards</td></tr>
<tr><td>Select climax green grass species with a high nutrient content and those that have a high leaf to stem ratio. Delicate feeders, using the higher parts of grasses from 8 cm above ground – not close croppers like wildebeest or zebra. In any given locality, two or three grass species make up the bulk of diet.</td><td>Prefer medium height green grasses and have a narrow range of acceptable grass species.</td><td>Strong predilection for young green grass shoots up to 60cm tall. Appear to select for stage of grass growth rather than species per se.</td></tr>
<tr><td colspan="3">All are sensitive to habitat changes and have critical habitat requirements<br>Physiognomic changes to vegetation structure such as those brought about by elephants are capable of a major impact on all three species. Loss of canopy trees resulting in changes to the species composition and structure of grass swards and the trampling effects of large numbers of elephant are all potentially negative influences. Overutilisation, inter-specific competition and trampling of grass by cattle and other large mammal species also renders habitats less favourable for roan, sable and tsessebe.</td></tr>
<tr><td>Sensitive to any increase in the density of woody plants or reduction in grass cover.</td><td>Unable to cope with superabundant grass in good rainfall years. Grass swards are underutilised, resulting in favourable conditions for tick irruptions.</td><td>Structural changes to habitats which obstruct movement, affect access to water, visibility and cover all have a major impact on tsessebe.</td></tr>
<tr><td colspan="3">As a result of these factors, the distribution of all three species is patchy and discontinuous across their range.</td></tr>
</table>

**Table 3.** Grass species eaten by roan, sable and tsessebe

| Roan | Sable | Tsessebe |
|---|---|---|
| *Andropogon schirensis* | | |
| *Aristida spp* | | |
| | *Brachiaria brizantha* | |
| *Brachiaria nigropedata* | *Brachiaria nigropedata* | *Bracharia nigropedata* |
| | *Cynodon dactylon* | *Cynodon dactylon* |
| *Digitaria pentzii* | *Digitaria pentzii* | *Digitaria pentzii* |
| *Digitaria serriata* | | |
| *Digitaria spp* | | |
| | | *Eragrostis chloromelas* |
| *Eragrostis curvula* | | |
| | *Eragrostis gummiflua* | |
| *Eragrostis plana* | | |
| *Eragrostic superba* | | |
| *Eragrostis jeffreysii* | *Eragrostis jeffreysii* | |
| *Heteropogon contortus* | *Heteropogon contortus* | *Heteropogon contortus* |
| *Hyparrhenia hirta* | *Hyparrhenia hirta* | *Hyparrhenia hirta* |
| *Hyparrhenia spp* | | |
| | *Hyperthelia dissoluta* | *Hyperthelia dissoluta* |
| *Melinis spp* | | |
| *Panicum colorata* | | |
| *Panicum kalaharense* | | |
| *Panicum maximum* | *Panicum maximum* | |
| | *Pogonarthria squarrosa* | |
| *Rhyncelytrum repens* | | *Rhynchelytrum repens* |
| | *Schyzachyrium jeffreysii* | |
| *Schizachyrium sanguineum* | | |
| *Schmidtia pappophoroides* | | |
| | *Setaria perennis* | *Setaria perennis* |
| *Setaria woodii* | | |
| *Setaria spp* | | |
| | | *Sorghum verticilaster* |
| *Sporobolus fimbriatus* | | |
| *Themeda triandra* | *Themeda triandra* | *Themeda triandra* |
| | *Trachypogon spicatus* | |
| *Trichoneura grandiglumis* | | |
| *Triraphis schinzii* | | |
| | *Urochloa bolbodes* | |

*Grass species which are common to roan, sable and tsessebe* (darker shading)
*Grass species which are common to two of the three antelope species* (lighter shading)

An examination of the table shows the following grass genuses are common to the diet of roan (R), sable (S) and tsessebe (T)

| | |
|---|---|
| Genus common to RST | *Brachiaria, Digitaria, Eragrostis, Heteropogon, Hyparrhenia, Setaria, Themeda* |
| Genus common to RS only | *Panicum, Schizachyrium* |
| Genus common to RT only | *Rhynchelytrum* |
| Genus common to ST only | *Cynodon, Hyperthelia* |

**Table 4.** Woody plant species in the diet of roan and sable

| **Species** | **Locality** |
|---|---|
| *Acacia ataxacantha* | Waterberg, Namibia |
| *Acacia karroo* | Matopos NP, Zimbabwe |
| *Acacia* spp. | Percy Fyfe Nature Reserve, South Africa |
| *Dichrostachys cinerea* | Matopos NP, Zimbabwe |
| *Dombeya rotundifolia* | Matopos NP, Zimbabwe |
| *Faurea saligna* | Kruger NP, South Africa |
| *Grewia flava* | Matopos NP, Zimbabwe |
| *Grewia monticola* | Matopos NP, Zimbabwe |
| *Grewia reticulata* | Waterberg, Namibia |
| *Lippia javanica* | Matopos NP, Zimbabwe |
| *Lippia oatzii* | Matopos NP, Zimbabwe |
| *Lonchocarpus nelsii* | Waterberg, Namibia |
| *Ochna pulchra* | Waterberg, Namibia |
| *Olea africana* | Kruger NP, South Africa |
| *Philenoptera violacea** | Percy Fyfe Nature Reserve, South Africa |
| *Tarchonanthus camphoratus* | Matopos NP, Zimbabwe |
| *Rhus lancea* | Kruger NP, South Africa & Matopos NP, Zimbabwe |
| *Rhus pyroides* | Kruger NP, South Africa |
| *Ziziphus mucronata* | Matopos NP, Zimbabwe |

* Previously *Lonchocarpus capassa*

### d. Reproduction and Population Dynamics

There is sufficient similarity in the biological parameters which determine the population dynamics of roan, sable and tsessebe to permit a generic population model to be used to examine their expected breeding performance under average conditions. The key parameters have been derived from Erb (1993), Dunham, Robertson & Swanepoel (2003), Dunham and Robertson (2001), Grobler (1974, 1979, 1980, 1981a), Joubert and Bronkhorst (1977), Penzhorn and van der Merwe (1993) and Smithers (1983) and are summarised in **Table 5** below.

**Table 5**. Reproductive parameters for roan, sable and tsessebe

| | |
|---|---|
| Seasonal breeding | Roan breed throughout the year; sable give birth to calves January-March; tsessebe give birth to calves October-November. |
| Gestation | All 8-9 months |
| Age at first conception | Almost all females conceive after about two years |
| Age at first parturition | Almost all females produce calves in third year of life |
| Fecundity (adults) | All adult females are capable of producing a calf every year – fecundity of roan may be slightly above unity in favourable conditions |
| Longevity | Few animals survive beyond 12 years of age in the wild |
| Breeding longevity | Females are probably capable of breeding throughout their adult life although fecundity may be reduced in last few years |
| Mortality (juveniles) | About 25% in average years |
| Mortality (yearlings) | Females about 5%, males generally higher |
| Mortality (adult males) | Around 10%, increasing in the last few years of life |
| Mortality (adult females) | Less than 5% except in last few years of life |
| Adult sex ratio ♀♀:♂♂ | About 2:1 depending on hunting regimes and predation |

A simple population model using these parameters is given in **Appendix 1**. Under average conditions, roan, sable and tsessebe populations could be expected to increase at a rate of slightly under 14% per annum when they are below ecological carrying capacity.[1]

The term "average conditions" is loaded. In semi-arid ecosystems, variations in annual rainfall may have profound effects on the performance of these three species. Dunham and Robertson (2001) and Dunham, Robertson and Swanepoel (2003) demonstrated a strong relationship between the survival of tsessebe and the accumulated surplus or deficit in rainfall over a long period. They also found a strong correlation between adult and juvenile mortality and the rainfall in the late dry season. Rainfall in late dry season appears to be critical, affecting the animals' condition, survival rate, late stage of pregnancy and early stage of lactation.

1. Sable and tsessebe are recorded as reaching densities of over 4/$km^2$ in favourable habitats where rainfall is 500-600mm per year. At this level of rainfall, the ceiling densities for roan seldom exceed 2/$km^2$ (Erb 1993).

The population models developed by Dunham *et al* based on these variables (which also take into account tsessebe numbers, i.e. density dependence) appear to explain very adequately the variations in tsessebe populations in both Kruger National Park and on a mixed cattle/game ranch in Zimbabwe. Erb (1993) modelled the roan population in the Waterberg Plateau Park in Namibia incorporating the late dry season rainfall and obtained a very close fit between the actual population estimates and the number predicted from the model. In a study of sable in Zimbabwe, Grobler (1981) found that any animals weakened by stress during the dry season were likely to die from parasites soon after onset of rains. This phenomenon appeared particularly to affect neonatal mortality and subsequent juvenile mortality when losses increased towards end of the dry season caused by a downward trend in nutrition.

It seems eminently feasible that the long term surplus or deficit in rainfall[2] could be the main determinant of the vegetation structure, particularly of grasslands, in any given locality. A prolonged drying out process would affect water tables and the catenas in vegetation from river banks to the upper reaches of catchments. Species such as tsessebe would find their preferred habitats shrinking to narrow bands close to rivers. Sable and roan would be affected by changes in species composition in grass swards and shifts between perennial and annual grasses.

I have examined the extent to which the given regime of adult female and juvenile mortality in **Appendix 1** (which was derived for 'average conditions') would have to change in order to throw the 'generic' population into a decline **(Table 6)**. In the two tables, each age-specific female survival rate has been changed by the proportion indicated.

**Table 6.** Sensitivity of the population to changes in adult female and juvenile survival

**Table 6a**. Effects of changes in adult female survival on population growth rate

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Change in adult female survival % | +2% | +1% | 0 | -5% | -10% | -15% | -20% |
| Rate of population growth % | 15.5 | 14.5 | 13.6 | 8.9 | 4.2 | 0.0 | Decline |

**Table 6b**: Effects of changes in juvenile survival on population growth rate

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Change in juvenile survival % | +30% | +20% | +10% | 0 | -10% | -20% | -30% | -40% | -50% | -55% | -60% |
| Rate of population growth % | 19.7 | 17.4 | 15.6 | 13.6 | 11.5 | 9.3 | 6.8 | 4.1 | 1.0 | 0.0 | -ve |

In the population model of Appendix 1, juvenile survival was set at 75% (a mortality of 25%). It is apparent from Table 6b that the population can tolerate very large increases in juvenile mortality – if survival is halved, the population continues to increase – albeit at a low growth rate (1%). The same is not true for adult female survival (for the purposes of this test, all female age classes other than juveniles were treated as 'adults'). An overall decrease of 15% in the existing schedule of age-specific survival rates of adult females brings population growth to zero. The linkage between rainfall and adult mortality would not have to be particularly pronounced to produce major swings in the population.

2. In mathematical terms, this is effectively the integral of the deviations above and below the mean rainfall. It is the area under the curve of surpluses and deficits.

**e. Distribution**

(1) Regional Distribution

The distribution of roan, sable and tsessebe in southern Africa in relation to average annual rainfall is shown in **Figures 6-8** (pages 17,18,19). The data are from ASG(1998a) and are somewhat crude at the scale of individual subpopulations. Nevertheless, it is notable that –

- **There are no 'naturally' occurring populations of roan, sable or tsessebe below the 400mm rainfall isohyet**;
- Apart from a very few minor introduced populations of sable and tsessebe elsewhere in the region,[3] **Namibia is the only southern African country attempting to maintain populations of roan, sable and tsessebe in areas where the average rainfall is below 400mm**.[4]
- **Many of the observed population 'crashes' in roan, sable and tsessebe populations in the region have occurred in areas where the average annual rainfall is close to the lower limit which the species can tolerate**.

Mills, Biggs and Whyte (1995) concluded that rainfall was the principal determinant of numbers of common ungulates in southern African savannas. This fundamental constraint appears to receive too little emphasis in the plethora of proposed research studies and management measures designed to address the declines in roan, sable and tsessebe in parts of southern Africa (e.g. Grant and van der Walt 2000, Grant *et al* 2002, Harrington 1995, Harrington et al 1999, RARE 2002 and numerous other references). Dunham and Robertson (2001) demonstrate very clearly that rainfall accounts for the observed declines in tsessebe populations in Kruger National Park yet there appears to be a reluctance to accept this too-simple finding or apply it to other 'rare species' populations.

(2) Distribution of Roan, Sable and Tsessebe in Namibia

In the next three figures, the distribution of each species is shown in relation to rainfall.

**Roan**

The present and historical distribution of roan antelope in Namibia is shown in **Fig. 9** (page 20). The original range for the species has been taken from Shortridge (1934) and falls entirely above the 400mm rainfall isohyet. Hahn (1925) records roan as far east as 14ºE along the Cunene River in Ovamboland although noting that these were temporary movements during the rains. Gaerdes (1963) has examined early records of roan and gives none outside the range mapped by Shortridge. Joubert and Mostert (1975) note that the range for roan had decreased considerably since Shortridge's work.

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3. Below the 400mm rainfall isohyet, introduced populations of sable and tsessebe occur on private land in the vicinity of the Limpopo River in the northern province of South Africa and in the Beit Bridge area of Zimbabwe, and there is an introduced population of tsessebe in the Vaalbos National Park near Kimberley in South Africa.

4. The African Antelope Specialist Group (ASG 1998) remark that the populations of roan, sable and tsessebe in Namibia are outside of the species' 'natural range'.

The present 'natural range' for roan includes a variable number of animals in the East and West Caprivi, Khaudum Game Reserve and the Nyae Nyae Conservancy. These are not separate subpopulations: rather they are the extreme animals on the outskirts of the larger roan population in northern Botswana.

Roan were introduced to Etosha National Park in 1970 and to the Waterberg Plateau Park in 1975. The Kaross area in the west of Etosha where the main roan population is located falls below the 300mm rainfall isohyet and the population has not thrived (see next section on numbers). The Waterberg population is above the 400mm rainfall isohyet and has done better.

The various commercial farms onto which roan have been introduced have been accurately plotted in **Fig. 8**. Most of the farms lie below the 400mm rainfall isohyet[5] and it is likely that the long-term survival of roan on these properties will be dependent on supplementary feeding.

### Sable

The present and historical distribution of sable antelope in Namibia is shown in **Fig. 10** (page 21). Shortridge (1934) did not record the species outside of the Caprivi and it is not mentioned by Hahn (1925) as occurring in Ovamboland. Joubert and Mostert (1975, page 21) refer to sable in their list of "unrecorded mammals" and regard the odd sightings of the species in Caprivi as temporary excursions of Botswana animals. However, surveys of the Caprivi since 1980 suggest that there is a permanent population in several parts of the Caprivi.[6]

Sable were introduced to Etosha in 1978 and today there is a small population in the Khaobendes paddock in the extreme west of Etosha National Park which has remained fairly constant at around 50 animals for some years and there are about 30 sable in the park proper (Killian, pers. comm.). Except for the eastern end of the Park, the entire area falls below the 400mm rainfall contour and must be regarded as marginal range for sable. Sable were introduced to the Waterberg Plateau Park in 1980 and they have increased to around 100 animals over the past twenty years.

There are a large number of sable on commercial farms (two-thirds of the national population) but the majority of the properties shown in **Fig. 10** lie below the 400mm rainfall isohyet in marginal habitats for the species. As with roan, it is likely that they will require supplementary feeding in below average rainfall years to maintain their numbers.

### Tsessebe

The present and historical distribution of tsessebe in Namibia is shown in **Fig. 11** (page 22). The early range for tsessebe has been taken from Shortridge (1934) and it is notable that the species did not occur below the 500mm rainfall isohyet. Shortridge notes that the species was occasionally seen in what is now the extreme northerly end of Khaudum Game Reserve and, as recently as the mid-1980s, they were recorded during aerial surveys of this area.

---

5. One farm, the Ohorongo Game Reserve, lies below the 300mm rainfall isohyet and is not far from the Etosha Kaross population.

6. Mahango National Park, the western Core Area of the Caprivi Strip and the Kwando Triangle.

In the Caprivi, tsessebe were relatively abundant in the early part of the twentieth century. Gaerdes (1969) does not mention the species outside of the Caprivi and it is not mentioned by Hahn (1925) as occurring in Ovamboland.

Tsessebe were recorded in significant numbers in the Caprivi[7] in 1994 in two independent and comprehensive air surveys (ULG 1994 and Rodwell *et al* 1995). Since then there have not been any surveys covering all of the Caprivi in a single year – however, the limited surveys which have been done (Craig 1998 and Craig 2000) suggest that the tsessebe populations in the Caprivi have almost disappeared. Craig (1998) saw tsessebe in small numbers (fewer than 30 animals) in both Mahango and in the Kwando Triangle but, in the last air survey of Mahango (Craig 2000), no tsessebe were seen.

Tsessebe were unsuccessfully introduced to the Waterberg Plateau Park in 1981 with all of the founder population dying before being released from the holding paddock. In May 1984 a male was transferred from Khoabendes to Waterberg and in May 1985 14 adults were received from Percy Fyfe Nature Reserve, Transvaal (Erb 1992). The population has not thrived and only two animals are thought to be surviving now.

There are seven populations of tsessebe on commercial farms (**Fig.11**), four of which number more than 20 animals. Apart from one small group (12 animals) on Kamapu-Oos,[8] all of these newly established populations lie below the 400mm rainfall isohyet in far from optimum locations.

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Summarising this section, the most suitable habitats for roan, sable and tsessebe lie in the extreme north-west of Namibia where mean annual rainfall is above 500mm – primarily in the Caprivi and Kavango regions (**Fig.12**). Over the long term, the three species should survive above the 400mm isohyet but they will always be vulnerable to droughts in this zone.

Not unexpectedly, the highest human population densities also occur in the most favourable habitats for the three species. However, the parts of the former 'natural range' for roan, sable and tsessebe in which human densities exceed 10 persons/km$^2$ are less than 10% of the total potential range and, in theory at any rate, the potential still exists for the north-west of the country to carry large populations of all three species. However, competition with cattle (whose numbers are not indicated in maps of human population density) will undoubtedly reduce the available range.

Namibia's 'wild' populations of roan, sable and tsessebe all lie on the fringe of the larger Botswana populations. The present international veterinary fences separating the two countries limit the movements of the animals and this could result in isolated subpopulations on either side of the fence.

The combined limiting effects of rainfall, human settlement and veterinary fences are considered again Section 1.g on page 40.

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7. Tsessebe were recorded in Mahango, the Kwando Triangle and Mudumu.

8. Farm No. 24, Otjiwarongo District.

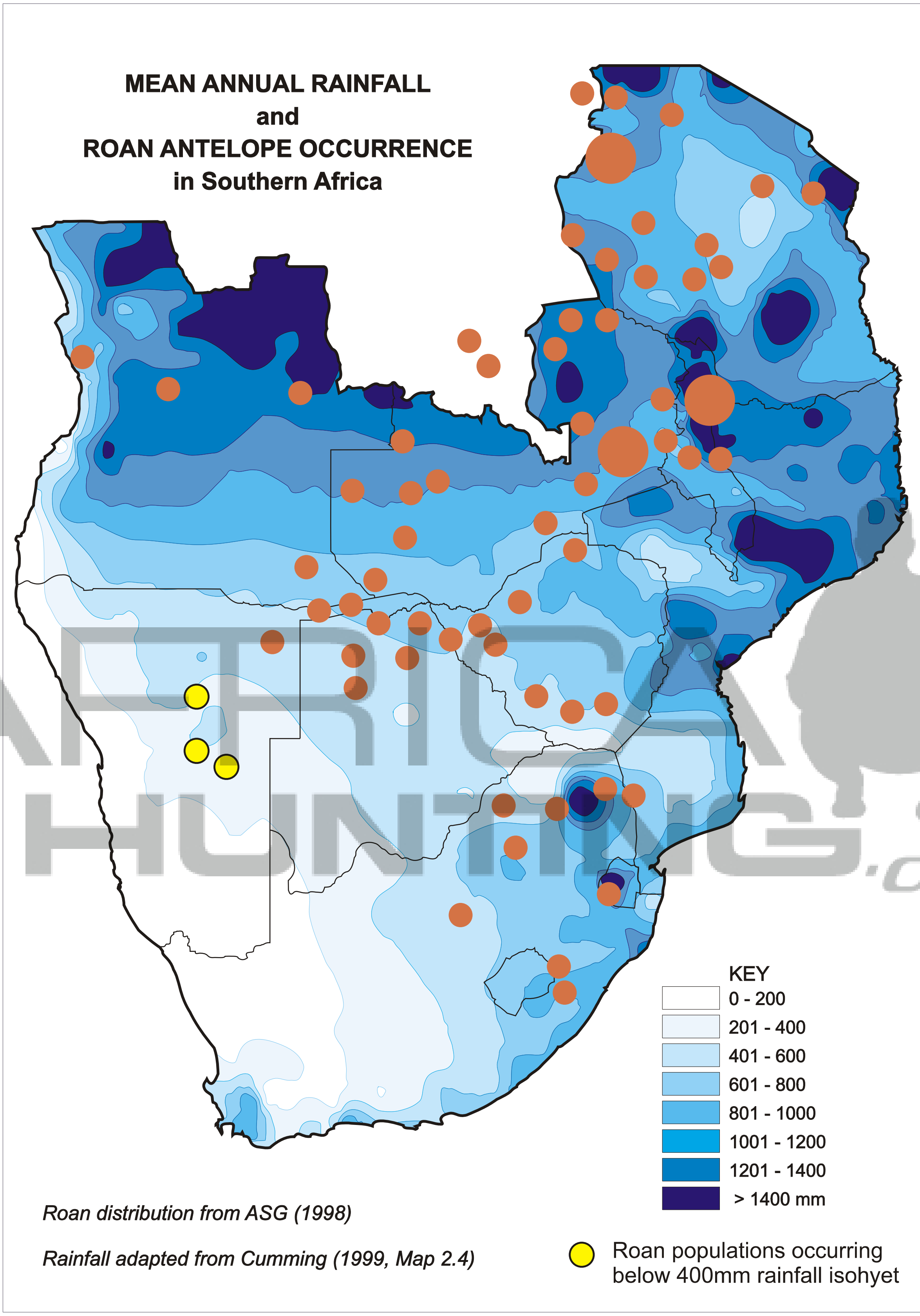



**Figure 6**. Distribution of roan antelope in southern Africa in relation to annual rainfall

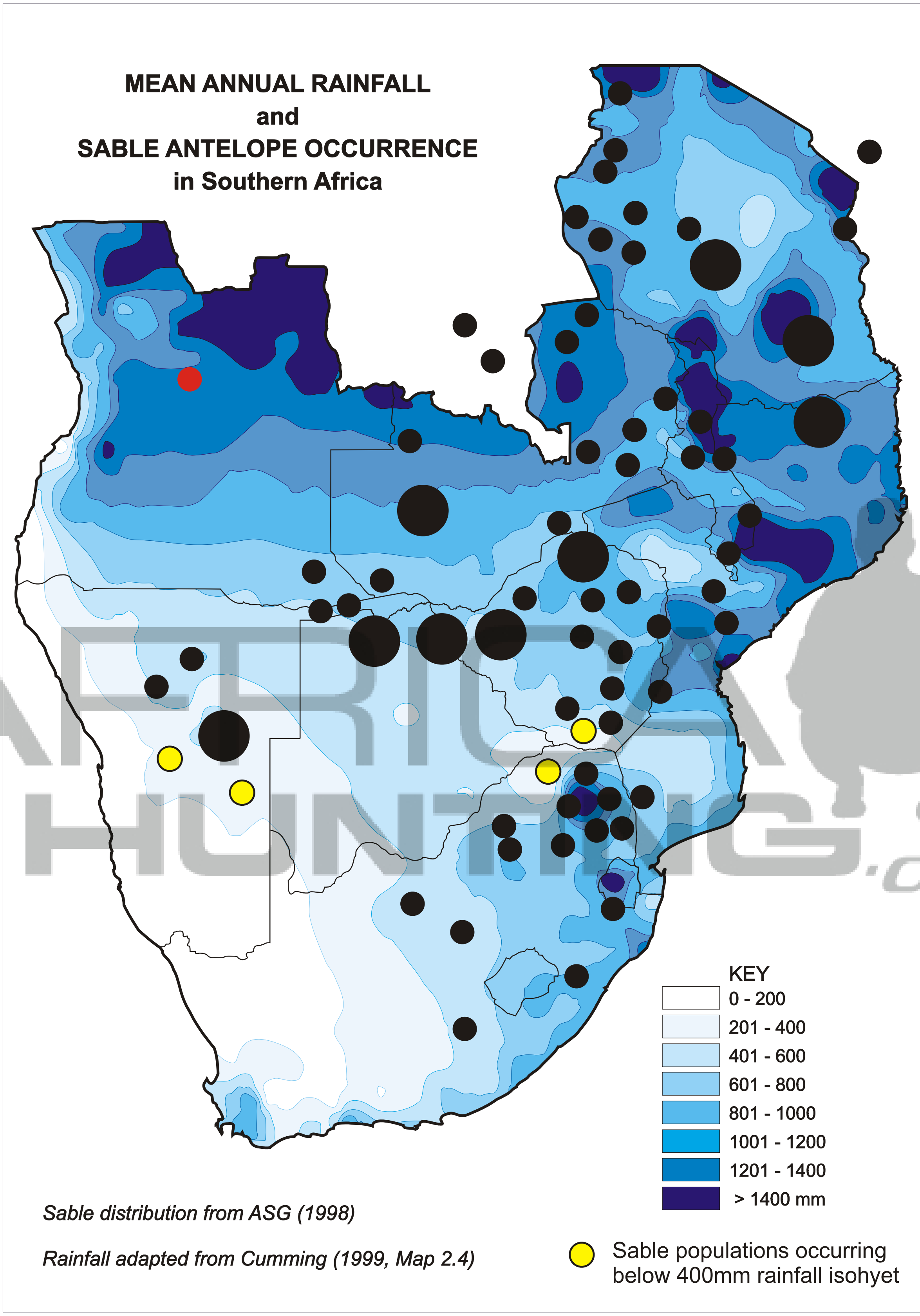





**Figure 7**. Distribution of sable antelope in southern Africa in relation to annual rainfall

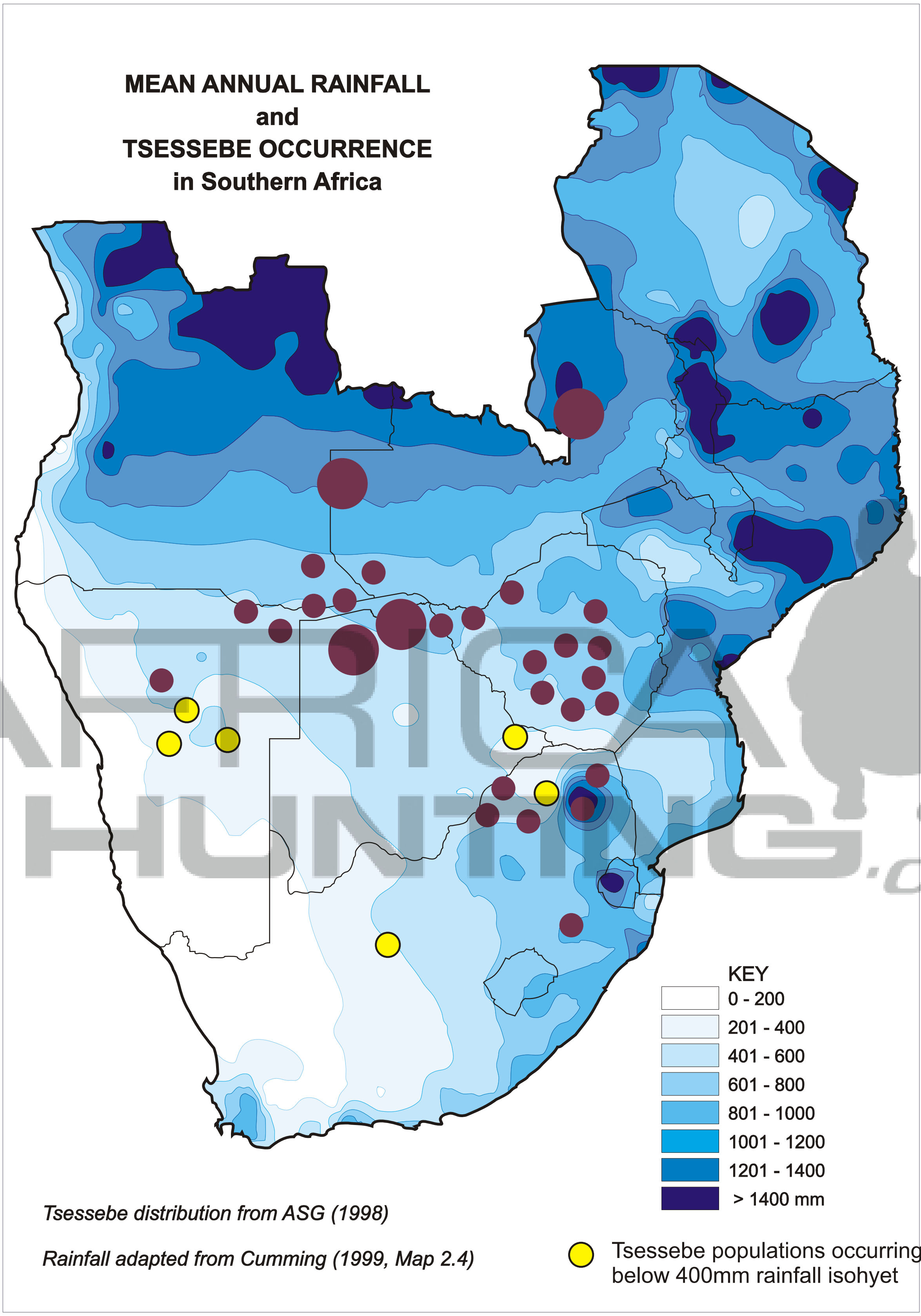
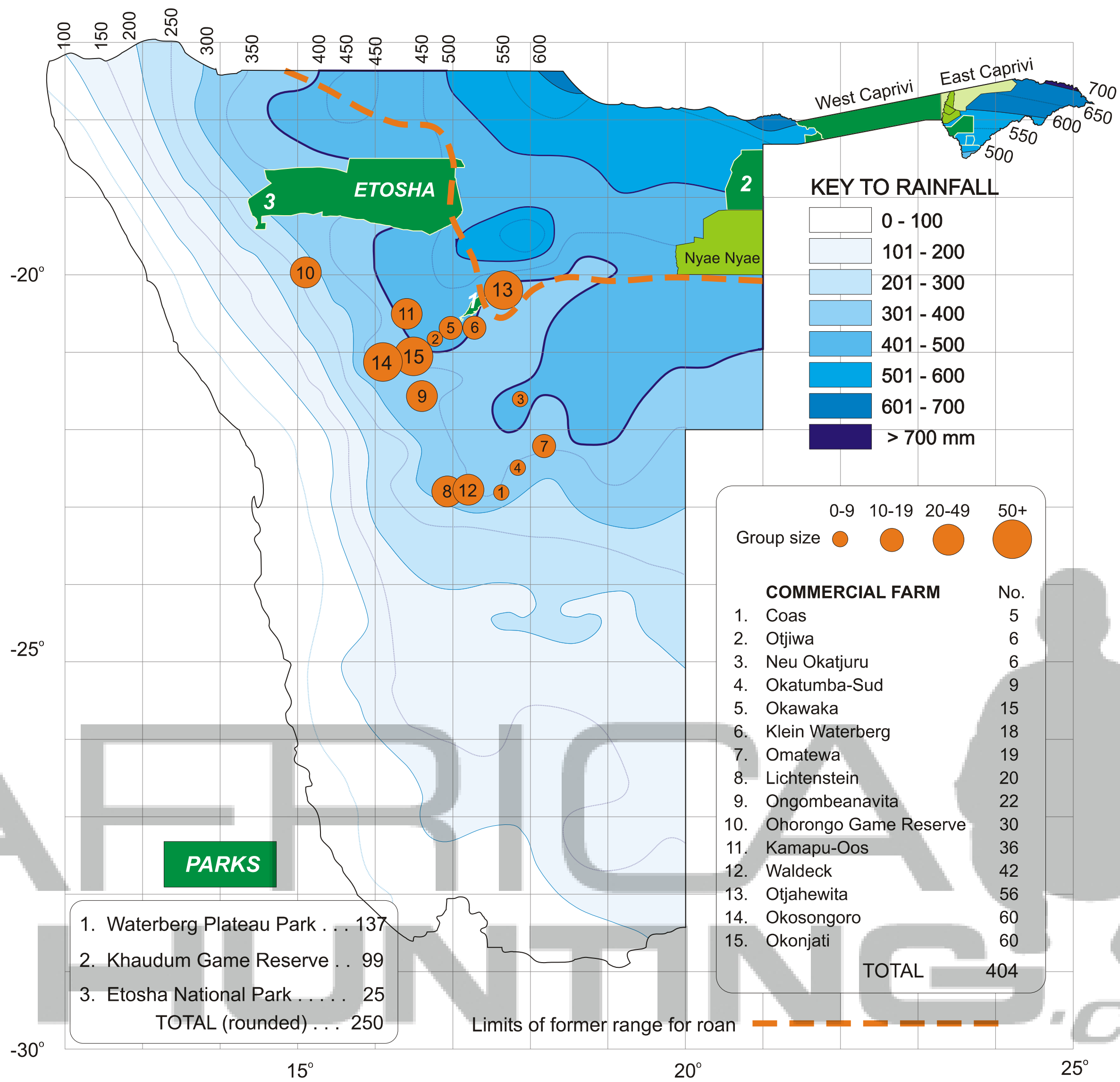




**Figure 8**. Distribution of tsessebe in southern Africa in relation to annual rainfall

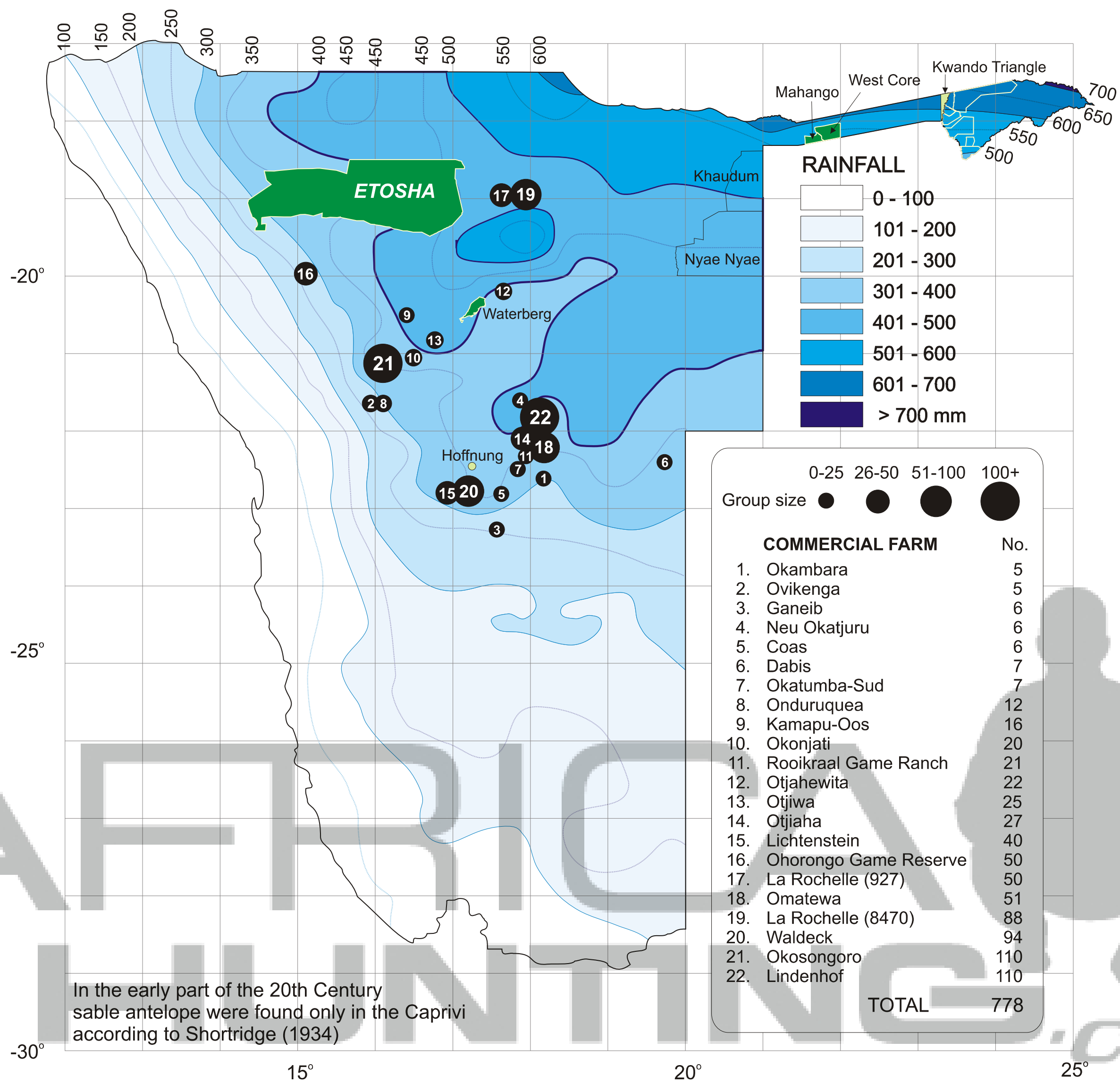





SUMMARY TABLE (rounded numbers)

| | |
|---|---|
| COMMERCIAL FARMS | 400 |
| STATE PROTECTED AREAS (excluding Caprivi) | 250 |
| CONSERVANCIES (Nyae Nyae) | 100 |
| WEST CAPRIVI (including Mahango and Kwando Triangle) | 25 |
| EAST CAPRIVI (lincluding Mudumu, Forest Reserve and and Conservancies) | 25 |
| **TOTAL** | **800** |

**Figure 9**. Distribution of Roan Antelope in Namibia

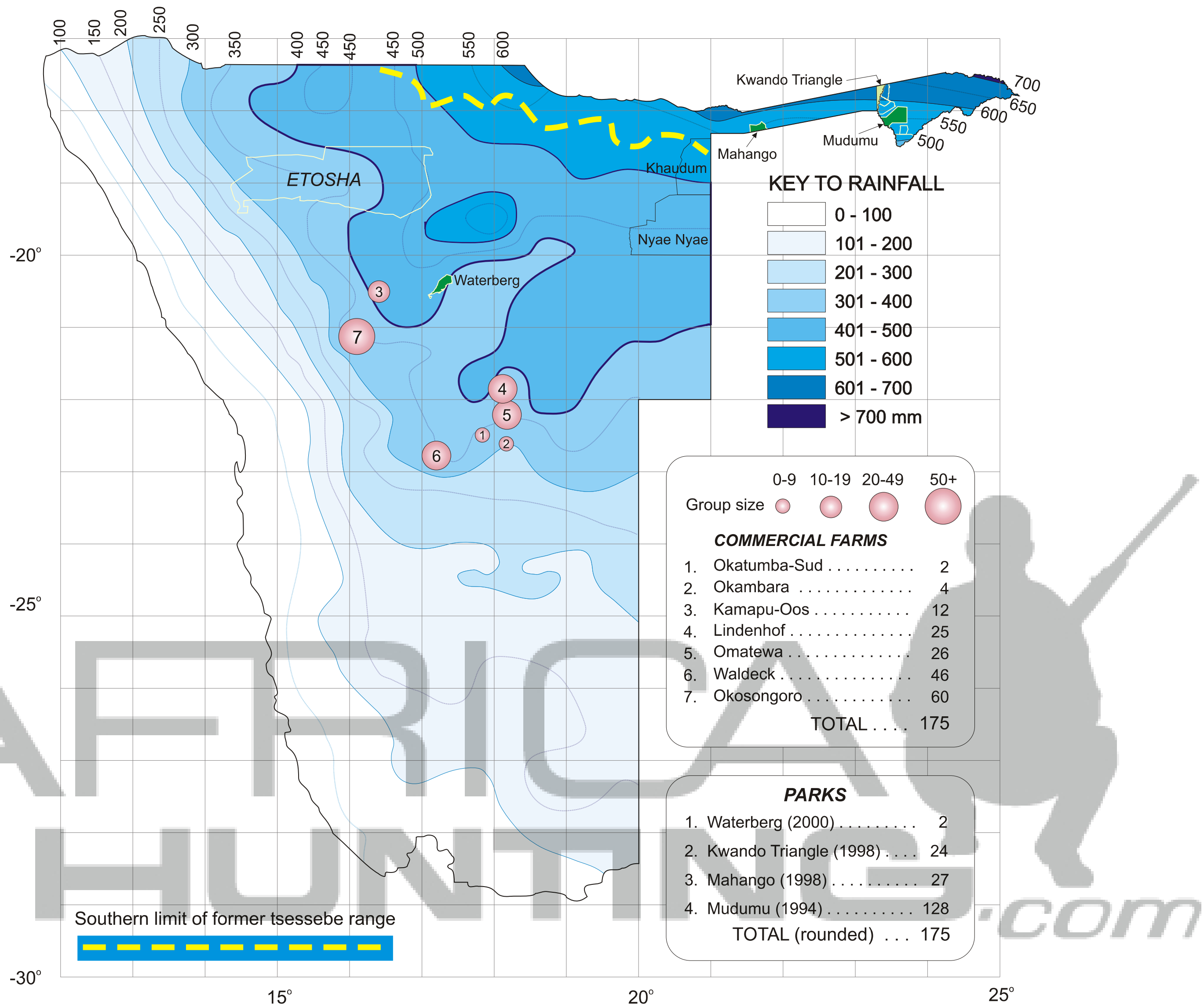





SUMMARY TABLE (rounded numbers)

| | | | |
|---|---|---|---|
| COMMERCIAL FARMS | | | 800 |
| STATE PROTECTED AREAS | Hoffnung Part II | 1 | |
| | Western Core (1998) | 21 | |
| | Kwando Triangle (1998) | 70 | |
| | Etosha National Park (2003) | 78 | |
| | Waterberg Plateau Park (2000) | 119 | |
| | Mahango Game Reserve (2000) | 130 | |
| | TOTAL | 419 | 400 |
| | **TOTAL** | | **1,200** |

**Figure 10**. Distribution of Sable Antelope in Namibia




SUMMARY TABLE (rounded numbers)

| | |
|---|---|
| COMMERCIAL FARMS | 175 |
| STATE PROTECTED AREAS | 175 |
| **TOTAL** | **350** |

**Figure 11**. Distribution of Tsessebe in Namibia

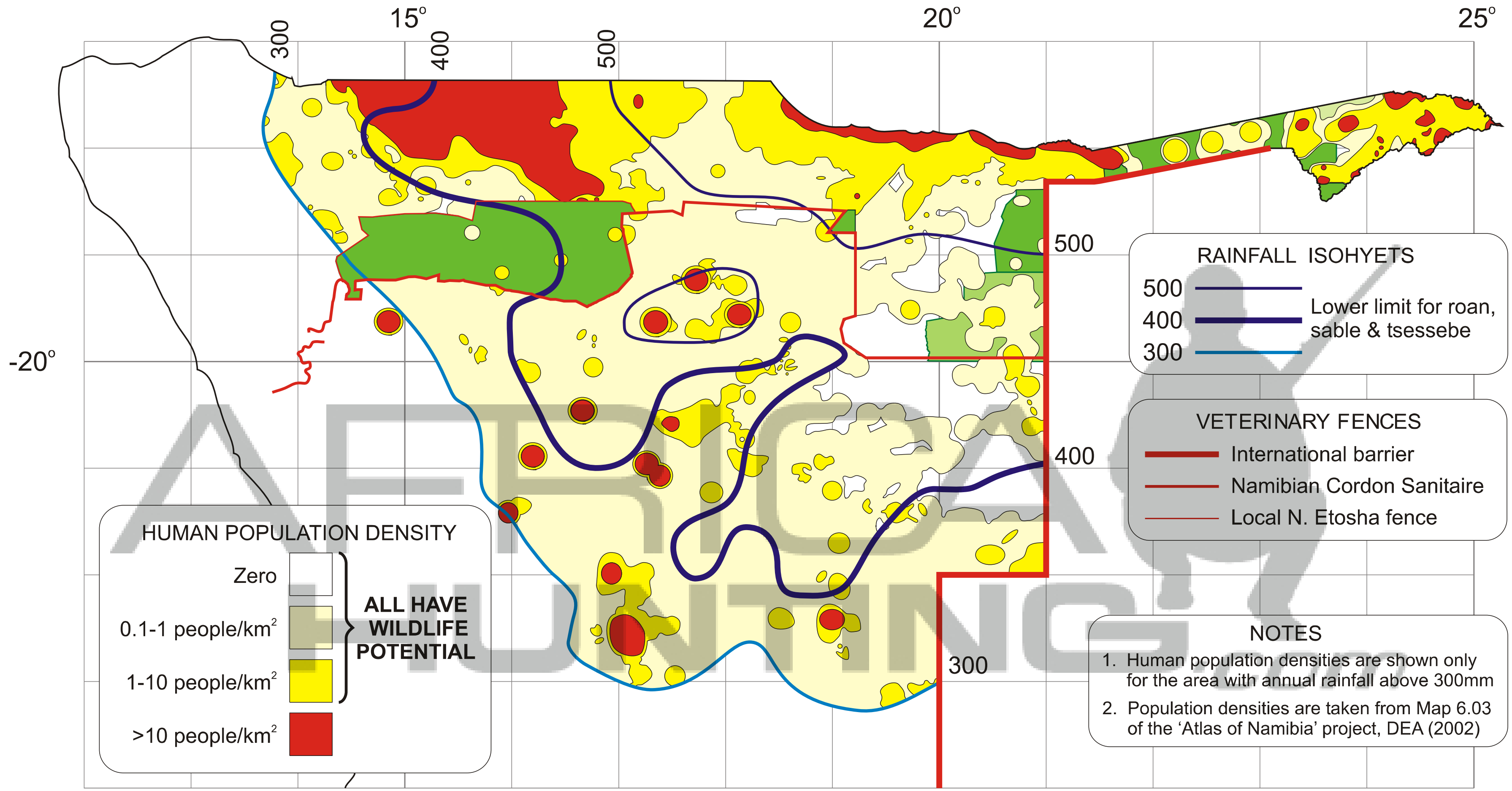



**Figure 12**. The Potential Range for Roan, Sable and Tsessebe in Namibia showing Rainfall, Human Population Densities and Veterinary Fences

### f. Numbers

Most aerial surveys tend to focus on elephants and buffalo and, as a result, roan, sable and tsessebe are usually under-counted. Sable are more visible from the air than roan and tsessebe so that the estimates for this species may be better than the other two. In deriving estimates for these species a dual problem may occur. If the animals are not present in large groups or large numbers, they tend not to be seen and the resultant estimates suffer from large confidence intervals because too few animals make up the sample for the estimate. If all the animals are being seen but the population is sparse, the estimates will still have large confidence intervals for the same reason. Typical confidence limits for estimates of the species are seldom better than ± 50% of the value of the estimate even when the numbers are fairly high, and caution needs to be exercised in pronouncing apparent upward or downward trends in populations.

The data which follow are not very valuable for comparative purposes or for detecting trends because the same areas have not been surveyed consistently from year to year (this effect is particularly prevalent in the Caprivi) and because of the variety of survey techniques which have been used on different surveys.[9] At present there is no acceptable alternative to the standard transect survey method or the random block count method. Systems which rely on "total counts" or "actual observations" are statistically inferior because no accuracy or precision can be attached to the estimate. In the final part of this report under 'best practices' for management, the subject is pursued further.

(1) Namibia

The data for roan, sable and tsessebe from surveys carried out in Namibia since 1970 are presented in **Appendix 2** and shown in **Figs. 12-19** on the pages which follow.[10] Also shown on each of these figures is the cumulative surplus/deficit in rainfall since the 1960s and the late dry season rainfall. The rainfall data are presented in **Appendix 3**.

Dunham and Robertson (2001) found that a relationship of the following form adequately described the rise and fall of tsessebe numbers in Kruger National Park –

$$\textit{Adult survival} = \boldsymbol{f}\left(\textit{(Dry season rainfall)}, \int \textit{(Annual rainfall)}, \textit{(Tsessebe density)}\right)$$

Adult tsessebe survival is a function of the amount of dry season rainfall, the integral of the annual rainfall (the accumulated deficit/surplus) and the numbers of tsessebe actually present at the time. The effects of these variables on a tsessebe population would be as follows –

- Rainfall in the late dry season appears to be critical, affecting the animals' ability to maintain condition and, hence, survival. The effect on females during the late stage of pregnancy and the early stage of lactation is particularly pronounced.

9. The types of surveys which have been carried out include waterhole counts, total counts from fixed wing aircraft, total counts from helicopters and sample surveys based on line transects with calibrated strip widths.

10. Where estimates have been based on standard sample surveys this is indicated for the year concerned.

- The long term surplus and deficit in annual rainfall appears to act on habitats. A prolonged sequence of years where rainfall remains below the average may result in unfavourable physiognomic changes in habitats.

- The last variable, population density, would act negatively on population increase. The higher the number of animals, the greater would be the degree of intra-specific competition for food and the amount of energy expended by adult males on maintaining territories. With the low numbers of tsessebe (and roan and sable) in the various areas where they are present in Namibia, this effect is unlikely to be marked.

Erb (1993) found that the relationship between early season rainfall and calving success was important for roan antelope in the Waterberg. Roan start to calve as early as August when the veld is still dry. Good rains in September/October result in an early green flush which provides lactating cows with the necessary dietary protein to meet a demand which escalates during late pregnancy and early lactation.

I would like to have developed a model incorporating these rainfall parameters and observed the extent to which it explained the performance of roan, sable and tsessebe populations in Namibia. Unfortunately, the population estimates for all areas (with the exception of roan in the Waterberg from 1975-1990) are too erratic to justify any attempts to fit modelled data to observed numbers. The data of **Figs. 12-19** allow at best a broad overview of trends in rainfall and population numbers but, in examining the data, it is necessary to be conscious at all times that many of the observed swings in population numbers may be no more than artifices arising from irregular and incomplete surveys. The following broad observations can be made –

- In all of the main areas where roan, sable and tsessebe population numbers have been estimated since the 1970s,[11] it is apparent that the accumulated rainfall surplus reached a peak in the five years between 1975 and 1980. It was also during this time that the populations of all three species appeared to be booming.

- After 1980 the surplus began to decrease although it did not change to a deficit in all areas simultaneously.[12] After 1994 all areas went into a rainfall deficit mode[13] and this appears, on most of the figures, to coincide with population 'slumps' for all species populations.

11. Etosha National Park, Waterberg Plateau Park, Bushmanland (including Khaudum and the Nyae Nyae Conservancy) and East and West Caprivi.

12. Year in which rainfall surplus changed to a deficit: Etosha – 1982; Waterberg – 1991; Bushmanland and West Caprivi – 1994; East Caprivi – 1991. It must noted that this transition from surplus to deficit is dependent on the time span of data considered (1960-1997): with a longer time span the zero point could shift upwards or downwards.

13. The most recent rainfall data (1997 onwards) is awaited from the Namibia Weather Bureau and is not shown on the figures.

- The impression given from the figures is that as long as the cumulative rainfall is in a surplus mode populations appear to be maintaining themselves or increasing. It is not necessary to hypothesize that there is any tight, direct relationship between the surplus rainfall and the breeding performance – in fact, other limiting factors may well be operating when the rainfall is in this mode. As soon as the cumulative rainfall changes into a deficit mode, this becomes the factor limiting the population.

- It might be expected that this relationship with the cumulative rainfall surpluses and deficits becomes increasingly critical as the lower rainfall limits of the species range are approached. In the Eastern Caprivi, where annual rainfall is normally well above 500mm, the effects appear less striking. In Kruger National Park, the range preferred by roan and tsessebe is in a marginal rainfall area and the rainfall deficit/surplus relationship is strong. The decline of roan and tsessebe since the 1970s in north-western Zimbabwe may be due to the same phenomenon.

- There is little to be gleaned from the late dry season rainfall data shown in the figures – mainly because the small ups and downs in population numbers from year to year which this factor would influence are obscured by the poor population estimates.

The following observations relate to the individual figures –

Fig.12: The roan population in Etosha National Park crashed sharply in 1982-83 coinciding exactly with the transition from a cumulative rainfall surplus to a deficit. Since then its numbers have hovered around below 100 animals. This population (mainly in Kaross) is in an area below the 300mm rainfall isohyet and it can be expected that it will always suffer from any small deficit in rainfall.

Fig.13: The introduction of roan to the Waterberg Plateau Park coincided fortuitously with an optimum part of the rainfall cycle. Since the curve has moved into a deficit mode, the population has decreased to well below 200 animals.

Fig.14: The roan population in Bushmanland was at its zenith (over 500 animals) in 1985 when the cumulative rainfall surplus was also at a peak. Since this went into deficit mode in 1994, roan estimates have not exceeded 100 animals.

Fig.15: At first sight, the roan in East and West Caprivi would appear to have reached a peak in 1992-94 (not that 150 animals necessarily represents much of a 'peak'). In fact the real peak was probably that shown for 1980 when the rainfall surplus was high – thereafter the survey data is erratic and the so-called peak in 1992-94 relates more to a time when a number of comprehensive surveys were carried out. The most recent survey data from 1998 onwards suggests very low roan numbers and the cumulative rainfall deficit may well be the cause of this.

Fig.16: The sable population in Etosha has hovered around 50 animals for a number years.[14] The Khaobendes paddock in the extreme west of the park cannot be viewed as ideal sable habitat either from a rainfall or vegetation point of view. The introduced sable population in the Waterberg increased to about 150 animals while the cumulative rainfall curve was in a surplus mode but appears to have declined since then.

Fig.17: The Caprivi sable population appeared to reach a peak of over 1,000 animals in 1994 (over 500 animals in both the West and the East) – however this coincided with two comprehensive surveys done in that year (Rodwell *et al* 1995 and ULG 1994). It is difficult to state whether sable numbers have decreased as drastically as indicated because there have been no comparable surveys since 1994. If they have declined, then it is to be noted that the cumulative rainfall data from both Andara and Katima Mulilo indicate a deficit.

Fig.18: Tsessebe were introduced to Etosha in 1978 and appear to have gone extinct. The numbers are too low to draw any conclusions about a relationship with the cumulative rainfall graph – it may be pure coincidence that they crashed exactly at the time when this went into a deficit mode. In any case, it is unlikely that the rather special habitat requirements of tsessebe would be satisfied in Etosha.

The Waterberg tsessebe population appears never to have exceeded 20 animals and Erb (1992) notes that a larger founder population is an urgent necessity. However, it is possible that the required ecotonal habitats for tsessebe do not occur in the park.

Tsessebe have not been seen in Khaudum since 1987. However, there is always a possibility that re-colonisation will occur from Botswana when the cumulative rainfall regime moves once again into a surplus mode.

Fig.19: Tsessebe numbers were modest (>100) in East Caprivi in 1980 when the cumulative rainfall surplus was at its peak. As with the sable, the population estimates thereafter are erratic and it is far from certain that the decline which appeared to take place between 1980 and 1994 was real. In 1994 more than 100 tsessebe were estimated in Mudumu and, given that the cumulative rainfall surplus persisted throughout this period, it is most likely that this population had been in place all the time. After 1991 the cumulative rainfall changed to a deficit and the current status of the species must regarded as uncertain. Being linked to the larger Botswana population, the possibility exists that animals will re-appear when conditions are favourable.

The figures provide plausible evidence for the linkage between roan, sable and tsessebe numbers and cumulative rainfall surpluses and deficits. However, it is not intended to suggest that this is the only mechanism affecting the species populations. Other factors such as human population increases, new areas opened up for settlement, competition with cattle, veterinary fences and illegal hunting are all likely to exert a negative influence. However, the analysis does suggest that when the cumulative rainfall enters a deficit mode, this factor is likely to override all other limiting factors.

14. Werner Killian (pers. comm. Feb, 2003) estimates there are about 50 sable in the Khaobendes paddock and a further 28 at large in the greater park.

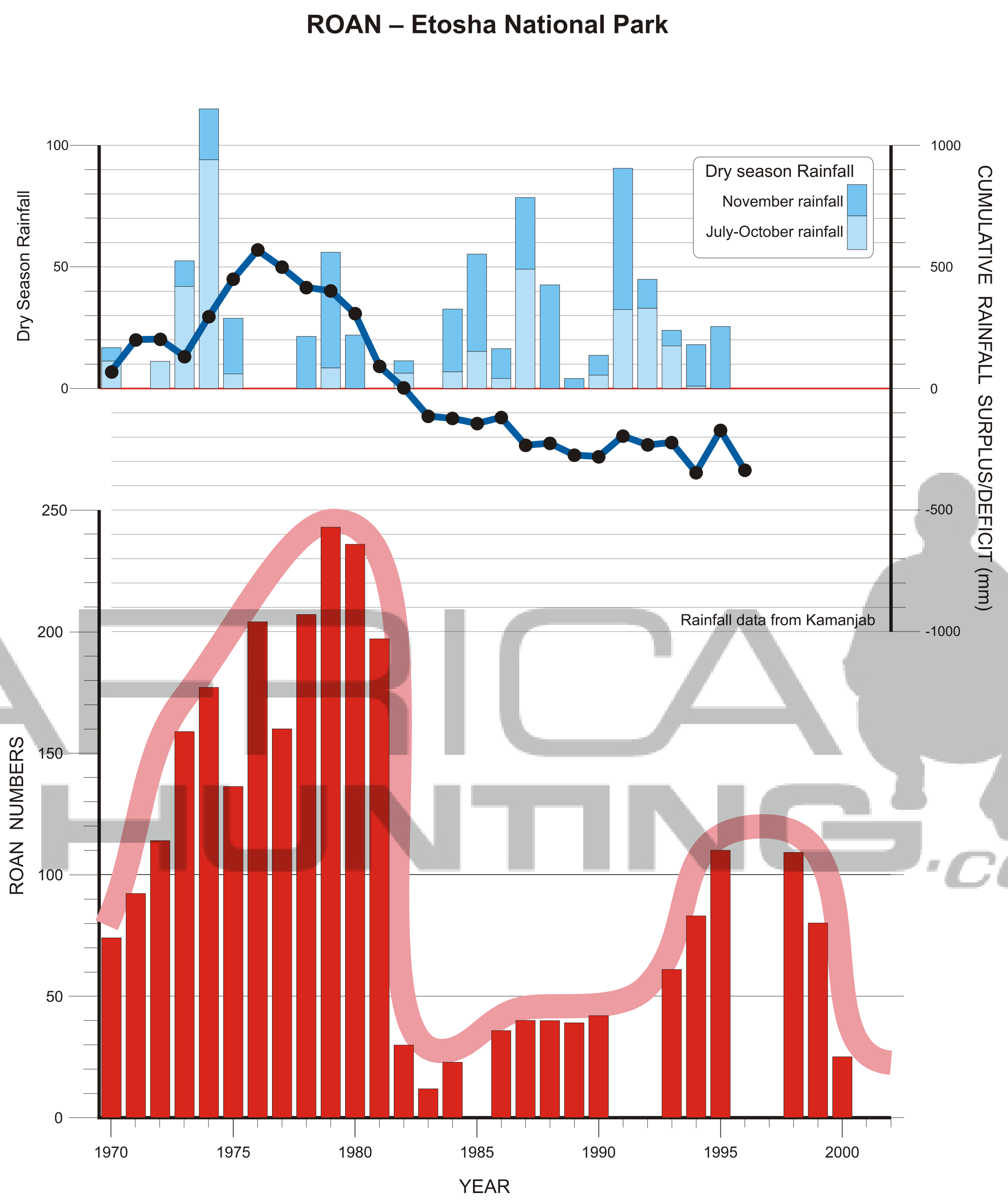



**Figure 13**. Estimates of the roan population in Etosha National Park

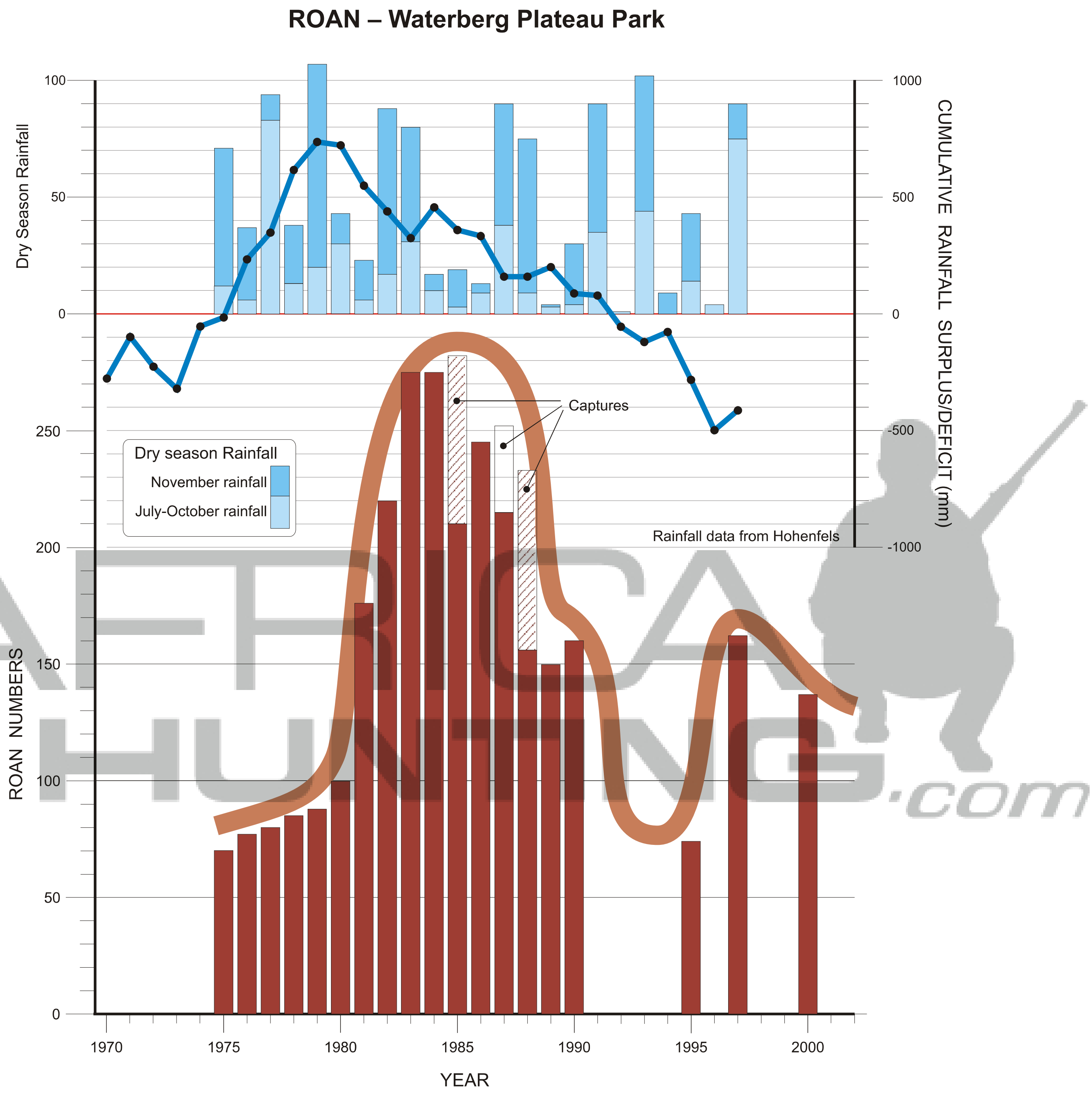



**Figure 14.** Estimates of the Roan Population in Waterberg Plateau Park

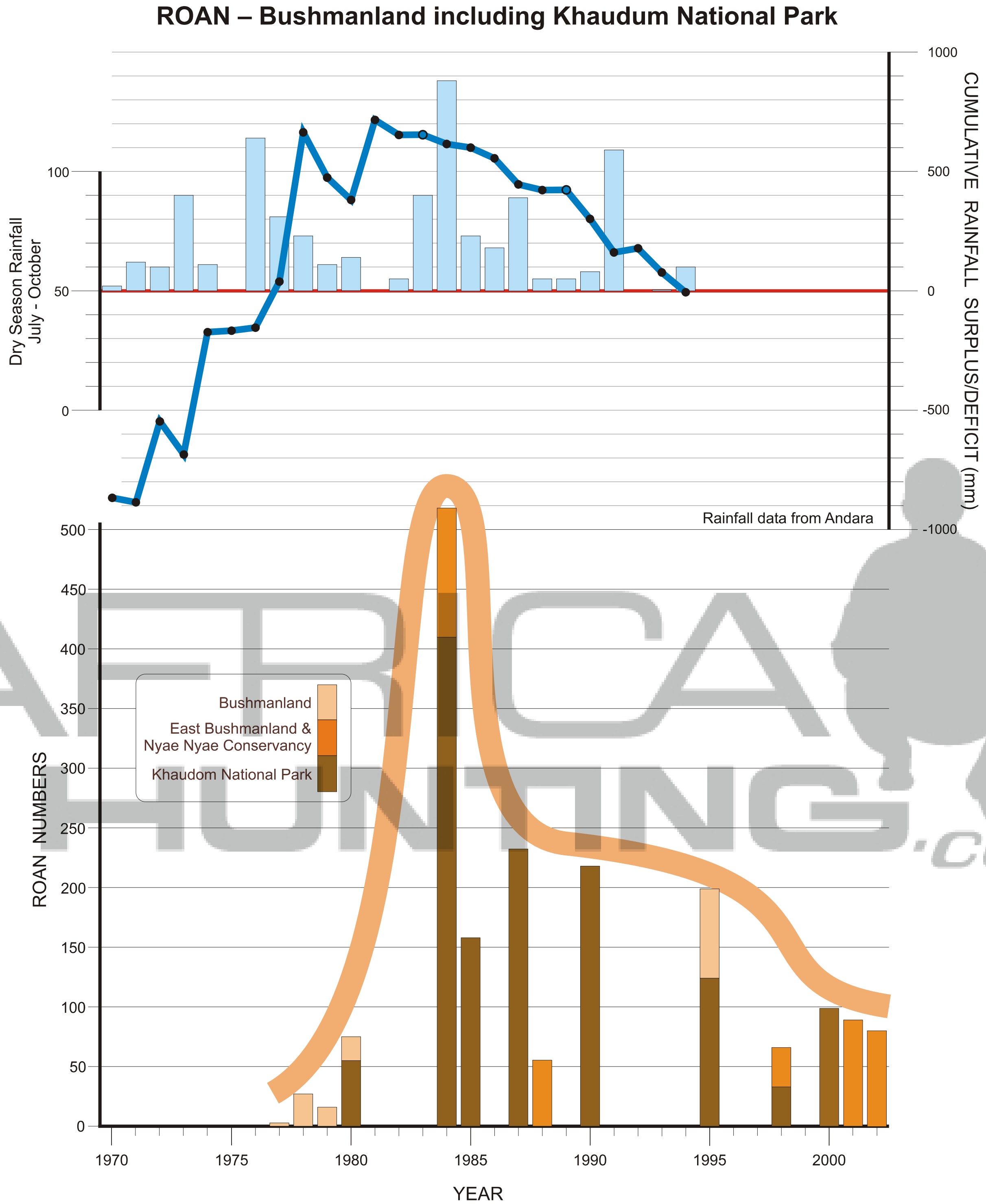



**Figure 15**. Estimates of the Roan Population in Bushmanland including Khaudum

## ROAN – East and West Caprivi

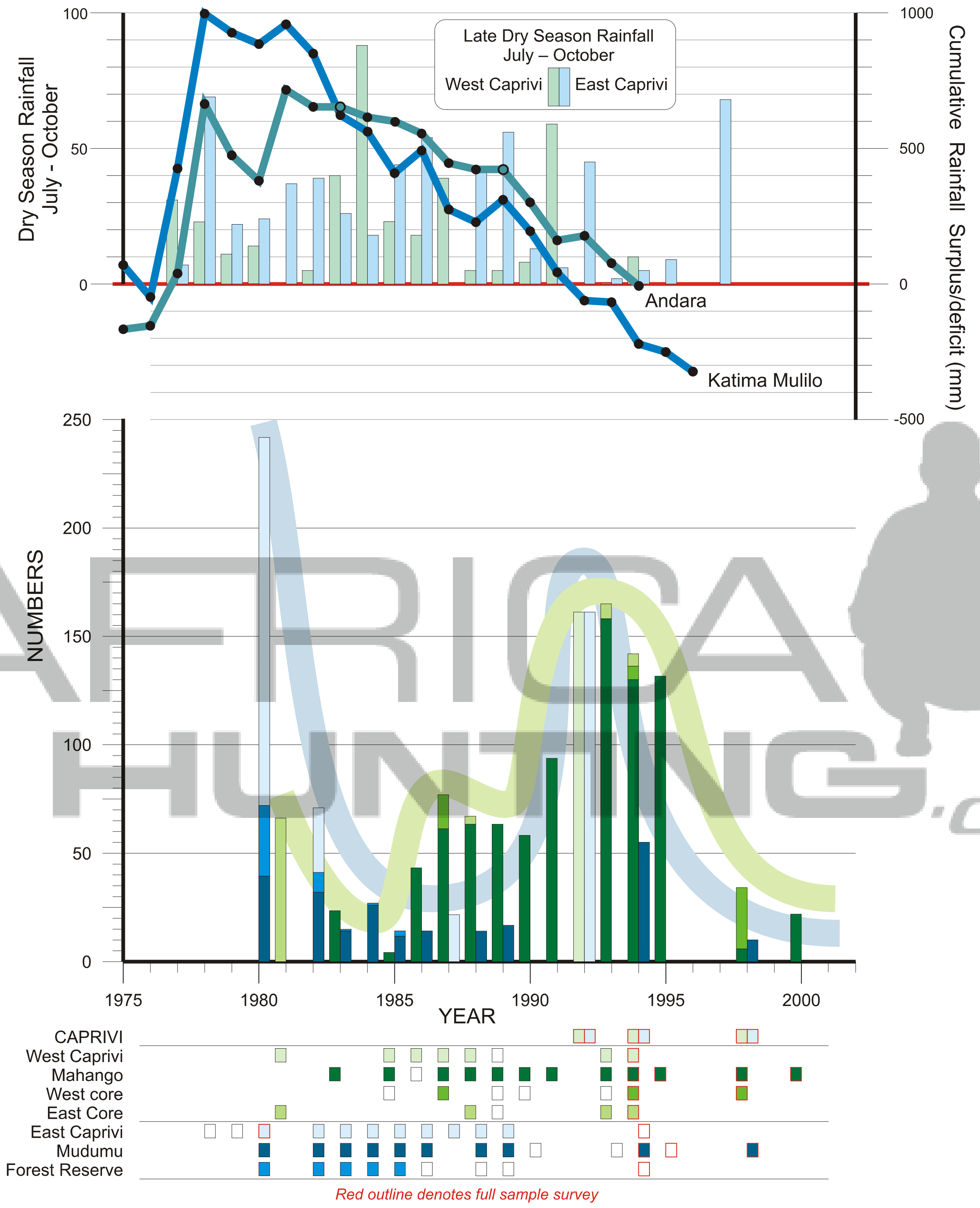



**Figure 16**. Estimates of Roan Populations in East and West Caprivi

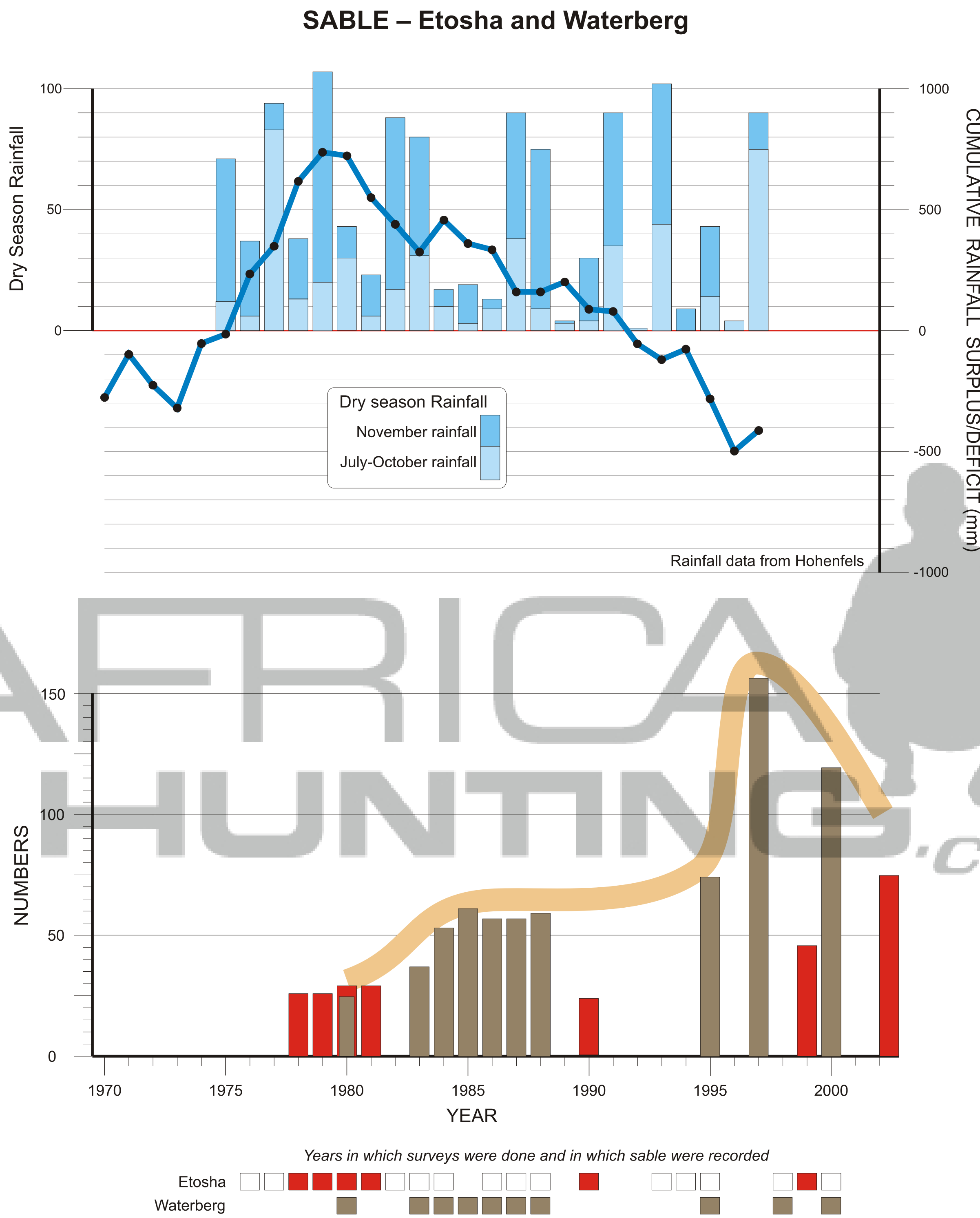



**Figure 17**. Estimates of Sable Populations in Etosha and Waterberg

## SABLE – Caprivi

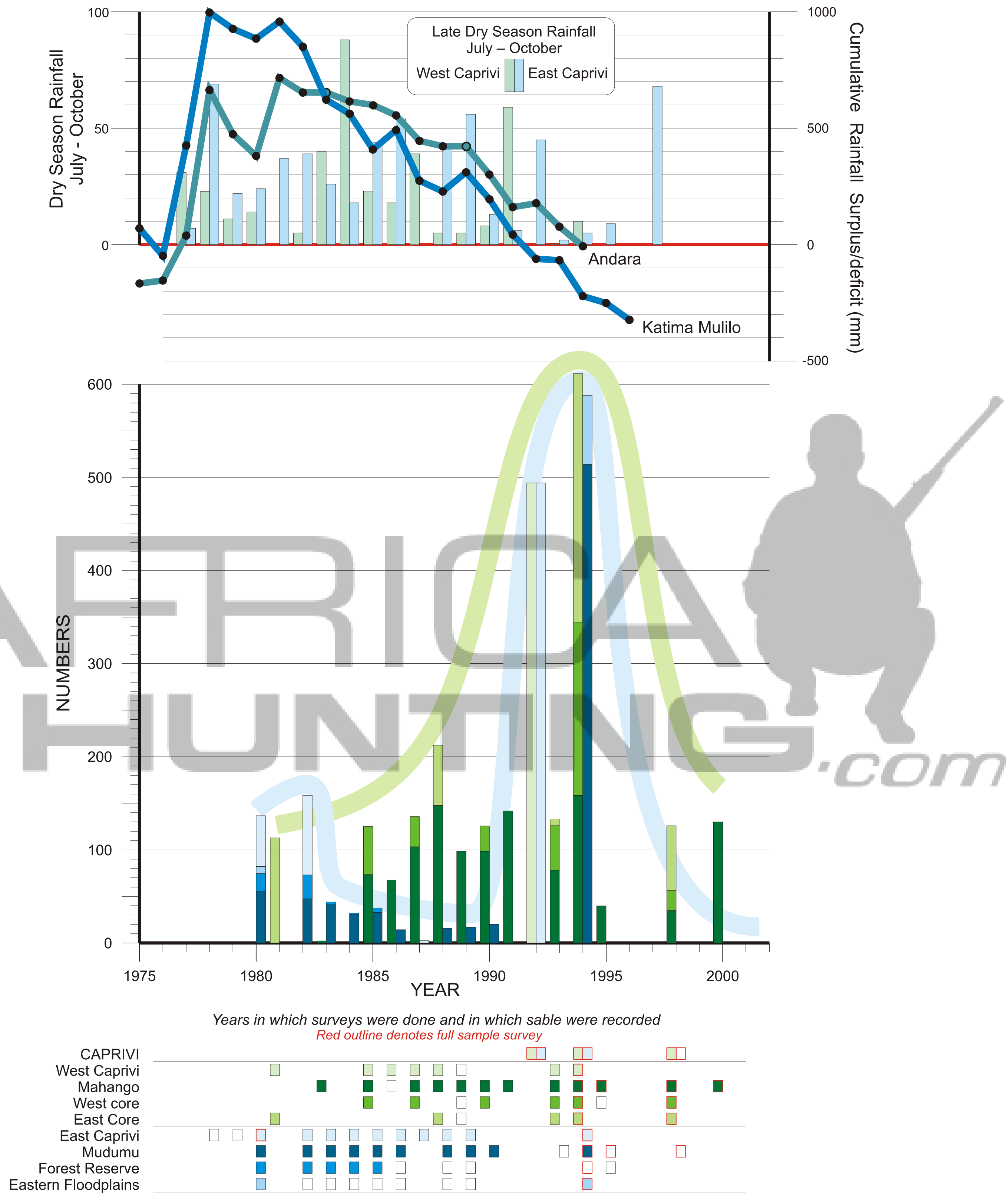





**Figure 18.** Estimates of Sable Populations in East and West Caprivi

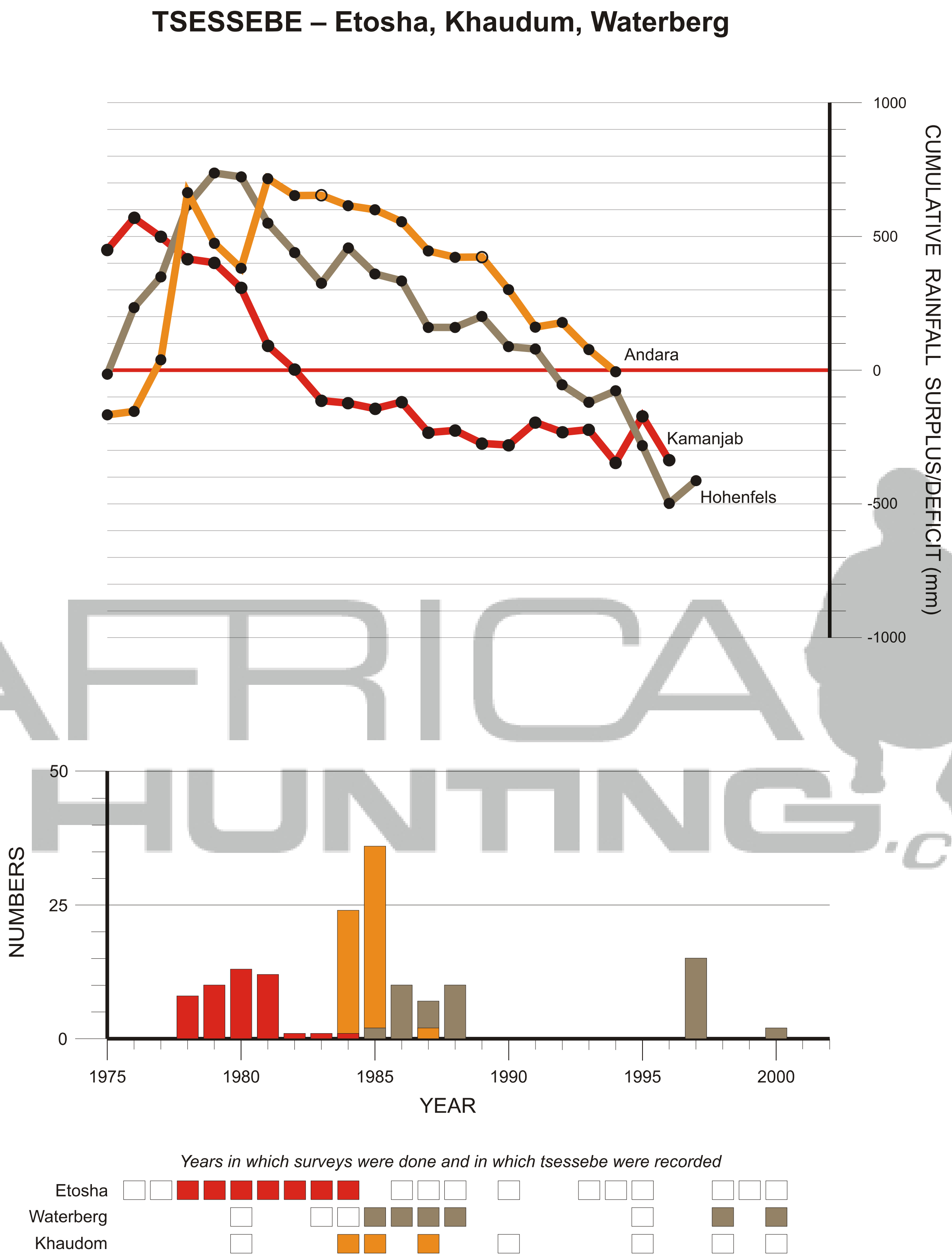





**Figure 19**. Estimates of Tsessebe Populations in Etosha, Khaudum and Waterberg

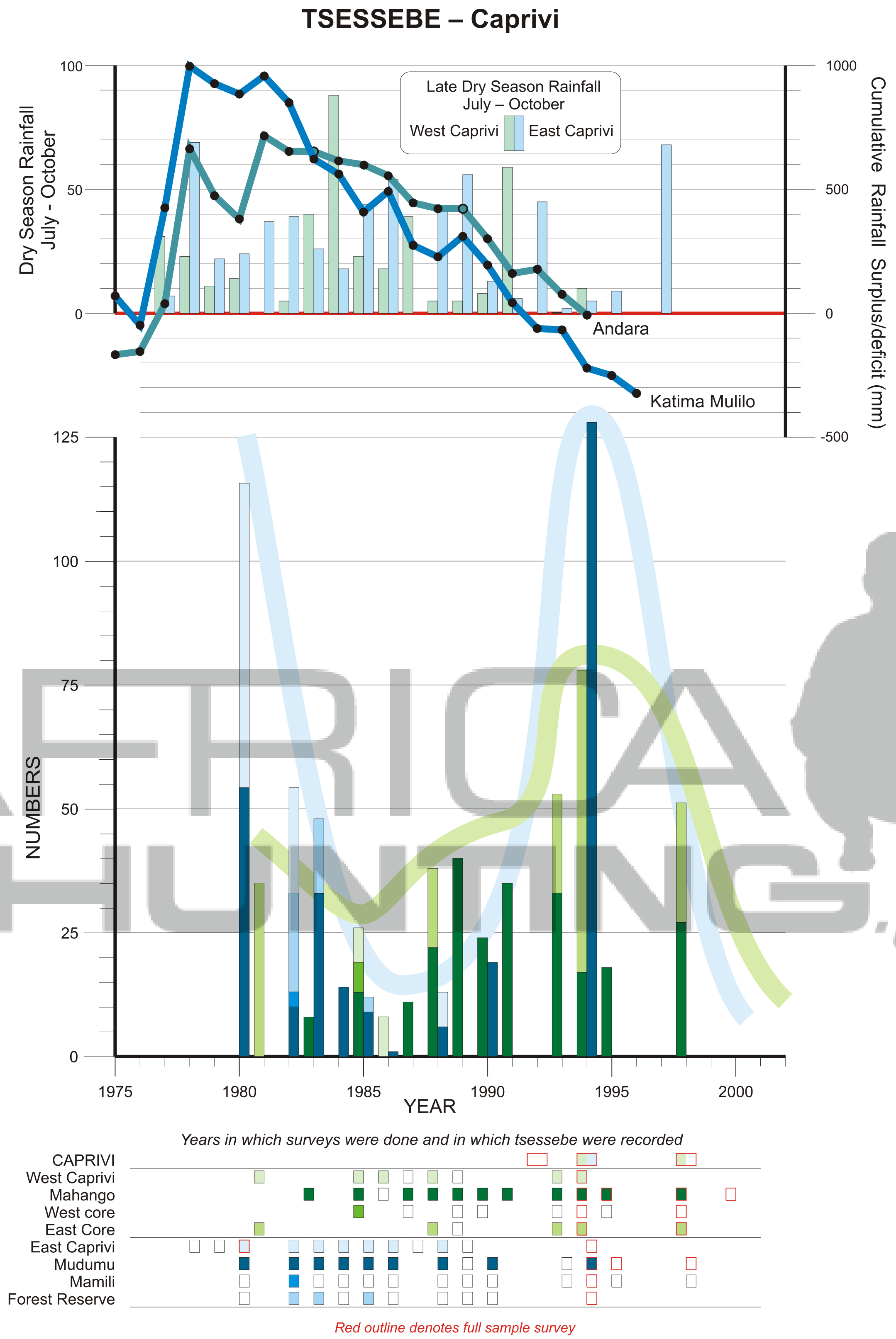



**Figure 20**. Estimates of Tsessebe Populations in East and West Caprivi

(2) <u>Neighbouring countries</u>

The countries neighbouring Namibia with populations of roan, sable and tsessebe are Angola, Botswana, Zambia and Zimbabwe. No data is to hand for Zambia and Angola.

The wildlife authorities in Botswana have systematically carried out nation-wide aerial surveys of large mammals in both dry and wet seasons for most years since 1987.[15] ULG (1995) produced pooled estimates of the northern Botswana roan, sable and tsessebe populations and, in the table below, these have been compared with the estimates for the Caprivi in 1994 when two comprehensive surveys were carried out.

| | **Roan** | **Sable** | **Tsessebe** | **Area** |
|---|---|---|---|---|
| Estimate | 1,357 | 3,138 | 10,015 | 145,605 $km^2$ |
| Confidence intervals | ± 49 % | ± 35 % | ± 22 % | |
| Density ($km^2$/animal) | 107 | 46 | 15 | |
| Caprivi population (1994) | 197 | 1,200 | 206 | 20,000 $km^2$ |
| Percentage of Botswana figures | 15 % | 38 % | 2 % | 14 % |

The overall densities of the three species are very low in both Botswana and Namibia. In relation to the areas involved, in 1994 the Namibian sable population was at a higher density than the Botswana population, the roan population was more or less at the same density and the tsessebe population was at a much lower density. It is perhaps to be expected that tsessebe numbers in northern Botswana would be high because of the optimum habitats in the vicinity of the Okavango Swamps. Movements of animals between Botswana and the Caprivi are likely to be at their lowest during the dry season and, therefore, the dry season estimates for the Caprivi are probably indicative of the size of the "permanently resident" populations.

The linkages between the roan, sable and tsessebe populations in north-west Zimbabwe and the Caprivi are more tenuous than those of Botswana-Namibia 'axis'. The survey results are only presented in the context of a long term vision for a trans-frontier conservation area where these species populations are able to move freely between Botswana, Namibia and Zimbabwe. The realities of the present situation are that although veterinary control fences do not theoretically prevent movements of Zimbabwe wildlife westwards into northern Botswana,[16] only minor movements have been recorded.[17] This may be because the physical gap between the international boundary and the nearest permanent water supplies in Chobe National Park is sufficiently large to deter most movement except in the wet season. Beyond that, the access for Zimbabwean animals to the eastern end of the Caprivi is barred by relatively dense human settlement.

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15. A request has been made to the Botswana wildlife authorities for recent survey results of roan, sable and tsessebe and the data is expected in due course.

16. Except in the extreme south-western corner of Hwange National Park where the international boundary fence has caused the deaths of a large number of animals of many species.

17. An exception may be the roan population around Kazuma Pan on the Botswana-Zimbabwe border about 100km south of Kazungula.

Sample count aerial surveys have been consistently and regularly carried out in north-western Matabeleland area of Zimbabwe since 1980 and some of the estimates[18] are presented below.

The roan population in Matabeleland North was estimated at over 1,000 animals in the early 1980s. Since then it has declined drastically. The confidence intervals on the surveys in 1998 and 1999 are such that there is no significant difference between the two estimates. The present population is thought to be about 300 animals.

Sable numbers have remained fairly constant at about 5-6,000 animals. The areas of basalt soils in Matabeleland North provide optimum habitats for sable and the Matetsi Safari Area is renowned for its consistently high hunting trophy quality.

Prior to 1995, aerial surveys in Matabeleland North focussed almost entirely on elephant, buffalo and sable[19] – which explains the absence of any meaningful data for tsessebe which have never been abundant in this region.

| Year | Roan | Sable | Tsessebe |
|---|---|---|---|
| 1989 | 213 | | |
| 1990 | | | |
| 1991 | | 7,484 | |
| 1992 | 31 | 12,713 | – |
| 1993 | 32 | 6,598 | 7 |
| 1994 | 218 | 5,356 | – |
| 1995 | | | |
| 1996 | | | |
| 1997 | 113 | 5,613 | |
| 1998 | 806 | 5,424 | – |
| 1999 | 315 | 5,636 | 316 |
| 2000 | | – *no survey* – | |
| 2001 | 292 | 5,854 | 80 |

The estimates for the three species permit little speculation about relationships with long term cumulative surpluses and deficits in rainfall – perhaps because the region enjoys a relatively high rainfall like Katima Mulilo (usually above 500mm).

With the low densities of the populations of all three species in the Caprivi and Bushmanland linkages with the Botswana population are highly desirable.

(i) The subpopulations in the west of the Caprivi (Mahango and the western "Core Area") are effectively isolated from the remainder of the Caprivi by the arid terrain in the central part of the Caprivi Game Reserve and also effectively isolated from Botswana by the veterinary fence along the international boundary.

(ii) If settlement and subsistence agriculture continue to develop in the vicinity of the Kwando River in Namibia, the subpopulations in Mudumu and the western "Core Area" of Caprivi Game Reserve will become isolated and will be linked only through Botswana.

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18. The blank cells are those for which data was not available at the time of writing this report.

19. It was considered that reliable aerial survey estimates could only be obtained for these three species and hence other species were excluded (this probably resulted in better survey results than many of the present day surveys which attempt to record all species!). Species such as roan and black rhino were sufficiently rare that they were always recorded when seen.

## g. Behaviour

Roan, sable and tsessebe have been the subject of a number of PhD and MSc theses in the southern African region (e.g. Erb 1993, Garstang 1982, Grobler 1978, Joubert 1976, Wilson 1975) and it would be possible to include a wealth of of interesting observations on the behaviour of the three species. However, the behavioural attributes which should be included in this report are those which have implications for management and therefore the discussion will be kept brief.

The question of territoriality has obvious implications for management. Species which are strongly tied to territories are likely to be vulnerable in semi-arid environments when drought or habitat changes alter their situations. Species which have the flexibility to be able to undertake local migrations when water or food is limiting may have a survival advantage. It may only be necessary for the females of the species to possess this attribute to ensure the persistence of populations.

Intra-specific aggression and competition are established behavioural characteristics of all three species and are an adaptation to ensure sufficient good quality nutrition. However, they are unlikely to play a significant rôle at the low densities at which most of the ‘wild’ populations in Namibia occur. They may be factors to be taken into account in managing enclosed populations on commercial farms or in small protected areas such as the Waterberg Plateau Park. Wilson and Hirst (1977) note that when roan and sable are constrained on small properties or areas of low quality habitat, intra-specific aggression and competition with other species intensifies.

A brief description of the relevant points relating to home ranges and territory for the three species follows.

<u>Roan</u>

The social structure of a roan population consists of nursery herds, bachelor groups and dominant bulls (Smithers 1983). They are gregarious animals with breeding herds usually numbering 10-20 individuals – although as many 80 have been recorded in a single group. Breeding herd home ranges vary from 60 – 100 km$^2$ (Erb 1993). Social hierarchies are well developed in both sexes. Males are forced out of the herd at 2-3 years of age and either become solitary or form bachelor groups. Breeding groups are usually led by the dominant female.

Depending on the situation, roan may or may not exhibit territorial behaviour. In some areas dominant bulls have an ‘activity zone’ rather than a territory and defend a harem of females, e.g. in Kruger National Park a specific male is usually associated with a particular female group throughout the year (Joubert 1976). On the other hand, there are instances of males establishing territories through which a group of females with their offspring may move, e.g. in the Waterberg (Erb 1993). The determining factor for which of these two modes of behaviour is adopted may be the degree of aridity. Roan may be forced to move over a large range in low rainfall areas prone to sporadic droughts – in which case it would seem pointless to defend a territory. Where the rainfall is higher and less erratic or in areas which are relatively small and constrained (e.g. in the Waterberg) the situation may be more favourable for the males to invest in territory.

Sable

As with roan, sable are gregarious, form similar-sized herds and their social structure consists of nursery herds, bachelor groups and dominant bulls (Grobler 1978). Unlike roan and tsessebe, sable bulls appear to be strictly territorial and are never attached to a mobile group of females. The home ranges of territorial males lie between 25-40ha whereas breeding herds use ranges of 2-5 $km^2$. Juvenile males are evicted from herds at about 3 years old by dominant males and, at 5-6 years of age, they are ready to establish their own territories, either by challenging dominant males or by dispersing to set up a new territories.

Tsessebe

Although tsessebe share similar social structures with both roan and sable, subtle differences also exist. Average herd sizes are generally smaller, e.g. (excluding juveniles) less than 4 in northern Botswana (Child *et al* 1972); less than 6 in Zimbabwe and Kruger National Park (Grobler 1973, Joubert and Bronkhorst 1977) and about 8 animals in the P.W.Willis Nature Reserve, South Africa (Garstang 1982).

Dominant tsessebe males establish fixed territories but, unlike sable, a specific harem herd is usually associated with each bull. This harem herd also has a fixed home range but it may not necessarily coincide exactly with that of the bull because of the partiality of females for particular habitat types. Garstang (1982) found that these harem home ranges overlapped in the hot/wet season but not in the cool/dry season. There is a high degree of fidelity to breeding herds (i.e. no new animals from other groups are permitted to join the herds). Tsessebe in Kruger National Park are fairly sedentary under such a system (Joubert and Bronkhorst 1977). However, other social structures have been observed where harem herds move between male territories at will – as in the case of sable. Child *et al* (1972) observed seasonal changes in home ranges at Kwhai in Botswana.

This ability of both roan and tsessebe to alter their system of range use according to circumstances ought to enhance their survival. However, of the three species, sable would appear to be slightly more numerous than both roan and tsessebe in the 'natural range' in north-east Namibia.

### h. Limiting Factors

Coe, Cumming and Philipson (1976) noted that it was a distinct characteristic of large mammal communities in African savannas that, although many species might contribute to the biological diversity in any area, the major biomass contribution would be made by a limited number of species. Usually, these dominant species are bulk feeders such as elephant, buffalo and hippo. There seem to be very few cases where specialist feeders such as roan, sable or tsessebe have ever been a significant component of the large mammal biomass.[20] Thus, in developing a management plan for roan, sable and tsessebe, **there should be no expectations that any of these three species might ever come to dominate a savanna landscape in Namibia**.

Far from becoming dominants in southern African savannas, roan, sable and tsessebe populations have declined in many areas in recent years and given conservationists cause for grave concern. A welter of plausible hypotheses have been put forward for these declines[21] but few unifying theories have emerged.

One such theory has been put forward by Dunham and Robertson (2001) where they demonstrate the correspondence of the observed numbers of tsessebe in Kruger National Park from 1977-2000 with the long term cumulative deficits and surpluses in annual rainfall and the late dry season rainfall (see page 24). In a study of tsessebe on a mixed cattle and game ranch in south-western Zimbabwe, the same variables accounted for an observed decline in tsessebe (Dunham *et al* 2003).[22]

Wilson and Hirst (1977) saw the whole subject of factors limiting roan and sable as a complex one involving disease, malnutrition and habitat quality and thought that nutritional status might be affecting populations. Grant *et al* (2002) review the various hypotheses which have been in place at various times to explain the decline in roan, sable and tsessebe in Kruger National Park and the effects of the management actions which have resulted from these hypotheses. Dunham and Robertson (2001) and (Dunham *et al* 2003) reviewed hypotheses put forward to account for the tsessebe decline in both Kruger and Shangani and were able to dismiss all of the following – based either on the fact that they could not account for the situations over the full time period or that the data supporting them were inadequate –

(1) Competition with other wild herbivores;

(2) Predation;

(3) Fire;

(4) Effects of artificial waterpoints;

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20. In southern Africa, the exceptions might be the roan population on the Nyika plateau in Malawi, the Matetsi sable population and the tsessebe populations on Shangani Ranch and De Beers Block in Zimbabwe.

21. Wilson and Hirst (1975), Harrington (1995), Harrington *et al* (1999), Grant and van der Walt (2000), Grant *et al* (2002) and RARE (2002).

22. An additional variable, that of competition with cattle, had to be incorporated into the equation in order to fit a population model closely to the observed data.

(5) Illegal hunting;
(6) Emigration;
(7) Excessive sport hunting and capture offtakes; and
(8) Direct food shortages caused by poor rainfall in any given year.

Animals were suffering from undernutrition – and might even have been killed by predators because of this – but these were proximate rather than ultimate causes. The only satisfactory explanations for the overall population performance under a range of rainfall conditions lay in the relationship with the long term cumulative rainfall deficit/surplus and the late dry season rainfall. Rainfall in late dry season appears to be critical, affecting animals' condition, survival rate, late stages of pregnancy and early stages of lactation. On Shangani Ranch, an increase in cattle stocking rates midway through the time span under consideration caused direct competition for food which resulted in a negative correlation of cattle and tsessebe biomass. The more serious indirect effects of competition with cattle in the longer term were the structural changes in habitats caused by bush encroachment following a high biomass of cattle.

In my assessment of the data from this study, the limiting factors for roan, sable and tsessebe can probably be arranged in a hierarchy –

(1) Many of the areas in which it is being attempted to conserve roan, sable and tsessebe lie below the lower rainfall limit which the subcontinental data indicates are acceptable for the species.

(2) In the areas which are marginal for the species from a rainfall perspective (300-400mm of annual rainfall), the performance of all three species appears linked to the long term cumulative rainfall surpluses and deficits.

(3) A surplus in the accumulated rainfall need not necessarily produce a linear increase in population growth rates – it should rather be seen as the removal of a primary limiting factor.

(4) When it occurs, **a deficit in the accumulated rainfall is likely to be the primary limiting factor** for roan, sable and tsessebe populations. All management efforts directed at secondary factors are unlikely to surmount this fundamentally negative effect.

(5) Given that the rainfall regime is favourable (i.e. in a period of accumulated surplus), management efforts directed at a number of other potentially limiting factors may enhance population growth – e.g. illegal hunting, fire, provision of artificial water in specific locations.

(6) Management interventions aimed at reducing competition with other species do not appear compatible with the general aim of increasing biological diversity. This simply results in an ongoing need for such interventions which, when they are withdrawn, result in the situation reverting to the *status quo*. However, the specific case of elephants may be an exception (see next paragraph).

(7) Roan, sable and tsessebe are specialist feeders with habitat requirements which, despite much research, may not yet be fully understood. In the Sebungwe region in Zimbabwe all three species have been in decline for a number of years (roan and tsessebe are almost extinct). This coincides with a period where the elephant population has continued to increase and has wrought major structural changes in habitats – changes which have not been favourable to roan, sable and tsessebe. If sable and roan prefer parkland savannas with dappled sunlight shining through tree canopies to favour specific grass communities, then those conditions have gone. **The negative influence of large numbers of elephants on the habitats required by the three species is likely to be the most severe limiting factor after rainfall**.

(8) Roan, sable and tsessebe may be susceptible to various **diseases** of which anthrax is likely to be the most serious (Pienaar 1961). De Vos and Imes (1976) document a rare skin disease contracted by sable in a holding facility in Kruger National Park However, there is no evidence in the literature that disease has ever been a significant limiting factor for these species and, if it were, there is little in the way of management measures available to mitigate the effects (de Vos *et al* 1973). Together, predation and disease tend to be secondary factors acting on undernourished animals. Disease may differentially affect juveniles but the resultant mortality is likely to cause population fluctuations rather than any long term alterations to basic population growth rates (Sinclair 1974b).

(9) **Veterinary fences are an important limiting factor** in their influence on movements of roan, sable and tsessebe between Botswana and Namibia. Many populations are becoming isolated as a result of the placement of fences.[23]

(10) Within the Caprivi and to the west of Khaudum Game Reserve **the *ad hoc* location and spread of human communities and their cattle** is resulting in loss of wildlife range and direct competition for grazing resources. In the background study on buffalo which preceded this work (Martin 2002), unplanned human settlement was seen as more than a 'limiting factor' – it was a direct threat to the long term survival of the species.

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23. e.g. Mahango, Khaudum and Nyae Nyae.

## 2. SIGNIFICANCE OF THE THREE SPECIES

### a. Conservation Significance

In the *Background Study on Southern Savanna Buffalo* immediately prior to this, the Taxon Data Sheet of IUCN's (1997) Conservation Assessment and Management Plan (CAMP) was completed as part of the work. This was not a particularly worthwhile exercise as the data sheet is intended to capture the conservation status of the global population of the species and is not applicable to subpopulations within that global population. For this reason, the CAMP form has been omitted from this study.

Under the IUCN Red Data Book system, roan sable and tsessebe are all classified as "Lower Risk (conservation dependent)" by the Antelope Specialist Group (ASG 1998) and it is evident from the distributional data of Figures 2-4 that these species cannot be regarded as threatened in any global or regional context. All three species are of conservation concern at the national level in Namibia because their numbers are low and the various subpopulations making up the national metapopulation are isolated from one another. However, it has been observed earlier in this study that most of the main body of the country is outside the limit of the rainfall range in which the three species are found 'naturally'.[24] Although substantial populations of roan and sable (and, to a lesser extent, tsessebe) have been built up on private land in the main body of the country, it would be a mistake to regard these as secure because of their permanent vulnerability to rainfall regimes.[25] Because the areas in which roan, sable and tsessebe are found 'naturally' in north-eastern Namibia are spatially linked to larger populations in Botswana, they would not qualify independently for any category of threat based on population numbers.

The greatest danger to the Namibian populations of these species is the potential fragmentation which could arise if links were severed with the Botswana population due to injudicious application of veterinary control fencing or the spread of settlement and subsistence agriculture in the north east of the country.

It was difficult to argue on conservation grounds that more buffalo were needed in Namibia (Martin 2002c). However, the case for roan, sable and tsessebe is stronger. If they were to disappear from their former range in north-eastern Namibia where the rainfall conditions are favourable, this would be a loss of biological diversity and a failure of wildlife management. **Their persistence in viable numbers could be seen as an indicator of ecosystem health**. Several factors threaten ecosystems in north-eastern Namibia including the uncontrolled spread of human settlement, an overabundance of cattle (with the attendant veterinary control measures) and, perhaps greatest of the threats for roan, sable and tsessebe, is the burgeoning elephant population which is likely to modify their habitats unacceptably.

24. The Antelope Specialist Group describes the Namibian populations as 'extra-limital'.

25. They may also become vulnerable to political factors such as a demand for land re-distribution. In Zimbabwe, thousands of animals worth millions of dollars in recently introduced wildlife populations on private land have been killed in less than two years in the course of land invasions.

## b. Economic Significance

In examining the potential contribution of buffalo to non-hunting tourism income, it was stated that the presence of buffalo would be unlikely to cause any marginal increase in tourism income if they were introduced into the main body of the country or if they were more abundant in the Caprivi (Martin 2002c). The same may not be true for roan, sable and tsessebe. Substantial numbers of animals of these species are likely to impress game-viewing tourists and might result in a marginal increase in wildlife tourism. The effect is likely to be more pronounced in the Caprivi or Khaudum than in (say) Etosha, which is already a guaranteed tourist destination. However, it would be difficult to attach quantitative values to this proposition.

A corollary to the possible enhancement which substantial populations of roan, sable and tsessebe might bring to tourism in the north-east of the country is the negative impression which their disappearance from their former range would give. For knowledgeable tourists visiting the Caprivi or Khaudum, the absence of roan, sable and tsessebe is likely to be noted unfavourably.

At the outset of this study, my main preoccupation was with the precarious conservation status of these species and I gave little thought to their possible value in the sport hunting industry. However, as they are all highly prized hunting trophies (sable and roan more so than tsessebe), it would be derelict not to attempt to assess the potential economic (or financial) contribution that their inclusion in international sport hunting quotas might make.

To explore the financial and potential land use rôle of the three species, two scenarios are examined in **Appendix 4** and the results are summarised in **Table 7** below. It is a relatively simple financial exercise with no pretensions to being a full economic analysis on the lines of the various studies carried out by Barnes (see Bibliography).

**Table 7.** The potential impact of roan, sable and tsessebe on sport hunting income

| | WITHOUT ROAN, SABLE AND TSESSEBE | WITH ROAN, SABLE AND TSESSEBE |
|---|---|---|
| Area | 4,000 $km^2$ | 4,000 $km^2$ |
| International hunting client days | 664 | 2,952 |
| Gross income US$/hectare | 5.90 | 10.06 |
| Operating costs US$/hectare | 1.09 | 4.37 |
| Net income US$/hectare | 4.81 | 5.69 |
| Potential net earnings from 4,000$km^2$ | 1,923,020 | 2,275,280 |

The assumptions and methods used to perform the analysis are given in detail in Appendix 4 and summarised briefly on the next page together with a discussion of the results.

(i) The financial modelling for sport hunting is limited to consideration of a 'core wildlife range' of about 4,000$km^2$ in the Caprivi.

(ii) Two hypothetical communities of species populations which might be expected in this core area at 'carrying capacity' are developed – one without roan, sable and tsessebe and the other with numbers of these species at modest densities typical of southern African savannas with rainfall above 500mm. In both scenarios, the densities of species have been adjusted so that the total metabolic biomass of the wildlife community is the same (1LSU/10ha).

(iii) Hunting quotas are set for each scenario and the hunts are 'packaged' into different types of hunts aimed at maximising the income possible from the available animals.[26]

(iv) The presence of significant numbers of roan, sable and tsessebe results in a very large increase in the number of hunter-days possible with international clients (2,952 v.664)

(v) A safari operator needs about 180 hunter days/year to be viable and, therefore, the hunting quota when roan, sable and tsessebe are included would allow for as many as 16 operators, each using 250$km^2$.

(vi) The annual operating costs for a safari operator are calculated for a single camp hunting operation in 250$km^2$. The capital costs of setting up the operation are included in the operating costs by depreciating the capital over 5 years and recovering one-fifth of the cost each year. The operating costs are about US$4.37/ha.

(vii) In the scenario without roan, sable and tsessebe, the number of international client hunter-days allows only for about four safari operators each hunting some 1,000$km^2$. It has been assumed that the operating costs calculated as outlined in the previous paragraph would not change significantly because the hunting area is increased – which reduces the unit cost to about one-quarter (i.e. US$1.09/ha).

(viii) In this same scenario, there is a large quota of minor plains game animals available which simply cannot be marketed on international hunts because there are insufficient premier trophy animals to which to attach them. It is assumed that these would sold by the operator on 'biltong hunts' at a lower daily rate and at half the trophy fee which international clients would pay. This type of hunting would involve the safari operator in little cost because the 'biltong hunters' would largely fend for themselves.

The net outcome of this analysis is interesting. The gross income from the sport hunting almost doubles as a result of altering the species composition of the wildlife community to include substantial numbers of roan, sable and tsessebe. However, the costs of realising this income also increase – so that the net income produced is only some 18% higher.

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26. The packaging process is entirely automated within the table using Boolean logic and simulates the normal procedure which safari operators use to market their hunts.

This analysis could have been performed in many different ways. Alternative configurations of safari hunting operations could be developed which improve the profit margin. The amounts set for trophy fees and for daily rates are not independent and are very much up to the individual operator. The hunting client will take into account the combination of both in choosing a safari (i.e. the 'bottom line'). However, the prices which have been used are representative of the sport hunting industry in southern and central Africa.

All costs and income have been internalised within a safari operator's budget. The apparent profit of US$5.7/ha (a 130% profit margin for the operating cost of US$4.4/ha) would not, of course, accrue to the operator. This is the sum from which all state revenue or community income would be derived and it is obvious that a very large surplus would be available. If the safari operator were left with a 50% profit on operations (US$2.2/ha),[27] the balance available as concession rental or community income under any form of joint venture or would be US$3.5/ha. This is almost double the projected cash income for most conservancies in the Caprivi.

This analysis shows that roan, sable and tsessebe have the potential, through their value in the sport hunting industry, to raise the overall value of net income from land significantly if their numbers can be increased to the modest levels used in the calculations. It was shown in the recent buffalo study that an increase in the numbers of this species alone could double the returns from land use in the Caprivi. Enhancing roan, sable and tsessebe populations within the species mix would further increase income. As existing wildlife uses are financially and economically more profitable than subsistence agriculture and cattle husbandry, the potential rôle of these species in a land use context is very significant.

It should also be expected that the development of substantial populations of roan, sable and tsessebe on private farms will increase their viability. Barnes (*et al* 2001) state that in the medium to long term the comparative advantages of land use based on domestic livestock can be expected to decline as international subsidies are phased out. They also point out that the comparative advantages of wildlife land uses can be expected to increase over time, due to continuing rapid expansion in international tourist markets, increasing scarcity of wildlife elsewhere, and the development of markets to capture international wildlife non-use values as income. Their results show that commercial livestock ranching has limited potential to compete economically with wildlife use because it is capital intensive and requires access to external markets.

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27. Due to intense competition in the safari hunting industry in southern Africa, few safari operators are realising profits of 50% – far more common are margins below 20%.

I conclude this section by repeating some more general observations on the wildlife industry made in the previous study (Martin 2002c).

In the development of the wildlife sector, non-consumptive tourism on high quality wildlife land will give by far the greatest economic returns (Barnes 2001, Martin 1999). However, only a limited amount of land in any country is suitable for high quality game viewing tourism and, if wildlife is to compete with alternative land uses over larger tracts of land, then it is necessary to harness a range of sustainable uses to maximise the income from wildlife. Safari hunting is one such use. Martin (1995) found that whilst high quality eco-tourism could very easily realise net returns greater than US$25/ha, the net income values for safari hunting reached a ceiling of about US$7/ha. This may, in many situations, be the highest valued use for wildlife and the highest valued overall land use.

Safari hunting is capable of producing competitive returns from land with less capital investment than that required for non-hunting tourism and with a lower adverse ecological impact. It has other advantages. Whilst it may take several years for any non-hunting tourism venture to build up markets, the returns from sport hunting are almost instantaneous – provided a minimum population of wildlife is present. This feature may be very important in the development of local community wildlife programmes where benefits are needed from the outset in order to provide the incentives for wildlife conservation.

Barnes (*et al* 2002) observe that instability in markets for wildlife can affect sustainability and give examples to show that recent political events in southern Africa have severely affected growth in non-consumptive tourism in parts of Namibia including some of the conservancies examined in their study. Safari hunting has been demonstrated to be far less susceptible to these types of market perturbations. It may be that the political instability to which Barnes (*ibid*) are referring obliquely is the present traumatic situation in Zimbabwe. It is significant to note that whilst the Zimbabwe ecotourism market collapsed very shortly after the inception of the said ‘political events’, its safari hunting market has persisted throughout – albeit slightly reduced in volume in the 2002 hunting season. A similar situation existed during the ‘liberation war’ in the 1970s in Zimbabwe. Where there was no ecotourism activity to speak of, a viable and resilient safari hunting industry continued throughout the war. This consideration should affect decision-taking on land uses in the areas of this study.

## 3. STAKEHOLDING

Much of this main section on stakeholders remains the same as that written for the *Background Study on Southern Savanna Buffalo* (Martin 2000c). The new material includes a geographic identification of stakeholders based on rainfall, which follows logically from the first main section ("Biological Information").

### a. Stakeholders

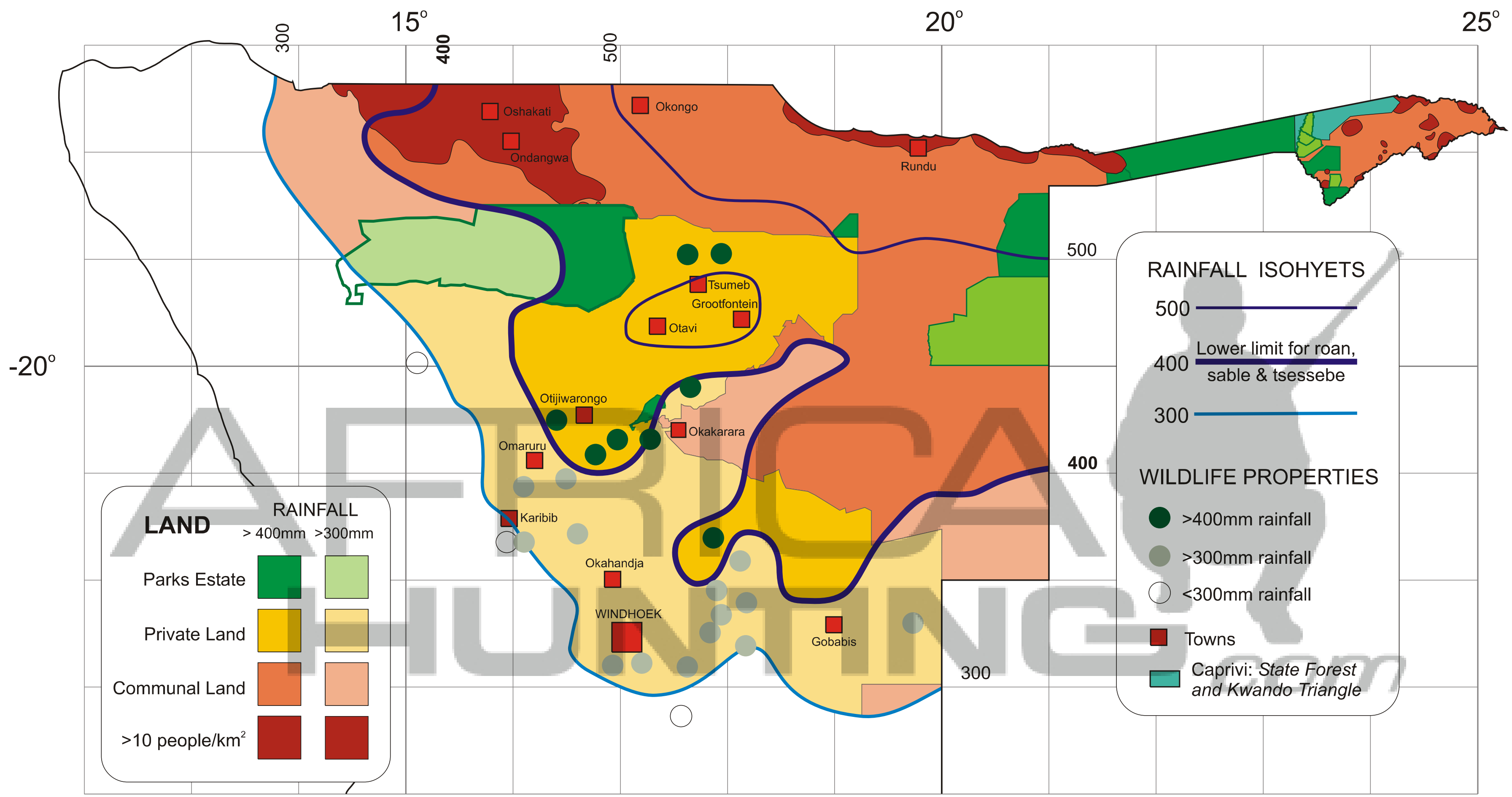
The term 'stakeholder' is often loosely applied and may include a range of parties whose so-called 'stakes' differ considerably in scale. For this reason it is essential to distinguish between various degrees of stakeholders and to base decisions on the magnitude of the 'stake' which each party brings to the table. The primary stakeholders who are affected by the occurrence, abundance or absence of roan, sable and tsessebe in Namibia are landholders, including those with traditional landholdings. Secondary stakeholders are those who have a direct financial investment in the land and the wildlife industry. Tertiary stakeholders are those who have an interest in the conservation of buffalo but do not contribute financially to the process.

Roan, sable and tsessebe occur 'naturally' in areas with an average annual rainfall above 400mm. In Namibia, the three species have been introduced to a number of areas, both in national parks and on private land, where the rainfall is well below this level. A conclusion of this study is that the populations living outside the 'natural' range of the three species will always be vulnerable to the vicissitudes of rainfall and, in the long term, attempts to maintain the species in such areas will be frustrating and ineffective.[28] The policy focus of the Ministry of the Environment and Tourism should be to promote populations of roan, sable and tsessebe in areas where they are likely to succeed.

If such a policy were to be adopted, the first step would be the identification of suitable areas. Land tenure categories in the part of Namibia which lies above the 400mm rainfall isohyet are mapped in **Fig. 21** on the next page. This should define the potential primary stakeholders under any new policy. They would consist of the landholders (the State, communal lands and commercial farms) highlighted in bold colours on the map. The *de facto* situation that there are a number of roan, sable and tsessebe populations established between the 300mm and 400mm rainfall isohyets (and even a few commercial farms lying below the 300mm isohyet) is also shown on the map and it is not suggested that, under any new State policy, the stakeholders in these areas should immediately be abandoned or dispossessed of their animals. However, it should be conscious policy to avoid further investment in such areas and to promote populations in the areas where they are more likely to be successful.

Also shown on the map are those parts of communal lands above the 400mm rainfall isohyet in the extreme north of Namibia where human population densities exceed 10 persons/km$^2$ and where it would be unlikely that populations of roan, sable and tsessebe could be established.

28. It is possible that with a substantial amount of supplementary feeding, some commercial farms will be successful in maintaining populations of roan, sable and tsessebe in low rainfall areas. However, this is not seen as a sustainable long term strategy for developing the wildlife industry. If wildlife is to out-compete cattle as a form of land use it should not rely on 'subsidies' to species populations.




Land tenure categories are taken from Map 5.21 of the 'Atlas of Namibia' project, DEA (2002)

**Figure 21**. Land Tenure in Namibia above the 400mm Rainfall Isohyet

In **Table 8** below, the areas lying above the 400mm rainfall isohyet which have populations of roan, sable or tsessebe (or have had them in the recent past) are listed. In the future, these landholders should be seen as the primary stakeholders, together with any new protected areas, conservancies[29] or commercial farms which might become recipients of the three species.

**Table 8.** Areas above the 400mm rainfall isohyet with roan, sable or tsessebe populations

| Land Category | Individual Areas (km$^2$) | Total Area (km$^2$ rounded) |
|---|---|---|
| **State Conservation Areas** [30] | | 20,700 |
| Etosha National Park [31] | 7,500 | |
| Waterberg Plateau Park | 403 | |
| Khaudum National Park | 3,841 | |
| Mangetti Game Camp | 480 | |
| Mahango Game Park | 200 | |
| Popa Game Reserve | 20 | |
| Caprivi Game Park | 5,500 | |
| Mudumu National Park | 1,000 | |
| Mamili National Park | 280 | |
| Caprivi State Forest | 1,496 | |
| **Conservancies**[32] | | 10,700 |
| Nyae Nyae | 9,003 | |
| Kwandu | 190 | |
| Mayuni | 151 | |
| Mashi | 250 | |
| Wuparo | 190 | |
| Salambala | 930 | |
| **Private Land** | | 700 |
| La Rochelle (MU927) | 100 | |
| La Rochelle (MU8470) | 100 | |
| Kamapu -Oos | 120 | |
| Otjiwa | 80 | |
| Neu Okatjuru | 100 | |
| Okawaka | 120 | |
| Klein Waterberg | 120 | |
| | **TOTAL AREA (km$^2$)** | **32,100** |

29. In 1996, a legislative amendment provided for custodial rights over wildlife to be granted to communities on communal land subject to their forming and registering "*Conservancies*". The provision grants partial rights for common property management and use of wildlife in defined areas. By the end of 2002, 15 conservancies had been registered, and some 35 more were in the process of being formed (Travel News Namibia 2002).
30. The areas given for the Caprivi State Protected Areas are approximate, pending gazetting notices
31. The total area of Etosha is 22,912 km$^2$ of which about one-third is above the 400mm rainfall isohyet.
32. Three additional conservancies are proposed in the Caprivi: Malengalenga, Lianshulu and Impalila

The suitable regions in Namibia for roan, sable and tsessebe are the Caprivi; Okavango, Ohangwena and Oshikoto(excluding the areas of high human density in the extreme north of these regions); the southern parts of Omusati and Oshana regions (north of Etosha Pan in the lower human density parts of these regions); Otzondjupa (excluding the lower rainfall area at extreme southerly end of the region); the northern part of Omaheke region (north of Gobabis); and a small part in the extreme east of the Cunene region south of Etosha.

Recognition should be given to the fact that the largest populations of roan, sable and tsessebe in Namibia are now on commercial farms (see Figs.9-11) – albeit that many of these populations are in less than optimum locations. It is notable that, in relative terms, the amount of land in this category is very small – in Table 8 on the previous page, the seven farms with roan, sable and tsessebe which lie above the 400mm rainfall isohyet add up to less than 1,000 km$^2$ and the total area of all the other farms which hold these species (about 18) does not amount to 2,000 km$^2$. There is considerable scope for increasing the number of primary stakeholders in the Tsumeb, Grootfontein, Outjo (extreme east), Otjiwarongo and northern parts of the Okahandja and Gobabis farming districts.

In the very large areas of communal land above the 400mm rainfall contour where human populations are at densities less than 10 persons/km$^2$ (see Figs.12 and 21) there is considerable potential to expand the number of conservancies. Areas which are strategically important for the future viability of roan, sable and tsessebe are the eastern and western Caprivi, the area of Bushmanland immediately west of Khaudum, the areas north of Etosha (at its eastern end), and the areas west and south of Nyae Nyae conservancy.

Secondary stakeholders are those who are not landholders but who are investing in the development of wildlife-based land use in these areas. This group includes hunting outfitters, professional hunters, hunting guides, tourist lodge operators, businesses involved in processing trophies and, in general, all support systems for the wildlife industry. The group would also include all those organisations assisting to develop conservancy programmes, which are listed in full in the background study on buffalo (Martin 2000c). The large international donors investing funds in community based wildlife management tend to direct their investments through local NGOs but should also be seen as secondary stakeholders.

Tertiary stakeholders would include various wildlife societies and individuals concerned in general for wildlife conservation and the tourists who enjoy the recreational opportunities of Namibia.

### b. Stakeholder Institutions – Present and Future

The progress which Namibia has made in developing policies and legislation which empower landholders to manage their wildlife resources both on commercial farms and in communal lands was noted in Martin (2000c) – as was the impressive record of development of the wildlife industry and the positive spirit of co-operation amongst the State, NGOs and private sector towards the larger goals.

In the same study, some disquiet was expressed that the initial positive steps towards devolution of rights over wildlife, for both communal land conservancies and private land, were not being followed by further progress. Institutional development in the wildlife industry in Namibia appeared stuck in a state of 'aborted devolution' (Murphree 1998).

The legislation (RN 1975) classifies various wildlife species into categories of "game" – such as "Specially Protected Game" (Schedule 3) "Protected Game" (Schedule 4) and "Huntable Game"(Schedule 5). Roan, sable and tsessebe are "Protected Game" – which implies that permits are needed from the Minister for these species to be hunted (and, presumably, for the capture or sale of live animals of the species). This type of legislation acts negatively towards the conservation of species because it fails to align authority, responsibility and incentives (Murphree 2000).[33] Authority without responsibility is meaningless or obstructive, responsibility without authority cannot be effective and, without responsibility or authority, there are no incentives to invest, manage or control. The governing hypothesis is, that given full authority over wildlife resources, the incentives will be present for landholders to use them sustainably.

Despite the fact that cattle are of a lower economic value than wildlife on commercial farms in Namibia (Barnes and de Jager 1995), the present system of mixed cattle and wildlife farming is likely to persist. The fact that Namibian farmers do not enjoy the same rights over their wildlife as they do over their cattle could be the single most important factor which is slowing down the progress of farmers converting to 'pure' wildlife systems. In competitive land use situations it is imperative that the rights of a wildlife farmer are no different to those which he enjoys over his cattle if he is to make choices which value one resource above the other.

Other perverse incentives are present in the legislation. The rights over "Huntable Game" which are conferred on private landholders if their properties are fenced to certain standards[34] would seem to mitigate against the desirable amalgamation of adjacent wildlife properties. Where roan, sable and tsessebe are concerned, it is evident that many of the populations on commercial ranches are being held at densities which exceed the carrying capacity for low rainfall areas. The formation of large "conservancies" (of the order of 1,000$km^2$ or more) would greatly enhance the likelihood of survival of the three species in times of drought and improve their breeding performance when rainfall conditions are favourable. Rather than pursue a "custodianship policy" under which commercial farmers are allowed to keep certain valuable wildlife species which are seen as the property of the State, greater incentives would be provided if the State used species such as roan, sable and tsessebe to promote the formation of larger amalgamated wildlife areas amongst commercial farmers – without attempting to retain controls on the use of the species.

The same principles apply to conservancies.

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33. It is of interest that the only species which are a conservation failure in Zimbabwe are those which have been classified as "Specially Protected Species" (there are no categories equivalent to the Namibian "Protected Game" and "Huntable Game"). Roan antelope are Specially Protected Species in Zimbabwe and this categorisation has been responsible for their decline. Because the State retains the authority to control hunting and sale of live animals of the species, there is no investment in increasing their numbers.

34. In primary legislation, it is surprising to see detailed specifications for game fences. This type of technical detail belongs in regulations and subsidiary legislation.

To conclude this section on future stakeholder institutions, it would seem there are good reasons to examine the rôle of State Protected Conservation Areas in relation to neighbouring communities (including commercial farmers). In many places in the optimum range for roan, sable and tsessebe, there are configurations of parks and their neighbours which, as they stand, are not ideal. In the Caprivi, in particular, the mosaic of small parks and small conservancies would benefit from being amalgamated into larger, more viable blocks of land under wildlife management. Opportunities arise in respect of Khaudum and Nyae Nyae Conservancy to benefit from joint management on a large scale. Corbett and Jones (2002, p19) raise the the option of partnerships in management and revenue-sharing arrangements and, inevitably, this would mean the development of new co-management institutions (Ruitenbeek and Carter 2001).

At the coming World Parks Congress,[35] the agenda will be dominated by the topic of relationships between protected areas and their neighbours. At a recent workshop[36] on *Local Communities, Equity and Protected Areas* aimed at preparing for the World Congress, the new Director-General of IUCN gave an inspirational address which indicated that the time had come to find new models for protected areas which were more resilient than those of the past. This is a challenge where Namibia could lead the way for other countries in the southern African region.

### c. Towards Trans-Boundary Institutions

The complexity of the proposed 'Four-Corners Trans-Frontier Conservation Area' is daunting (Martin 2002a). To develop institutions involving not only the national governments of five countries (Angola, Botswana, Namibia, Zambia and Zimbabwe) but also the other primary stakeholders is a formidable task made more complicated by the different legal systems and institutional approaches which have already evolved in each country. This complexity was recognised in the round-table discussions at the inception of this study and a pragmatic approach was agreed upon whereby the larger vision of a massive trans-frontier area, whilst being recognised as an ultimate goal, should be preceded by the building of a number of incremental initiatives aimed at collaboration between Namibia and its immediate neighbour, Botswana.

Following the completion of the background study on buffalo (Martin 2002), the Ministry of the Environment, the Namibia Nature Foundation, the WWF LIFE Programme and the Botswana Department of Wildlife and National Parks initiated the first step towards collaboration by holding a workshop in Kasane, Botswana, at the end of November 2002 to discuss specific areas of co-operation with regard to buffalo and to consider further wildlife species which merited joint management.

A notional institution for collaboration between Botswana and Namibia was presented at the meeting for discussion purposes (**Fig.22**, page 55). The design of the institution was specifically aimed at the matching of ecological, functional and jurisdictional scales as outlined by Murphree (2000). The initial focus of the institution was on the Caprivi but, when roan, sable and tsessebe become involved, the institution should take into account stakeholders on either side of the north-south international border in the region of Khaudum and Nyae Nyae Conservancy.

35. Durban, South Africa, 8-17 September, 2003.

36. Workshop titled *Local Communities, Equity and Protected Areas* hosted by The Programme for Land and Agrarian Studies (PLAAS), Africa Resources Trust (ART) and IUCN, 26-28th October, Pretoria, S. Africa.

A key question is whether at the international level (i.e. between Botswana and Namibia) representation will be confined to government representatives or whether other primary stakeholders will participate (i.e. local community representatives from both countries).[37] The proposal in Fig.22 is that local communities should be represented but, ultimately, the decision on this issue lies between the two governments. The features of the organogram are as follows –

(i) The organisation consists only of primary stakeholders and only involves two levels. A third level (not shown in the diagram) is the individual membership of each conservancy in Namibia and each community area organisation in Botswana.

(ii) In Namibia, the individual conservancies would delegate limited powers upwards to an 'Association' which will represent them at the second level (CAs). This could comprise the existing Communal Lands Boards or be an association created especially for this purpose. The arguments in favour of using the Communal Lands Boards are that the interests of communities who have not formed conservancies would also be represented.

(iii) A similar association would need to be identified on the Botswana side of the border to represent the various areas under community wildlife management.[38] This could be the relevant Land Board.

(iv) The individual parks in northern Namibia and Botswana report to their Directorates which are represented on the second tier in each half of the structure.

(v) In Namibia, the Directorate of Scientific Services is also represented in the second tier. In Botswana, the equivalent agency is contained with the Department of Wildlife and National Parks.

(vi) The veterinary authorities from both countries are also represented at the second level.

(vii) These two groups at the second level from Botswana and Namibia meet to constitute the international 'institution' which addresses joint management issues.

It could be argued that many more parties should participate in the final bilateral forum including more senior government representatives. In line with both governments' efforts to decentralise, it seems more logical that this forum be treated as a technical and advisory panel which reports back to the relevant ministries on matters which may require high level decisions. If the principles of delegation upwards and accountability downwards are adhered to, there is no reason why all of the representatives at the national level cannot report back their particular constituencies rather than overload the international forum with unnecessary numbers. Finally, if it is agreed between the two delegations, there is no reason why any observers who may contribute to the discussion are not invited to the forum.

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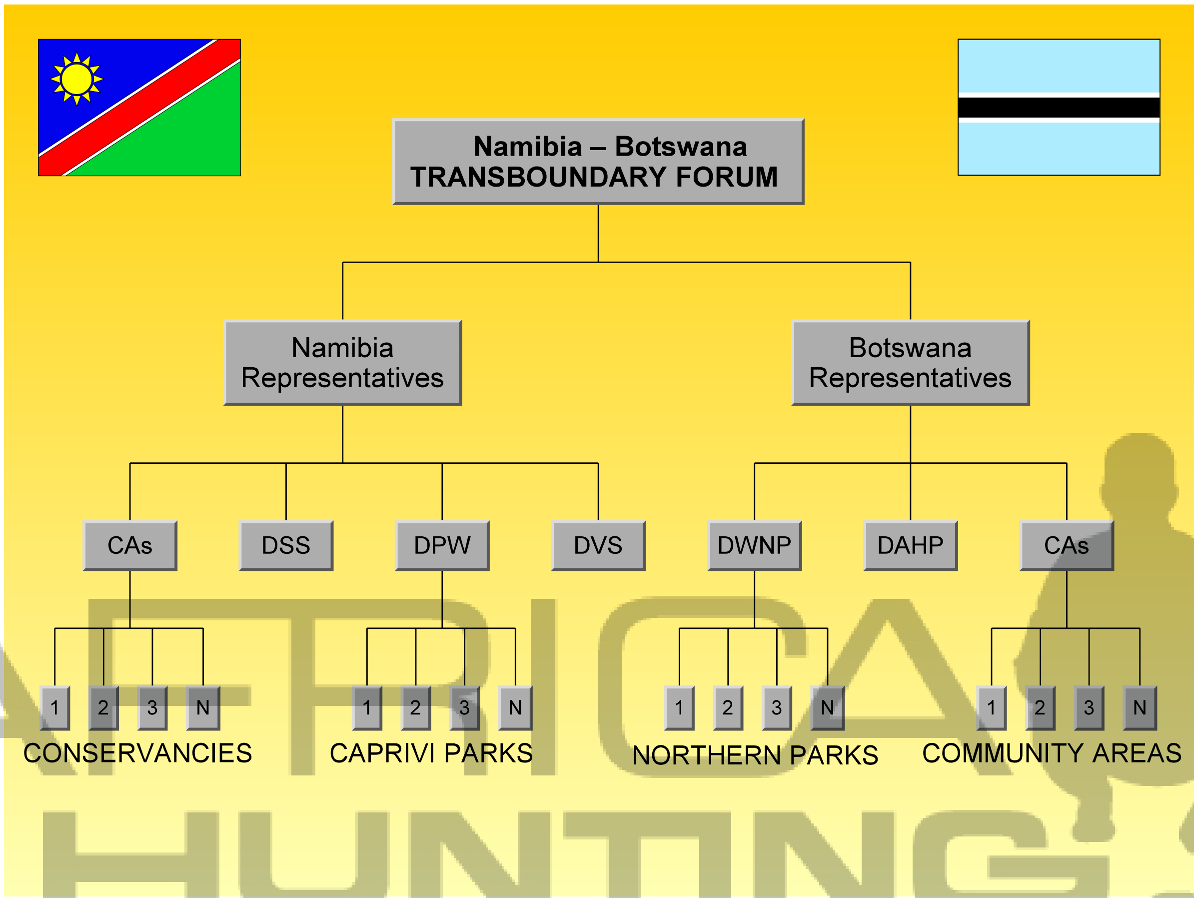
37. There was no such participation at this inception meeting in Kasane. For Botswana, representation was confined entirely to wildlife department staff and, on the Namibian side, only government staff and NGOs participated. It is possible in future meetings that this representation will be broadened.

38. The workshop identified a potential trans-boundary community collaborative opportunity in the Salambala Conservancy and the Chobe Enclave.

**Figure 22**. A Notional Institution for Botswana-Namibia Management of Shared Wildlife Species Populations






Key to Acronyms used in the diagram – *see text for a fuller explanation of the structure*

Namibia:
- CAs – Conservancies Association
- DSS – Directorate of Scientific Services
- DPW – Directorate of Parks and Wildlife
- DVS – Directorate of Veterinary Services

Botswana:
- DWNP -- Department of Wildlife and National Parks
- DAHP – Department of Animal Health and Production
- CAs – Community Areas Association

# 4. MANAGEMENT

The main finding of this study is that roan, sable and tsessebe are very much at the mercy of rainfall and that this effect is most pronounced near the limits of the 'natural range' for all three species, i.e. in areas with an annual rainfall lower than 400mm. With annual rainfall in most of Namibia falling below 400mm, the initial reaction to this finding is that there is little that can be done to secure the future survival of the three species.

There is, in fact, a great deal that can be done. Firstly, about one-quarter of the country does have an annual rainfall which is above 400mm and this zone must be the focus for conserving roan, sable and tsessebe. Within this zone, all of the conventional measures that enhance wildlife populations such as effective law enforcement, fire management and provision of water should be in place. But there are also opportunities to be pro-active within this zone. The establishment of new populations of roan, sable and tsessebe on any land where they are likely to be secure should proceed as rapidly as circumstances will permit. In this way, risk will be spread and the likelihood of ensuring the survival of the species is far greater.

Finally, continued collaboration with Botswana on the shared populations of these species is likely to produce benefits related to scale. Given that spatial linkages can be maintained and enhanced, the probability of the three species going extinct simultaneously throughout the region is minimal.

## a. Present and Future Management of Roan, Sable and Tsessebe

### (1) Protecting Existing Populations

Roan, sable and tsessebe will benefit from the general management measures aimed at conserving wildlife in State Protected Areas[39] and Conservancies. Within State Protected Areas a major effort is being made at present to contain illegal hunting, control fires and, in general, to implement park plans. The present MET staff numbers, equipment and infrastructure in many parts of Namibia are insufficient to meet the challenges (PW 1998, page iii) but improvements are taking place in all these aspects. Martin (1996) examined the minimum requirements of game guards and budgets for effective functioning of State Protected Areas and this analysis is summarised in **Appendix 5**.

Based on the formulae of Appendix 5, notional budgets have been developed for the protected areas which lie in the north of Namibia above the 400mm rainfall isohyet (**Table 9**, next page). The required operating budget for all of the State Areas is slightly under **US$3 million** per annum.

It is of interest to note the effect of managing several small areas in the Caprivi rather than a single large area. The operating costs required for managing the Caprivi Parks (including the Forest Reserve and the Kwando Triangle) as individual areas is almost US$2 million, i.e. almost two-thirds of the total budget. Were these areas to be managed as a single unit, the budget required for the Caprivi is halved and the total budget is reduced to less than US$2 million.

39. Uncertainties surrounding the exact designation and final boundaries of many State Protected Conservation Areas in Namibia (Mendelsohn and Roberts 1997, p7; PW 1998) add to the law enforcement difficulties of the wildlife department. Clearly, a resolution of these issues will set the base line against which many other land use and conservation plans can be developed.

**Table 9.** Required Operating Costs for State Protected Areas in the Potential Range for Roan, Sable and Tsessebe

| State Conservation Areas | Total Area km² | Required Number of Guards | Required Annual Operating Budgets - US$ |
|---|---|---|---|
| Popa Falls Game Reserve | 20 | 5 | 122,000 |
| Mahango Game Park | 200 | 15 | 177,000 |
| Mamili National Park | 280 | 17 | 193,000 |
| Waterberg Plateau Park | 403 | 21 | 216,000 |
| Mangetti Game Camp | 480 | 22 | 228,000 |
| Mudumu National Park | 1,000 | 32 | 300,000 |
| Caprivi State Forest | 1,496 | 39 | 359,000 |
| Khaudum National Park | 3,841 | 62 | 586,000 |
| Caprivi Game Park | 5,500 | 75 | 727,000 |
| **TOTALS . . .** | **13,220** | **288** | **2,908,000** |

Notes:

The eastern end of Etosha National Park, which is listed amongst the protected areas in Table 8, has been left out of this table because it is assumed that adequate operating budgets for the whole of Etosha are in place.

The operating costs for the Kwando Triangle are assumed to be included in the budget for the Caprivi Game Park



*Costs of managing Caprivi Parks*

| State Conservation Areas | Total Area km² | Required Number of Guards | Required Annual Operating Budgets - US$ |
|---|---|---|---|
| Popa Falls Game Reserve | 20 | 5 | 122,000 |
| Mahango Game Park | 200 | 15 | 177,000 |
| Mamili National Park | 280 | 17 | 193,000 |
| Mudumu National Park | 1,000 | 32 | 300,000 |
| Caprivi State Forest | 1,496 | 39 | 359,000 |
| Caprivi Game Park | 5,500 | 75 | 727,000 |
| **TOTALS . . .** | **8,496** | **183** | **1,878,000** |
| *Managed as a single unit . . .* | *8,496* | *93* | *963,000* |

These budgets set a critical threshold. Where the State provides an annual operating budget equal to or greater than required, there is a high probability that the area will be adequately managed and conserved. Where budgets are lower than the amounts needed, it is unlikely that a wildlife agency will be able to handle any determined onslaught by illegal hunters. Shortfalls in the budgets provide a strong reason (but not the only reason) for seeking new institutions involving partnerships with neighbouring communities.

Progress with Conservancies in the Caprivi is impressive. Many of the apparently overwhelming conservation tasks expected of State wildlife agencies are likely to be reduced when protected areas are surrounded by functioning community land use systems based on wildlife and natural resources. The question which a State wildlife agency needs to ask itself is whether the combination of stand-alone parks (which may be seriously underfunded) and conservancies together provide the right land use planning framework for the future. In the section of this report on Stakeholders (page 53), the potential rôle of State Protected Areas in catalysing land use based on wildlife over a wider area was raised. Moves towards this will require continued innovation from enlightened Namibian bureaucrats and a re-definition of classic protected models.

(2) Land Use Planning

In the previous study on buffalo (Martin 2002c), it was argued that *ad hoc* settlement, clearing of land for agriculture and cattle grazing were resulting in a large loss of potential range for buffalo. Throughout the area of Namibia above the 400mm rainfall isohyet, this factor is likely to exert a strong negative influence on roan, sable and tsessebe populations. The process is not one which the Ministry of Environment and Tourism would normally be expected to influence greatly. However, unless the Ministry does involve itself in a pro-active manner in land use planning, it is likely that much of the high potential for land use under wildlife (which should be a national priority to realise) will be foregone.

(3) Veterinary Fences

The influence of veterinary fences on the well-being of roan, sable and tsessebe populations is less critical than for buffalo (Martin 2000c). Nevertheless, the fences along the international boundary between Namibia and Botswana undoubtedly impede movement of the three species and act against the maintenance of spatial linkages between the subpopulations. The effects are likely to be most severe in the vicinity of Khaudum, Nyae Nyae, Mahango and the Caprivi Game Park.

(4) Establishing New Populations

Translocations of roan, sable and tsessebe to commercial farms have proved a success,[40] although many of these farms are located in areas with lower rainfall than might be preferred. The establishment of roan and sable populations in Waterberg Plateau Park has also been successful and it is of interest that this park lies close to, but above, the 400mm rainfall isohyet. It is the main reservoir for the Ministry of Environment to draw from in establishing further populations of roan and it makes sense to remove animals continuously from the population to ensure that it remains below carrying capacity and able to breed at the maximum rate.

It is strongly recommended that the Ministry of Environment continue to pursue an aggressive policy of establishing new roan, sable and tsessebe populations. The features of such a policy should be –

40. The present numbers of these species on private land are estimated as: roan – 404, sable – 778, tsessebe – 175.

(i) New populations will only be established in areas with an annual rainfall higher than 400mm per annum (see Fig.21, page 49);

(ii) The chosen locality for any new introductions should be secure (see previous two subsections) so that factors such as illegal hunting, loss of range and competition with cattle are not likely to impede population growth;

(iii) The habitats in the selected areas should be suitable for the introduced species – with roan and sable this unlikely to be as great an issue as with tsessebe, whose habitat preferences are fairly narrow and ecotonal.[41]

(iv) The category of land on which the new population is being established (i.e. whether it is a State protected area, conservancy or commercial farm) should be of secondary importance and should not be subject to political influence;

(v) In establishing new populations of roan, sable and tsessebe, the Ministry should use the opportunity to promote the conversion of larger areas of land to wildlife management. Accordingly, no special conditions (such as those pertaining to the "Custodianship Scheme") should be attached to the introductions.

(5) <u>Illegal hunting</u>

Levels of illegal hunting could affect the survival of roan, sable and tsessebe on both State Land and Conservancies. The population model developed in **Appendix 1** has been used to explore the maximum illegal harvest which a population of roan, sable or tsessebe could sustain. It is assumed that mortality would affect both sexes and all ages equally. The calculation of the number of years a population would take to reach 2,500 animals is based on an assumed starting population of 250 animals (which is not far off the present estimates for the populations of all three species in their "natural range"), i.e. the time it would take for the population to increase ten-fold.

| Illegal harvest % | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rate of population growth % | 13.6 | 12.5 | 11.4 | 10.2 | 9.1 | 7.9 | 6.8 | 5.7 | 4.5 | 3.4 | 2.3 | 1.1 | 0.2 |
| Years to reach 2,500 animals | 18 | 20 | 22 | 24 | 27 | 31 | 34 | 42 | 53 | 69 | 102 | 211 | ∞ |

The assumptions in this analysis are that the generic population model is suitable for all three species and that the model applies only in a situation where rainfall is above 400mm and is not in any major long term rainfall deficit mode (see page 24). Without any illegal hunting the population grows at slightly under 14% per annum and it can sustain a maximum offtake of about 12%. The higher the proportional offtake, the lower is the growth rate of the population and the effects become severe above a 6% offtake.

41. Dunham and Robertson (2003) give a detailed description of the habitats for tsessebe on Shangani Ranch in south-western Zimbabwe. The population of tsessebe on this and neighbouring ranches was, until recently, the largest single subpopulation in Africa.

To examine rates of population decline when the illegal harvest exceeds 12%, it is not useful to examine percentage offtakes because these result in a lower and lower number of animals being killed as the population declines so that the population tends to stabilise at some low level. A more realistic examination of rates of decline for unsustainable harvests has been done with a fixed number being removed from the population each year which inevitably results in extinction. In the table below, the number of years to extinction is shown for various fixed offtakes from a starting population of 1,000 animals.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Illegal harvest (% of 1,000 animals) | 14 | 15 | 16 | 17 | 20 | 25 | 30 | 40 | 50 |
| Fixed annual offtake | 140 | 150 | 160 | 170 | 200 | 250 | 300 | 400 | 500 |
| Years to extinction | 29 | 20 | 15 | 13 | 9 | 7 | 5 | 4 | 3 |

(6) Sport Hunting

I have used the population model of **Appendix 1** (page 66) to explore the effects of hunting quotas on roan, sable and tsessebe populations (**Fig.23** below). Again, the assumptions are that one model suits all. Hunting selectivity is centred on the 8-9 year old males, with 40% of trophies coming from this age group, but the rest spread fairly evenly over the range of age classes. The model works by attempting to take the available quota of trophy animals from the various age classes in the proportions set by the selectivity profile (i.e. if the quota was 100 animals it would take 5 animals from the 5 year old age-class, 10 animals from the 6 year-old age class, 15 animals from the 7 year-old age class . . . and so on). However, if there are insufficient animals in any age class to meet the quota demand, the animals are then sought in the age class immediately below it (as would happen in practice). The percentage quotas apply to the total population and it is assumed that males under 5 years old would not be hunted.

**Fig.23**. Effect of hunting quotas on age structure of adult males in the population

As the quota is increased from zero, the older age classes are 'cleaned out' very quickly. A quota of 1% results in all animals older than 12 years being removed from the population, 1.5% removes all animals 9 years and older and, at 2%, all 8 year-olds have gone, leaving only 7 year-olds and younger males to breed. This would suggest that **sport hunting quotas for roan, sable and tsessebe should never exceed 2%**. The annual recruitment to the part of the age pyramid from which males are hunted is very low – the proportion of males recruited annually to the 5 year age class is about 3% of the population and, to the 8 year-old age group, it is about 2% of the population. Thus a hunting quota of 2% will claim every male 8 years old and over.

The sex ratio in the population in the absence of hunting is 1♂:2♀♀ and, as hunting quotas increase, this shifts in favour of females. With the quota at 2%, the sex ratio becomes 1♂:3.3♀♀.

I conclude this section on sport hunting by discussing the methodology for setting quotas and monitoring sustainability. It is not necessary to know the numbers of animals in the population in order to set sustainable quotas – indeed a system based on population estimates is likely to be far less robust than an adaptive management system (Holling 1978, Bell 1986, Martin 1999) because, firstly, the confidence intervals on population estimates are very large and, secondly, the area of interest is not the total number of animals in the population but the number of adult males older than (say) 8 years – which is only about 3% of the population.

The key parameter to be monitored is the age of trophies taken from the population. If a criterion is set that there should always be a sufficient number of prime breeding males, then the requirement is that amongst the trophies (regardless of the selectivity of the hunting regime), there should be a representative number of males in the age classes above 7 years old. As soon as the cohort of hunted animals is missing all of the age classes older than 7 years of age, this is a robust indicator that the population is being overhunted and the quota should be reduced. An initial quota might be set by the crude method of applying 2% to the population estimate but thereafter that quota should be adjusted upwards or downwards by the 'hard data' (as opposed to the 'soft data' of population estimates) which comes from measuring trophies. Methods of ageing roan, sable and tsessebe from their dentition or horns are available (Grobler 1979,1980; Joubert 1976; Child *et al* 1972; Huntley 1973) – which could easily be applied by local community monitoring staff with some training. It is logical that conservancies should take on this monitoring rôle in all areas where the species are hunted in conservancies since it is effectively their resource being managed.[42] In State protected areas where there is hunting this would be the responsibility of the parks staff.

The principle can be applied to the hunting of any species. Adaptive management is a better methodology than the blind application of percentage offtakes to populations since it tests the underlying hypotheses about population age structures and the sustainability of hunting quotas. In the case of roan, sable and tsessebe there is perhaps a more important reason for monitoring quotas by this method which is discussed in the next subsection.

42. The development of conservancy monitoring systems by the NACSO unit (Namibian Association of CBNRM Support Organisations) is impressive and may be well-suited to carrying out this specific monitoring.

(7) Monitoring

In general, most monitoring activities should be applied within an adaptive management framework. Bell (pers.comm. 2000) said "*In the early stages many of us saw adaptive management as a research process to reduce uncertainties. These days it should be stated as part of the definition of adaptive management that intensive levels of research or monitoring which will result in a system being too expensive, and hence unsustainable, cannot and should not be attempted.*" An example has been given of the use of adaptive management to set hunting quotas where there is a focussed objective and monitoring is aimed at realising that objective. A second situation arises, specifically within the Transboundary Species Project, with the need to assess whether the objective of increasing roan, sable and tsessebe populations is being achieved.

Present air survey techniques are not suited to precise or accurate estimates of roan, sable and tsessebe populations for the reasons given on page 24. However, this method is the best there is at present. The population estimates for all species in the Caprivi, for example, would be greatly improved if annual surveys using the standard methodology of Craig (2000) were done at a fairly high sampling intensity (10-20%) using the same strata on every survey and, where possible, the same observers. The budgets outlined in Table 9 (page 57) contain a provision for such a survey for each area every year.

There is an alternative (or additional) method that might be attempted for roan, sable and tsessebe which makes use of the monitoring data obtained from sport hunting. The data in Fig.23 show the shape of the age pyramid to be expected at different levels of hunting quotas. For example, if the hunting quota is 2% there are unlikely to be any males older than 8 years in the population. If the ages of the animals taken in any year are accurately determined and if it is found (say) that there are 7 year-old animals in the population but no 8 year-olds, one might be justified in assuming that the actual numbers of animals killed in the year concerned **is 2% of the population**. This permits a reverse calculation to be carried out: if 10 animals were hunted and this, according to the age structure model should be 2% of the population, then total population would be 500 animals.[43]

Obviously a large number of assumptions go into this method – including the assumption that the adult male survival rate and the selectivity for trophies are close to the values used in the model and that the age determinations can be carried out with some accuracy. However, over several hunting seasons through some iterations with the model and through deliberately pursuing a course of active, adaptive management[44], it might be possible to simultaneously refine the model, obtain better estimates of the populations from which the hunting trophies are derived and arrive at optimum hunting quotas.

43. A drawback of this type of calculation is that the quotient consists of a large number divided by a small number and the corresponding scope for error is very large.

44. i.e. the hunting quotas are deliberately varied, even in some cases to levels which are likely to be too high, in order to learn more about the population characteristics.

(8) Elephants

In the discussion of factors possibly limiting roan, sable and tsessebe populations (page 40), the large elephant population in the Caprivi (5,000-10,000 animals) was put forward as perhaps being responsible for fundamental structural changes to habitats. In areas where annual rainfall is 500-600mm, elephant densities greater than 1/km$^2$ result in marked changes to woody vegetation and it can be presumed that the grazing sward is also affected. There have been no population reductions of elephant in either northern Botswana or Caprivi as part of ecosystem management in recent times (if ever) and this management option could be considered. It is a topic which should be discussed jointly with the Botswana authorities.

(9) Artificial water

More habitats could be made available for roan, sable and tsessebe by the supply of artificial water – particularly in the Caprivi Strip and Bushmanland. All of these species are water-dependent[45] and seldom move further than a few kilometres from surface water (Table 2, page 9). In the Caprivi, this means they are tied to the large rivers for a large part of every year. This limits the ability of the populations in the eastern and western ends of the Caprivi Game Reserve to maintain contact and, in conjunction with the veterinary fences along the Botswana border and a hostile environment in Angola, could result in the total isolation of various subpopulations.

The development of game water supplies in the large Kalahari Sands area of the Caprivi Game Reserve would not be simple: Mendelsohn and Roberts (1997, page 39) show the average depth of water below the surface as varying from as much as 300 metres in the west of the Caprivi Strip to 35 metres in the east. A number of boreholes have been sunk in the area but most are non-functional or would only provide small quantities of water. However, this latter feature might prove valuable to roan, sable and tsessebe: if large amounts of water were available it is highly likely that the water points would be captured by elephants and large buffalo herds.

(10) Fire

Roan and sable are not particularly attracted to burns but tsessebe are – although they will seldom move more than short distances in order to feed on a burn (Joubert and Bronkhorst 1977). Fire can be a valuable tool to improve habitats for tsessebe: where bush encroachment has occurred through excessive cattle grazing, judicious burning may return areas to grassland.

In the Caprivi, the marginal gains which roan, sable and tsessebe might get from careful use of fire are more likely to be nullified by the loss of grazing caused by the existing fire regimes. Mendelsohn and Roberts (1997, pages 24-25) present a compelling picture of the gravity of the fire situation with burns commencing as early as April each year and continuing until December when over 60% of the vegetation has been burnt and the total count of individual fires may have exceeded 3,000. It seems that at one time there was an extensive network of firebreaks in Caprivi to control fires and it would obviously be beneficial if these could be resuscitated.

45. Garstang (1982) observes that tsessebe have 'aesthetic preferences' for certain types of surface water and will generally avoid drinking at concrete water troughs.

### b. Transboundary Issues

A number of areas have been identified in this report where collaboration between Botswana and Namibia could enhance roan, sable and tsessebe populations. These are presented below in the form of a possible agenda for the next joint workshop with Botswana.

Botswana's roan population is about 1,500 animals, its sable population is about 3,000 and its tsessebe population is one of the largest in Africa – of the same order as Zambia's at about 10,000 animals. Together Botswana and Zambia hold more than two-thirds of Africa's tsessebe. Thus, Namibia stands to be the greater beneficiary from co-operation with Botswana on management issues than *vice-versa*. Namibia's primary conservation objectives are to increase numbers of roan, sable and tsessebe and to avoid fragmentation of the populations. Maintaining spatial linkages with Botswana will be important in achieving this.

The question of the scale at which roan, sable and tsessebe populations should be managed is an important one. In this course of this study it has not been possible to identify discrete subpopulations but it is known that movements of all three species are considerably less than is the case for buffalo. Therefore, the scale under consideration at the outset of this collaborative process need not necessarily embrace the full northern Botswana populations of the three species but could focus on the animals in Namibia and Botswana which are located within a certain distance (e.g. 50km) of the international boundary. Later, it may be possible to refine management to specific subpopulations.

Perhaps the key determinant of roan, sable and tsessebe numbers is rainfall and, if this is so, the remaining factors might seem to be of secondary importance. I do not personally believe this is so and identify a number of management issues which could make a substantial difference and where co-operation would be worthwhile. Most of the issues remain the same as those affecting buffalo but they differ individually in their priorities. They are listed below in order of importance.

(1) <u>Elephants</u>

The impact of the very large elephant population in the project area (more than 100,000 animals) on roan, sable and tsessebe habitats is viewed in this study as the most important factor after rainfall. Elephant management is a high-level issue where technical collaboration is essential.

(2) <u>Introductions</u>

Botswana might be able to provide animals from their large reservoir of tsessebe for introduction to identified project sites in Namibia in the areas which have been identified as having the greatest likelihood of success in re-establishing populations. Although roan and sable in Botswana are less abundant, there may be potential for introductions of these species, too – or the deliberate establishment of trans-border populations of all three species in specific localities.

(3) Illegal Hunting

Levels of illegal hunting in the Caprivi are higher than in northern Botswana and, if these cannot be contained, it will have a deleterious effect on Namibia's resident roan, sable and tsessebe populations. It is less likely to affect the larger populations of these species in Botswana, by virtue of the localised nature of the species' distribution (unlike the buffalo situation). Nevertheless, there may be collaborative measures that could assist in reducing illegal hunting in both countries.

(4) Veterinary Control Measures

Veterinary control measures are less of an issue with roan, sable and tsessebe than they are with buffalo. However, they are a factor acting to disrupt linkages between the Namibia and Botswana populations and should still be addressed with some priority. The trend in Namibia towards isolated subpopulations in Caprivi, Khaudum and Nyae Nyae is of concern. Scott-Wilson (2000) put forward four options to mitigate the effects of veterinary fences in northern Botswana and decisions are still awaited on these options – or an alternative solution.

(5) Population Estimates

The inadequacy of present air survey techniques for counting roan, sable and tsessebe is highlighted in this study and is reflected in the high confidence limits of both the Botswana and Namibian population estimates. In most years, Botswana conducts a national air survey of all of the northern wildlife areas which is done to the highest scientific standards. It would be cost-effective to extend the coverage of this survey into the roan, sable and tsessebe range in Namibia, with the extra costs being met by Namibia. This could be a major step forward in standardising air surveys between the two countries.

(6) Fire

The Caprivi suffers from an excessive burning regime every year. Whilst few of these fires originate from Botswana, this may be an area where co-operative effort would result in a reduction in the number and extent of fires.

(7) Liaison on Hunting Quotas

It is unlikely that excessive sport hunting quotas in either Namibia and Botswana would be likely to affect each other's safari hunting industry significantly because of the localised subpopulations which make up the roan, sable and tsessebe distribution. However, it is possible that in specific localities on either side of the international border there are good reasons to cooperate on joint hunting management. This is an area of liaison which would require little effort and could produce significant economic and conservation gains. In the areas on either side of the international border where hunting is taking place from what may be the same herds, there is good case for developing local institutions at the appropriate scale which would enable the proceeds from an overall quota to be shared proportionally amongst the participating community areas.

## A Generic Population Model for Roan, Sable and Tsessebe

Using the broad reproductive parameters given in Table 5 of the main report (page 12), a simple population model has been constructed using a computer spreadsheet which enables analysis of population growth rates and age structures.

| | |
|---|---|
| START | 0 |
| YEAR | 1 |

Nominal starting population: **1,000**

| AGE | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | TOTALS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Starting Cohort | | | | | | | | | | | | | |
| Males | 114 | 76 | 53 | 40 | 32 | 25 | 20 | 16 | 12 | 8 | 3 | 0 | 399 |
| Females | 114 | 96 | 80 | 68 | 58 | 50 | 43 | 36 | 29 | 18 | 8 | 1 | 601 |
| Running Cohort (population from previous year) | | | | | | | | | | | | | |
| Males | 114 | 76 | 53 | 40 | 32 | 25 | 20 | 16 | 12 | 8 | 3 | 0 | 399 |
| Females | 114 | 96 | 80 | 68 | 58 | 50 | 43 | 36 | 29 | 18 | 8 | 1 | 601 |
| Fecundity | 0.00 | 0.00 | 0.75 | 0.95 | 0.97 | 0.98 | 0.98 | 0.97 | 0.95 | 0.50 | 0.25 | 0.00 | |
| Calves | 0 | 0 | 60 | 64.6 | 56.3 | 49 | 42.1 | 34.9 | 27.5 | 9 | 2 | 0 | 346 |
| Population after births | | | | | | | | | | | | | |
| Males | 173 | 114 | 76 | 53 | 40 | 32 | 25 | 20 | 16 | 12 | 8 | 3 | 572 |
| Females | 173 | 114 | 96 | 80 | 68 | 58 | 50 | 43 | 36 | 29 | 18 | 8 | 773 |
| Population after annual mortality | | | | | | | | | | | | | |
| Survival ♂ | 0.75 | 0.75 | 0.80 | 0.85 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.70 | 0.50 | 0.10 | |
| Survival ♀ | 0.75 | 0.95 | 0.95 | 0.97 | 0.97 | 0.98 | 0.98 | 0.95 | 0.90 | 0.70 | 0.50 | 0.10 | |
| Males | 130 | 86 | 61 | 45 | 36 | 29 | 23 | 18 | 14 | 8 | 4 | 0 | 454 |
| Females | 130 | 109 | 92 | 78 | 66 | 57 | 49 | 41 | 33 | 21 | 9 | 1 | 686 |

| | |
|---|---|
| TOTAL POPULATION | **1140** |
| RATE OF GROWTH % | **14.00** |
| ADULT SEX RATIO | **2.01** |

The model behaves in a manner similar to the Leslie matrix (Leslie 1984) but the calculations of births and deaths are separated into successive operations because it is designed to cycle within the row operations of a computer spreadsheet. The model operates as follows –

(i) The starting year is set to zero, and a nominal starting population and average female fecundity are set in the indicated cells.

(ii) In the two rows immediately following, the starting population is divided into equal numbers of males and females and further divided into numbers in each age class which approximate a stable age distribution.

(iii) In the first year of the model, this cohort of males and females is transferred to the next two rows of the model ("Running cohort"). On each successive cycle of the model thereafter, the running cohort derives its population values (males and females) from the last two lines of the model.

(iv) On each cycle of the model the individual number of females in each class is multiplied by the fecundity in the cell immediately below it to give the number of calves produced by each female age class.

(v) The number of calves is summed at the end of the row, divided by two and inserted in the first two cells of the next two rows ("Population after births"). At the same time the number of males and females in each cell of the running cohort above is moved forward by one year and inserted in the cells following the one year old age class, i.e. at the same time as the births occur each animal in the population ages by one year.

(vi) The individual male and female cells of the "population after births" are then multiplied by the survival values in the next row to give the "Population after annual mortality".

(vii) The population is then totalised and the growth rate is calculated using the increase in the population over the number at the start of that particular cycle (which is the total number of animals in the "Running cohort").

(viii) The cycle is then repeated as many times as desired (usually until the age structure becomes stable and the growth rate does not change from year to year).



The female survival values have been adjusted from their nominal starting values to give a sex ratio of 1 male : 2 females when the population has reached a stable age distribution.

The model has been amplified on the next page to examine the effects of illegal hunting and sport hunting. These two 'treatments are inserted into the spreadsheet after the population has undergone its first step in the annual cycle. The model sequence is –

Births → Age by One Year → Illegal Hunting → Sport Hunting → Natural Mortality

For illegal hunting it is assumed that there is no selectivity – all animals in the population have an equal likelihood of being killed. When population numbers are low, the spreadsheet may give errors due to rounding and the actual number of animals killed may be more or less than the expected number. To avoid this effect, in the original spreadsheet compensation is performed using random numbers to round up or round down the numbers until the expected number matches the actual number of deaths. This is not shown in the table overleaf.

The modelling process for sport hunting is slightly more complicated. Firstly, it is assumed that the quotas will be set as a proportion of the total population after it has enjoyed its annual increment of births, i.e. it does not take into account the numbers of animals killed illegally and, in this respect it is likely to be representative present practices.

## Expanded model to examine population response to illegal hunting and sport hunting

START: 1

**YEAR**: 20

Nominal starting population: **1,000**

| **AGE** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | **TOTALS** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Starting Cohort | | | | | | | | | | | | | |
| Males | 114 | 76 | 53 | 40 | 32 | 25 | 20 | 16 | 12 | 8 | 3 | 0 | 399 |
| Females | 114 | 96 | 80 | 68 | 58 | 50 | 43 | 36 | 29 | 18 | 8 | 1 | 601 |
| Running Cohort (population from previous year) | | | | | | | | | | | | | |
| Males | 926 | 611 | 430 | 321 | 246 | 167 | 0 | 0 | 0 | 0 | 0 | 0 | 2,701 |
| Females | 927 | 774 | 647 | 553 | 473 | 407 | 351 | 293 | 234 | 144 | 64 | 6 | 4,873 |
| Fecundity | 0.00 | 0.00 | 0.75 | 0.95 | 0.97 | 0.98 | 0.98 | 0.97 | 0.95 | 0.50 | 0.25 | 0.00 | |
| Calves | 0 | 0 | 485.3 | 532.4 | 458.8 | 398.9 | 344.0 | 284.2 | 222.3 | 72.0 | 16.0 | 0.0 | 2,855 |
| Population after births | | | | | | | | | | | | | |
| Males | 1,403 | 926 | 611 | 430 | 321 | 246 | 167 | 0 | 0 | 0 | 0 | 0 | 4,104 |
| Females | 1,404 | 927 | 774 | 647 | 553 | 473 | 407 | 351 | 293 | 234 | 144 | 64 | 6,271 |
| **Illegal hunting** — Percent of population **2** % — Expected offtake **208** | | | | | | | | | | | | | |
| Male offtake | 28 | 19 | 12 | 9 | 6 | 5 | 3 | 0 | 0 | 0 | 0 | 0 | 82 |
| Female offtake | 28 | 19 | 15 | 13 | 11 | 9 | 8 | 7 | 6 | 5 | 3 | 1 | 125 |
| Males | 1,375 | 907 | 599 | 421 | 315 | 241 | 164 | 0 | 0 | 0 | 0 | 0 | 4,022 |
| Females | 1,376 | 908 | 759 | 634 | 542 | 464 | 399 | 344 | 287 | 229 | 141 | 63 | 6,146 |
| **Sport hunting** — Quota 2 % — Expected offtake **208** | | | | | | | | | | | | | |
| Selectivity % | – | – | – | – | *5* | *10* | *15* | *20* | *20* | *15* | *10* | *5* | |
| Offtake 1 | | | | | 10 | 21 | 31 | 42 | 42 | 31 | 21 | 10 | 208 |
| Deficits | | | | | 0 | 0 | 0 | -42 | -42 | -31 | -21 | -10 | -146 |
| Surpluses | | | | | 305 | 220 | 133 | 0 | 0 | 0 | 0 | 0 | 658 |
| Adjustments | | | | | 512 | 207 | -13 | -146 | -104 | -62 | -31 | -10 | |
| Corrected | | | | | 10 | 34 | 164 | | | | | | 208 |
| Males | 1,375 | 907 | 599 | 421 | 305 | 207 | 0 | 0 | 0 | 0 | 0 | 0 | 3,814 |
| Population after annual mortality | | | | | | | | | | | | | |
| Survival ♂ | 0.75 | 0.75 | 0.80 | 0.85 | 0.90 | 0.90 | 0.90 | 0.90 | 0.90 | 0.70 | 0.50 | 0.10 | |
| Survival ♀ | 0.75 | 0.95 | 0.95 | 0.97 | 0.97 | 0.98 | 0.98 | 0.95 | 0.90 | 0.70 | 0.50 | 0.10 | |
| Males | 1,032 | 681 | 479 | 358 | 275 | 186 | 0 | 0 | 0 | 0 | 0 | 0 | 3,011 |
| Females | 1,032 | 863 | 722 | 615 | 526 | 455 | 392 | 327 | 259 | 161 | 71 | 7 | 5,430 |

| | |
|---|---|
| TOTAL POPULATION | **8,441** |
| RATE OF GROWTH % | **11.45** |
| ADULT SEX RATIO | **3.44** |

The sport hunting simulation works as follows –

(i) It is assumed that sport hunting is restricted to males only and no males under the age of 5 years will be taken as trophies;

(ii) The hunting quota is calculated as a percentage of the total population after births and the number of animals expected to be taken is presented in a cell in the same row;

(iii) In the next row ('Selectivity') a set of age-specific hunting selectivities are assumed – for any given hunting quota, 5% of the quota will taken from the 5 year-olds, 10% from the 6 year-olds, 15% from the 7-year olds . . . and so on up to the twelve year-olds; .

(iv) In the next row ('Mortality') the theoretical offtake from each age class is calculated;

(v) The male population may not be able to provide the trophies in the proportions demanded, so that the shortfalls in each age class are the calculated in the next row ('Deficits');

(vi) In the next row ('Surpluses') the male age classes which will have a surplus of animals after the age-specific hunting quotas have been deducted are identified and the surpluses calculated;

(vii) In the next row ('Adjustments'), the deficit/surplus is cumulated, beginning with the oldest age class;

(viii) In the next row ('Corrected'), the number of males to be deducted from each age class is calculated by scanning the + and - signs in the previous row. If there is a negative value, the number inserted in the cell is simply the maximum number of animals for that age class, i.e. all of the animals in the age class concerned will be killed. At the point where the cell entry changes from negative to positive the required deficits are made up from the available animals in the younger age classes.

(ix) In the last row ('Males'), the remaining population of males is calculated by deducting the number in the row above;

(x) The model then continues with the normal calculation of age-specific survival and completes its cycle.

In this way, the effect of hunting quotas which exceed the offtake possible from the older age classes can be compensated for by obtaining younger animals – as would the case in real life.

A full set of tests of the sustainable limits of illegal hunting and sport hunting have been done and these are presented in the main body of the report.

## Air survey estimates for Roan, Sable and Tsessebe in Namibia

The tables on the next three pages summarise all air surveys (or, in some cases, best estimates when these are not based on air surveys) which have been carried in the areas where roan, sable and tsessebe occur (or have occurred) since 1970. Data for commercial farms (DSS 2003) is not included in the tables but is shown on Figures 9-11 of the main report.

The starting point for the tables is the report by DSS (2002) summarising most of the air surveys done in Namibia. Additional data has been added from –

DSS (2003) National estimates for Roan, Sable and Tsessebe, 2003

Erb (1992) Best estimates for roan in Waterberg Plateau Park

Erb (1993) Improved estimates for sable and tsessebe in Waterberg Plateau Park

Craig (1998) Additional data for Khaudum, Bushmanland and Caprivi

Craig (2000) New data for north-eastern Namibia

Killian (2003, pers. comm.) Recent information on sable and roan in Etosha

LIFE (2002) Population estimates from the Nyae Nyae Conservancy

Rodwell, Tagg and Grobler (1995) Survey of the Caprivi in 1994 and summary data of previous Caprivi surveys

ULG (1994) Survey of the Caprivi in 1994



In cases where more than one estimate has been available for the same area in the same year, the higher of the two estimates has been put in the table. Italics have been used for some numbers in the subtotals for the east and west Caprivi where the survey results for individual areas within the east and west Caprivi add up to a subtotal which is lower than a separate survey result for the east or west Caprivi as a whole. In such a case the higher total has been used.

| Year | ETOSHA: Main Park | West Etosha | Kaross | Khaobendes | Kaross + Khaobendes | Total | WATERBERG: Waterberg | Waterberg captures | BUSHMANLAND: Bushmanland | Bushmanland + Nyae Nyae | Khaudum | Total | WESTERN CAPRIVI: Mahango | Western Core | Central Caprivi | Eastern Core | Subtotal | EASTERN CAPRIVI: Mudumu | Mamili | Forest Reserve | Eastern Floodplain | Subtotal | Total | ROAN GRAND TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1970 | – | • | • | 74 | • | 74 | • | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | – |
| 1971 | – | • | • | 92 | 89 | 92 | • | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | 92 |
| 1972 | • | • | • | • | 114 | 114 | • | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | 114 |
| 1973 | – | • | • | • | 159 | 159 | • | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | 159 |
| 1974 | – | • | • | • | 177 | 177 | • | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | 177 |
| 1975 | – | • | • | • | 136 | 136 | 70 | 70 | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | 206 |
| 1976 | – | • | • | • | 204 | 204 | 77 | 7 | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | 281 |
| 1977 | – | • | • | • | 160 | 160 | 80 | | 3 | • | • | 3 | • | • | • | • | • | • | • | • | • | • | • | 243 |
| 1978 | – | 5 | • | • | 202 | 207 | 85 | | 27 | • | • | 27 | • | • | • | • | • | • | • | • | • | 0 | 0 | 319 |
| 1979 | 0 | • | • | • | 243 | 243 | 88 | | 16 | • | • | 16 | • | • | • | • | • | • | • | • | • | 0 | 0 | 347 |
| 1980 | • | 13 | • | • | 223 | 236 | 100 | | 55 | • | 20 | 75 | • | • | • | • | • | 39 | 0 | 33 | 0 | *243* | 243 | 654 |
| 1981 | • | • | • | • | 197 | 197 | 176 | 16 | • | • | • | • | • | • | • | 66 | 66 | • | • | • | • | • | 0 | 373 |
| 1982 | 19 | • | • | • | 11 | 30 | 220 | | • | • | • | • | • | • | • | • | • | 32 | 0 | 9 | 0 | *71* | 71 | 321 |
| 1983 | • | 0 | • | • | 12 | 12 | 275 | | • | • | • | • | 24 | • | • | • | 24 | 14 | 0 | 1 | 0 | 15 | 39 | 326 |
| 1984 | 2 | 0 | • | • | 21 | 23 | 275 | | • | 108 | 410 | 518 | • | • | • | • | • | 26 | 0 | 1 | 0 | 27 | 27 | 843 |
| 1985 | • | • | • | • | • | • | 210 | -72 | • | • | 159 | 159 | 4 | – | • | • | 4 | 12 | 0 | 2 | 0 | 14 | 18 | 387 |
| 1986 | • | 0 | • | 36 | • | 36 | 245 | | • | • | • | • | 43 | • | • | • | 43 | 14 | 0 | 0 | 0 | 14 | 57 | 338 |
| 1987 | • | • | 40 | | • | 40 | 215 | -37 | • | • | 237 | 237 | 61 | 16 | • | • | 77 | • | • | • | • | *22* | 99 | 591 |
| 1988 | • | • | 40 | | • | 40 | 156 | -77 | • | 56 | • | 56 | 63 | • | • | 4 | 67 | 14 | 0 | 0 | • | 14 | 81 | 333 |
| 1989 | • | • | • | | 39 | 39 | 150 | | • | • | • | • | 63 | 0 | • | 0 | 63 | 17 | 0 | 0 | 0 | 17 | 80 | 269 |
| 1990 | 0 | • | 20 | | 42 | 42 | 160 | | • | 0 | 220 | 220 | 58 | 0 | • | • | 58 | 0 | 0 | • | • | 0 | 58 | 480 |
| 1991 | • | • | • | | • | • | • | | • | • | • | • | 94 | • | • | • | 94 | • | • | • | • | • | 94 | 94 |
| 1992 | • | • | • | | • | • | • | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | *323* | 323 |
| 1993 | • | • | 61 | | • | 61 | • | | • | • | • | • | 158 | • | • | 7 | 165 | 0 | 0 | • | • | 0 | 165 | 226 |
| 1994 | • | • | 83 | | • | 83 | • | | • | • | • | • | 130 | 6 | 0 | 6 | 142 | 55 | 0 | 0 | 0 | 55 | 197 | 280 |
| 1995 | 0 | • | 110 | | • | 110 | 74 | | | 124 | 75 | 199 | 107 | • | • | • | 107 | 0 | • | • | • | 0 | 107 | 490 |
| 1996 | • | • | | | • | 0 | • | | | • | • | • | • | • | • | • | • | • | • | • | • | • | 0 | 0 |
| 1997 | • | • | | | • | 0 | • | | | • | • | • | • | • | • | • | • | • | • | • | • | • | 0 | 162 |
| 1998 | 29 | • | | | 80 | 109 | 162 | | 33 | • | 33 | 66 | 6 | 28 | • | • | 34 | 10 | • | • | • | 10 | 44 | 219 |
| 1999 | • | • | | | 80 | 80 | • | | | • | • | • | • | • | • | • | • | • | • | • | • | • | 0 | 80 |
| 2000 | 25 | • | | | | 25 | 137 | | | 0 | 99 | 99 | 22 | • | • | • | 22 | • | • | • | • | • | 22 | 283 |
| 2001 | | | | | | | | | | 89 | | | | | | | | | | | | | | |
| 2002 | | | | | | | | | | 80 | | | | | | | | | | | | | | |

• No survey – Species not on list of animals surveyed 0 Species not seen on survey

## SABLE

| | ETOSHA | | | | | | WATERBERG | | BUSHMANLAND | | | | WESTERN CAPRIVI | | | | | EASTERN CAPRIVI | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Main Park | West Etosha | Kaross | Khaobendes | Kaross + Khaobendes | Total | Waterberg | Waterberg captures | Bushmanland | Bushmanland + Nyae Nyae | Khaudum | Total | Mahango | Western Core | Central Caprivi | Eastern Core | Subtotal | Mudumu | Mamili | Forest Reserve | Eastern Floodplain | Subtotal | Total | GRAND TOTAL |
| 1970 | – | • | • | • | • | – | • | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | – |
| 1971 | – | • | • | – | – | – | • | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | – |
| 1972 | • | • | • | • | • | – | • | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | – |
| 1973 | – | • | • | • | – | – | • | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | – |
| 1974 | – | • | • | • | – | – | • | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | – |
| 1975 | – | • | • | • | 0 | 0 | • | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | 0 |
| 1976 | – | • | 0 | • | 0 | 0 | • | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | 0 |
| 1977 | – | • | • | • | 0 | 0 | • | | – | • | • | – | • | • | • | • | • | • | • | • | • | • | • | 0 |
| 1978 | – | – | • | • | 26 | 26 | • | 25 | – | • | • | – | • | • | • | • | • | • | • | • | • | 0 | 0 | 26 |
| 1979 | – | • | • | • | 26 | 26 | • | | – | • | • | – | • | • | • | • | • | • | • | • | • | 0 | 0 | 26 |
| 1980 | • | 0 | • | • | 29 | 29 | 25 | 6 | – | • | – | – | • | • | • | • | • | 55 | 0 | 19 | 8 | *137* | 137 | 191 |
| 1981 | • | • | • | • | 29 | 29 | • | 29 | • | • | • | • | • | • | • | 113 | 113 | • | • | • | • | • | 113 | 142 |
| 1982 | – | • | • | • | 0 | 0 | • | -2 | • | • | • | • | • | • | • | • | • | 47 | 0 | 26 | 0 | *158* | 158 | 158 |
| 1983 | • | 0 | • | • | 0 | 0 | 37 | -2 | • | • | • | • | 1 | • | • | • | 1 | 41 | 0 | 3 | 0 | 44 | 45 | 82 |
| 1984 | – | 0 | • | • | 0 | 0 | 53 | -1 | • | – | – | – | • | • | • | • | • | 31 | 0 | 1 | 0 | 32 | 32 | 85 |
| 1985 | • | • | • | • | • | • | 61 | -3 | • | • | – | – | 73 | 52 | • | • | 125 | 33 | 0 | 4 | 0 | 37 | 162 | 223 |
| 1986 | • | – | • | – | • | – | 57 | -2 | • | • | • | • | 68 | • | • | • | 68 | 14 | 0 | 0 | 0 | 14 | 82 | 139 |
| 1987 | – | • | – | | • | – | 57 | -3 | • | • | – | – | 103 | 33 | • | • | 136 | • | • | • | • | 2 | 138 | 195 |
| 1988 | • | • | – | | • | – | 59 | | • | – | • | – | 148 | • | • | 64 | 212 | 16 | 0 | 0 | • | 16 | 228 | 287 |
| 1989 | • | • | • | | 0 | 0 | • | | • | • | • | • | 99 | 0 | • | 0 | 99 | 17 | 0 | 0 | 0 | 17 | 116 | 116 |
| 1990 | – | • | 20 | | 24 | 44 | • | | • | – | – | – | 98 | 28 | • | • | 126 | 20 | 0 | • | • | 20 | 146 | 190 |
| 1991 | • | • | • | | • | • | • | | • | • | • | • | 142 | • | • | • | 142 | • | • | • | • | • | 142 | 142 |
| 1992 | • | • | • | | • | • | • | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | *989* | 989 |
| 1993 | • | • | 0 | | • | 0 | • | | • | • | • | • | 78 | 48 | • | 7 | 133 | 0 | 0 | • | • | 0 | 133 | 133 |
| 1994 | • | • | 0 | | • | 0 | • | | • | • | • | • | 158 | 187 | 2 | 265 | 612 | 514 | 0 | 0 | 74 | 588 | 1200 | 1200 |
| 1995 | – | • | 0 | | • | 0 | 74 | | | – | – | – | 40 | • | • | • | 40 | 0 | • | • | • | 0 | 40 | 114 |
| 1996 | • | • | | | • | • | • | | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • |
| 1997 | • | • | | | • | • | • | | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • |
| 1998 | – | • | | | – | – | 157 | | – | • | – | – | 35 | 21 | • | 70 | 126 | 0 | • | • | • | 0 | *128* | 285 |
| 1999 | • | • | | | 46 | 46 | • | | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | 46 |
| 2000 | – | • | | | 50 | 50 | 119 | | | – | – | – | 130 | • | • | • | 130 | • | • | • | • | • | 130 | 299 |
| 2001 | | | | | | | | | | – | | | | | | | | | | | | | | |
| 2002 | | | | | | | | | | – | | | | | | | | | | | | | | |

• No survey – Species not on list of animals surveyed 0 Species not seen on survey

**TSESSEBE**

| Year | ETOSHA | | | | | | WATERBERG | | BUSHMANLAND | | | | WESTERN CAPRIVI | | | | | EASTERN CAPRIVI | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Main Park | West Etosha | Kaross | Khaobendes | Kaross + Khaobendes | Total | Waterberg | Waterberg captures | Bushmanland | Bushmanland + Nyae Nyae | Khaudum | Total | Mahango | Western Core | Central Caprivi | Eastern Core | Subtotal | Mudumu | Mamili | Forest Reserve | Eastern Floodplain | Subtotal | Total | GRAND TOTAL |
| 1970 | – | • | • | • | • | – | • | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | – |
| 1971 | – | • | • | – | – | – | • | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | – |
| 1972 | • | • | • | • | 0 | 0 | • | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | – |
| 1973 | – | • | • | • | 1 | 1 | • | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | – |
| 1974 | – | • | • | • | 0 | 0 | • | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | – |
| 1975 | – | • | • | • | 0 | 0 | • | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | 0 |
| 1976 | – | • | 0 | • | 0 | 0 | • | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | 0 |
| 1977 | – | • | • | • | 0 | 0 | • | | – | • | • | – | • | • | • | • | • | • | • | • | • | • | • | 0 |
| 1978 | – | – | • | • | 8 | 8 | • | | – | • | • | – | • | • | • | • | 0 | • | • | • | • | 0 | 0 | 8 |
| 1979 | – | • | • | • | 10 | 10 | • | | – | • | • | – | • | • | • | • | 0 | • | • | • | • | 0 | 0 | 10 |
| 1980 | • | – | • | • | 13 | 13 | 7 | 7 | – | • | 0 | 0 | • | • | • | • | • | 54 | 0 | 0 | 0 | *116* | 116 | 136 |
| 1981 | • | • | • | • | 12 | 12 | 0 | | • | • | • | • | • | • | • | 35 | 35 | • | • | • | • | • | 35 | 47 |
| 1982 | – | • | • | • | 1 | 1 | • | | • | • | • | • | • | • | • | • | • | 10 | 3 | 15 | 0 | *54* | 54 | 55 |
| 1983 | • | – | • | • | 1 | 1 | • | | • | • | • | • | 8 | • | • | • | 8 | 33 | 0 | 15 | 0 | 48 | 56 | 57 |
| 1984 | – | – | • | • | 1 | 1 | 1 | 1 | • | – | 24 | 24 | • | • | • | • | • | 31 | 0 | 1 | 0 | 32 | 32 | 58 |
| 1985 | • | • | • | • | • | • | 16 | 14 | • | • | 36 | 36 | 13 | 6 | • | • | *26* | 9 | 0 | 3 | 0 | 12 | 38 | 90 |
| 1986 | • | – | • | – | • | – | 11 | | • | • | • | • | 0 | • | • | • | *8* | 1 | 0 | 0 | 0 | 1 | 9 | 20 |
| 1987 | – | • | – | | • | – | 13 | | • | • | – | 2 | 11 | 0 | • | • | 11 | • | • | • | • | 0 | 11 | 26 |
| 1988 | • | • | – | | • | – | 15 | | • | – | • | – | 22 | • | • | 16 | 38 | 6 | 0 | 0 | • | *13* | 51 | 66 |
| 1989 | • | • | • | | 0 | 0 | 19 | | • | • | • | • | 40 | 0 | • | 0 | 40 | 0 | 0 | 0 | 0 | 0 | 40 | 59 |
| 1990 | – | • | – | | 0 | 0 | 18 | | • | – | 0 | 0 | 24 | 0 | • | • | 24 | 19 | 0 | • | • | 19 | 43 | 61 |
| 1991 | • | • | • | | • | • | • | | • | • | • | • | 35 | • | • | • | 35 | • | • | • | • | • | 35 | 35 |
| 1992 | • | • | • | | • | • | • | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | *0* | 0 |
| 1993 | • | • | – | | • | – | • | | • | • | • | • | 33 | 0 | • | 20 | 53 | 0 | 0 | • | • | 0 | 53 | 53 |
| 1994 | • | • | – | | • | – | • | | • | • | • | • | 17 | 0 | 0 | 61 | 78 | 128 | 0 | 0 | 0 | 128 | 206 | 206 |
| 1995 | – | • | – | | • | – | 0 | | – | • | 0 | 0 | 18 | • | • | • | 18 | 0 | • | • | • | 0 | 18 | 18 |
| 1996 | • | • | | | • | • | • | | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • |
| 1997 | • | • | | | • | • | • | | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • |
| 1998 | – | • | | | – | – | 15 | | | – | 0 | 0 | 27 | – | • | 24 | 51 | 0 | • | • | • | 0 | 51 | 66 |
| 1999 | • | • | | | 0 | 0 | • | | | • | • | • | • | • | • | • | • | • | • | • | • | • | • | 0 |
| 2000 | – | • | | | – | – | 2 | | | – | 0 | 0 | 0 | • | • | • | 0 | • | • | • | • | • | 0 | 2 |
| 2001 | | | | | | | | | | – | | | | | | | | | | | | | | |
| 2002 | | | | | | | | | | – | | | | | | | | | | | | | | |

• No survey – Species not on list of animals surveyed 0 Species not seen on survey

## Rainfall Data for Selected Sites

In order to examine the effects of the accumulated surplus and deficit in rainfall and the late dry season rainfall on the roan, sable and tsessebe populations in northern Namibia, long term data were needed for several different areas – Etosha, Waterberg, Khaudum, East Caprivi and West Caprivi. These data were very kindly provided by John Mendelsohn of the Department of Environmental Affairs. The relevant sites for which rainfall data were available are –

| | | *Data used* |
|---|---|---|
| Etosha | – Kamanjab, Ermo, Uries Ekango, Otjitambi and Ondjou . . . . . . . | **Kamanjab** |
| Waterberg | – Otjiwarongo, Okakarara, Hohenfels, Okosongomingo, Etekero . | **Hohenfels** |
| Khaudum and West Caprivi | – Andara . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . | **Andara** |
| East Caprivi | – Katima Mulilo and Sesheke . . . . . . . . . . . . . . . . . . . . . . . . . | **Katima Mulilo** |

Where multiple sites were available, the data were plotted and examined. In all cases the differences between nearby rainfall stations in any particular locality were not great and so one station was selected for each area – mainly on the basis of the completeness and length of the rainfall record. The four rainfall sites selected had records going back to 1960-61[46] and these are shown on the pages which follow.

The seasonal rainfall for any given year was obtained by totalling the months July-December for the previous year and adding this to the rainfall from January to June for the given year. The mean annual rainfall was derived from the average of all the seasonal rainfall figures. The accumulated rainfall surplus/deficit for each year was calculated by subtracting the mean annual rainfall from the actual rainfall for each year and cumulating the resulting positive and negative values, beginning with the first year in the data sequence.

On examining the cumulative surplus/deficit data it was apparent that the data did not have a zero mean.[47] Dunham and Robertson (2001, 2003), in using the cumulative surplus/deficit in rainfall for modelling populations, simply began their data sequence with whatever the data value happened to be in the first year of their analysis. In this case I have forced the data sequence to have a zero mean by subtracting a fixed amount from each point on the curve such that the curve has equal areas above and below zero. In a sense, this gives an absolute value to the concept of deficit and surplus: the shape of the curve is unaltered but the total of the deficit area is equal to the total of the surplus area – lending credence to the idea of a constant long term mean. The calculations of the data used in **Figs. 12-19** are given in the tables which follow, together with the the dry season rainfall.

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46. Unfortunately, the data for the most recent years (1997 onwards) were not available. Contact has been made with the Namibian Weather Bureau and the data has been promised. However it has not yet been received.

47. This is entirely to be expected. If one considers a sine wave where exactly one wave length is contained within the start and end of the data span (i.e. the first half cycle of the sine wave has positive values reaching a peak at a quarter wave length and the second half cycle has negative values reaching a trough at three-quarters of the wave length), then the integral of this curve is entirely positive. The area under the curve reaches a peak at the half-wavelength point and then decreases to zero as the negative values are subtracted in the second half of the cycle.

## KAMANJAB

| YEAR | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | TOTAL | Seasonal Total | DEFICIT/SURPLUS 1961 ➔ | DEFICIT/SURPLUS Zero Mean | Dry Season Rainfall Jul-Oct | Dry Season Rainfall Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Monthly rainfall (mm) | | | | | | | | | | | | | | | | | |
| 1961 | 20.0 | 50.5 | 68.0 | 23.0 | 26.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 66.0 | 9.5 | 263.0 | | | | | |
| 1962 | 18.5 | 43.5 | 13.0 | 67.5 | 0.0 | 0.0 | 0.0 | 16.5 | 0.0 | 1.0 | 31.0 | 14.5 | 205.5 | 218 | -70 | -407 | | |
| 1963 | 179.5 | 49.0 | 177.5 | 79.0 | 0.0 | 0.0 | 0.0 | 0.0 | 6.0 | 0.0 | 70.5 | 7.5 | 569.0 | 548 | 189 | -148 | | |
| 1964 | 8.5 | 101.4 | 13.7 | 33.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 9.0 | 5.5 | 8.2 | 180.1 | 241.4 | 142 | -195 | | |
| 1965 | 72.5 | 96.0 | 47.5 | 29.5 | 0.0 | 0.0 | 0.0 | 0.0 | 20.5 | 0.0 | 12.5 | 0.0 | 278.5 | 268.2 | 122 | -215 | | |
| 1966 | 157.0 | 17.0 | 304.7 | 24.5 | 0.0 | 0.0 | 0.0 | 0.0 | 5.0 | 16.0 | 0.0 | 19.0 | 543.2 | 536.2 | 370 | 33 | | |
| 1967 | 60.0 | 86.5 | 122.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 14.0 | 87.0 | 98.5 | 468.0 | 308.5 | 390 | 53 | | |
| 1968 | 21.0 | 40.5 | 80.2 | 7.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 39.5 | 24.5 | 213.2 | 348.7 | 450 | 113 | | |
| 1969 | 47.0 | 112.5 | 88.5 | 5.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 | 10.5 | 15.0 | 282.5 | 317 | 479 | 142 | | |
| 1970 | 89.5 | 49.5 | 48.5 | 1.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 11.0 | 5.5 | 0.0 | 205.5 | 218.5 | 409 | 72 | 11 | 6 |
| 1971 | 78.5 | 271.0 | 37.5 | 4.0 | 3.0 | 7.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 45.0 | 446.0 | 417.5 | 538 | 201 | 0 | 0 |
| 1972 | 112.0 | 9.5 | 124.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 11.0 | 0.0 | 0.0 | 256.5 | 290.5 | 540 | 203 | 11 | 0 |
| 1973 | 8.5 | 0.0 | 133.5 | 65.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 42.0 | 10.5 | 0.0 | 259.5 | 218 | 469 | 132 | 42 | 11 |
| 1974 | 170.5 | 189.5 | 40.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 94.0 | 21.0 | 0.0 | 515.0 | 452.5 | 634 | 296 | 94 | 21 |
| 1975 | 44.5 | 105.5 | 163.5 | 13.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 6.0 | 23.0 | 0.0 | 355.5 | 441.5 | 787 | 450 | 6 | 23 |
| 1976 | 148.5 | 86.5 | 108.0 | 34.5 | 0.0 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 8.0 | 386.5 | 407.5 | 906 | 569 | 0 | 0 |
| 1977 | 53.0 | 43.5 | 75.5 | 37.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 24.0 | 233.9 | 217.9 | 835 | 498 | 0 | 0 |
| 1978 | 74.7 | 51.8 | 55.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 21.6 | 0.0 | 203.8 | 206.2 | 753 | 416 | 0 | 22 |
| 1979 | 123.0 | 105.2 | 20.0 | 0.0 | 5.0 | 0.0 | 0.0 | 0.0 | 2.5 | 6.0 | 47.5 | 0.0 | 309.2 | 274.8 | 739 | 402 | 8.5 | 48 |
| 1980 | 0.0 | 44.0 | 94.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 21.0 | 7.0 | 166.4 | 194.4 | 645 | 308 | 0 | 21 |
| 1981 | 10.5 | 0.0 | 33.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 43.5 | 71.5 | 428 | 91 | 0 | 0 |
| 1982 | 25.5 | 93.0 | 80.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 6.5 | 5.0 | 62.5 | 273.0 | 199 | 339 | 2 | 6.5 | 5 |
| 1983 | 49.0 | 24.6 | 24.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 28.5 | 126.6 | 172.1 | 223 | -114 | 0 | 0 |
| 1984 | 49.3 | 37.5 | 96.5 | 36.0 | 2.5 | 30.0 | 0.0 | 0.0 | 0.0 | 7.0 | 25.5 | 0.0 | 284.3 | 280.3 | 215 | -123 | 7 | 26 |
| 1985 | 97.0 | 63.0 | 61.0 | 0.0 | 13.5 | 0.0 | 0.0 | 0.0 | 0.0 | 15.5 | 35.0 | 0.0 | 285.0 | 267 | 193 | -144 | 15.5 | 35 |
| 1986 | 121.5 | 37.5 | 58.0 | 46.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.0 | 2.0 | 12.5 | 22.0 | 301.5 | 313.5 | 218 | -119 | 4 | 13 |
| 1987 | 3.0 | 95.0 | 5.0 | 32.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 49.0 | 29.5 | 9.0 | 223.0 | 174 | 104 | -233 | 49 | 30 |
| 1988 | 114.0 | 60.5 | 30.0 | 5.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 42.5 | 90.5 | 342.5 | 297 | 112 | -225 | 0 | 43 |
| 1989 | 13.0 | 43.0 | 10.0 | 40.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 | 5.0 | 115.5 | 239.5 | 63 | -274 | 0 | 4 |
| 1990 | 91.0 | 44.0 | 138.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.5 | 8.0 | 24.5 | 311.0 | 282 | 57 | -280 | 5.5 | 8 |
| 1991 | 129.5 | 104.0 | 102.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 13.5 | 19.0 | 58.0 | 58.5 | 484.5 | 373.5 | 142 | -195 | 32.5 | 58 |
| 1992 | 84.5 | 8.0 | 4.0 | 5.5 | 0.0 | 0.0 | 0.0 | 0.0 | 31.0 | 2.0 | 12.0 | 0.0 | 147.0 | 251 | 105 | -232 | 33 | 12 |
| 1993 | 76.0 | 45.0 | 123.0 | 10.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 17.5 | 6.5 | 66.5 | 344.5 | 299 | 115 | -222 | 17.5 | 7 |
| 1994 | 10.5 | 48.5 | 6.0 | 9.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 17.0 | 8.0 | 100.5 | 165 | -8 | -345 | 1 | 17 |
| 1995 | 0.0 | 298.5 | 109.0 | 28.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 25.5 | 1.0 | 462.0 | 461.5 | 165 | -172 | 0 | 26 |
| 1996 | 73.0 | 24.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 19.0 | 116.0 | 123.5 | -0 | -337 | 0 | 0 |

| STATISTICS | |
|---|---|
| Total | 10094.70 |
| Years | 35 |
| Average | 288.42 |
| DEFICIT /SURPLUS Offset for zero mean | 337.06 |

## HOHENFELS

| YEAR | Monthly rainfall (mm) Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | TOTAL | Seasonal Total | DEFICIT/SURPLUS 1961 → | DEFICIT/SURPLUS Zero Mean | Dry Season Rainfall Jul-Oct | Dry Season Rainfall Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1961 | 82.3 | 61.4 | 112.0 | 69.3 | 15.5 | 0.3 | 0.0 | 0.0 | 0.0 | 1.2 | 32.5 | 11.0 | 385.5 | | | | | |
| 1962 | 41.5 | 60.4 | 14.0 | 31.8 | 0.0 | 0.0 | 0.0 | 27.0 | 0.0 | 43.0 | 13.5 | 4.0 | 235.2 | 192.4 | -241 | -655 | | |
| 1963 | 284.0 | 0.0 | 170.0 | 40.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 174.0 | 49.0 | 717.0 | 581.5 | -93 | -507 | | |
| 1964 | 40.0 | 64.0 | 34.0 | 0.0 | 2.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 30.0 | 31.5 | 202.0 | 363.5 | -164 | -577 | | |
| 1965 | 90.5 | 65.0 | 97.5 | 111.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 48.0 | 12.5 | 424.5 | 425.5 | -172 | -585 | | |
| 1966 | 316.5 | 56.8 | 45.5 | 46.0 | 0.0 | 0.0 | 0.0 | 0.0 | 30.8 | 0.0 | 0.0 | 57.0 | 552.6 | 525.3 | -80 | -494 | | |
| 1967 | 159.0 | 198.0 | 74.0 | 16.0 | 57.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 166.7 | 102.5 | 773.2 | 591.8 | 78 | -336 | | |
| 1968 | 86.0 | 48.0 | 184.7 | 4.9 | 22.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 93.0 | 61.0 | 499.6 | 614.8 | 259 | -154 | | |
| 1969 | 75.0 | 141.0 | 101.5 | 53.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 23.0 | 41.5 | 435.0 | 524.5 | 350 | -64 | | |
| 1970 | 120.0 | 23.0 | 13.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 47.0 | 6.5 | 142.0 | 351.7 | 220.7 | 137 | -277 | | |
| 1971 | 79.5 | 265.0 | 27.0 | 45.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 | 420.5 | 612 | 315 | -98 | | |
| 1972 | 117.0 | 4.0 | 137.0 | 44.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 6.0 | 17.0 | 41.5 | 367.0 | 306.5 | 188 | -226 | | |
| 1973 | 14.0 | 0.0 | 214.0 | 46.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 24.0 | 56.5 | 63.5 | 418.5 | 339 | 93 | -320 | | |
| 1974 | 319.0 | 188.0 | 37.0 | 10.0 | 0.0 | 3.0 | 0.0 | 0.0 | 0.0 | 36.0 | 43.0 | 21.0 | 657.0 | 701 | 361 | -53 | | |
| 1975 | 107.0 | 64.0 | 137.0 | 64.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 12.0 | 59.0 | 23.0 | 466.0 | 472 | 399 | -15 | 12 | 59 |
| 1976 | 233.0 | 204.0 | 110.5 | 33.5 | 0.0 | 7.0 | 0.0 | 0.0 | 0.0 | 6.0 | 31.0 | 35.0 | 660.0 | 682 | 647 | 234 | 6 | 31 |
| 1977 | 147.0 | 200.5 | 59.0 | 62.0 | 9.0 | 0.0 | 0.0 | 0.0 | 0.0 | 83.0 | 11.0 | 74.5 | 646.0 | 549.5 | 763 | 349 | 83 | 11 |
| 1978 | 246.0 | 164.5 | 60.5 | 57.0 | 5.0 | 0.0 | 0.0 | 3.5 | 0.0 | 9.0 | 25.5 | 69.0 | 640.0 | 701.5 | 1031 | 617 | 13 | 26 |
| 1979 | 103.5 | 322.0 | 3.0 | 15.0 | 3.0 | 0.0 | 0.0 | 0.0 | 2.0 | 18.0 | 86.5 | 33.5 | 586.5 | 553.5 | 1151 | 737 | 20 | 87 |
| 1980 | 60.0 | 104.0 | 112.0 | 4.0 | 0.0 | 0.0 | 0.0 | 0.0 | 30.0 | 0.0 | 13.0 | 74.0 | 397.0 | 420 | 1137 | 723 | 30 | 13 |
| 1981 | 53.0 | 68.0 | 18.0 | 4.0 | 0.0 | 0.0 | 0.0 | 6.0 | 0.0 | 0.0 | 16.5 | 0.0 | 165.5 | 260 | 963 | 550 | 6 | 17 |
| 1982 | 66.5 | 140.5 | 62.0 | 32.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.0 | 15.0 | 71.0 | 53.0 | 442.0 | 323.5 | 853 | 440 | 17 | 71 |
| 1983 | 74.5 | 21.5 | 32.0 | 9.0 | 7.5 | 34.0 | 0.0 | 0.0 | 0.0 | 31.0 | 49.0 | 162.5 | 421.0 | 319.5 | 739 | 325 | 31 | 49 |
| 1984 | 48.0 | 60.0 | 77.5 | 137.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 9.5 | 7.0 | 7.0 | 346.5 | 565.5 | 871 | 457 | 10 | 7 |
| 1985 | 160.0 | 109.2 | 25.0 | 18.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.0 | 16.0 | 24.5 | 356.4 | 336.4 | 773 | 360 | 3 | 16 |
| 1986 | 84.5 | 226.0 | 53.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 8.5 | 4.0 | 24.0 | 400.5 | 407.5 | 747 | 334 | 9 | 4 |
| 1987 | 14.0 | 125.0 | 38.0 | 38.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 38.0 | 52.0 | 14.0 | 319.0 | 251.5 | 565 | 151 | 38 | 52 |
| 1988 | 98.0 | 57.0 | 0.0 | 183.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 9.0 | 66.0 | 82.0 | 495.0 | 442 | 573 | 160 | 9 | 66 |
| 1989 | 101.0 | 167.0 | 6.0 | 41.0 | 3.0 | 0.0 | 0.0 | 0.0 | 0.0 | 3.0 | 1.0 | 5.0 | 327.0 | 475 | 615 | 201 | 3 | 1 |
| 1990 | 114.0 | 49.0 | 112.0 | 37.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 | 26.0 | 70.0 | 412.0 | 321 | 502 | 88 | 4 | 26 |
| 1991 | 113.0 | 211.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 12.0 | 23.0 | 55.0 | 106.0 | 520.0 | 424 | 492 | 79 | 35 | 55 |
| 1992 | 34.0 | 3.0 | 64.0 | 3.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 0.0 | 0.0 | 14.0 | 119.0 | 300 | 358 | -55 | 1 | 0 |
| 1993 | 85.0 | 180.0 | 43.0 | 46.0 | 0.0 | 0.0 | 0.0 | 2.0 | 0.0 | 42.0 | 58.0 | 34.0 | 490.0 | 369 | 294 | -120 | 44 | 58 |
| 1994 | 276.0 | 44.0 | 16.0 | 4.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 9.0 | 5.0 | 354.0 | 476 | 336 | -77 | 0 | 9 |
| 1995 | 18.0 | 118.0 | 74.0 | 5.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 | 10.0 | 29.0 | 12.0 | 270.0 | 229 | 131 | -282 | 14 | 29 |
| 1996 | 98.0 | 35.5 | 12.5 | 16.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 | 0.0 | 63.0 | 229.5 | 217.5 | -85 | -498 | 4 | 0 |
| 1997 | 229.0 | 94.0 | 108.5 | 20.0 | 0.0 | 0.0 | 0.0 | 0.0 | 17.0 | 58.0 | 15.0 | 122.0 | 663.5 | 518.5 | 0 | -413 | 75 | 15 |

| STATISTICS | |
|---|---|
| Total | 15612.9 |
| Years | 36 |
| Average | 433.7 |

DEFICIT/SURPLUS
Offset for zero mean
413.45

## ANDARA

| YEAR | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | TOTAL | Seasonal Total | DEFICIT/SURPLUS 1961 ➔ | DEFICIT/SURPLUS Zero Mean | Dry Season Rainfall Jul-Oct | Dry Season Rainfall Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1961 | 71.7 | 97.4 | 171.6 | 47.5 | 9.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 43.9 | 66.5 | 508.1 | | | | | |
| 1962 | 154.2 | 161.7 | 11.3 | 37.2 | 0.0 | 0.0 | 0.0 | 3.0 | 0.0 | 0.0 | 77.3 | 130.1 | 574.8 | 475.0 | -104.0 | -109.0 | | |
| 1963 | 137.6 | 66.0 | 67.3 | 3.5 | 0.0 | 0.0 | 0.0 | 0.0 | 1.1 | 40.0 | 137.6 | 72.0 | 525.1 | 485.0 | -198.0 | -203.0 | | |
| 1964 | 24.0 | 23.5 | 31.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 6.2 | 20.0 | 108.7 | 213.9 | 330.0 | -447.0 | -453.0 | | |
| 1965 | 57.5 | 67.0 | 15.0 | 37.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 9.5 | 34.3 | 46.5 | 267.3 | 312.0 | -714.0 | -720.0 | | |
| 1966 | 160.5 | 257.6 | 175.5 | 25.6 | 0.0 | 6.0 | 0.0 | 0.2 | 16.5 | 0.0 | 29.5 | 63.0 | 734.4 | 716.0 | -578.0 | -583.0 | | |
| 1967 | 193.5 | 89.0 | 99.5 | 61.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 19.0 | 223.0 | 69.0 | 754.3 | 553.0 | -604.0 | -609.0 | | |
| 1968 | 171.5 | 78.5 | 79.0 | 11.5 | 0.0 | 0.0 | 0.0 | 0.0 | 1.5 | 0.0 | 38.0 | 53.5 | 433.5 | 652.0 | -531.0 | -537.0 | | |
| 1969 | 108.5 | 173.5 | 78.5 | 6.1 | 0.0 | 0.0 | 0.0 | 0.0 | 4.0 | 24.0 | 63.0 | 72.0 | 529.6 | 460.0 | -650.0 | -656.0 | | |
| 1970 | 58.5 | 125.5 | 21.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 2.0 | 58.0 | 115.5 | 380.5 | 368.0 | -861.0 | -867.0 | 2 | 58 |
| 1971 | 231.7 | 152.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 12.0 | 98.0 | 78.6 | 572.8 | 560.0 | -880.0 | -886.0 | 12 | 98 |
| 1972 | 294.5 | 54.6 | 365.0 | 14.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 10.0 | 17.5 | 19.9 | 776.1 | 917.0 | -542.0 | -547.0 | 10 | 18 |
| 1973 | 88.0 | 213.5 | 84.5 | 7.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 39.8 | 49.5 | 296.0 | 778.9 | 441.0 | -680.0 | -685.0 | 40 | 50 |
| 1974 | 273.9 | 274.8 | 19.5 | 132.5 | 5.0 | 0.0 | 0.0 | 0.0 | 10.0 | 1.1 | 51.6 | 27.7 | 796.1 | 1091.0 | -168.0 | -173.0 | 11 | 52 |
| 1975 | 147.0 | 141.0 | 188.5 | 11.0 | 7.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 22.0 | 82.7 | 599.2 | 585.0 | -162.0 | -167.0 | 0 | 22 |
| 1976 | 180.0 | 133.0 | 131.0 | 34.5 | 9.0 | 0.0 | 0.0 | 0.0 | 35.0 | 29.0 | 77.5 | 35.9 | 664.9 | 592.0 | -148.0 | -154.0 | 64 | 78 |
| 1977 | 58.3 | 321.0 | 180.2 | 20.5 | 14.0 | 0.0 | 0.0 | 0.0 | 16.5 | 14.0 | 56.3 | 262.5 | 943.3 | 771.0 | 44.0 | 39.0 | 31 | 56 |
| 1978 | 201.5 | 448.5 | 190.9 | 14.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 22.6 | 58.0 | 77.0 | 1012.5 | 1204.0 | 670.0 | 664.0 | 23 | 58 |
| 1979 | 96.5 | 91.2 | 41.5 | 2.5 | 0.0 | 0.0 | 0.0 | 5.0 | 3.0 | 3.0 | 116.5 | 65.5 | 424.7 | 389.0 | 480.0 | 475.0 | 11 | 117 |
| 1980 | 75.0 | 150.5 | 51.6 | 15.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 14.0 | 247.6 | 77.0 | 630.7 | 485.0 | 386.0 | 381.0 | 14 | 248 |
| 1981 | 112.5 | 306.5 | 154.5 | 0.0 | 0.0 | 2.0 | 0.0 | 0.0 | 0.0 | 0.0 | 121.3 | 23.0 | 719.8 | 914.0 | 722.0 | 716.0 | 0 | 121 |
| 1982 | 57.4 | 134.9 | 109.8 | 69.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.5 | 4.5 | 7.5 | 388.3 | 516.0 | 659.0 | 653.0 | 5 | 5 |
| 1983 | — | — | — | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 39.7 | 17.8 | 160.3 | — | 579.0 | 659.0 | 654.0 | 40 | 18 |
| 1984 | 21.8 | 118.3 | 151.2 | 31.5 | 0.0 | 0.0 | 0.0 | 1.0 | 4.9 | 82.5 | 21.4 | 44.2 | 476.8 | 541.0 | 621.0 | 615.0 | 88 | 21 |
| 1985 | 197.6 | 181.0 | 30.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 23.3 | 1.5 | 151.3 | 585.4 | 563.0 | 605.0 | 600.0 | 23 | 2 |
| 1986 | 94.5 | 112.6 | 112.3 | 38.4 | 0.0 | 0.0 | 0.0 | 0.0 | 17.6 | 0.0 | 103.7 | 88.8 | 567.9 | 534.0 | 560.0 | 555.0 | 18 | 104 |
| 1987 | 61.6 | 141.0 | 35.4 | 0.0 | 21.4 | 0.0 | 0.0 | 0.0 | 9.0 | 29.9 | 31.1 | 128.4 | 457.8 | 470.0 | 451.0 | 446.0 | 39 | 31 |
| 1988 | 50.2 | 143.7 | 72.6 | 90.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 4.4 | 66.4 | 148.0 | 576.3 | 556.0 | 428.0 | 422.0 | 5 | 66 |
| 1989 | — | — | — | — | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.7 | 51.4 | 25.6 | — | 579.0 | 428.0 | 423.0 | 5 | 51 |
| 1990 | 113.5 | 128.6 | 67.2 | 66.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 8.0 | 19.7 | 127.6 | 530.7 | 457.0 | 306.0 | 301.0 | 8 | 20 |
| 1991 | 100.2 | 107.3 | 76.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 58.5 | 64.8 | 244.7 | 651.8 | 439.0 | 167.0 | 161.0 | 59 | 65 |
| 1992 | 84.7 | 76.7 | 66.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 17.5 | 36.1 | 281.4 | 596.0 | 184.0 | 178.0 | 0 | 18 |
| 1993 | 249.5 | 101.0 | 35.5 | 38.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 8.5 | 67.3 | 500.8 | 478.0 | 82.0 | 77.0 | 1 | 9 |
| 1994 | 263.5 | 131.6 | 20.0 | 4.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 10.0 | 36.0 | 60.5 | 526.1 | 496.0 | 0.0 | -6.0 | 10 | 36 |
| 1995 | 3.5 | 54.0 | 41.0 | 41.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | — | — | — | — | 579.0 | 0.0 | -5.0 | 0 | |

Monthly rainfall (mm)

Mean rainfall used where data is missing

| STATISTICS | |
|---|---|
| Total | 19680.7 |
| Years | 34 |
| Average | 578.8 |

DEFICIT /SURPLUS
Offset for zero mean
5.41

## KATIMA MULILO

| YEAR | Jan | Feb | Mar | Apr | May | June | July | Aug | Sept | Oct | Nov | Dec | TOTAL | Seasonal Total | DEFICIT/SURPLUS 1960 → | DEFICIT/SURPLUS Zero Mean | Dry Season Rainfall Jul-Oct | Dry Season Rainfall Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Monthly rainfall (mm) | | | | | | | | | | | | | | | | | |
| 1960 | 89.4 | 178.3 | 121.3 | 24.8 | 10.0 | 0.0 | 0.0 | 0.0 | 2.0 | 4.0 | 125.5 | 41.8 | 597.1 | | | | | |
| 1961 | 154.3 | 58.9 | 235.5 | 41.8 | 2.5 | 0.0 | 0.0 | 0.0 | 0.0 | 8.8 | 72.4 | 68.8 | 643.0 | 666 | 39 | -284 | | |
| 1962 | 242.4 | 104.7 | 15.4 | 28.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.4 | 93.0 | 286.7 | 772.3 | 541 | -48 | -371 | | |
| 1963 | 195.8 | 223.2 | 44.7 | 0.0 | 0.0 | 7.5 | 0.0 | 0.0 | 0.0 | 58.4 | 86.7 | 197.3 | 813.6 | 852 | 177 | -146 | | |
| 1964 | 87.2 | 54.4 | 1.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 7.5 | 18.7 | 42.5 | 51.2 | 263.0 | 486 | 35 | -289 | | |
| 1965 | 75.6 | 50.5 | 9.2 | 14.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.7 | 73.2 | 72.5 | 296.1 | 269 | -324 | -647 | | |
| 1966 | 68.5 | 185.4 | 140.0 | 16.5 | 0.0 | 5.4 | 0.0 | 6.0 | 0.0 | 12.0 | 34.5 | 156.9 | 625.2 | 563 | -389 | -712 | | |
| 1967 | 239.6 | 79.0 | 68.0 | 10.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 124.3 | 109.9 | 156.9 | 788.2 | 607 | -410 | -733 | | |
| 1968 | 239.8 | 86.8 | 50.8 | 50.2 | 0.7 | 0.0 | 0.0 | 0.0 | 1.8 | 14.5 | 38.8 | 95.2 | 578.6 | 819 | -219 | -542 | | |
| 1969 | 91.1 | 142.8 | 195.5 | 1.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 26.2 | 82.2 | 168.8 | 708.1 | 581 | -265 | -588 | | |
| 1970 | 120.1 | 54.5 | 14.0 | 6.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.5 | 5.4 | 123.9 | 136.6 | 461.6 | 472 | -420 | -743 | 6 | 124 |
| 1971 | 268.7 | 54.4 | 13.0 | 3.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 8.8 | 98.0 | 125.5 | 571.9 | 606 | -442 | -765 | 9 | 98 |
| 1972 | 411.3 | 77.3 | 226.4 | 57.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 9.2 | 27.4 | 80.0 | 889.1 | 1005 | -65 | -388 | 9 | 27 |
| 1973 | 64.9 | 166.2 | 40.1 | 7.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 55.0 | 41.7 | 236.3 | 612.1 | 396 | -297 | -620 | 55 | 42 |
| 1974 | 206.1 | 465.6 | 101.7 | 13.2 | 0.0 | 0.0 | 0.0 | 0.0 | 7.5 | 28.0 | 120.0 | 319.0 | 1261.1 | 1120 | 195 | -128 | 36 | 120 |
| 1975 | 99.2 | 90.7 | 135.7 | 16.5 | 8.9 | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 | 17.8 | 92.4 | 461.6 | 826 | 393 | 70 | 0 | 18 |
| 1976 | 191.0 | 62.9 | 122.2 | 15.9 | 7.0 | 0.0 | 0.0 | 0.0 | 27.1 | 21.5 | 150.0 | 151.4 | 749.0 | 510 | 275 | -48 | 49 | 150 |
| 1977 | 97.7 | 379.0 | 236.4 | 38.8 | 0.6 | 0.0 | 0.0 | 0.4 | 6.1 | 0.0 | 68.5 | 302.2 | 1129.7 | 1103 | 749 | 426 | 7 | 69 |
| 1978 | 231.7 | 418.3 | 111.7 | 59.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 68.5 | 72.2 | 75.6 | 1037.7 | 1199 | 1320 | 997 | 69 | 72 |
| 1979 | 135.8 | 145.9 | 44.5 | 10.2 | 5.0 | 0.0 | 0.0 | 2.7 | 0.0 | 19.3 | 72.6 | 54.8 | 490.8 | 558 | 1250 | 927 | 22 | 73 |
| 1980 | 99.6 | 159.7 | 164.0 | 12.4 | 0.0 | 0.0 | 0.0 | 0.8 | 9.1 | 14.0 | 84.8 | 92.4 | 636.8 | 585 | 1208 | 885 | 24 | 85 |
| 1981 | 227.9 | 189.7 | 66.7 | 11.7 | 0.0 | 3.7 | 0.0 | 0.0 | 4.3 | 32.4 | 75.6 | 140.4 | 752.4 | 701 | 1281 | 958 | 37 | 76 |
| 1982 | 94.9 | 131.8 | 5.2 | 34.6 | 1.1 | 0.0 | 0.0 | 0.0 | 0.0 | 39.4 | 47.2 | 43.5 | 397.7 | 520 | 1174 | 850 | 39 | 47 |
| 1983 | 122.2 | 51.5 | 35.1 | 56.4 | 5.1 | 0.0 | 0.0 | 0.0 | 0.0 | 25.6 | 76.6 | 150.3 | 522.8 | 400 | 946 | 623 | 26 | 77 |
| 1984 | 77.4 | 93.0 | 134.9 | 8.0 | 0.8 | 0.0 | 0.4 | 0.1 | 7.2 | 10.5 | 90.2 | 51.3 | 473.8 | 567 | 885 | 562 | 18 | 90 |
| 1985 | 167.8 | 72.3 | 62.5 | 12.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 43.5 | 66.1 | 197.1 | 621.6 | 475 | 732 | 409 | 44 | 66 |
| 1986 | 216.0 | 63.8 | 106.6 | 17.3 | 0.0 | 0.0 | 0.0 | 0.0 | 2.1 | 52.2 | 82.1 | 91.9 | 632.0 | 710 | 815 | 492 | 54 | 82 |
| 1987 | 30.0 | 112.8 | 37.0 | 3.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 51.7 | 198.8 | 433.7 | 412 | 599 | 275 | 0 | 52 |
| 1988 | 30.8 | 221.7 | 60.9 | 16.5 | 0.0 | 0.0 | 0.0 | 0.0 | 18.7 | 23.9 | 36.2 | 184.3 | 593.0 | 580 | 551 | 228 | 43 | 36 |
| 1989 | 249.6 | 151.9 | 43.2 | 2.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 56.0 | 21.5 | 98.6 | 623.4 | 710 | 634 | 311 | 56 | 22 |
| 1990 | 193.2 | 43.9 | 46.0 | 52.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 13.0 | 17.5 | 72.7 | 439.1 | 512 | 518 | 195 | 13 | 18 |
| 1991 | 72.9 | 157.4 | 141.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 6.0 | 86.6 | 281.1 | 745.6 | 475 | 366 | 43 | 6 | 87 |
| 1992 | 36.6 | 3.3 | 108.2 | 2.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 44.9 | 49.8 | 135.4 | 380.8 | 524 | 262 | -61 | 45 | 50 |
| 1993 | 158.7 | 165.6 | 31.2 | 36.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.7 | 0.5 | 148.6 | 70.1 | 612.4 | 622 | 256 | -67 | 2 | 149 |
| 1994 | 101.8 | 125.2 | 25.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.4 | 34.5 | 154.5 | 447.0 | 474 | 102 | -221 | 5 | 35 |
| 1995 | 146.0 | 175.4 | 61.7 | 7.8 | 12.1 | 0.0 | 0.0 | 0.0 | 0.0 | 9.4 | 60.5 | 187.9 | 660.8 | 597 | 72 | -251 | 9 | 61 |
| 1996 | 139.4 | 117.4 | 41.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 109.1 | 95.2 | 503.0 | 557 | 1 | -323 | 0 | 109 |
| 1997 | 173.5 | 147.6 | 99.9 | 1.8 | 0.0 | 0.0 | 0.0 | 0.0 | 11.8 | 56.1 | 27.8 | 91.5 | 610.0 | 627 | -0 | -323 | 68 | 28 |

| STATISTICS | |
|---|---|
| Total | 23224.7 |
| Years | 37 |
| Average | 627.7 |
| DEFICIT /SURPLUS Offset for zero mean | 323.1 |

## Financial Analysis of Sport Hunting Potential for Roan, Sable and Tsessebe

This Appendix consists of seven tables all of which are linked as spreadsheets. The analysis of sport hunting potential is carried out as follows –

In **Table A** a hypothetical wildlife population which might be typical of an area of 1,000km$^2$ the Caprivi is set up in two stages. Firstly, the various species are assigned nominal densities which are used to calculate the total metabolic biomass in Livestock Unit equivalents (LSUs). The densities of the grazers are then adjusted by a multiplier to make the overall stocking rate exactly equal to 10ha/LSU – which has arbitrarily been chosen as the carrying capacity for such an area. In this first table there are no roan, sable or tsessebe.

In **Table B**, roan, sable and tsessebe are included at densities which they might achieve in an area of suitable habitat with average annual rainfall above 500mm. In order to preserve the carrying capacity of 10ha/LSU, the densities of the other grazing species are reduced to accommodate the newcomers (again by using a simple multiplying factor).

Hunting quotas for the two scenarios are calculated and transferred to **Table C** where the species are organised into groups based on the value of the trophy fees.

In **Tables D and E** the quotas for the two scenarios (with and without roan, sable and tsessebe) are automatically packaged into a set of hunts and the total number of hunter-days which this generates is calculated together with the gross income from daily rates and trophy fees.

In **Table F** the operating costs for a single safari operator hunting an area of 250km$^2$ are calculated. The reason that an area of 250km$^2$ has been chosen is that the number of hunter days generated in Table E are sufficiently large to justify 4 separate safari operators in an area of 1,000km$^2$.

**Table G** is the cost and land use summary. It is assumed that roan, sable and tsessebe numbers on which the calculation is based could be achieved over a core area in the Caprivi of about 4,000km$^2$. The quota generated by the scenario without roan sable and tsessebe is dominated by 'low-value' species which cannot easily be packaged into hunts which would attract international clients and, to maximise the use of the quota, most of the animals would have to be taken by 'biltong hunters' within the southern African region. The number of international hunting client days is sufficient to warrant only one safari operator in 1,000km$^2$ and it is assumed in the final table that the operating costs for a single safari operator in the larger area would remain much the same as those calculated for an operator in 250km$^2$ (mileage costs would increase but the remainder of the costs are linked more to the number of hunter days).

In the scenario which includes roan, sable and tsessebe, the number of international hunting client days increases to over 700 which would justify the allocation of four separate hunting concessions in 1,000km$^2$. This causes the overall operating costs to increase and, despite the fact that the gross income per hectare doubles when roan, sable and tsessebe are part of the hunting quota, the net income is only increased by about 20% over the scenario without these key species.

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## Financial Analysis of Sport Hunting Potential for Roan, Sable and Tsessebe

**Table A: Optimal stocking rates and hunting quotas for an area of 1,000km² in the Caprivi assuming no roan, sable and tsessebe present**

| *Factor 1.99071* Species | Density /km² | Initial population | Model population | Unit LSU | Total LSUs | QUOTA % | QUOTA N |
|---|---|---|---|---|---|---|---|
| Buffalo | 0.25 | 250 | 250 | 1.00 | 250.0 | 2.5 | 6 |
| Bushbuck | 0.05 | 50 | 100 | 0.12 | 11.9 | 3 | 3 |
| Duiker | 1.00 | 1,000 | 1,991 | 0.08 | 159.3 | 3 | 60 |
| Eland | 0.25 | 250 | 498 | 1.00 | 497.7 | 2 | 10 |
| Elephant | 1.00 | 1,000 | 1,000 | 3.33 | 3330.0 | 0.5 | 5 |
| Giraffe | 0.05 | 50 | 50 | 1.34 | 67.0 | 5 | 3 |
| Impala | 10.00 | 10,000 | 19,907 | 0.14 | 2787.0 | 3 | 597 |
| Kudu | 3.00 | 3,000 | 3,000 | 0.40 | 1200.0 | 2 | 60 |
| Leopard | 0.05 | 50 | 50 | – | 0.0 | 6 | 3 |
| Lion | 0.03 | 30 | 30 | – | 0.0 | 6 | 2 |
| Reedbuck | 0.10 | 100 | 199 | 0.14 | 27.9 | 3 | 6 |
| Steenbok | 2.00 | 2,000 | 3,981 | 0.10 | 398.1 | 3 | 119 |
| Waterbuck | 0.25 | 250 | 498 | 0.45 | 224.0 | 2 | 10 |
| Warthog | 2.00 | 2,000 | 3,981 | 0.18 | 716.7 | 3 | 119 |
| Wildebeest (Blue) | 0.10 | 100 | 199 | 0.40 | 79.6 | 3 | 6 |
| Zebra (Burchell's) | 0.20 | 200 | 398 | 0.63 | 250.8 | 5 | 20 |
| | | | | TOTAL LSUs | 10000.0 | | 1029 |
| | | | | Ha/LSU | 10.0 | | |

NOTES

1. The aim of this table is to create a 'model population' of large mammal species which would be typical for a well-stocked savanna system in an area of 1,000km² where rainfall is 500-600mm per annum and the habitats are suitable for roan, sable and tsessebe (although these species are not included in this first table). On this basis, lechwe, sitatunga and hippo have been excluded. The population is that which might be expected in the central area of the Caprivi around the Kwando River and relates to the 'core' wildlife range.
2. The assigned densities are based on crude potential for the Caprivi and experience from similar savannas.
3. Unit livestock biomass values are the same as those used by Barnes and de Jager (1995)
4. The rows which have been shaded are those species likely to be affected by any inter-specific competition with roan, sable and tsessebe.
5. The 'Model Population' is obtained by multiplying the initial population numbers in the shaded rows upwards by the factor in the top left hand corner of the table which has been selected so that the total stocking density is 1LSU/10ha.
6. The quota percentages are typical for safari hunting in southern Africa being adjusted upwards when trophy quality is less critical (e.g Zebra - 5%) and downwards where high trophy quality is important (e.g. elephant 0.5%).

**The numbers of the grazing species have to be more or less double those assumed at the start of this exercise in order to achieve an overall stocking density of 1LSU/10ha.**

**Table B: Optimal stocking rates and hunting quotas for an area of 1,000km² in the Caprivi assuming roan, sable and tsessebe are present**

| *Factor 1.327* Species | Density /km² | Initial population | Model population | Unit LSU | Total LSUs | QUOTA % | QUOTA N |
|---|---|---|---|---|---|---|---|
| Buffalo | 0.25 | 250 | 250 | 1.00 | 250.0 | 2.5 | 6 |
| Bushbuck | 0.05 | 50 | 50 | 0.12 | 6.0 | 3 | 2 |
| Duiker | 1.00 | 1,000 | 1,327 | 0.08 | 106.2 | 3 | 40 |
| Eland | 0.25 | 250 | 332 | 1.00 | 331.8 | 2 | 7 |
| Elephant | 1.00 | 1,000 | 1,000 | 3.33 | 3330.0 | 0.5 | 5 |
| Giraffe | 0.05 | 50 | 50 | 1.34 | 67.0 | 5 | 3 |
| Impala | 10.00 | 10,000 | 13,270 | 0.14 | 1857.8 | 3 | 398 |
| Kudu | 3.00 | 3,000 | 3,000 | 0.40 | 1200.0 | 2 | 60 |
| Leopard | 0.05 | 50 | 50 | – | 0.0 | 6 | 3 |
| Lion | 0.03 | 30 | 30 | – | 0.0 | 6 | 2 |
| Reedbuck | 0.10 | 100 | 133 | 0.14 | 18.6 | 3 | 4 |
| **ROAN** | 1.00 | 1,000 | 1,000 | 0.65 | 650.0 | 2 | 20 |
| **SABLE** | 2.00 | 2,000 | 2,000 | 0.40 | 800.0 | 2 | 40 |
| **TSESSEBE** | 1.00 | 1,000 | 1,000 | 0.27 | 270.0 | 2 | 20 |
| Steenbok | 2.00 | 2,000 | 2,654 | 0.10 | 265.4 | 3 | 80 |
| Waterbuck | 0.25 | 250 | 332 | 0.45 | 149.3 | 2 | 7 |
| Warthog | 2.00 | 2,000 | 2,654 | 0.18 | 477.7 | 3 | 80 |
| Wildebeest (Blue) | 0.10 | 100 | 133 | 0.40 | 53.1 | 3 | 4 |
| Zebra (Burchell's) | 0.20 | 200 | 265 | 0.63 | 167.2 | 5 | 13 |
| | | | | TOTAL LSUs | 10000.0 | | 794 |
| | | | | Ha/LSU | 10.0 | | |

NOTES

1. In this table the 'model population' includes roan, sable and tsessebe populations and the numbers of other grazing animals have been reduced to allow for the new populations.
2. The assigned densities for roan, sable and tsessebe are based on crude potential for the Caprivi and experience from similar savannas.
3. The 'Model Population' is obtained by multiplying the initial population numbers in the shaded rows by the factor in the top left hand corner of the table which has been selected so that the total stocking density is 1LSU/10ha. The roan, sable and tsessebe numbers are assumed constant.
4. The quota percentages for roan, sable and tsessebe are based on the findings of the population model (Appendix 1) and for the other species they remain the same as those in Table A.

**In order to accommodate the roan, sable and tsessebe populations at the assumed densities, the numbers of other grazers given in Table A are reduced by about one-third in order to maintain a stocking level of 1 LSU/10ha.**

### Table C: Trophy fees and quota value

| | | SCENARIO A | | | SCENARIO B | | |
|---|---|---|---|---|---|---|---|
| **Species** | **Trophy Fee** | **N** | **Quota value** | **#** | **N** | **Quota value** | **#** |
| ***Premier Species*** | | | | | | | |
| ELEPHANT | 7,500 | 5 | 37,500 | ***5*** | 5 | 37,500 | ***5*** |
| BUFFALO | 5,000 | 6 | 30,000 | ***6*** | 6 | 30,000 | ***6*** |
| LION | 4,000 | 2 | 8,000 | ***2*** | 2 | 8,000 | ***2*** |
| LEOPARD | 3,000 | 3 | 9,000 | ***3*** | 3 | 9,000 | ***3*** |
| ***Plains Game - A*** | | | | ***0*** | | | ***60*** |
| Roan | 2,000 | – | 0 | | 20 | 40,000 | |
| Sable | 2,000 | – | 0 | | 40 | 80,000 | |
| ***Plains Game - B*** | | | | ***23*** | | | ***37*** |
| Eland | 1,500 | 10 | 15,000 | | 7 | 10,500 | |
| Giraffe | 1,500 | 3 | 4,500 | | 3 | 4,500 | |
| Tsessebe | 1,500 | – | 0 | | 20 | 30,000 | |
| Waterbuck | 1,500 | 10 | 15,000 | | 7 | 10,500 | |
| ***Plains Game - C*** | | | | ***95*** | | | ***83*** |
| Bushbuck | 750 | 3 | 2,250 | | 2 | 1,500 | |
| Kudu | 750 | 60 | 45,000 | | 60 | 45,000 | |
| Reedbuck | 750 | 6 | 4,500 | | 4 | 3,000 | |
| Wildebeest (Blue) | 750 | 6 | 4,500 | | 4 | 3,000 | |
| Zebra (Burchell's) | 750 | 20 | 15,000 | | 13 | 9,750 | |
| ***Plains Game - D*** | | | | ***895*** | | | ***598*** |
| Impala | 375 | 597 | 223,875 | | 398 | 149,250 | |
| Duiker | 375 | 60 | 22,500 | | 40 | 15,000 | |
| Steenbok | 375 | 119 | 44,625 | | 80 | 30,000 | |
| Warthog | 375 | 119 | 44,625 | | 80 | 30,000 | |
| **TOTAL TROPHY FEE VALUE US$** | | | **525,875** | | | **546,500** | |

NOTES

1. Trophy fee values are based on Himavundu (2001) but have been adjusted in some cases to be more closely aligned with the regional averages.
2. Roan, sable and tsessebe are absent from **Scenario A** and included in **Scenario B**. The quotas for the two scenarios are taken from **Table A** and **Table B** respectively.
3. For simplicity in packaging the hunts (see following tables), the trophy fees have been averaged and rounded over groups of animals.

**The total 'book' value of the quotas from the two scenarios is not greatly different. However, because the majority of hunts under Scenario A ending up being sold as 'biltong hunts' at half of the international trophy fee, the full value of the trophies under Scenario A is not realised.**

## HUNT PACKAGING

### Table D: Packaging of Hunts with Roan, Sable and Tsessebe not available

| | Elephant | Buffalo | Lion | Leopard | Plains Game A | B | C | D |
|---|---|---|---|---|---|---|---|---|
| Overall Quota | 5 | 6 | 2 | 3 | 0 | 23 | 95 | 895 |
| Trophy fee | 7,500 | 5,000 | 4,000 | 3,000 | 2,000 | 1,500 | 750 | 375 |
| **Hunt composition** | | | | | | | | |
| Big Game Safari | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 6 |
| Elephant hunt | 1 | | | | | 2 | 3 | 6 |
| Buffalo hunt | | 1 | | | | 2 | 3 | 6 |
| Cat Hunt | | | – 1 – | | | 2 | 3 | 6 |
| Premier Plains Game | | | | | 1 | 1 | 2 | 5 |
| Plains Game | | | | | | 1 | 2 | 5 |
| Biltong hunt | | | | | | | – 10 – | |
| Quota remaining after – | | | | | | | | |
| Big Game Safaris | 3 | 4 | 0 | 1 | 0 | 17 | 89 | 883 |
| Elephant hunts | 0 | 4 | 0 | 1 | 0 | 11 | 80 | 865 |
| Buffalo hunts | 0 | 0 | 0 | 1 | 0 | 3 | 68 | 841 |
| Cat hunts | | | 0 | 1 | 0 | 1 | 65 | 835 |
| Premier Plains Game hunts | | | | 0 | 0 | 1 | 65 | 835 |
| Plains Game hunts | | | | | | 0 | 63 | 830 |
| Biltong hunts | | | | | | | 0 | 0 |

| | Big Game Safaris | Elephant Hunts | Buffalo Hunts | Cat Hunts | Premier Plains Game | Plains Game Hunts | Biltong Hunts | TOTALS |
|---|---|---|---|---|---|---|---|---|
| Number of hunts | 2 | 3 | 4 | 1 | 0 | 1 | 89 | 100 |
| Elephant | 2 | 3 | | | | | | 5 |
| Buffalo | 2 | | 4 | | | | | 6 |
| Lion | 2 | | | 0 | | | | 2 |
| Leopard | 2 | | | 1 | | | | 3 |
| Plains Game species - A | 0 | | | | 0 | | | 0 |
| Plains Game species - B | 6 | 6 | 8 | 2 | 0 | 1 | | 23 |
| Plains Game species - C | 6 | 9 | 12 | 3 | 0 | 2 | 63 | 95 |
| Plains Game species - D | 12 | 18 | 24 | 6 | 0 | 5 | 830 | 895 |
| Safari days | 21 | 16 | 14 | 12 | 10 | 8 | 6 | |
| Total Hunter days | 42 | 48 | 56 | 12 | 0 | 8 | 534 | 700 |
| Daily rates | 1,500 | 1,250 | 1,000 | 750 | 500 | 250 | 100 | |
| Gross income daily rates | 63,000 | 60,000 | 56,000 | 9,000 | 0 | 2,000 | 53,400 | 243,400 |
| Trophy fees | 57,000 | 45,000 | 50,000 | 10,500 | 0 | 4,875 | 179,250 | 346,625 |
| GROSS INCOME | 120,000 | 105,000 | 106,000 | 19,500 | 0 | 6,875 | 232,650 | 590,025 |
| | | | | | | **Gross income/hectare** | | **5.90** |

## HUNT PACKAGING

### Table E: Packaging of Hunts with Roan, Sable and Tsessebe available

| | | | | | Plains Game | | | |
|---|---|---|---|---|---|---|---|---|
| | Elephant | Buffalo | Lion | Leopard | A | B | C | D |
| Overall Quota | 5 | 6 | 2 | 3 | 60 | 37 | 83 | 598 |
| Trophy fee | 7,500 | 5,000 | 4,000 | 3,000 | 2,000 | 1,500 | 750 | 375 |
| **Hunt composition** | | | | | | | | |
| Big Game Safari | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 6 |
| Elephant hunt | 1 | | | | | 2 | 3 | 6 |
| Buffalo hunt | | 1 | | | | 2 | 3 | 6 |
| Cat Hunt | | | – 1 – | | | 2 | 3 | 6 |
| Premier Plains Game | | | | | 1 | 1 | 2 | 5 |
| Plains Game | | | | | | 1 | 2 | 5 |
| Biltong hunt | | | | | | | – 10 – | |
| Quota remaining after – | | | | | | | | |
| Big Game Safaris | 3 | 4 | 0 | 1 | 58 | 33 | 77 | 586 |
| Elephant hunts | 0 | 4 | 0 | 1 | 58 | 27 | 68 | 568 |
| Buffalo hunts | 0 | 0 | 0 | 1 | 58 | 19 | 56 | 544 |
| Cat hunts | | | 0 | 1 | 58 | 17 | 53 | 538 |
| Premier Plains Game hunts | | | | 0 | 0 | 0 | 0 | 144 |
| Plains Game hunts | | | | | | 0 | 0 | 144 |
| Biltong hunts | | | | | | | 0 | 0 |

| | Big Game Safaris | Elephant Hunts | Buffalo Hunts | Cat Hunts | Premier Plains Game | Plains Game Hunts | Biltong Hunts | TOTALS |
|---|---|---|---|---|---|---|---|---|
| Number of hunts | 2 | 3 | 4 | 1 | 58 | 0 | 14 | 82 |
| Elephant | 2 | 3 | | | | | | 5 |
| Buffalo | 2 | | 4 | | | | | 6 |
| Lion | 2 | | | 0 | | | | 2 |
| Leopard | 2 | | | 1 | | | | 3 |
| Plains Game species - A | 2 | | | | 58 | | | 60 |
| Plains Game species - B | 4 | 6 | 8 | 2 | 17 | 0 | | 37 |
| Plains Game species - C | 6 | 9 | 12 | 3 | 53 | 0 | 0 | 83 |
| Plains Game species - D | 12 | 18 | 24 | 6 | 394 | 0 | 144 | 598 |
| Safari days | 21 | 16 | 14 | 12 | 10 | 8 | 6 | |
| Total Hunter days | 42 | 48 | 56 | 12 | 580 | 0 | 84 | 822 |
| Daily rates | 1,500 | 1,250 | 1,000 | 750 | 500 | 250 | 100 | |
| Gross income daily rates | 63,000 | 60,000 | 56,000 | 9,000 | 290,000 | 0 | 8,400 | 486,400 |
| Trophy fees | 58,000 | 45,000 | 50,000 | 10,500 | 329,000 | 0 | 27,000 | 519,500 |
| GROSS INCOME | 121,000 | 105,000 | 106,000 | 19,500 | 619,000 | 0 | 35,400 | 1,005,900 |
| | | | | | | **Gross income/hectare** | | **10.06** |

Tables D and E are fully automated and will package any given hunting quota provided the first assumption below is met. The overall quotas from Table C are automatically transferred to the first row of Tables D and E and the hunt packaging follows from these quotas. The composition of each of the types of hunt (e.g. Big Game Safari, Elephant hunt etc) can be adjusted by entering the number of animals in each species category which will be taken on the particular type of hunt and the hunt packaging process will take this into account.

**ASSUMPTIONS** for **Table D** and **Table E**

1. There are more Category D animals than will be needed to complement the main hunts and the balance of these animals will end up in biltong hunts.
2. A Big Game Safari is a 21 day hunt at a daily rate of US$1,500/day. It includes an elephant, 1 buffalo, both large cats, 1 Category A, 2 Category B, 3 Category C and 6 Category D Plains Game species (which includes an allowance for baits for the cats). If there are insufficient Category A or Category B Plains Game animals, the deficit is made up with Category B and Category C Plains Game animals.
3. An Elephant Hunt is an 16 day safari at a daily rate of US$1,250 day. It includes an elephant, 2 Category B, 3 Category C and 6 Category D Plains Game species. If there are insufficient Category B Plains Game animals, the deficit is made up with Category C Plains Game animals.
4. A Buffalo Hunt is a 14 day safari at a daily rate of US$1,000 day. It includes a buffalo, 2 Category B, 3 Category C and 6 Category D Plains Game species.
5. A Cat hunt is a 12 day safari at a daily rate of US$750/day. It includes a lion or a leopard, 2 Category B, 3 Category C and 6 Category D Plains Game species (which includes an allowance for baits for the cat). If there are insufficient Category B animals to make up the quota, Category C animals are used.
6. A Premier Plains Game safari is a 10 day hunt at US$500/day which includes 1 Category A, 1 Category B, 2 Category C and 5 Category D Plains Game species. If the needed number of Category B species are not available, then they are substituted with Category C species. If the needed number of Category C species are not available, then they are substituted with Category D species.
7. A Plains Game safari is a 8 day hunt at US$250/day which includes 1 Category B, 2 Category C and 5 Category D Plains Game species.
8. The remaining animals are sold on 6 day Biltong Hunts at US$100/day. The typical number of animals expected to be taken on a Biltong Hunt is 10 and the trophy fees are halved.
9. All hunts are assumed to be carried out by a single client.
10. All financial amounts are in United States dollars.

**Table F: Calculation of Operating Costs** for 250 km$^2$ *All figures are in United States dollars*

**CAPITAL** (Capital costs are depreciated over 5 years and added to operating costs)

| # | ITEM | Quantity | Unit Cost US$ | Amounts | Totals |
|---|---|---|---|---|---|
| 1 | **Vehicles** | | | | |
| 2 | 4x4 | 5 | 20,000 | 100,000 | |
| 3 | Fuel Storage | 1 | 250 | 250 | |
| 4 | Tools | 1 | 500 | 500 | |
| 5 | Vehicle Spares | 1 | 1,000 | 1,000 | 101,750 |
| 6 | **Accommodation** | | | | |
| 7 | Clients | 3 | 1,000 | 3,000 | |
| 8 | Staff - senior | 4 | 500 | 2,000 | |
| 9 | Staff - junior | 17 | 200 | 3,400 | |
| 10 | Bathrooms | 6 | 200 | 1,200 | |
| 11 | Kitchen | 1 | 500 | 500 | |
| 12 | Dining Room | 1 | 300 | 300 | 10,400 |
| 13 | **Equipment** | | | | |
| 14 | Refrigerators | 2 | 300 | 600 | |
| 15 | Deep Freeze | 1 | 300 | 300 | |
| 16 | Furniture | 1 | 300 | 300 | |
| 17 | Pots, pans, cutlery, crockery | 1 | 500 | 500 | |
| 18 | Lighting | 1 | 1,500 | 1,500 | 3,200 |
| 19 | Water supply | 1 | 1,500 | 1,500 | 1,500 |
| 20 | | | | TOTAL | 116,850 |
| 21 | **CAPITAL: Amount to be recovered annually** | | | | **23,370** |
| 22 | **OPERATING COSTS** | | | | |
| 23 | **Staff salaries** (costs are for 6 month hunting season) | | | | |
| 24 | Professional Hunter US$/day | 180 | 200 | 36,000 | |
| 25 | Learner Hunter | 1 | 4,000 | 4,000 | |
| 26 | Camp Manager | 1 | 3,000 | 3,000 | |
| 27 | Cooks | 2 | 1,000 | 2,000 | |
| 28 | Waiters | 2 | 500 | 1,000 | |
| 29 | Scouts | 5 | 300 | 1,500 | |
| 30 | Skinners | 2 | 400 | 800 | |
| 31 | Trackers | 2 | 400 | 800 | |
| 32 | Driver | 1 | 500 | 500 | |
| 33 | PR/Community relations | 1 | 2,000 | 2,000 | |
| 34 | General workers | 3 | 200 | 600 | 52,200 |
| 35 | **Vehicles** | | | | |
| 36 | Fuel (litres) | 10000 | 1 | 10,000 | |
| 37 | Lubricants (litres) | 100 | 5 | 500 | 10,500 |
| 38 | **Camp** | | | | |
| 39 | Annual refurbishment | 1 | 5,000 | 5,000 | |
| 40 | Gas (kg) | 200 | 5 | 1,000 | |
| 41 | Miscellaneous | 1 | 1,000 | 1,000 | 7,000 |
| 42 | **Food and drink** | | | | |
| 43 | Clients (2) US$/day | 180 | 50 | 9,000 | |
| 44 | Senior staff (4) | 180 | 20 | 3,600 | |
| 45 | Junior Staff (17) | 180 | 20 | 3,600 | 16,200 |
| | **Total annual operating costs** for 250km$^2$, including capital replacement | | | | **109,270** |
| | **Annual operating costs/ha** | | | | **4.37** |

**NOTES on Table F** (row number references)

The scenario with roan, sable and tsessebe present (**Table E**) results in a total of 822 hunter days of which 738 entail international safaris and the remainder (84) are biltong hunts . This would justify 4 separate operators in an area of 1,000$km^2$ each with approximately 180 days of hunting (ignoring the biltong hunts.

Without roan, sable and tsessebe, there are only 166 international safari hunter days which would only justify one safari operator. The remaining hunt days (534) are all in the biltong hunt category. This theoretically reduces the operating costs per hectare by a factor of 4.

2. Vehicles are for (a) Professional hunter (b) Learner hunter (c) Camp manager (d) PR officer (e) Standby
4. All vehicle maintenance is done on site. Provision for tyres, tubes etc is included under spares.
6. Rustic or tented accommodation will be used for the hunting camp
7. Provision has been made for up to three clients
18. Lighting includes a 25kva generator
19. Water supply includes 2 pumps, watertank and piping
21. All capital items are written off over 5 years and the total capital cost is included in the operating costs
24. The professional hunter is paid on a daily rate of US$200/day for actual days hunted
29. Scouts are used for anti-poaching in 250$km^2$
36. Fuel provision includes generator and water pumps.
39. ‘Annual refurbishment’ includes camp maintenance costs during the hunting season and at start-up each year
40. Gas is used in the kitchen for cooking
41. ‘Miscellaneous’ camp operating costs includes cleaning materials, toilet paper, cooking oils, salt, pepper, sauces, napkins etc.
42. All staff are fed whilst in the field

For the purposes of this exercise, all extra charges such as government tourism levies, CITES tags and documentation, transfers to hunting camps etc. are assumed to be passed on to the client with no mark-ups.



**Table G: COST AND LAND USE SUMMARY**

| | WITHOUT ROAN, SABLE AND TSESSEBE | WITH ROAN, SABLE AND TSESSEBE |
|---|---|---|
| Area | 4,000 $km^2$ | 4,000 $km^2$ |
| Gross income US$/hectare | 5.90 | 10.06 |
| Operating costs US$/hectare | 1.09 | 4.37 |
| Net income US$/hectare | 4.81 | 5.69 |
| Potential net earnings from 4,000sq.km | 1,923,020 | 2,275,280 |

NOTES

1. It is assumed that these values could be achieved over a core area of about 4,000$km^2$ in the Caprivi.
2. Gross income/hectare is calculated in Tables D & E.
3. Operating costs are calculated in Table F. The operating costs for the scenario without roan, sable and tsessebe have been reduced to one quarter of the amount when these species are present because it would require only one safari operator to realise the full value of the available hunting – as opposed to 4 safari operators in the other case.
4. This net income includes no payments to government or local communities for the safari concession. However, the net income to the safari operator indicates the margins available for these payments.

## Protected Area Requirements in Southern Africa

Martin (1996) empirically derived the relationship that the number of men required for effective patrolling against illegal hunting in any park was approximately equal to the square root of the area of the park. The relationship was based on the relative success of the different protected areas in Zimbabwe using the criterion that, under effective patrolling, illegal hunters will be found within less than two days.

$$\textit{Number of men:} \quad N_S = \sqrt{A}$$

— where A is expressed in square kilometres

| PARK SIZE km$^2$ | 1 | 5 | 10 | 50 | 100 | 500 | 1,000 | 5,000 | 10,000 |
|---|---|---|---|---|---|---|---|---|---|
| NUMBER OF MEN | 1 | 2 | 3 | 7 | 10 | 22 | 32 | 71 | 100 |

Martin (1997) developed standard spreadsheets for calculating the operating costs and capital requirements based on this relationship. The number of men determines the annual running cost for any park. The budget is made up of salaries, field allowances, equipment, transport and maintenance costs and includes provisions for senior field and research staff. Allowing for variations in salaries and fuel costs from country to country in the region, the operational costs are approximately given by the formula —

$$\textit{Annual Recurrent Expenditure/km}^2 \quad C_R = US\$50 \left( 1 + \frac{2}{A} + \frac{3}{\sqrt{A}} \right)$$

The capital requirements to set up a new park from scratch are also dependent on the total staff complement in the park and vary slightly depending on building costs across the region. The required capital per unit area is approximately given by —

$$\textit{Total Capital Expenditure/km}^2 \quad C_C = US\$500 \left( 1 + \frac{1}{A} + \frac{1}{\sqrt{A}} \right)$$

— where A is expressed in thousands of square kilometres in both formulas

**STAFF NUMBERS, OPERATING COSTS AND CAPITAL REQUIREMENTS FOR VARIOUS PARK SIZES**

| PARK SIZE km$^2$ | Number of Field Staff Required | Operating Costs US$/km$^2$/year | Total Operating Cost US$/year | Capital Required US$/km$^2$ | Total Capital US$ |
|---|---|---|---|---|---|
| 1 | 1 | 104,793 | 104,793 | 516,311 | 516,311 |
| 2 | 1 | 53,404 | 106,808 | 261,680 | 523,361 |
| 5 | 2 | 22,171 | 110,857 | 107,571 | 537,855 |
| 10 | 3 | 11,550 | 115,500 | 55,500 | 555,000 |
| 20 | 4 | 6,111 | 122,213 | 29,036 | 580,711 |
| 50 | 7 | 2,721 | 136,041 | 12,736 | 636,803 |
| 100 | 10 | 1,524 | 152,434 | 7,081 | 708,114 |
| 200 | 14 | 885 | 177,082 | 4,118 | 823,607 |
| 500 | 22 | 462 | 231,066 | 2,207 | 1,103,553 |
| 1,000 | 32 | 300 | 300,000 | 1,500 | 1,500,000 |
| 2,000 | 45 | 206 | 412,132 | 1,104 | 2,207,107 |
| 5,000 | 71 | 137 | 685,410 | 824 | 4,118,034 |
| 10,000 | 100 | 107 | 1,074,342 | 708 | 7,081,139 |
| 20,000 | 141 | 89 | 1,770,820 | 637 | 12,736,068 |
| 50,000 | 224 | 73 | 3,660,660 | 581 | 29,035,534 |
| 100,000 | 316 | 66 | 6,600,000 | 555 | 55,500,000 |

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