THE DETERMINATION OF ACCEPTABLE HIPPOPOTAMUS (*HIPPOPOTAMUS AMPHIBIUS*, LINN.) DENSITIES IN THE CROCODILE RIVER, OUTSIDE THE KRUGER NATIONAL PARK.

J.J. EKSTEEN

A research report submitted to the Faculty of Science, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree Master of Science in Quantitative Conservation Biology.

Declaration

I declare that this research report is my own, unaided work.
It is being submitted for the Degree of Master of Science in Quantitative Conservation Biology at the University of Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at any other University.

J.J. Eksteen
31 January, 1993.

TABLE OF CONTENTS

Abstract

The aim of the study was to provide a basis for the determination of acceptable hippo densities along the Crocodile River, outside the Kruger National Park. Hippo densities have to be acceptable to land-users, who suffer hippo damage, and to the conservation authority, responsible for the resources along the river. Hippo numbers and distribution in the study area were determined by using a combination of aerial census and ground count. The hippo population number was estimated at 88 animals. Hippo distribution was influenced by flow speed of water. No hippos were observed in river sections with steep gradients, (>6.0 m/km), while major herds were observed at low gradients (<3.5 m/km). A mean density of 0.6 hippo per km was calculated, with a maximum of 2,5 hippos/km at Kaapmuiden, next to the Kruger National Park. TPA Nature Conservation records on hippo complaints were analyzed, and no relationship between the occurrence of hippo damage and hippo density could be found. There were strong indications that hippo damage are caused by individual problem hippo. The majority of land-users (92 %) supported the conservation of hippos. The size of the area available to hippo was determined for distances of 5 km up- and down-river from the major hippo herds. The average distance that hippo could move away from the river was 336 m, a severe restriction when compared to the generally assumed hippo grazing range of 3.2 km. Hippo access to grazing was assessed by determining the effective grazing area.

Effective grazing area at study sites was on average 437 ha, which represents 6.8 % of the area represented by a 5 km grazing range. The size of the effective grazing area will vary from year to year, depending on the crops that will be planted. The land-users attitudes might be influenced by the type of crop planted. A grazing gradient with the highest impact close to the hippo pools was found. TPA Nature Conservation regarded the grazing impact as acceptable, considering observations were made in the late dry season of a below average rainfall year.

Uittreksel

Die doel van die studie was die verskaffing van 'n basis vir die bepaling van aanvaarbare seekoei-digthede langs die Krokodilrivier, buite die Nasionale Kruger Wildtuin. Seekoei-digthede moet aanvaarbaar wees vir grondgebruikers, wat skade kan lei, en vir die bewaringsinstansie wat verantwoordelik is vir die hulpbronne langs die rivier. Seekoeigetalle en verspreiding is bepaal met 'n lugsensus en 'n grondtelling. Die seekoeibevolking is geskat op 88 seekoeie. Seekoeiverspreiding was beinvloed deur die vloeispoed van water. Geen seekoeie is waargeneem in rivier gedeeltes met steil gradiente (>6 m/km), terwyl die groot troppe waargeneem is by lae gradiente, (<3.5 m/km). 'n Gemiddelde digtheid van 0,6 seekoeie per km is bereken, met 'n maksimum van 2,5 seekoeie/km by Kaapmuiden, naby die Nasionale Kruger Wildtuin. Die TPA Natuurbewaring register met klagtes oor seekoeie is ontleed, en geen verwantskap

tussen die voorkoms van seekoeiskade en seekoeidigtheid kon gekry word nie. Daar is sterk aanduidings dat individuele probleemdiere vir seekoeiskade verantwoordelik is. Die meerderheid grondgebruikers, (92 %), het aangedui dat hulle seekoeibewaring ondersteun. Die grootte van die gebiede wat beskikbaar was vir seekoeie is bepaal vir afstande van 5 km rivier-op en -af van die groter seekoeitroppe. Die gemiddelde afstand van seekoei versperrings vanaf die river was 336 m, 'n ernstige beperking wanneer dit vergelyk word met die aanvaarde seekoeiweiradius van 3.2 km. Die beskikbaarheid van weiding vir seekoeie was bepaal deur die grootte van die gebied wat effektief weiding bied te bepaal. Die grootte van die effektiewe weidingsgebied by die studie persele was gemiddeld 437 ha, wat 6.8 % van die area binne 'n wei afstand van 5 km vanaf die rivier verteenwoordig. Die grootte van die effektiewe weidingsgebied sal van jaar tot jaar varieer, afhangende van die gewasse wat geplant word. Die grondgebruiker se verdraagsaamheid teenoor seekoeie kan ook beinvloed word deur die tipe gewas wat geplant word. 'n Weidingsgradient, met die hoogste impak naby die seekoeigate is gevind. TPA Natuurbewaring beskou die huidige weidingsimpak van seekoeie as aanvaarbaar.

1. Introduction

Historically, hippopotamus (Hippopotamus amphibius Linn.) inhabited practically all the rivers, lakes and lagoons of Southern Africa from the Cape to the Zambezi (Du Plessis 1969). As they are amphibious they were necessarily confined, within this wide range, to areas with sufficient water to provide for their needs. Water and adequate grazing are the two most important requisites of hippo (Estes 1992). Therefore their distribution was discontinuous and patchy.

Where hippos occur outside large conservation areas, they often occur where cultivation of crops is a major land use. Many cultivated lands are close to the rivers because of the availability of water and productivity of soils. Hippos are notorious damagers of crops, and this leads to confrontation between farmers and hippos. In areas where problems were experienced this sometimes lead to their local extirpation (Smithers, 1983).

In South Africa hippos currently survive only in the northern and eastern Transvaal and northern Natal. With regard to the Crocodile River in the eastern Transvaal, several elderly residents report that no hippos occurred on farms around Nelspruit before the mid 1960's. This conforms with a report by Kettlitz (1962, cited by Joubert 1967), that hippos were found in the Letaba, Selati and Olifants

Rivers to the west of the Kruger National Park, with no mention of the Crocodile River.

Since the early 1900's, hippo numbers inside the Kruger Park increased to such an extent that hippo culling was deemed necessary (Pienaar, Van Wyk & Fairall 1966 ; Whyte 1988, unpublished manuscript). During 1992 a total of 424 hippos was counted by National Parks Board personnel in the Crocodile River within the Kruger Park, (Viljoen 1993).

The rivers in the Transvaal Lowveld are open systems, and aquatic organisms can move unhindered up- and down-river. The high number of hippos inside the Kruger National Park most likely served as a source of hippos for emigration upstream to the west of the Park. Since hippos were first reported in the Nelspruit area in the mid 1960's the numbers of hippo have increased.

Hippos are area selective grazers with a preference for short green grass. The estimated daily food intake on a dry mass basis is between 16 and 20 kg for adult hippos, (Laws 1968; Owen-Smith 1988). With such a large intake, consumption of planted crops by a few hippos can cause considerable damage. Damage by trampling sometimes exceeds the damage by consumption. Hippos may become aggressive towards human beings, and various deaths and injuries have been reported. These events often receive a lot of publicity.

Entries in the complaints register, kept at the Eastern Region Office of the Chief Directorate of Nature and Environmental Conservation in Transvaal (TPA Nature Conservation), indicate that the number of complaints about hippos rose between the early 1970's and the mid 1980's. Farmers tried a wide range of preventative measures to keep hippos away from their crops. Several landowners erected electric fences which seem to be effective in preventing hippo damage. However, these fences and other structures (eg. railway lines, roads, fences) limit the area available to hippos.

All the hippos in the Crocodile River, outside the Kruger National Park, occur on private land where the major land-use activities are cultivation of crops, orchards and the use of veld for grazing. No private nature reserves or game farms border onto the river. If and when hippo damage occurs, it is the private land-user who suffers damage. However, TPA Nature Conservation is responsible for the management of the hippo population outside the Kruger National Park. This involves the removal of individual problem animals and injured animals through capture or culling.

In order to find a working relationship between land-users and the conservation authority, hippo densities have to be determined that will be acceptable to both parties. In this regard not much was known about the concerns of the land-users, but overgrazing of the riparian zone is of concern to TPA Nature Conservation.

The field work for this study took place from September 1992 to December 1992. This meant that the field work was done in the dry season of a below average rainfall year. According to the South African Weather Bureau, the annual rainfall in Nelspruit for 1992 was 434 mm, which represents only 57 % of the mean annual rainfall of 761,4 mm.

1.1 Study Objective and Key Questions

The overall objective of this study was to provide a basis for the determination of acceptable hippo densities in the Crocodile River, outside the Kruger National Park. To this end, the following key questions were identified:

1) How abundant are hippos in the Crocodile River ?
2) What problems are land-users experiencing with hippos ?
3) Is there a relation between the occurrence of hippo damage and hippo densities ?
4) What is the attitude of the land-users towards hippos ?
5) What level of crop damage by hippos would be acceptable to land-users ?
6) What is the size of the area available to hippos ?
7) How much of the area available to hippos offers grazing for hippos ?
8) What is the grazing impact on the veld in the area available to hippos ?
9) Are other grazers competing with hippos ?

1.2 Study area

The section of the Crocodile River which was surveyed stretches 142 km from the Braam Raubenheimer Dam (25^0 22′ S, 30^0 24′ E) near Lydenburg to the boundary of the Kruger National Park (25^0 32′ S, 31^0 22′ E) near Kaapmuiden, (see Figure 1).

The stretch of river forming the study area has a predominantly rocky bottom with occasional deposits of gravel and coarse sand. The river is associated with foothills of the Eastern Transvaal Escarpment. Occasional waterfalls occur. The flow of water can be described as fast, but with slow-flowing pools. Several weirs have been constructed across the river.

On the farms adjacent to the river, the major land-use activities include cultivated lands, orchards, cultivated pastures and veld used as grazing.

2. Methods

2.1 Hippopotamus numbers and distribution

According to Attwell (1963) the hippopotamus is a species which is possibly more easily counted than any other ungulate, although this depends on the nature of their refuges. In the past hippo censuses have been done on foot (Scotcher 1978), from boats (Ansell 1965 ; Attwell 1963 ; Laws & Clough 1966), fixed wing aircraft (Field 1970 ; Olivier & Laurie 1974) and helicopters (Taylor 1987, unpublished manuscript ; Viljoen 1980 ; Viljoen 1989). Karstad & Hudson (1984) and Tembo (1987) used combinations of aerial and ground counts to determine hippopotamus numbers.

In this study, the number of hippos was firstly determined by a total aerial count from a helicopter, and secondly by a total ground count. Although TPA Nature Conservation use the aerial census technique to attain a population index annually, the ground count was used to determine the hippo numbers more accurately. Karstad & Hudson (1984) and Tembo (1987) also used combinations of aerial and ground counts, and also reported higher figures during ground counts.

The aerial census method used, was very similar to that used in the Kruger National Park. Ideally, the census should take place during the late winter when the rivers are low and relatively clean, and on a warm sunny day following a cold night. In this study a Bell Jet Ranger helicopter was used with all four doors removed, and a crew consisting of a pilot, a navigator/data-recorder and two observers. The direction of the flight was away from the sun, and an average height of 40 m above the river was maintained at a speed of approximately 80 km per hour. Hippo sightings were recorded directly onto a topographical 1:50 000 map, noting exact locality and group size. If a satisfactory count of a herd of hippo could not be done during the initial fly-over, the helicopter circled until a satisfactory count of the herd was obtained. Dams close to the river were also surveyed during the census.

The following aerial counts were carried out:

1) On 6 September 1992, from 08h00 to 09h00, between the Kruger National Park border and the western end of the Crocodile River gorge.
2) On 7 September 1992, from 08h00 to 10h00, between the western end of the Crocodile River gorge to Montrose.
3) On 8 September 1992 from 08h00 to 10h00, between Elands river confluence, below Montrose, to the Braam Raubenheimer Dam.

From 8 to 12 September 1992 , the aerial counts were followed by ground counts along the Crocodile River, between the Kruger National Park border and Montrose. Ground counts were done between 07h00 to 11h00 and 15h00 to 18h00. During ground counts, 2 observers walked on each side of the river and the hippo numbers and distribution were marked on 1:50 000 topographical maps.

As hippo densities are commonly expressed as the number of hippos per kilometre of river, this expression was also used for this part of the study. The number of hippos counted by the census method which yielded the highest figure was regarded as the minimum hippo population size. The minimum population number of hippo was used to determine their density per kilometre of river. The river was divided into different sections by using prominent markers along the river such as bridges, weirs, waterfalls and gorges. Hippopotamus densities were expressed as the number of hippos counted in each section per the length of river of that section.

Hippos are more abundant in wide slow-flowing reaches of rivers than in rapids and rocky patches (Attwell 1963). The gradient of a river gives an indication of the general speed of water flow in the river (Kleynhans personal communication[1]). The gradient of river sections where

[1] Dr. C.J. Kleynhans, Specialist Services, TPA Nature Conservation, P.O.Box 59019, Karenpark, 0118

hippos occurred was compared with the sections without hippos. The gradients were determined by the difference between altitudes of the upper and lower boundaries of each section. Contours on orthophotos with a scale of 1:10 000 were used to determine the altitudes.

Several methods of multivariate analysis have been used to analyse the complex inter-relationships between herbivores and the many facets of their environment (Beardall, Joubert & Retief 1984). Many traditional multivariate analysis methods suffer drawbacks when applied to ecological data. Correspondence analysis is a technique which provides a graphical display of data arranged in a two-way table of rows and columns. Beardall et al. (1984) reported that correspondence analysis holds promise for more advanced in-depth studies of animal/habitat relationships. Simca, version 1.2 (Greenacre, 1985) was used to do a correspondence analysis using the river gradient, number of dams next to the river and hippo numbers in the various river sections. In the correspondence analysis, the river gradient was divided into three equal classes, namely 0 - 3.3 m/km, 3.3 - 6.6 m/km and 6.6 - 9.9 m/km.

Attwell (1963) and Yoaciel (1981) pointed out that routine sexing of hippopotamus is not possible. Therefore no attempt was made to sex hippos during this part of the study.

2.2 Hippo problems

Complaints from land-users about hippos were registered at the regional office of TPA Nature Conservation in Nelspruit. The records on the number of problem hippos that had to be removed was available for the period 1980 to 1992, while records on the number of complaints received were available for the period from July 1990 to 1992. These records were analyzed to determine if :

1) significant differences existed between the number of problem hippos, or the number of complaints received per river section, and
2) the number of problem hippos and/or the number of complaints received were related to hippo density.

For this purpose Chi-square tests were used. The existence of a relation between the number of complaints received per river section, and the hippo density in the section during 1992 was investigated by regression techniques.

In order to determine whether hippo damage is a seasonal occurence, the number of problem hippo, and the number of complaints was related to monthly rainfall figures, using regression techniques and analysis of variance. The sample sizes along the Crocodile River were relatively small. Therefore, additional records from other rivers in the Eastern Transvaal Lowveld, the Blyde and Olifants Rivers, were also used. These relations were also investigated using the monthly rainfall figures lagged by one month, as the effect of rainfal on vegetation might only be visible after a period of vegetation growth. For example, wildebeest and other ungulates follow the patchy rainfall and waves of nutritious regrowth, and move about the Serengeti plains in 2 - 4 week rotations, (Coughenour 1991).

The sexes and age-groups of the problem hippos shot in the area between 1980 and 1992 were assessed to determine if the problem hippos were from a specific age class and sex.

2.3 Attitudes of land-users

In recent years the occurrence of hippo damage to crops, their involvement in accidents on the roads and the threat they pose to canoeists on the river has received wide media coverage. The articles in the media generally indicated that farmers and certain sectors of the public were against the presence of hippos in the river. As the attitudes of the majority of land-users would determine the amount of effort needed for the long term conservation of hippos outside large conservation areas, it was important to learn more about these.

In order to get a complete picture of attitudes of land-users towards hippos, a questionnaire was drawn up with the cooperation of the Human Research Sciences Council. The addresses of the target land-owners were obtained from the Lowveld Irrigation Board. The questionnaire was circulated among the land-users adjacent to the river. It included specific questions about farming operations, problems experienced with hippos, attitudes towards hippos and attitudes towards the current management of the hippo population. A copy of the questionnaire is included as Appendix A.

The response to this questionnaire was analyzed to determine if the spatial distribution of the land-users, hippos, farming practices and farm sizes had an influence on the attitudes of the landowners. The methods used were:

1) regression techniques to determine the relation between hippo density, and the percentage of landowners supporting hippo conservation;

2) a Chi-square test to determine if significant differences existed in the attitudes of land-users practising different agricultural activities;

3) a Chi-square test to determine if significant differences existed between land-users on small farms and big farms; and

4) the questionnaires were also assessed to determine:

(i) how much support the future conservation of hippo may have among the land-users adjacent to the river;

(ii) the effectiveness of preventative measures;

(iii) the acceptability of the current levels of damage;

(iv) types of damage.

2.4 Available area

In the study area, the natural movement of hippos away from the river is limited by sturdy fences along major roads and railway lines, electric fences and some standard camp fences around agricultural fields, while canals with steep cemented walls, and buildings, also affect hippo movements. It is conventionally assumed that the grazing range of hippos extend 3.2 km from the river or lake margin (Owen-Smith, 1988), although distances of 5 km are also well within reach of hippos (Petrides & Swank 1965 ; Lock 1972).

Study sites were established at locations where more than five hippos were observed during the censusses. Five study sites were established, and their locations are shown in Figure 1. The study sites at Alkmaar and Cairn/Halls border onto each other. The inhabited hippo pool was taken as the centre of each study site. The study sites extended 5 km up and down river from the inhabited pools, and, away from the riverbank up to the first barrier intended to stop hippo movement. The distance of 5 km was used in preference to the conventional grazing range of 3.2 km as hippos might be forced to move further up and down river because of the limitation to movements away from the river.

To determine the average distance of the hippo barriers away from the river, a transect was set up every 200 m along the river at each study site. The length of the transect represented the shortest distance between the riverbank and the first hippo barrier encountered along the transect. The positions of the barriers were plotted onto 1:10 000 orthophotos. The sizes of the areas available to hippos were then determined using a digital planimeter.

The area available to hippos refers to the area where hippo movement is not limited. It was often the case that the area with available grazing was less than the area available to hippos. This was due to the presence of areas like granite outcrops and ploughed lands for example. To determine the size of the effective grazing area, orthophotos were used to divide the area available to hippos into relatively homogeneous units. Some aspects mentioned by Edwards (1981) were used to divide the area into units. These aspects were landform, geology, vegetation physiognomy and agricultural activities. A unit represented an area with relatively homogeneous landform, vegetation and/or agricultural activities.

On the orthophotos relatively undisturbed natural vegetation, orchards, lands and disturbed areas could easily be identified. Disturbed areas included all buildings, cemented canals, quarries, cuttings, old construction campsites and old buildings. The characteristic granitic outcrops of the Nelspruit area, and hills with very steep slopes, were classed as steep hills. The woody vegetation was classified physiognomically and grouped into the following physiognomic classes:

1. closed, where canopies were interlocking ;

2. intermediate, where woody plant canopies were close but not touching ;

3. open, where woody plants were separated by distances further than the average canopy diameter (Mueller-Dombois & Ellenberg (1974).

It was sometimes difficult to distinguish between the intermediate and open physiognomic classes of the natural vegetation. These divisions were checked on site, to ensure that the vegetation and current land-use practises were the same as identified on the orthophotos.

The intermediate and open physiognomic classes were grouped together, and called veld. The closed canopy physiognomic class was called bush. The site visits also detected changes in land-use activities. These were marked on the orthophotos. Citrus and litchi orchards were the only orchards in the study area that were under irrigation. In these, the grass directly under the trees was kept short while the grass between the trees was cut less frequently. Grass in pecan orchards was cut short at the end of the summer, and stunted with herbicide to ensure a sward of less than 10 cm high, so as to facilitate the collection of nuts. Mango and avocado orchards had little grass as mostly bare soil occurs under these trees. Therefore, the different orchards were grouped into the land units: citrus/litchi, pecan, and avocado/mango.

Lands were divided into old lands, unplanted lands, and planted fields. As the 1991/92 rainfall season was below average, several farmers prepared lands during the start of the 1991/92 rainfall season, but left the lands unplanted when low rainfall occurred.

The land units were marked on the orthophotos, and the areas of the units were determined using a digital planimeter. The areas of land units with little or no grass cover were subtracted from the available area to determine the effective grazing area. The units which offered little or no grazing were bush, avocado/mango orchards, and empty lands. Koppies were excluded as being inaccessible to hippos.

According to Edwards (1981) stocking density refers to the number of specified animal units and land area at any instant in time, and is expressed as animal units per hectare. The stocking density can influence the competition for, and utilisation of preferred vegetation. The grazing densities of hippo at each study site was determined by dividing the number of hippo present by the effective grazing area.

No reports on the production of grass in the study area could be found. In an effort to estimate whether the effective grazing area will be able to sustain the numbers of hippo at the study sites, stocking guidelines used by the Extention Officers of the Department of Agriculture in Nelspruit were used.

2.5 Grazing impact

Grazing animals affect pastures by defoliation, treading and excretion. Each of these factors affect forage production, forage quality and botanical composition (Mentis 1981; Danckwerts 1989). Animals also affect one another, and this may influence the way they defoliate, tread and excrete. The amount of inter- and intraspecific competition for grazing is largely determined by the grazer stocking rate (Mentis 1981). The questionnaire circulated among the land-users, as described in section 2.3, included a section on the numbers of livestock and other animals utilising the vegetation in the area available to hippo. The numbers of livestock observed during the field work in the area available to hippos were also recorded. Livestock Units (LU), as described by Meissner (1982), were used to express the stocking rate of grazers in the area available to hippo. As farmers know and use LU in the expression of stocking rates, the hippo numbers at the study sites were converted to LU's, to enhance discussions with land-users.

Hippos are area selective rather than species selective grazers, that is, they select grassland physiognomies that best satisfy their feeding requirements (Scotcher, Stewart & Breen 1978). A gradient of grazing impact by hippo, with the highest impact being close to the hippo pools, was reported by Olivier & Laurie (1974). Several authors reported over-utilisation of the available grazing by hippo (Bere 1959; Eltringham 1974; Lock 1972; O'Connor & Campbell 1986; Ogen-Odoi & Dillworth 1987; Petrides & Swank 1965 and Viljoen 1980).

Hippos are dependant on water for refuges. A result of this dependency is the creation of zones of varying impact, or piospheres, around water sources (Andrew 1988). The piosphere pattern is characterised by a sacrifice zone of varying width where the intensity of herbivore activity is the greatest. Many other herbivores concentrate their activities along rivers, especially during the dry season.

Officials from TPA Nature Nature Conservation indicated that they regard acceptable hippo densities as those densities where over-utilisation of the grazing in the area available to hippos does not occur. Over-utilisation of the vegetation should be avoided as plants that are utilised too often and/or too severely become damaged (Bothma 1986 ; Mentis 1981). Their production, vigour, competitive ability and seed production are affected. Overutilisation of the grass component invariably leads to a reduction in sward density (Edwards, 1981), which inevitably results in an increase in soil erosion (Whitlow 1988).

In this study, hippo impact assessments were carried out to determine if a gradient, such as that reported by Olivier & Laurie (1974), existed, and if so, how far it extended from the hippo pools. Observations on basal cover, as a measure of sward density, and grass height, as a measure of grazing were used to determine grazing impact.

The time available for the field work was limited. A random selection of study sites, although preferable, was not practical as more sites would have been needed than time allowed. Therefore the same study sites described in the section 2.4 were used.

At each study site a total of eleven 200 m long baselines parallel to the river were laid out approximately 10 - 15 m away from the waters edge. The layout of baselines and transects is illustrated in Figure 2. A distance of 200 m separated adjacent baselines. The middle of the central baseline was opposite the part of the hippo pool with the best defined hippo exit points. From each baseline a set of line transects perpendicular to the river were established at 20 m intervals. Along each transect-line a 0,25 m^2 quadrat marker was placed at 20 m intervals, until the end of the area available to hippo was reached.

The following observations were recorded for each quadrat:

1) position of the quadrat (quadrat number, relative homogenous unit);

2) physiognomy of surrounding woody vegetation, for a distance of 10 m from the quadrat;

3) type of grass (broadleave : wiry : creeping : forb) ;

4) herbaceous plant cover ;

5) height of the grass sward.

In order to compare observations taken at different quadrats, some classification of the environment was necessary so that observations of similar units could be grouped together. The same physiognomical classes of the woody vegetation as recommended by Mueller-Dombois & Ellenberg (1974), described in section 2.4, were used. The physiognomy of the woody vegetation within 10 m from the quadrat were recorded.

The identification of grass species during the end of the dry season was very difficult, especially where grazing occurred. Therefore, a broad characterisation of grass types was used for this study, namely: tufted broadleaved grasses, tufted wiry grasses, creeping grasses and forbs.

Using white paint, marks were made down one side of the quadrat marker at 0.5 cm intervals. Where the marked side of the quadrat marker touched basal area of herbaceous plants, the intercept of basal area was measured. At each quadrat, basal cover was recorded using the summed intercepts of herbaceous basal area.

Grazing herbivores reduce the height of the grass sward. Grass height is therefore a measure of grazing impact, if the species composition is similar at the various sites. In each quadrat the predominant height of the herbaceous leaf table was recorded. Grass height measurements were grouped into 10 cm intervals.

Frequency distributions were constructed to compare quadrat basal cover and grass height values. Median values were calculated in preference to the means, because data were not normally distributed. Comparisons of basal cover and grass height between relative homogenous units, quadrat distances on transect lines (away from the baselines next to the river), and baselines at different distances away from the hippo pools were done using the Kruskal-Wallis test. Where significant differences were indicated in the Kruskal-Wallis test, the a posteriori method for multiple comparison as described by Zar (1984) was used to determine between which of the units, baselines or transects significant differences occurred.

In September 1992, several fires occurred along the river, and natural veld at most study sites was affected, as well as some old lands and citrus orchards. Almost all the veld at the Alkmaar, Cairn/Halls and Karino study sites were burnt, while about 40 % of the veld at the Barvale study was burnt. At the Kaapmuiden study site only about 20 % of the available veld was burnt.

The restricted time period of this study and the large study area made it impossible to do major revisions to the project proposal to accomodate this occurrance. However, the existing methods were adapted to accomodate the effect of fires.

The majority of the area was burnt by head fires, burning with the winds. According to the land-users, they were unable to control these fires because of relatively strong winds. Trolloppe (1978) reported on the effects of surface fires occurring either as head or back fires, on the grass sward in savanna in the Eastern Cape. Results showed that head fires were less intense at ground level than back fires. Back fires had a significant depressive effect on the recovery of grass. Grasses and herbaceous plants are more tolerant of head fires because the majority of heat energy release during these fires is well above ground level, and away from the shoot apices of these species (Trollope 1984). Therefore, it was assumed that the basal cover of the perrennial species in the herbaceous layer were not severely affected, and basal cover observations were done on the burnt veld. However, observations on grass type and height could not be recorded at the burnt quadrats.

Initially, grass height in all three physiognomical classes for woody plants was to be compared with each other, but because of the fires the data-sets for grass height in the open and sparse canopy units were small. The patchy distribution of the quadrats in some units presented a problem when grass height between the relative homogenous units was compared. Therefore, only the grass height in the three types of orchards were analysed. Quadrats within 500 m of the hippo pool were grouped together and compared with quadrats further away.

3. Results

3.1 Hippo numbers

The numbers of hippo counted during the different censuses are listed in Table 1. Unless otherwise stated, the names in the table refer to bridges over the river. The ground count total of 88 hippo represents the minimum hippo population. Note that the ground counts revealed higher, or at least the same, hippo numbers than the aerial counts. This was especially true in river sections with dense riverine bush and aquatic weeds.

The dense riverine bush with overhanging trees and creepers occurred between the Broham weir and the confluence of the Elands and Crocodile rivers. The aquatic weeds, water hyacinth (*Eichhornia crassipes*) and water lettuce (*Pistia stratiotes*) and to a lesser extent kariba weed (*Salvinia molesta*) covered almost all the pools in the river between Karino and the Kruger National Park. The way hippos use these weeds for cover was obvious during both censuses. When disturbed, they immediately moved into the weeds. Once under this cover they were very difficult to observe, as they often kept only their nostrils above the water, while the rest of the body remained submerged. During ground counts observers were able to remain next to the pool for much longer periods, and therefore more accurate counts could be attained.

3.2 Hippo distribution

The maximum hippo density found during this study was 2.5 hippo per km of river, between the Kruger National Park and the Crocodile River Gorge (Table 1). The mean hippo density between the Kruger Park and the Braam Raubenheimer Dam was 0.6 hippo per km of river. However, Rohm (personal communication [2]) reported that hippo move up the river past Montrose falls on rare occasions. When they do, they stay there for short periods, and then move back to below the falls. The hippo density for the permanently occupied section, between the Kruger Park border and the confluence of the Elands and Crocodile rivers was 0.9 hippo per km of river.

The comparison of the gradient of the river and hippo density between different sections of the river is shown in Table 2. It is clear that all the hippo densities of more than one animal per km of river were found in river sections with gradients of less than 3.5 meters per km. Few or no hippos occurred where the river gradient exceeded 5 meters per km.

---

[2] E. Rohm. Conservation Services, Eastern Region, TPA Nature Conservation, P.O.Box 1232, Nelspruit, 1200

The graphical display of the correspondence analysis is shown in Figure 3. In the two dimensional projection, the plot of the points with respect to the first two dimensions (principal axes) contains the most variation that is displayable in two dimensions (Greenacre 1985). In Figure 3, three separate groupings of river gradient and river sections are clear. The first grouping, with gradient one, includes the river sections with the highest hippo densities in this study. The second grouping, with gradient 2, includes the river sections in this study with low hippo densities. The third grouping, with gradient 3, includes the river sections where no hippos were observed.

3.3 Hippo problems

There were no significant differences in the numbers of complaints received per river section. Likewise, there was no relationship between the number of complaints and the hippo density per river section.

The analysis of complaints about hippo problems, was based on the number of complaints received from land-users. It is known that some land-users who experienced hippo damage never complained. Therefore, this data did not reflect all the hippo damage that occurred in the area. Furthermore, number of observations used in this analysis was relatively small.

Although the number of problem hippo and the number of complaints along the Crocodile River, shown in Table 3, suggested that more reports of damage occurred during the dry season, no significant relationship with the monthly rainfall was found. Even with additional data from other lowveld rivers, and with the rainfall lagged by one month, no significant relationships were found.

The numbers of problem hippos shot in the Nelspruit area between 1980 and 1992, and the reasons for shooting them are shown in Table 4. This data suggested that males are more prone to become problem animals as only 18 % of the problem hippo were female. Intra-specific fighting was the cause of the majority of the injuries to hippos. Reports of these incidents were mainly received between August and October, and these animals often behaved aggressively, which implied that they had to be removed.

3.4 Attitudes of landowners

The media reports indicated that land-users along the river and other interested parties were against the presence of hippo in the Crocodile River, outside the Kruger National Park. These reports included three articles by the environmental magazine program 50/50, televised

10/10/1991, 05/04/1992 and 13/09/1992; and two articles in the local newspaper, The Lowvelder, published 29/11/1991 and 15/01/1993.

Forty of the 50 questionnaires were received back. Almost all, 92.5 %, of the respondents indicated that they wanted the hippo in the river, while only 7.5 % wanted the hippos removed. No relationship was found between land-user's attitudes and hippo density, or the size of the farming operation.

The Chi-square test showed that attitudes of land-users producing vegetables, were significantly different from the other land-users, ($p < 0.001$). However, none of the vegetable producers negatively disposed towards hippo had any preventative measures, and often suffered hippo damage. Contrary to this, all those who erected electrical fences wanted the hippos in the area.

Seventeen (40 %) of the respondents indicated that preventative measures were taken (Table 5). Of these only one person did not use an electric fence as a preventative measure, and he indicated that the standard cattle fence he was using was ineffective. Land-users regarded electric fencing as an effective and affordable preventative measure, provided these fences were erected properly and maintained.

According to respondents, hippo damage usually involved the consumption and trampling of vegetables, maize, and beans. Trampling of irrigation pipes and canals, broken fences, killing of livestock, damage to cars and injuries to labourers were also reported. Several landowners indicated that they changed or planned to change their farming operations to crops which hippos do not usually damage, i.e. orchards or tobacco.

All the respondents who supported hippo conservation indicated that the current level of damage was acceptable. Land-users defined acceptable hippo densities as those at which the electric fences were successful in preventing hippo damage. The majority of respondents also indicated that the current hippo densities were acceptable, as long as the problem individuals are removed as soon as they are identified. Some respondents indicated that their tolerance of hippos was influenced by the type of crop planted. If a prefered crop, like beans or sweet potatoes, was planted, they would not be as tolerant as when tobacco was planted.

3.5 Available grazing area

The average distances between the river bank and hippo barriers in each section are shown in Table 6. From this table it is clear that electric fencing, erected at a mean distance of 66 m from the river, was the barrier closest to the river. These fences were found to be of a permanent or temporary nature. Two land-users had temporary fences which were only erected when crops, prefered by hippo, were planted. Most land-users with permanent electric fences erected them close to the river, with the closest planted field some distance behind it, (sometimes more than 200 m).

The distance of disturbed areas from the river varied greatly between study sites, ranging between 40 m at Kaapmuiden and 225 m at Barvale. The squatter-like settlements at Kaapmuiden, at an average distance of 40 m away from the river, extended for about 2.6 km along the northern riverbank, past Matsulu. This was the only place in the study area where urban development limited the area available to a hippo herd numbering more than five animals.

The combined length of the various hippo barriers at the study sites was 100 km, which comprised the following:

- 31 km were fences next to railway lines;
- 25 km were fences along registered roads;
- 24 km were electric fences;
- 10 km were standard camp fences;
- 7 km were disturbed areas; and
- 3 km were steep koppies.

After refining the demarcations on the orthophotos during the site visits, the following relative homogenous units were identified : bush, veld, orchards, lands, disturbed areas and steep hills. The sizes of the various units are shown in Table   Barvale had the largest sections under steep hills and closed bush, (consisting mainly of Lantana camara shrubs), and the smallest area under orchards. The Kaapmuiden study site had the smallest percentage area covered by steep hills and lands, and the highest percentage area covered by veld and orchards.

Two relative homogenous units, namely orchards and lands were subdivided for the determination of effective grazing areas. Orchards were divided into citrus/litchi, pecan and mango orchards. Lands were divided into fields, unplanted lands and old lands.

The effective grazing area and effective grazing density at each study site are shown in Table 8. The average size of the effective grazing areas was 437 ha, which represents only 64 % of the area available to hippo in a study site. The smallest effective grazing area, 205 ha, was measured at the Barvale study site where much of the area available to hippo was steep hills or thickets. It is for this reason that the highest effective grazing density occurred at Barvale. The Kaapmuiden study site also had a high effective grazing density, because of the high hippo numbers at that site.

Orchards that offer grazing, namely citrus/litchi and pecan, formed 35 % of the effective grazing areas at the ... rn/Halls and Kaapmuiden study sites. During the study period the frequent occurrence of fresh hippo tracks recorded in citrus and pecan orchards indicated that the grass in these orchards formed an important component of their grazing. In the Karino and Kaapmuiden study sites hippo travelled distances of about 2 km up and down river to get to this grazing. This observation was made when field work was carried out in the same area on consecutive days, and was confirmed by trackers from TPA Nature Conservation.

The estimated numbers of livestock units (LU) that can be sustained at the study sites are shown in Table 9. The average number of LU's recommended at the study sites was 78.6 LU's, while the lowest, 33.0, was recommended at Barvale. (See Appendix B).

3.6 Grazing impact

At the Kaapmuiden study site, high numbers of cattle were grazing on parts of the southern river bank, and on the whole northern river bank. At the other study sites, the numbers of livestock grazing in the area available to hippos were low. At the Cairn/Halls and Barvale study sites no livestock were grazing in this area. The Karino and Alkmaar study sites both had only one land-user who utilised the grazing in this area for livestock. Both land-users occupied small areas, 8 ha and 12 ha respectively, and kept livestock only for domestic use. The total number of livestock grazing in the area available to hippo was 3 LU's at Karino and 7 LU's at Alkmaar. It was difficult to obtain numbers of livestock at the Kaapmuiden study site as the area available to hippos was utilised as a communal grazing area by people of Kangwane. In a discussion with the tribal Chief responsible for that area he complained that many people from outside his area were grazing their cattle there, and he had no idea of how many cattle were grazing. Based on personal observations, the number of livestock grazing in this area was estimated at 260 LAU's. This represents a livestock stocking rate of 1 LAU per 1.9 hectares.

Using the same methods as described by Meissner (1982), an average of 3.5 hippos per LU was calculated. The number of hippo livestock units at the various study sites are listed in Table 9. At Barvale the number of recommended LU's were close to the actual number of hippo LU's, (Table 9). The total number of LU's at Kaapmuiden, is much more than recommended livestock units. The highest total stocking rate of grazers, 1.5 ha per LU, occurred at Kaapmuiden. Cattle and hippo are both grazers, and at such a high stocking rate it was impossible to determine the hippo impact on the available grazing at this study site. Therefore, the Kaapmuiden study site was not included in the assessment of hippo grazing impact.

It was difficult to characterise the grazing in the relative homogenous unit, veld, because large areas of veld were burnt. Where the grass types could be recorded, the dominant grasses were tufted, broadleaved grasses. The first general rain fell in mid October. In the period between the fires and the rain, little grazing was available in the burnt sections. Most of the available grazing occurred in the citrus/litchi and pecan orchards.

Orchards, and specifically citrus and litchi orchards, were the units in which the most grass occured, especially during the period before the first rains. These orchards were irrigated until water restrictions were imposed in early August 1992. Grass in the citrus and litchi orchards was still green during September 1992, and in some cases had to be cut as part of the orchard management. Short grass beneath citrus trees was essential for a biological pest control measure. In pecan orchards very little grass growth occurred before the first rains in October. The dominant grass type in citrus/litchi and pecan orchards was mainly tufted, broadleaved grasses, with creeping grasses being locally abundant.

The herbaceous layer in old lands was dominated by forbs and wiry grasses. The grasses in this unit were dormant during the study period, and very little green grass was observed.

The frequency distribution of basal cover and grass height in the relative homogenous units at various distances could not always be compared with each other because of the fires, and the absence of units at some baselines and transects. However, for the distance between 0 to 100 m on the transects, most baselines had representation of the units which offered grazing. Therefore, the plots showing distribution of basal cover and grass height at the various units only show the data for the first 100 m on the transects.

The frequency distribution of basal cover in the relative homogenous units are shown in figures 4.1 to 4.5. The distribution of basal cover in the unit " veld", (figure 4.1), suggested an increase in basal cover with distance from the hippo pool. Note the decrease in the number of observations in the lowest basal cover class as distance from the hippo pool increased. At the same time, an increase in the number of observations in the 4 % and 6 % basal cover classes can also be observed. No similar patterns were suggested at any of the other relative homogenous units. The low basal cover of the herb layer under closed bush is clearly indicated in Figure 4.5.

The frequency distribution of grass height in the relative homogenous units is shown in figures 5.1 to 5.4. The frequency distribution of grass height classes in veld suggested a pattern of decrease in the lowest grass height range as distance from the hippo pool increased, and an increase in the frequency of grass height ranges 25 and 35 cm, while classes 45 and 55 cm did not seem to be affected. The same pattern is suggested in the citrus/litchi and pecan orchards. The absence of the taller grass height classes in orchards was probably due to the regular cutting of grass and growth suppresent treatments.

The median percentage basal cover values in the different land units varied between 0 % and 6 % (Table 9). The median percentage basal cover values under closed canopies and in lands was 0 %. There was an increase in percentage basal cover with increase in distance, both away from the river, and up or down the river from hippo pools at the sparse canopy and old lands units. The median grass height value in pecan orchards was lower than the median value of citrus/litchi orchards, at 5 cm and 15 cm respectively.

In the analysis of the basal cover, the Kruskal-Wallis test indicated significant differences in basal cover between the relative homogenous units ($p < 0.001$), between baseline distances from the hippo pool ($p < 0.034$), and between quadrat distances from the river ($p < 0.009$), (See Appendix B).

The _a posteriori_ multiple comparisons indicated that significant differences existed in basal cover between the some relative homogenous units (Appendix C). The basal cover value of units with an intermediate canopy spread was significantly different from the lower basal cover values in old lands and closed canopy bush ($p < 0.001$). Basal cover in orchards differed significantly from the lower values in old lands and closed bush ($p < 0.001$). Basal cover in vegetation with open woody plant canopy spread differed significantly from the lower values in closed bush ($p < 0.001$).

A gradient in basal cover was indicated for baselines at various distances along the river, (Appendix C). The basal cover at baselines 0 m (at the hippo pool) and 400 m differed significantly from the higher basal cover values at baseline 2000 m, ($p < 0.05$ and $p < 0.01$ respectively). A gradient in basal cover was also indicated for distances of quadrats away from the river. Basal cover at 10 m was significantly different from the higher values at distances 180 and 200 m, ($p < 0.05$).

In the analysis of the grass height, the Kruskal-Wallis test indicated significant differences in grass height between the three types of orchard ($p < 0.0.001$), and between baseline distances from the hippo pool ($p < 0.001$), (See Appendix D). No significant differences in grass height were found between quadrats at various distances from the river.

The a posteriori multiple comparison indicated that significant differences existed in grass height between certain orchards and certain baselines, (see Appendix E). The grass height in citrus/litchi orchards was significantly different from the lower grass height values in pecan orchards ($p < 0.01$), and mango orchards, ($p < 0.01$). The grass height value at the 400 m baseline was significantly different from the higher grass height values at the 1600 m baseline ($p < 0.001$), and the 2000 m baseline, ($p < 0.05$).

A gradient in grass height was also indicated in veld. There was a significant difference ($p < 0.019$) between grass heights within 500 m of the hippo pools, and those measured further away than 500 m.

4. Discussion and recommendations

The more important findings, which are discussed in this section, are as follows:

1) the ground counts revealed higher hippo numbers than the aerial count ;
2) hippo distribution was influenced by the speed of water flow in the river ;
3) hippo densities determined in this study were lower than densities reported elsewhere ;
4) the occurrence of hippo damage was not related to hippo density ;
5) the majority of the land-users were positive towards the presence of hippo in the river;
6) the attitudes of land-users towards hippos may vary from year to year;
7) hippo barriers severely limited the area available to hippos ;
8) basal cover and grass height observations indicated a grazing gradient from the hippo pools.

4.1 Ground count revealed higher hippo numbers than the aerial count

As with other studies, (Karstad & Hudson, 1984; and Tembo, 1987) where aerial and ground counts were carried out, a higher number of hippo was obtained with the ground count. When the results of the censusses were compared, the difference suggested an aerial census under-counting bias of approximately 23%. The comparison between the aerial and ground counts was done only once in this study. If a reliable under-count bias for aerial hippo censuses is to be determined, more repetitions of these combined censuses need to be undertaken.

Although the ground counts were more accurate, they were time consuming. The aerial census took three people approximately 2.5 hours from start to finish, for a total of 7.5 man hours, while the ground count took four people about 31 hours, for a total of 124 man hours.

For the purposes of the future management of the hippo population in the Crocodile River, outside the Kruger National Park, the continuation of the annual aerial censuses is recommended. It is not necesary to carry out intensive annual surveys, such as was done in this study. If a repeatable census technique is applied, trends in the numbers of animals counted will provide sufficient information for general population management (Bothma

1986). If there is a need for more accurate figures, a combination of aerial and ground counts is recommended.

4.2 Speed of water flow and distribution of hippo

According to Attwell (1963) hippo can adapt to a diversity of environments, as long as their basic requirements are met. The latter requirements are water deep enough to submerge in, and nearby grassland for grazing (Estes 1992 ; Haltenorth & Diller 1977). Hippos prefer relatively shallow water with gently shelving beaches, where they can lie half-immersed (Field 1970 ; Olivier & Laurie 1974), while relatively fast flowing rivers with rocky bottoms are avoided (Attwell 1963 ; Haltenorth & Diller 1977 ; Olivier & Laurie 1974). Females with calves prefer to suckle their young in shallow, slow flowing water.

In this study, it was found that the distribution of hippos was negatively related to river gradient. The river gradient, and consequently the speed of the water, seemed to affect hippo distribution more than the availability of grazing. Olivier & Laurie (1974) suggested that group size is determined, amongst other factors, by the amount of suitable aquatic habitat. Other authors also reported on the importance of this habitat requirement (Field 1970 ;

Luck & Wright 1959 ; Pienaar <u>et al</u>. 1966 ; Smithers 1983 ; Vesey-Fitzgerald, 1960).

Some concern existed with regard to the movement of hippos further upstream from Montrose. None of the land-users had taken any preventative measures, and they were apprehensive about the possibility of hippo damage if hippos inhabited this river section on a more permanent basis. The local canoe club officially requested that this section be kept free of hippo, so that they can utilise it for competitions. The river section between Montrose and Badfontein extends for approximately 46 km, and at present no hippo remain there permanently. The river gradient is steep, (>6 m/km), and the number of rapids is high, while the number of pools is low. Therefore, there is very little suitable aquatic habitat, and it is unlikely that it will ever be permanently occupied. The few pools that do exist, may provide some habitat, and the dispersal of hippos into this section will have to be monitored. If a decision is taken that no hippos may be allowed in this river section, an electric fence of approximately 500 m at Montrose falls should be sufficient to control hippo movements.

4.3 Hippo densities in this study were lower than reported densities

The hippo densities determined in this study were generally lower than those recorded elsewhere. Sidney (1965) recorded hippo densities of between 1.4 and 2.3 hippo per km in the Lundi River, while densities of 19.5 hippo per km were recorded in the Mara River, Kenya by Karstad & Hudson (1984), and 46.8 hippos per km in the Luangwa River, Zambia by Tembo (1987). The hippo population densities throughout the Kruger Park varied between 0.2 and 17 animals per km, both within and between rivers (Viljoen 1992).

In the Kruger Park section of the Crocodile River the mean hippo density was approximately 3.7 hippo per km, and it varied between 0 and 7.0 animals per km (Viljoen 1993). Viljoen (1980), working on the Olifants River outside the Kruger National Park, recorded the highest hippo densities in his study, 5.0 to 8.2 hippo per km, within 15 km of the Kruger Park boundary. The highest densities of hippo in this study of the Crocodile River, 2.4 hippo per km, occurred within 10 km of the Kruger National Park boundary.

Since the late 1960's, early 1970's hippos re-established themselves in the Nelspruit area after a long period of absence. The relatively low densities measured during the study period might be due to the fact that the colonization process is still under way, and the population still growing.

Although the study took place during a below average rainfall year, emmigration of hippo from the Kruger National Park during drought, as described by Pienaar et al. (1966), were not observed in the study area. An increase in the number of hippos between 1991 and 1992 was reported for the Kruger National Park section of the Crocodile River (Viljoen 1993). The same author reported an increase in the hippo density of the river section on the western boundary of the Kruger National Park .

If hippo numbers inside the Kruger Park are allowed to increase, the chances of hippo emmigration might be greater. This may have signicant implications for the management of hippo outside the park. Spinage (1962) indicated that individual hippo may break away from the herds in search of suitable waterholes once the population densties becomes to high.

4.4 Occurrence of hippo damage not related to hippo density

The lack of a relationship between hippo densities and the number of complaints indicated that the occurrence of hippo damage was not density related. This implied that control of the hippo population numbers at the sites with high hippo densities will not directly address the occurrence of hippo problems.

Instead, there are strong indications that the occurrence of hippo damage are related to the presence of individual problem animals. This has been illustrated repeatedly in the past, by the successful control of hippo damage through the removal of certain problem individuals (Rohm personal communication[3]). For example, during 1992 a problem hippo was identified and successfully removed from the Kaapmuiden study site. This changed the hippo density from 2.5 to 2.4 hippo per km, and the effective hippo density from 5.1 to 4.9 hippo per km^2. Although the hippo density was changed very little, no more hippo damage occurred. Therefore, if the objective of a hippo culling operation is to reduce hippo damage, it would have to be aimed at the segment of the population that is more prone to cause damage. The identification and removal of problem individuals in areas where hippo problems occur is important for the successful control of hippo damage.

The records kept by TPA Nature Conservation indicated that male hippo were more prone to become problem animals than females. No information was available on the sex ratio of the hippo population during this period, therefore, it would be dangerous to carry this assumption through.

---

[3] E. Rohm. Conservation Services, Eastern Region, T.P.A. Nature Conservation, P.O.Box 1232, Nelspruit, 1200.

Further monitoring could determine the sex ratio, and, together with continued record keeping of the sexes of hippos removed, this could provide important data necessary for management decisions. The influence of intra specific fighting as a potential source of aggressive problem animals and hippo mortality must be considered. The indications are that this was more common during the late dry season, which suggested that the occurrence of these fights might be influenced by a shortage of grazing in that period. In addition to this a reduction in the size of the aquatic habitat may exacerbate the situation.

4.5 Positive attitudes of the land-users

The questionnaire results indicated that the media reports on the negative feelings of land-users towards hippo did not reflect the real situation. The majority of land-users with river frontage indicated that they wanted hippos in the river.

It is important that hippo conservation is supported by the parties that will be directly affected if, and when hippo damage occurs. The positive attitude of land-users along the river and their willingness to become part of a hippo conservancy, indicated strong support for the conservation of hippos in the Crocodile River.

The farming community accepted the TPA Nature Conservation policy where no damage permits for hippo are issued if affected landowners did not take any precautionary measures. Electric fencing was accepted as an effective and affordable measure to prevent hippo damage, if they are properly erected and maintained.

The lack of any relationship between the attitudes of land-users and hippo density indicated that opposing attitudes are probably due to individual bias towards hippo rather than being based on valid reasons. The fact that one of the vegetable farmers who were opposed to hippo had an electric fence donated and erected by the local farmer's association, and still complained about the maintenance of that fence seems to confirm this individual bias.

Hippo are regarded as a communal resource, and the few land-users who do not support their conservation could limit the success of any conservation program. An extention program involving the promotion of electric fences or a change in farming practices could be directed at these individuals. The effective prevention of hippo damage might help to change their attitude towards hippo in general.

4.6 Variations in attitudes of land-users from year to year

This study took place in a year of below average rainfall and during the dry season, and a high incidence of hippo damage was expected due to a shortage of grazing. However, because of the low rainfall, and expected water restrictions, almost all the lands were left unplanted, and few complaints about hippo damage were received. The fact that several fields were left unplanted, thereby ruling out the chance of any hippo damage, might have added to the positive attitude of the majority of farmers. In the questionnaire, and during the study period, several land-users remarked that hippo were welcome to graze anywhere on their farms, as there were no crops to be damaged, but added that they might not have the same opinion if crops were planted. Once damage becomes a possibility, a change in the attitudes of land-users could not be ruled out, especially if a crop preferred by hippo (such as sweet potatoes, beans or maize) is planted. There are however, some crops like tobacco, which are not often damaged.

Further complications are that land-users producing crops normally follow a rotational farming practice. The order of which is often determined by market prices. Some farmers also believe in resting their lands, and some grazing was available in these fallow lands. Therefore, the amount and type of grazing in the lands available to hippos will change from year to year, together with the potential for damage that will be unacceptable to the land-users.

4.7 Hippo barriers severely limited area available to hippos

The distances which hippos travel in search of grazing were reported as between 0.6 km and 2 km (Mackie 1976), an average of 1.5 km (Olivier & Laurie 1974), approximately 3.2 km (Pienaar et al. 1966 ; Lock 1972; Owen-Smith 1988), up to 6 km (Field 1970) and 8 km during the dry season in heavily utilised grazing areas (Scotcher 1978). However, the conventionally accepted grazing range for hippos is 3.2 km from the river (Owen-Smith 1988). The average distance of 336 m between the river and hippo barriers determined in this study, is much less than the grazing ranges reported in the literature. It represents only 10.5 % of the conventionally accepted distance.

If hippos were able to utilise their conventionally assumed grazing range in each study site, an area of 3.2 km by 10 km on each riverbank would have been utilised. Thus, the total area that would have been utilised within a study site would have been 6400 hectares. The mean effective grazing area in this study, 437 hectares, represents only 6.8 % of the conventional grazing area. This figure clearly shows the severe reduction of area available to hippos outside the Kruger National Park.

It is difficult to determine the effect of human activities on hippo distribution. In broken terrain, such as within the study area, railway lines and major roads often follow the contours of valleys. Railway lines and roads are often situated parallel to rivers, and where they are close to the river, the fences erected next to them may limit the area available to hippos. In this study, fences along railway lines and major roads formed 56 % of the hippo barriers.

Currently, TPA Nature Conservation only issues a permit for the removal of hippos if the land-user has taken certain precautionary measures. The prescribed measure for planted fields is an electric fence. This means that more land-users are forced to erect electric fences. These are often erected close to the river. The average distance of electric fences from the river as determined in this study was 66 m. If, and when new electric fences are erected along the river, the size of the area available to hippos, and consequently the effective grazing densities, will be affected severely.

An extension programme promoting the use of temporary electric fences, or the production of a crop not often damaged by hippos, might prevent the severe limitation of the area available to hippos. It is possible to erect temporary fences at planted fields, only during the period that damage might occur. After the crops are harvested, the fences may be removed. By changing from permanent electric fencing to a temporary system and protecting only the preferred crops, two land-users in the study area increased the area available to hippos on their farms from 85 ha to 765 ha, and from 54 ha to 800 ha respectively. These increases will not always be possible when temporary fences are erected, but certainly indicates that major increases in the effective grazing area are possible.

Some farmers indicated that future changes in farming practices include the establishment of orchards on areas currently used as lands. This will enlarge the effective grazing area.

In some cases, such as the Barvale study site, the area available as grazing could be enlarged by effective clearing of the Lantana camara thickets along the river. This a declared weed and should be cleared by land-users.

The available grazing in orchards seemed to play a very important role in hippo feeding during the dry season. This was surprising as Viljoen (1980) reported low hippo densities at orchards and cultivated lands along the Olifants and Blyde Rivers, and high densities at nature reserves and game farms. Contrary to the latter, this study revealed that the highest hippo densities occurred close to orchards, possibly because of the absence of natural areas. Orchards proved to be an important source of grazing for hippo during the dry season. Due to the limited time available for this study, no further attention could be given to this aspect. Future research should therefore be directed more specifically at the relative grazing use in the various units.

The development of an urban area close to the river, as seen at Matsulu, can also cause severe limitation of available area for hippo. Some of the housing structures were erected below the 1 in 10 year floodline. The proximity of high numbers of people so close to hippo creates the inherent danger of people being injured or killed. Town planners and municipalities will have to take note of the dangers of these developments, and must ensure that existing developing guidelines are enforced. In his set of guidelines for development along wetland areas, Wyatt (1993) recommends that all development should take place above the 1 in 50 year floodline. This recommendation was made considering both human safety and wetland ecology, and it is relevant to this study as it includes riverbanks as wetlands.

The conservation authority responsible for the hippo population, and/or the conservancy, will have to remain informed as to changes which might affect the size of the area available to hippo. Any reduction in the effective grazing area will cause a increase in the effective grazing density. At high effective densities it is likely that the available resources might be over-utilized.

The effective densities of hippo populations have often been calculated assuming that grazing extends 3.2 km from the margin of the waterbody, as stated by Owen-Smith (1988). Reported hippo densities in rivers further north in Africa are much higher than the mean density determined in this study, which was 3.9 hippo per km^2. Densities averaged 19 per km^2 along the Nile River above Murchison Falls in Uganda, 10 per km^2 along the Semliki River in Zaire, and 8 per km^2 along the Luangwa River floodplain in Zambia (Laws, 1968 : Naylor, Caughley, Abel & Liberg 1973). Reported hippo densities in southern Africa are much lower. Along rivers in the Kruger National Park hippo densities averaged 1.1 per km^2 (Pienaar, Van Wyk & Fairall, 1966). Along the Crocodile River inside the Kruger National Park the effective hippo density was 2.2 hippo per km^2, with local densities of up to 4.7 hippo per km^2 (Viljoen 1992).

From the above it can be seen that the effective hippo densities inside the Kruger Park appear slightly lower than those measured outside. Unavailable areas inside the park such as steep hills and closed bush were not subtracted. Hippo inside the Kruger Park compete for grazing with high numbers of other species. In contrast, the livestock numbers outside the Kruger National Park are low, except for Kaapmuiden.

According to the estimated numbers of hippos that can be sustained at the study sites, the current hippo numbers can be sustained at most study sites. It must be emphasized that these were broad estimations. More detailed information about grass production in the various units will definitely work towards more accurate estimations of numbers of hippos that can be sustained. The high stocking rate at Kaapmuiden should be a source of concern, as the over-utilization of the vegetation is inevitable.

4.7 The presence of a grazing gradient from the hippo pools.

At all the study sites, except Kaapmuiden, low livestock densities occurred in the areas available to hippo. Therefore, hippos generally had very little competition for the grazing.

In this study, both indicators of grazing impact, basal cover and grass height, revealed a grazing gradient, with the highest impact being closest to the hippo pools. Both indicators of grazing impact showed that significant impact extended about 400 m from the pools. TPA Nature Conservation should take note that heavily grazed patches will always occur close to hippo herds.

The median basal cover values for the intermediate and sparse physiognomical classes, and orchards was 4 %

(Table 9). This basal cover value seems low when compared to basal cover values in other studies (Morris & Muller 1970; Edwards & Nel 1973 ; van Wyk 1967). However, grass monitoring occurs mostly during the growing season, and the basal cover values in this study were collected during the late dry season. Total basal cover in grassland shows significant seasonal changes, with basal cover decreasing with rainfall (Morris & Muller 1970). Therefore, a comparison of the basal cover values observed in this study, with published values, will be difficult. Based on discussions with van Rooyen (personal communication [4]), the median basal cover value of veld, 4 %, at a distance of 400 m from the hippo pool, was regarded by TPA Nature Conservation as an acceptable value for the late dry season.

Hippo feeding areas have been described as a mosaic of heavily grazed patches, interspersed with tall grass, woody vegetation and bare patches (Lock, 1972 ; Olivier & Laurie, 1974). The grass height distribution in veld, (Figure 4.1), suggests that such a mosaic may be present at baseline 0. Through these grazing mosaics, hippos promote structural heterogeneity in the vegetation, which is a desirable conservation objective. However, according to Owen-Smith (1988), hippos may transform stands of tussock grasses to lawn-like expanses of low-growing creeping

[4] Dr. N. van Rooyen. Department of Botany, University of Pretoria.

species. No evidence of extensive "lawns" were found during this study.

Although the grazing impact measured in this study was regarded as acceptable impact by TPA Nature Conservation, this might change if hippo numbers are allowed to increase, or if the effective grazing area becomes smaller. Several authors indicated that where local concentrations of hippos reached high effective densities, extensive grassland degradation was occurring (Bere 1959 ; Petrides & Swank 1965 ; Field, 1970 ; Lock 1972 ; Olivier & Laurie 19 ; ; Marshall & Sayer 1976 ; O'Connor & Campbell 1986 ; Tembo 1987). With reduced vegetation cover, soil erosion may be accelerated, and due to reduced fire frequency woody scrub may invade grassland (Owen-Smith 1988). Therefore, the relevant conservation agency, and/or the planned conservancy should monitor the numbers of hippos and their impact on the available grazing. It must also be remembered that deterioration in the grass cover generally takes place in association with below average rainfall.

5. Conclusion

The objective of this study was to provide a basis for the determination of acceptable hippo densities in the Crocodile River, outside the Kruger National Park. From the previous discussion it is evident that numerous factors have complicated the achievement of this objective. It is also evident that variables, such as rainfall, rotational cropping, variability in available grazing area and potential variability in the attitudes of land-users make it virtually impossible to determine the acceptable hippo densities.

Information have been gathered regarding all of the key questions. In some instances the observations done in this study could be used as the first observations in long-term monitoring.

To conclude this report, it is recommended that the continued monitoring of the situation be carried out by all concerned, together with the annual aerial census. TPA Nature Conservation should continue to react to complaints of hippo damage, by checking for preventative measures, followed by the removal of problem hippo, if deemed necessary. Land-users should be assisted in their efforts to form conservancies.

6. References

ANDREW, M.H. 1988. Grazing impact in relation to livestock watering points. Tree 3(12) : 336 - 339.

ANSELL, W.F.H. 1965. Hippo census on the Luangwa River. The Puku 3 : 15 - 27.

ATTWELL, R.I.G. 1963. Surveying Luangwa hippo. The Puku 1 : 29 - 50.

BEARDALL, G.M., JOUBERT, S.C.J. and RETIEF, P.F. 1984. An analysis of the use of correspondence analysis for the analysis of herbivore-habitat selection. S.Afr.J.Wildl.Res. 14(3) : 79 - 88.

BERE, R.M. 1959. Queen Elizabeth National Park : Uganda. The Hippopotamus problem and experiment. Oryx 5(3) : 116 - 124.

BOTHMA, J. DU P. (Ed.) 1986. Wildplaasbestuur. Van Schaik, Pretoria.

COUGHENOUR, M.B. 1991. Spatial components of plant-herbivore interactions in pastoral, ranching and native ungulate ecosystems. J.Range Mgmt. 44(6) : 530 - 542.

DANCKWERTS, J.E., 1989. The animal plant interaction. In : Veld management in the Eastern Cape. Eds. J.E. Danckwerts and W.R. Teague. Pasture Research section, Eastern Cape.

DU PLESSIS, S.F. 1969. The past and present distribution of the Perrissodactyla and Artiodactyla in Southern Africa. MSC thesis, University of Pretoria.

EDWARDS, P.J. 1981. Terms describing aspects of vegetation and its management. In: Veld and pature management, Ed. N.M. Tainton. Shuter & Shooter, Pietermaritzburg.

EDWARDS, P.J. & NEL, S.P., 1973. Short term effects of fertilizer and stocking rates on the Bankenveld: 1. Vegetational changes. Proc.Grassl.Soc.Sth.Afr. 8: 83 - 88.

ELTRINGHAM, S.K. 1974. Changes in the large mammal communities of Mweya peninsula, Rwenzori National Park, Uganda, following the removal of hippopotamus. J.Appl.Ecol. 11(3) : 855 - 865.

ESTES, R.D. 1992. The Behaviour Guide to African Mammals. The University of California Press, Berkeley, Los Angeles.

FIELD, C.R. 1970. A study of the feeding habits of the hippopotamus (Hippopotamus amphibius Linn.) in the Queen Elizabeth Park, Uganda, with some management implications. Zool. Afr. 5 : 71 - 86.

GREENACRE, M.J. 1985. Correspondence analysis. SIMCA 1.2. Program for IBM compatibles.

HALTENORTH, T. & DILLER, H. 1977. A Field Guide to the Mammals of Africa, including Madagascar. Collins, London.

JOUBERT, S.C.J. 1967. Wildlife of Southern Africa : The hippopotamus. Honours thesis. University of Pretoria.

KARSTAD, E.L. & HUDSON, R.J. 1984. Census of Mara River hippopotamus (Hippopotamus amphibius), southwest Kenya, 1980-1982. Afr. J. Ecol. 22 : 143 - 147.

LAWS, R.M. 1968. Interactions between elephant and hippopotamus populations and their environments. Proc. of the Symposium on Wildlife, Nairobi. E.Afr. 'Agric. & Forest. J. XXXIII : 140 - 147.

LAWS, R. M. & CLOUGH, G. 1966. Observations on reproduction in the hippopotamus, Hippopotamus amphibius, Linn. From: Comparative Biology of Reproduction in Mammals. Symposia of Zool. Soc. London, no 15 : 117 - 139. Academic Press London.

LOCK, J.M. 1972. The effects of hippopotamus grazing on grasslands. J. Ecol. 60 : 445 - 467.

LUCK, C.P. & WRIGHT, P.G. 1959. The body temperature of the hippopotamus. J. Physiol. 147 : 53 - 54.

MACKIE, C. 1976. Feeding habits of the hippopotamus on the Lundi River, Rhodesia. Arnoldia 7 : 1 - 16.

MEISSNER, H.H., 1982. Theory and application of a method to calculate forage intake of wild southern African ungulates for the purposes of estimating carrying capacity. S.Afr.Wildl.Res. 12 : 41 - 47.

MENTIS, M.T. 1981. The animal as a factor in pasture and veld management. In: Veld and pature management, Ed. N.M. Tainton. Shuter & Shooter, Pietermaritzburg.

MORRIS J.W. & MULLER, P.J., 1970. Seasonal variation of grassland basal cover. Proc.Grassl.Soc.Sth.Afr. 5 : 145 - 152.

MUELLER-DOMBOIS, D. & ELLENBERG, H., 1974. Aims and methods of vegetation ecology. John Wiley & Sons, New York.

NAYLOR, J.N., CAUGHLEY, G.J., ABEL, N.O. & LIBERG, O.N. 1973. Luangwa valley Conservation and Development Project, Zambia. Game management and habitat manipulation. Rome : FAO Report.

O'CONNOR, T.G. & CAMPBELL, B.M. 1986. Hippopotamus habitat relationships on the Lundi River, Gonarezhou National Park, Zimbabwe. Afr. J. Ecol. 24, 7 - 26.

OGEN-ODOI, A.A. & DILLWORTH, T.G., 1987. Effects of burning and hipopotamus grazing on savanna hare habitat utilization. Afr.J.Ecol. 25: 47 - 50.

OLIVIER, R.C.D. & LAURIE, W.A., 1974. Habitat utilization by hippopotamus in the Mara River. E. Afr. Wild. J. 12 : 249 - 271.

OWEN-SMITH, R.N. 1988. Megaherbivores - The influence of very large body size on ecology. Cambridge University Press, Cambridge.

PETRIDES, G.A. & SWANK, W.G. 1965. Population densities and range carrying capacity for large mammals in Queen Elizabeth National Park, Uganda. Zoologica Africana 1(1) : 209 - 225.

PIENAAR, U. DE V., VAN WYK, P. & FAIRALL, N. 1966. An experimental cropping scheme of hippopotamus in the Letaba River of the Kruger National Park. Koedoe 9 : 1 - 33.

SCOTCHER, J.S.B. 1978. Hippopotamus numbers and movements in Ndumu Game Reserve. The Lammergeyer 24 : 5 - 12.

SCOTCHER, J.S.B, STEWART, D.R.M & BREEN, C.M. 1978. The diet of the hippopotamus in the Ndumu Game Reserve, Natal, as determined by faecal analysis. S.Afr.J.Wildl. Res. 8(1) : 1 - 11.

SIDNEY, J. 1965. The past and present distribution of some African ungulates. Transactions of the Zoological Society of London. Published by the Society. 30 : 89 - 130.

SPINAGE, C.A. 1962. Animals of East Africa. Collins, London.

SMITHERS, R.H.N. 1983. The Mammals of the Southern African Subregion. Pretoria, University of Pretoria.

TAINTON, N.M., 1981. Veld and Pasture Management in South Africa. Shuter & Shooter, Pietermaritzburg.

TAYLOR, R.H. 1987, unpublished manuscript. Monitoring of hippopotamus populations in Natal & KwaZulu.

TEMBO, A. 1987. Population status of the hippopotamus on the Luangwa River, Zambia. Afr. J. Ecol. 25 : 71 - 77.

TROLLOPE, W.S.W., 1978. Fire behaviour - a preliminary study. Proc.Grassl.Soc.Sth.Afr. 13 : 123 - 128.

TROLLOPE, W.S.W., 1984. Fire in savanna. In: Ecological effects of fire in South African ecosystems. Eds. P.deV. Booysen and N.M. Tainton.

VAN WYK, J.J.P , 1967. Ekologiese studies in verband met die agteruitgang en rehabilitasie van grasbedekking in die Krokodilriviervallei, noordwes van Thabazimbi. Sth.Afr.Med.J. 41 : 1248 - 1253.

VESEY-FITZGERALD, D.F. 1960. Grazing succession among East African game animals J.Mammal. 41 : 161 - 172.

VILJOEN, P.C. 1980. Distribution and numbers of the hippopotamus in the Olifants and Blyde Rivers. S. Afr. J. Wildl. Res. 10 : 129 - 132.

VILJOEN, P.C. 1989 unpublished manuscript. Census results and culling quotas for hippo in the Kruger National Park. National Parks Board, Skukuza.

VILJOEN, P.C., 1992. Census results and culling quotas for hippopotami in the Kruger National Park : 1991. Scientific Services Section, National Parks Board, Skukuza.

VILJOEN, P.C., 1993. Census results and culling quotas for hippopotami in the Kruger National Park : 1992. Scientific Services Section, National Parks Board, Skukuza.

WHITLOW, R., 1988. Land degradation in Zimbabwe : A geographical survey. Department of Natural resources.

WHYTE, I.J. 1988, unpublished. Report on hippopotamus culling operations (87.07.20 - 87.09.11), a review of the current population management policy and culling technique and proposals to the Standing Committee for Wildlife Management for the future management of the Kruger National Park population.

WYATT, J., 1993. Wetlands - Field Guide. Renfreight Wetlands Campaign.

YOACIEL, S.M. 1981. Changes in the populations of large herbivores and in the vegetation community in Mweya Peninsula, Rwenzori National Park, Uganda. Afr. J. Ecol. 19 : 303 - 312.

ZAR, J.H. 1984. Biostatiscal analysis. (Second edition). Prentice Hall, New Jersey.

ACKNOWLEDGEMENTS

My promotor, Professor R.N. Owen-Smith.

The Transvaal Provincial Adminstration, Chief Directorate of Nature and Environmental Conservation who allowed me to do this course, and provided funding for specific parts of the field work.

Staff at the TPA Nature Conservation, Eastern Region Office, who supported me during the study, in particular :

- Kevan Zunckel for guidance, encouragement and support;
- S. Basson, B. Kroh, M. McKibbon, R. Roux, L. Steyn and E. Rohm who helped me during specific parts of the study;
- J. Malwane and M. Twala for able support during the fieldwork.

My wife, Desiree, and my family for patience, encouragement and support during the study.

Table 1: Results of the hippopotamus censuses in the Crocodile River (September 1992)

River section	Length of section (km)	Hippo census		Hippo density (no/km)
		Aerial census	Ground count	
Kruger Park boundary - Railway tunnel	10.6	22	26	2.5
Railway tunnel - Crocodile River Gorge(Wes	11.6	0	0	0.0
Gorge(West) - Krokodilpoort Station.	2.3	0	0	0.0
Krokodilpoort Station - Karino	8.7	11	13	1.5
Karino - Halls weir	19.4	0	2	0.1
Halls weir - Broham weir	13.0	18	18	1.4
Broham weir - Alkmaar bridge	7.5	10	14	1.9
Alkmaar - Schagen bridge	7.0	0	3	0.4
Schagen - Elands River confluence	14.7	7	12	0.8
Elands River - Braam Raubenheimer Dam	46.5	0	0	0.0
TOTAL	141.3	68	88	
MEAN				0.6

* Note hippo density calculated from ground count data

Table 2: Comparison of the gradient in the Crocodile River hippo density in the different river sections

River section	Hippo density (no/km)	River gradient (m/km)
Kruger Park boundary - Railway tunnel	2.5	3.3
Railway tunnel - Crocodile River Gorge (West)	0.0	9.9
Gorge (West) - Karino bridge	1.5	2.9
Karino - Halls weir	0.1	5.6
Halls weir - Broham weir	1.4	2.2
Broham weir - Alkmaar bridge	1.9	2.0
Alkmaar - Schagen bridge	0.4	3.5
Schagen - Elands River confluence	0.8	2.4
Elands River - Raubenheim Dam	0.0	8.4
MEAN	0.6	5.8

Table 3 : The average monthly rainfall figures and the number of problem hippo shot in the Nelspruit area and Hoedspruit area

Month	Mean monthly rainfall (mm)			Number of hippo s[illegible]		
Month	Nelspruit	Hoedspruit	Mean	Nelspruit	Hoedspruit	Total
January	172	110	141	2	0	2
February	124	77	100.5	2	1	3
March	86	60	73	7	1	8
April	49	20	34.5	4	8	12
May	12	10	11	3	8	11
June	6	5	5.5	10	3	13
July	11	6	8.5	8	3	11
August	9	5	7	6	6	12
September	28	19	23.5	6	3	9
October	69	42	55.5	15	5	20
November	112	60	86	5	8	13
December	128	90	109	5	1	6

Table 4 : Hippo destroyed in the Nelspruit area between 1980 and 1992.
(Records with TPA Nature Conservation, Nelspruit)

Hippo age group and sex	Reason for destroying				Total number destroyed
	Crop damage	Aggression or danger	Injuries		
			Fighting	Other	
Adult male	15	7	3	1	26
Sub-adult male	3	1	5	1	10
Adult female	5	1	0	2	8
Sub-adult female	0	0	0	0	0
Total	23	9	8	4	44

Table 5 : Results from the questionairre circulated among land users in the study area, September 1992.

Question	Reply (%)		
	Yes	No	Neutral
Do you want hippo in the river ?	92.5	7.5	0
Would you support a hippo conservancy	75.0	7.5	17.5
Did you take any preventative measures	42.5	57.5	0
Was this measure an electric fence ?	94.1	5.9	0
Was the electric fence successful ?	81.2	6.2	12.6

* Note, 50 questionnaires were circulated, of which 40 were returned. (80 % response)

Table 6 : The average distance between the river and hippo barriers, per study site.

Study site	Average barrier distance (m	Average distance of main hippo barriers (m)					
		Railway lines	Roads	Electric fences	Fences	Disturbed areas	Steep kopple
Kaapmuiden	273	457	345	76	None	40	150
Karino	306	255	411	47	240	73	213
Cairn/Halls	412	461	559	63	137	130	none
Alkmaar	424	313	583	70	167	115	287
Barvale	265	260	265	74	280	225	153
Mean	336	349	433	66	206	117	201

Table 7 : The sizes of the relative homogenous units at the study sites.

Study site	Veld	Orchards	Lands	Bush	Steep hill	Disturbed area
Kaapmuiden	324	179	6	33	6	11
Karino	292	99	198	6	6	19
Cairn/Halls	205	157	328	41	74	16
Alkmaar	343	223	188	60	26	17
Barvale	126	33	137	155	93	5
Mean	258	138	171	59	41	14

Table 8 : The sizes of the areas available to hippo, the effectice grazing areas, and the effectice grazing densities at the study sites.

Study site	Area available to hippo (ha)	Effective grazing areas (ha)	Effective grazing density (no.km)
Kaapmuiden	559	514	5.1
Karino	620	458	2.8
Cairn/Halls	821	434	3.5
Alkmaar	957	574	2.4
Barvale	549	205	5.9
Mean	681	437	3.7

Table 9: The current and recommended hippo stocking rate at the study sites, expressed as Meisner's (1982) livestock units (LU)

Study site	Effective grazing area (ha)	Hippo livestock units	Cattle livestock units	Total number of livestock units	Recommended number of livestock units	Total stocking rate (ha/LU)
Kaapmuiden	514.0	74.3	260.0	334.3	93.4	1.5
Karino	458.0	37.1	3.0	40.1	79.3	11.4
Cairn/Halls	434.0	51.4	0.0	51.4	77.3	8.4
Alkmaar	574.0	40.0	7.0	47.0	110.0	12.2
Barvale	205.0	34.4	0.0	34.4	33.0	6.0

Table 10: The median basal cover values of physiognomic classes and land-use classes at the different baselines.

Distance from pool	% Basal cover medians					
	Physiognomic classes			Land-use activities		
	closed	intermediate	open	orchard	old land	lands
0	0	2	0	2	0	0
400	0	4	4	4	0	0
800	0	4	4	4	0	0
1200	0	6	4	4	2	0
1600	0	6	6	4	4	0
2000	0	8	8	4	2	0

Figure 1 : The Crocodile River outside the Kruger National Park, showing locations mentioned in the text.

Major roads

Minor roads

Railway line

River

Study site

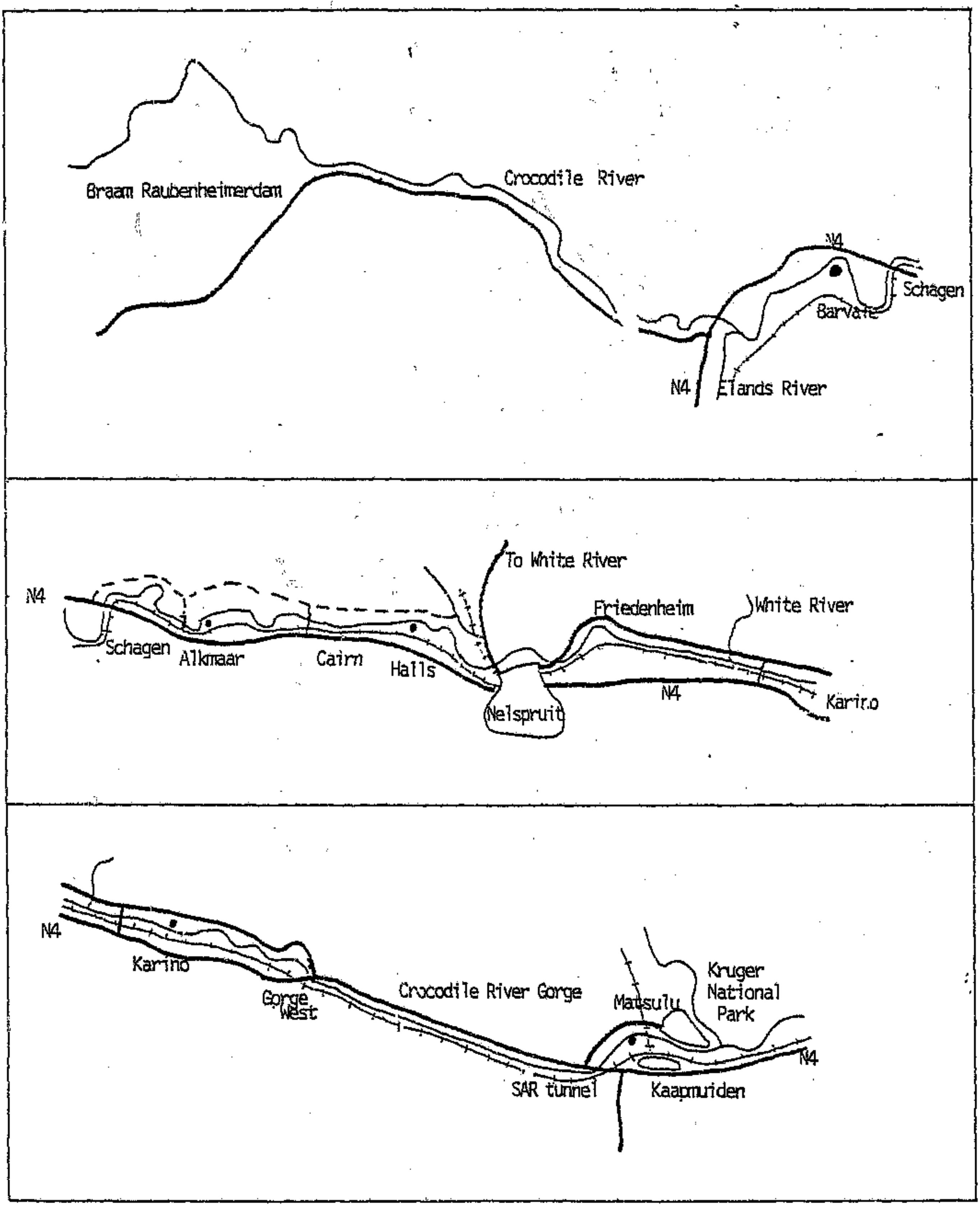
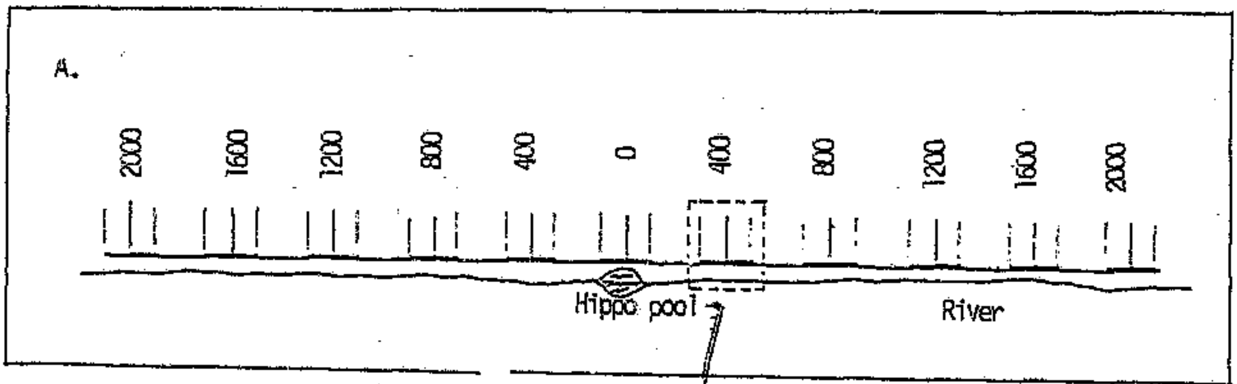

Braam Raubenheimerdam
Crocodile River
N4
Schagen
Barvale
N4
Elands River
To White River
N4
Friedenheim
White River
Schagen
Alkmaar
Cairn
Halls
Nelspruit
N4
Karino
N4
Karino
Gorge West
Crocodile River Gorge
Matsulu
Kruger National Park
N4
SAR tunnel
Kaapmuiden

Figure 2: A diagram of the outlay of study sites to determine grazing impact of hippo along the Crocodile River.

Figure 2 A: A diagram of the outlay of the set of baselines.

Figure 2 B: A diagram of the outlay of transect lines with quadrate distances indicated on transect lines.

2


A.
2000
1600
1200
800
400
0
400
800
1200
1600
2000
Hippo pool
River

2

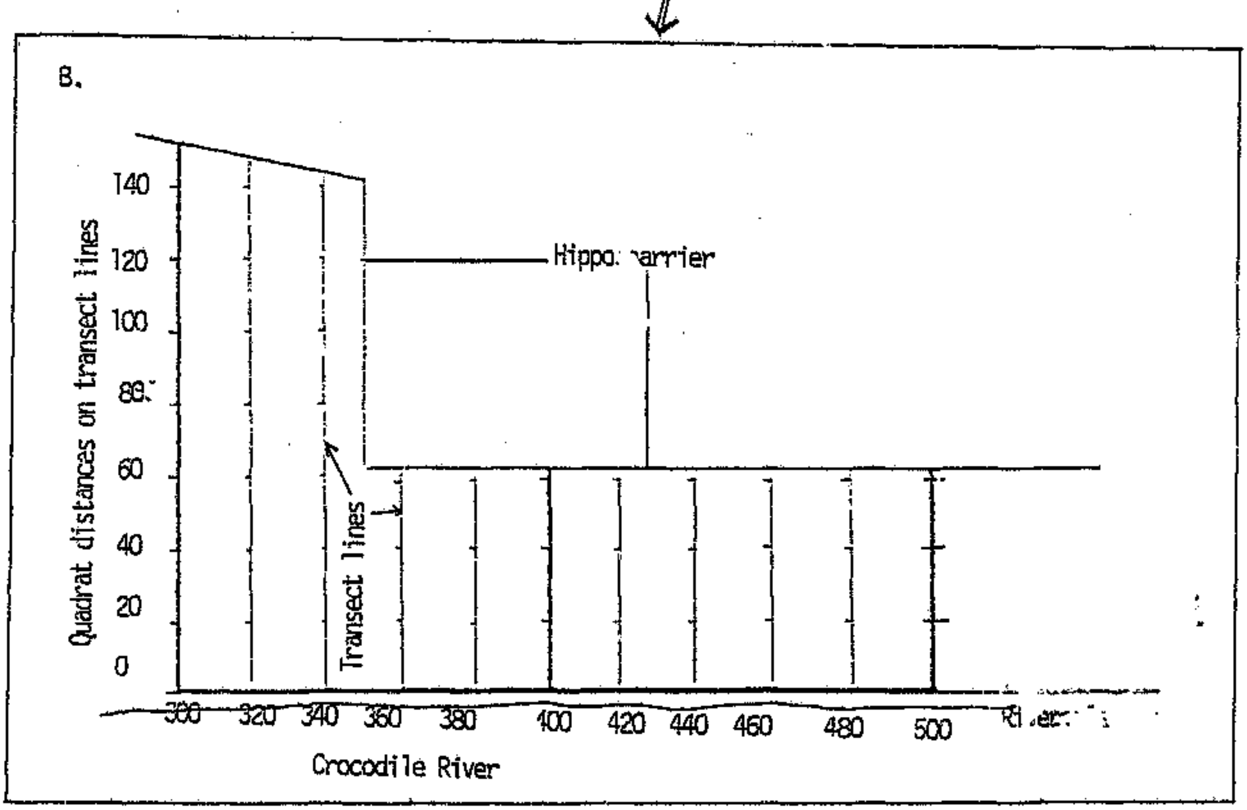

B.
Quadrat distances on transect lines
140
120
100
80
60
40
20
0
Hippo barrier
Transect lines
300
320
340
360
380
400
420
440
460
480
500
Crocodile River

FIGURE 3: GRAPHICAL DISPLAY OF CORRESPONDENCE ANALYSIS

S = RIVER SECTIONS	S1	= MONTROSE - BADFONTEIN
	S2	= SCHAGEN - MONTROSE
	S3	= ALKMAAR - SCHAGEN
	S4	= BROHAM - ALKMAAR
	S5	= HAALS WEIR - BROHAM
	S6	= KARINO - HALLS WEIR
	S7	= KROKODIL POORT - KARINO
	S8	= KROKODIL POORT
	S9	= KAAPMUIDEN - KROKODIL POORT
g = RIVER GRADIENT	g1	= 0 - 3.3 M/KM
	g2	= 3.4 - 6.6 M/KM
	g3	= 6.7 - 9.9 M/KM

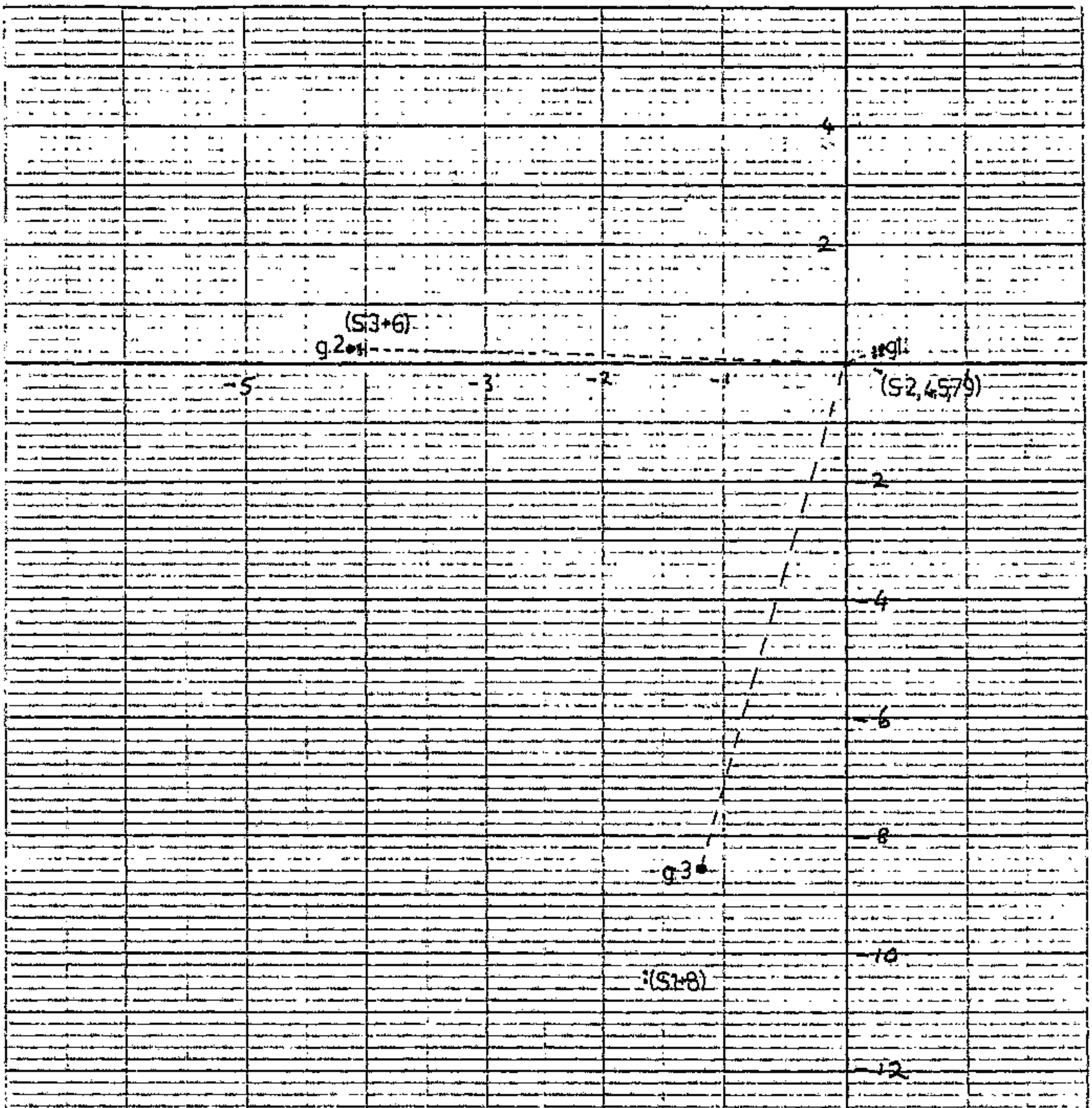


FIGURE 3 GRAPHICAL DISPLAY OF CORRESPONDENCE ANALYSIS

S= RIVER SECTION
g= GRADIENT

FIGURE 4.1 DISTRIBUTION OF BASAL COVER IN VELD, (0-100M FROM THE RIVER)

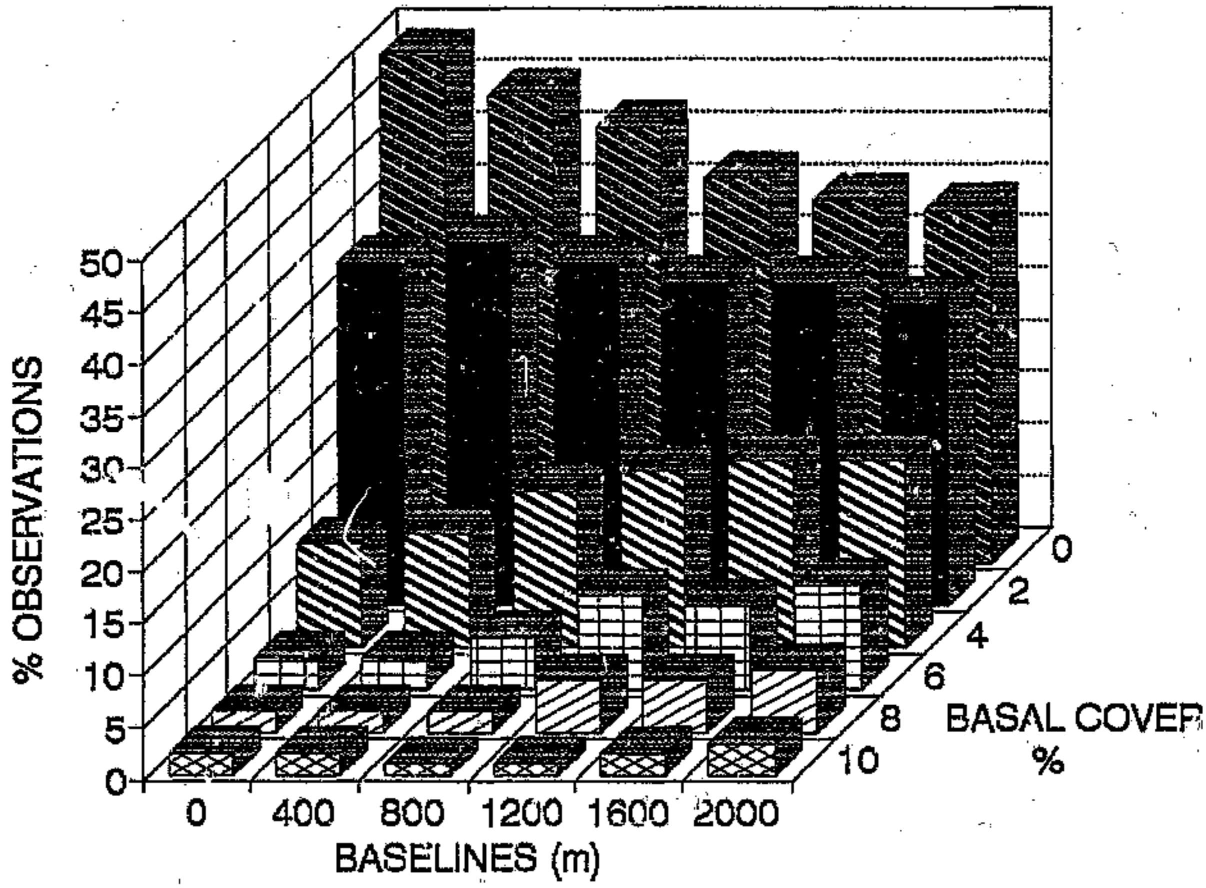


FIGURE 4.2 DISTRIBUTION OF BASAL COVER IN CITRUS ORCHARDS,(0-100 M FROM RIVER)

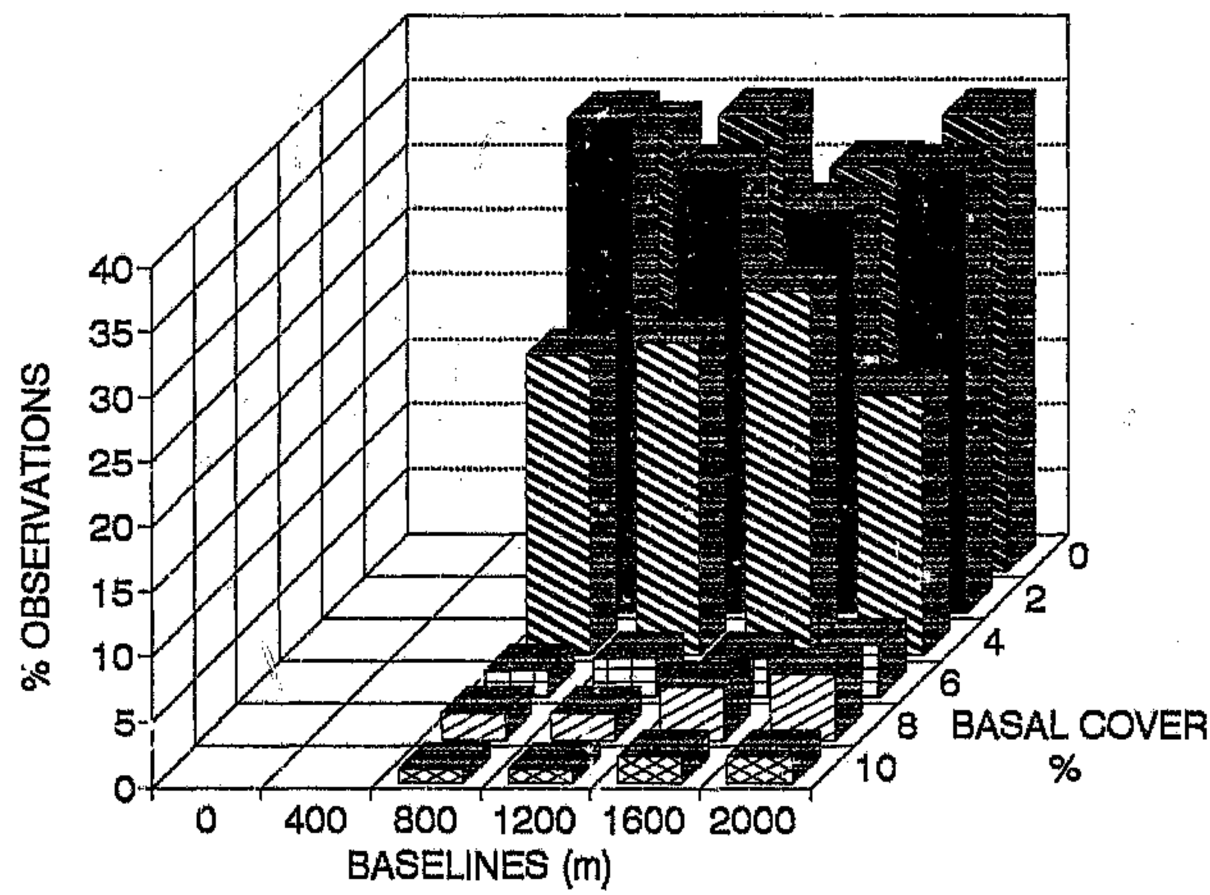


FIGURE 4.3 DISTRIBUTION OF BASAL COVER IN PECAN ORCHARDS, (0-100M FROM RIVER)

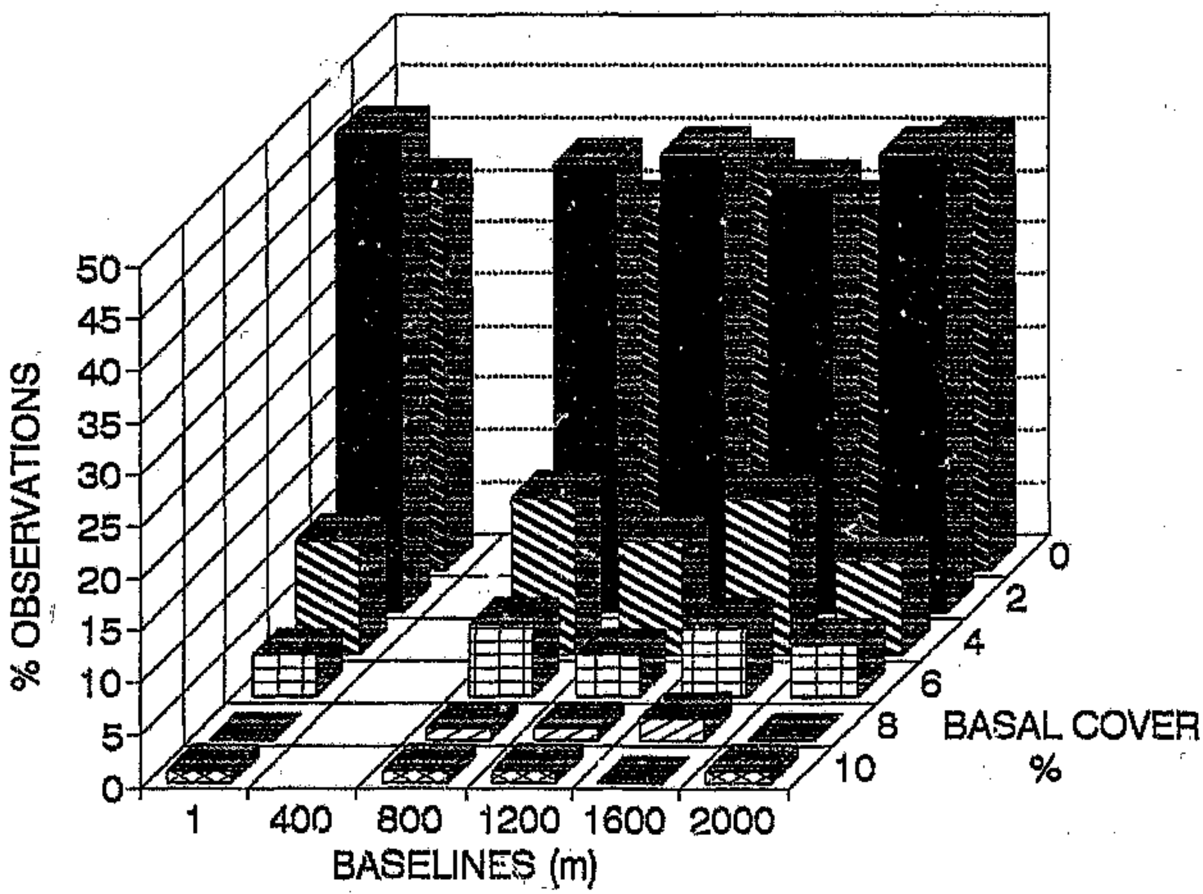


FIGURE 4.4 DISTRIBUTION OF BASAL COVER IN OLD LANDS, (0-100 M FROM THE RIVER)

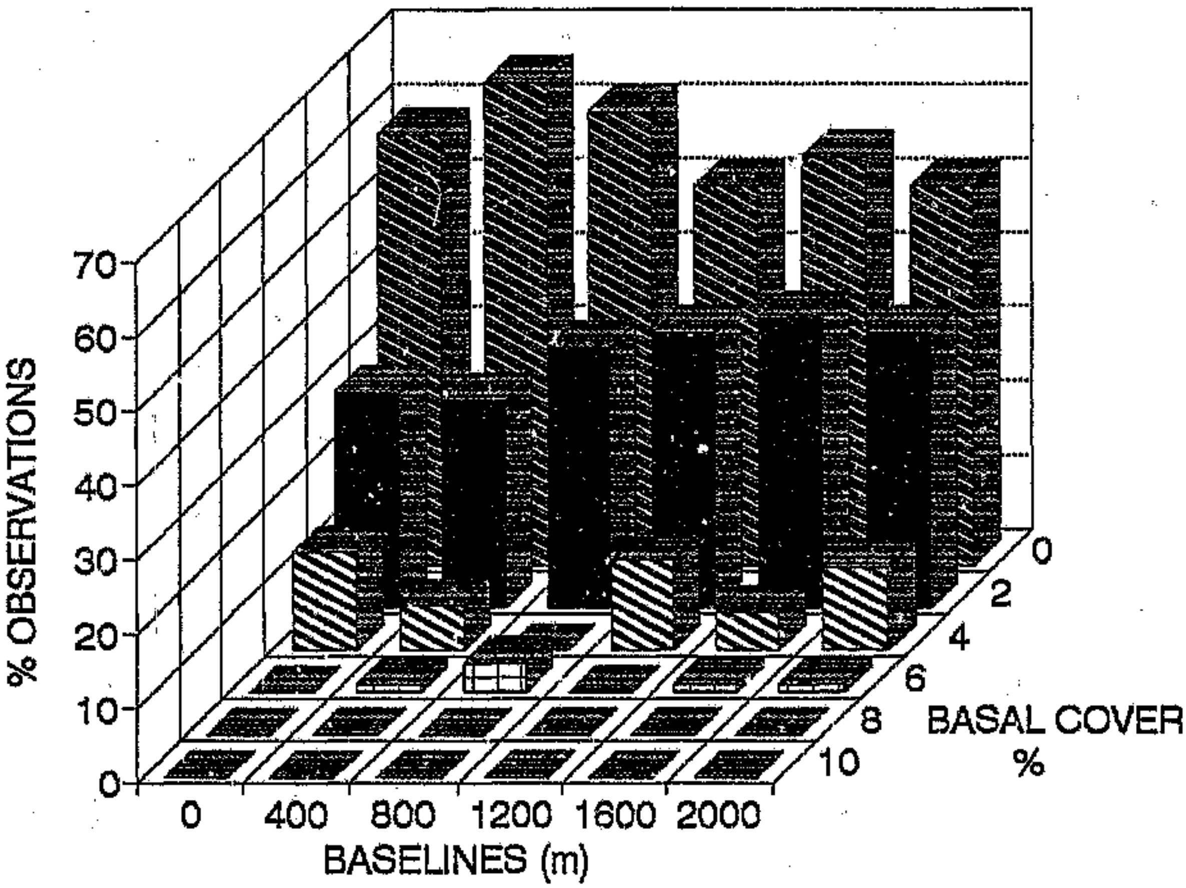


FIGURE 4.5 DISTRIBUTION OF BASAL COVER
IN CLOSED BUSH, (0-100M FROM RIVER)

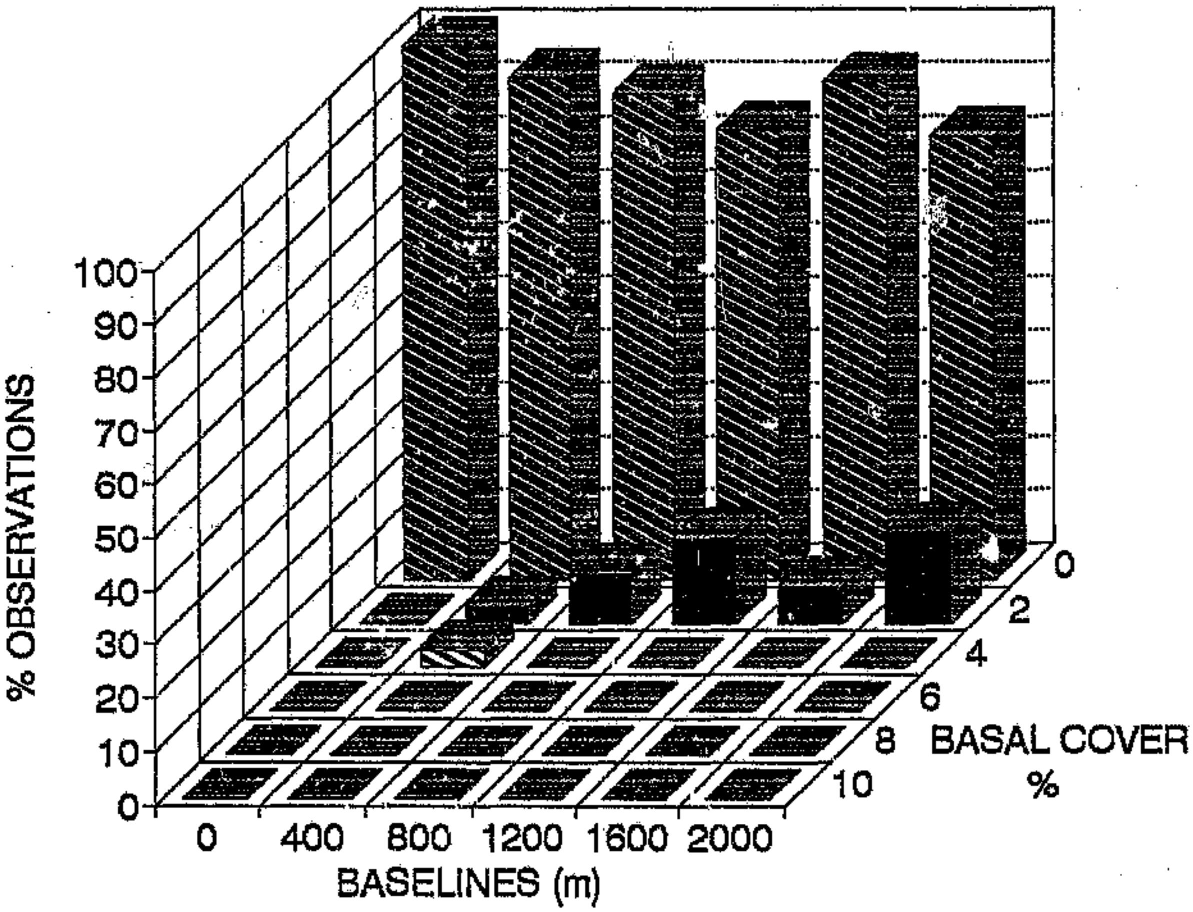


FIGURE 5.1 DISTRIBUTION OF GRASSHEIGHT IN VELD, (0-100M FROM RIVER)

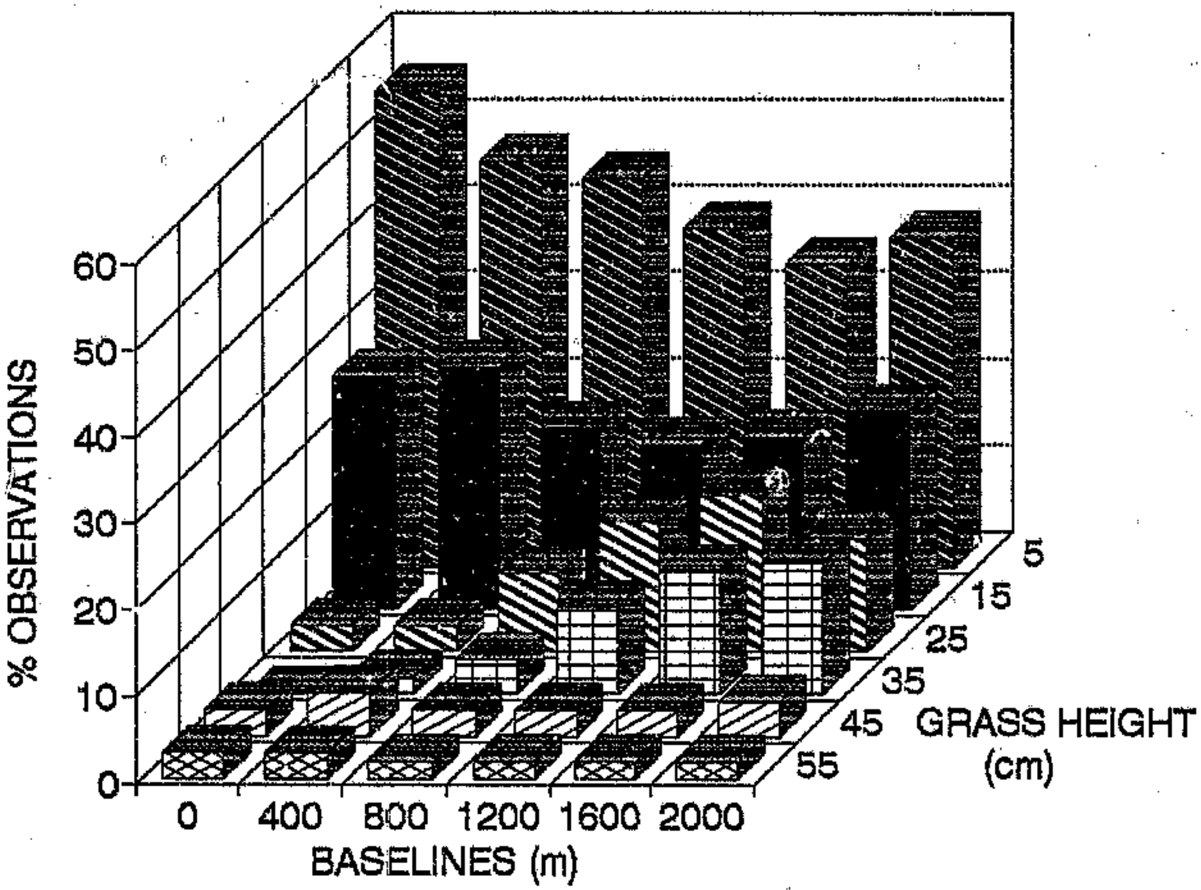


FIGURE 5.2 DISTRIBUTION OF GRASS HEIGHT IN CITRUS ORCHARDS, (0-100M FROM RIVER)

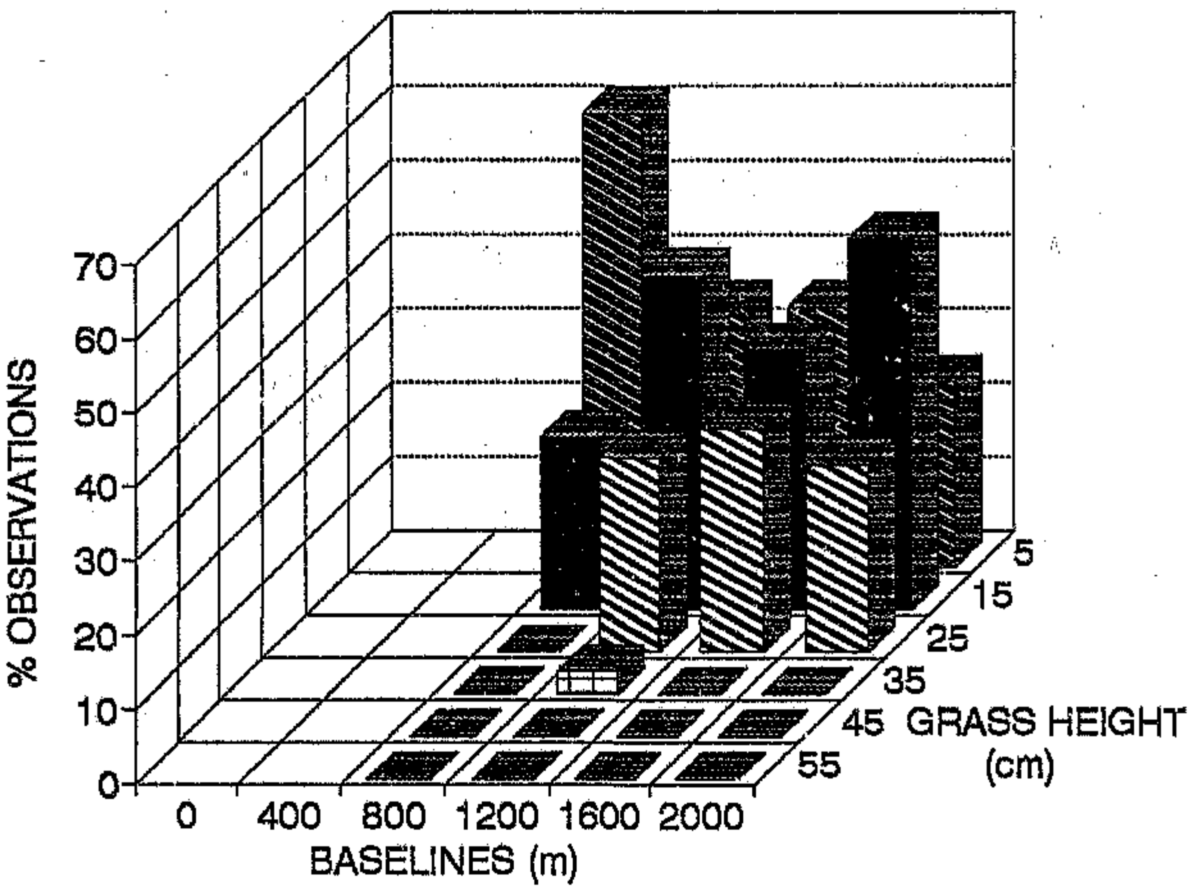


FIGURE 5.3 DISTRIBUTION OF GRASS HEIGHT IN PECAN ORCHARDS, (0-100M FROM RIVER)

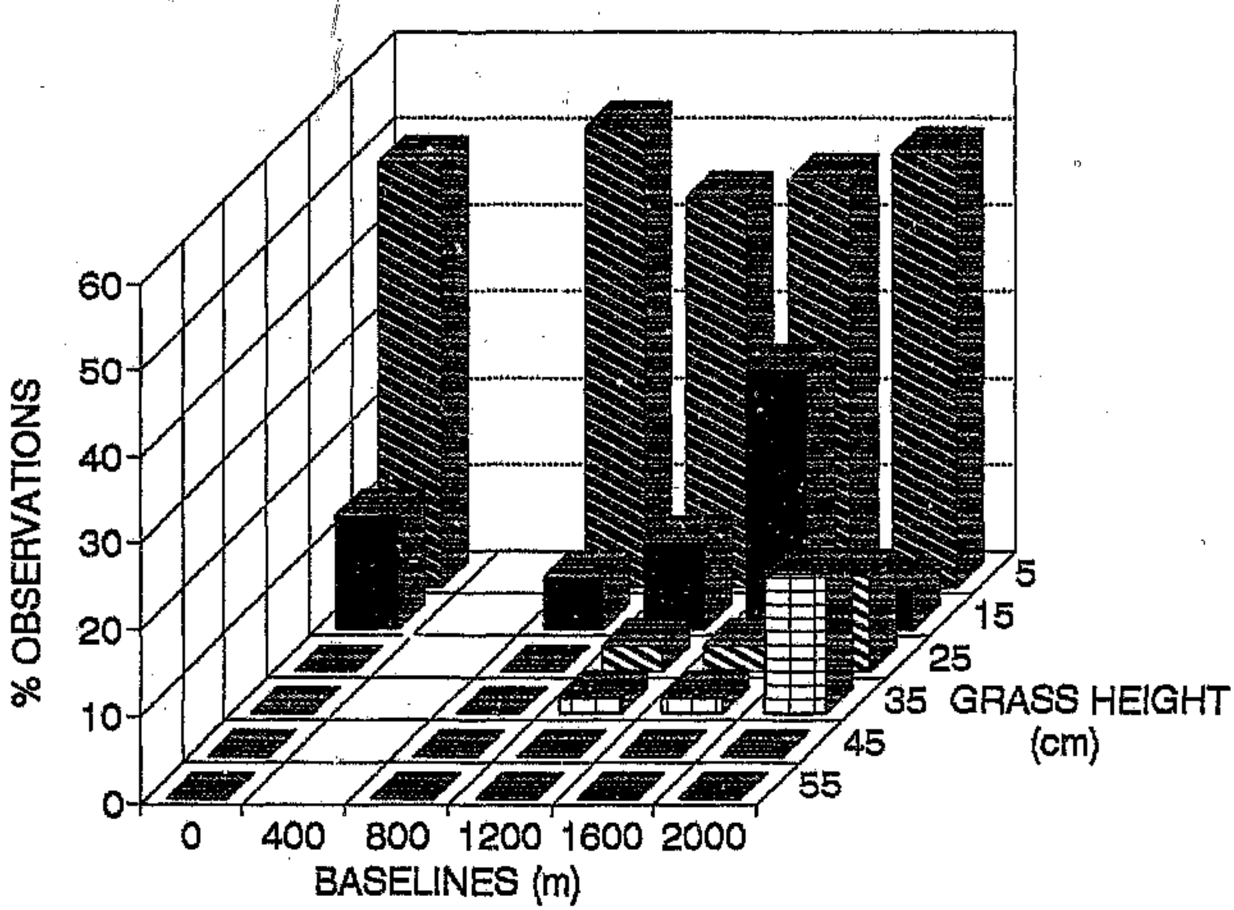
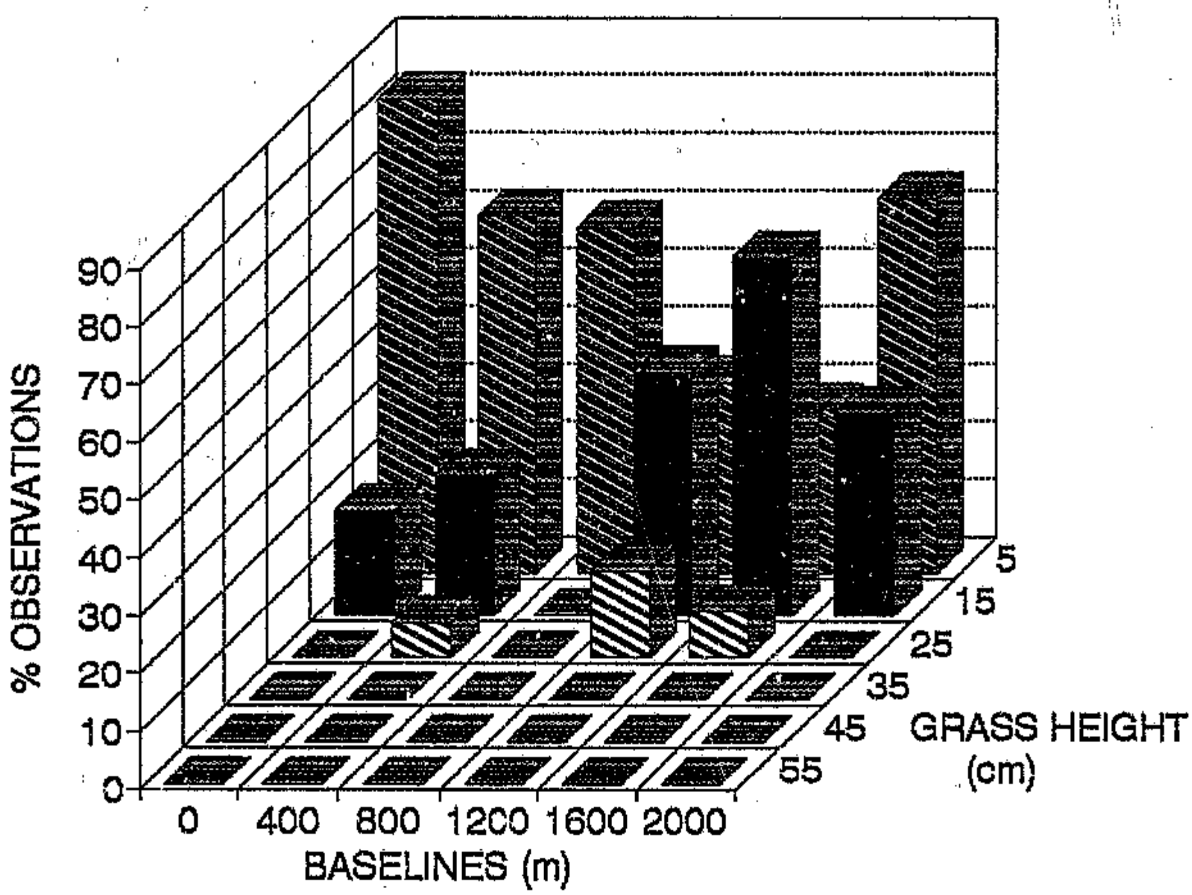


FIGURE 5.4 DISTRIBUTION OF GRASS HEIGHT IN OLD LANDS, (0-100 M FROM RIVER)



APPENDIX A

HIPPO QUESTIONNAIRE

NAME: ______________________________ PHONE: ________________
ADDRESS: ____
____
____

1. REGISTERED FARM NAME & NUMBER: ________________________

2. FARM SIZE: ____________________________ HA

3. FORMS OF LANDUSE: TYPE (if applicable): SIZE (HA)
(Cash crops, tobacco, orchards, pastures, livestock, eg.)

____
____
____
____
____
____
____
____
____
____

4. ARE THERE ANY HIPPO IN THE IMMEDIATE VICINITY OF YOUR FARM? (Permanent, temporary) ________________________
____
____

5. WHAT TIME OF THE YEAR ARE THE HIPPO THERE?
____
____

6. HAS DAMAGE BY HIPPO OCCURED ON YOUR PROPERTY?
WHAT WAS DAMAGED? ______________________________
____
____

WHAT TIME OF THE YEAR? ______________________________
____
____

WHAT WAS THE EXTENT OF THE DAMAGE? ____________________
____
____

7. WERE ANY PRECAUTIONS TAKEN? ____________________

WHAT? ____________________

DID IT WORK? ____________________

____

8. DO YOU USE THE AREA THAT HIPPO SOMETIMES UTILISE FOR GRAZING OF OTHER ANIMALS TOO? YES/NO

IF YES, WHAT? ____________________

ANIMAL NUMBERS ____________________

9. CAN HIPPO CONTINUE TO UTILISE THIS AREA FOR GRAZING?

____

10. HOW MANY HIPPO DO YOU THINK OCCUR IN THE AREA?

____

WE COUNTED __________ BETWEEN ____________________

DO YOU AGREE WITH IT? ____________________

____

____

11. WHAT IS YOUR OPINION ON THE FUTURE OF HIPPO IN THE CROCODILE RIVER, OUTSIDE THE KRUGER NATIONAL PARK?

DO YOU WANT HIPPO IN YOUR AREA? ____________________

HOW SHOULD THE HIPPO POPULATION BE MANAGED? ____________________

____

____

____

____

____

____

11. WE CALCULATED THE AREA AVAILABLE TO HIPPO IN YOUR AREA AS ____________ HA, HOW MANY HIPPO DO YOU THINK SHOULD BE ALLOWED IN THE AREA? ____________________

____

OTHER COMMENTS: ____________________

____

____

____

Appendix B

Recommended stocking rates at the study sites, according to prescribed stockingrates used by Department of Agriculture in the Eastern Transvaal Lowveld

Relative homogenous unit		STUDY SITE				
VELD		Kaapmuiden	Karino	Cairn/Halls	Alkmaar	Barvale
	Effective grazing are	335	291	205	343	126
	Recommended stocking rate (ha/LU)	6	6	5	5	5
	Recommended livestock units	55.8	48.5	41.0	68.6	25.2
CITRUS/LITCHI ORCHARD		Kaapmuiden	Karino	Cairn/Halls	Alkmaar	Barvale
	Effective grazing are	148	99	89	133	0
	Recommended stocking rate (ha/LU)	4.0	4.0	4.0	4.0	4.0
	Recommended livestock units	37.0	24.8	22.3	33.3	0.0
PECAN ORCHARD		Kaapmuiden	Karino	Cairn/Halls	Alkmaar	Barvale
	Effective grazing are	0	0	65	12	33
	Recommended stocking rate (ha/LU)	9.0	9.0	9.0	9.0	9.0
	Recommended livestock units	0.0	0.0	7.2	1.3	3.7
OLD LANDS		Kaapmuiden	Karino	Cairn/Halls	Alkmaar	Barvale
	Effective grazing are	6.0	66.0	75.0	86.0	46.0
	Recommended stocking rate (ha/LU)	11.0	11.0	11.0	11.0	11.0
	Recommended livestock units	0.5	6.0	6.8	7.8	4.2
RECOMMENDED TOTAL OF LIVESTOCK UNITS		93.4	79.3	77.3	111.0	33.0

APPENDIX .C.....

KRUSKAL-WALLIS ONE-WAY ANALYSIS OF VARIANCE FOR 265 CASES
DEPENDENT VARIABLE IS MEDBC
GROUPING VARIABLE IS ENVTYPE$

GROUP	COUNT	RANK SUM
CLOSE	23	1155.500
OPEN	54	9233.500
SPARSE	47	6326.000
ORCHARD	80	12413.500
OLDLAND	61	6116.500

KRUSKAL-WALLIS TEST STATISTIC = 71.586
PROBABILITY IS 0.000 ASSUMING CHI-SQUARE DISTRIBUTION WITH 4 DF

KRUSKAL-WALLIS ONE-WAY ANALYSIS OF VARIANCE FOR 265 CASES
DEPENDENT VARIABLE IS MEDBC
GROUPING VARIABLE IS DIST2

GROUP	COUNT	RANK SUM
0.000	39	5255.000
400.000	47	5760.500
800.000	53	6187.000
1200.000	45	6403.500
1600.000	42	5326.500
2000.000	39	6312.500

KRUSKAL-WALLIS TEST STATISTIC = 12.041
PROBABILITY IS 0.034 ASSUMING CHI-SQUARE DISTRIBUTION WITH 5 DF

KRUSKAL-WALLIS ONE-WAY ANALYSIS OF VARIANCE FOR 265 CASES
DEPENDENT VARIABLE IS MEDBC
GROUPING VARIABLE IS DIST1

GROUP	COUNT	RANK SUM
0.000	27	2494.500
20.000	26	2793.500
40.000	28	3622.000
60.000	27	3366.000
80.000	25	3065.500
100.000	24	3595.500
120.000	23	3128.000
140.000	19	2604.500
160.000	15	2410.500
180.000	13	2294.500
200.000	12	2073.500
220.000	7	971.500
240.000	6	715.500
260.000	4	494.500
280.000	4	785.500
300.000	2	221.000
320.000	1	176.500
340.000	1	176.500
360.000	1	256.000

KRUSKAL-WALLIS TEST STATISTIC = 35.047 PROBABILITY IS
0.009 ASSUMING CHI-SQUARE DISTRIBUTION WITH 18 DF

APPENDIX D

Output files of an a-posteriori multiple comparison with basal cover data (Done on a Quatro Pro Spreadsheet)

a-posteriori
Relative homogenous units

open	1	1				
orchard	2	ns	2			
sparse	3	ns	ns	3		
old land	4	sig 0.001	sig 0.001	ns	4	
closed	5	sig 0.001	sig 0.001	ns 0.001	ns	5

a-posteriori
Baseline distance from hippo pool

400	1	1					
800	2	ns	2				
0	3	ns	ns	3			
1200	4	ns	ns	ns			
1600	5	ns	ns	ns	ns	5	
2000	6	sig 0.01	sig 0.01	sig 0.05	ns	ns	6

a-posteriori
Quadrat distance on transect
Summary

180	1	1				
200	2	ns	2			
*	*	*	*	*		
*	*	*	*	*	*	
0	sig 0.05	sig 0.05	ns	ns	*	

APPENDIX E

KRUSKAL-WALLIS ONE-WAY ANALYSIS OF VARIANCE FOR 81 CASES
DEPENDENT VARIABLE IS GRASS
GROUPING VARIABLE IS ORCHARD$

GROUP	COUNT	RANK SUM
sitrus	39	2047.500
pecan	36	1183.500
mango	6	90.000

KRUSKAL-WALLIS TEST STATISTIC = 25.758
PROBABILITY IS 0.000 ASSUMING CHI-SQUARE DISTRIBUTION WITH 2 DF

KRUSKAL-WALLIS ONE-WAY ANALYSIS OF VARIANCE FOR 81 CASES
DEPENDENT VARIABLE IS GRASS
GROUPING VARIABLE IS BASE

GROUP	COUNT	RANK SUM
100.00	22	862.500
300.00	8	120.000
700.00	20	778.000
1100.00	5	252.500
1500.00	17	988.500
1900.00	9	319.500

KRUSKAL-WALLIS TEST STATISTIC = 25.089
PROBABILITY IS 0.000 ASSUMING CHI-SQUARE DISTRIBUTION WITH 5 DF

KRUSKAL-WALLIS ONE-WAY ANALYSIS OF VARIANCE FOR 66 CASES
DEPENDENT VARIABLE IS GRASS
GROUPING VARIABLE IS TRANS

GROUP	COUNT	RANK SUM
0.000	1	61.500
20.000	5	196.000
40.000	6	211.000
60.000	7	235.500
80.000	7	235.500
100.000	7	189.000
120.000	6	164.500
140.000	6	146.000
160.000	6	146.000
180.000	3	101.000
200.000	3	101.000
220.000	2	86.000
240.000	2	104.500
260.000	2	86.000
280.000	2	86.000
300.000	1	61.500

KRUSKAL-WALLIS TEST STATISTIC = 14.538
PROBABILITY IS 0.485 ASSUMING CHI-SQUARE DISTRIBUTION WITH 15 DF

APPENDIX F

Output files on an <u>a-posteriori</u> multiple comparison with data on grass height
(because of veld fires, only orchards are compared)

(Done on a Quatro Pro spreadsheet)

Relative homogenous units

citrus	1	1		
pecan	2	sig 0.01	2	
mango	3	sig 0.01	ns	3

Baseline distance from hippo pool

1600	1	1					
2000	2	ns	2				
1200	3	ns	ns	3			
0	4	ns	ns	ns	4		
800	5	ns	ns	ns	ns	5	
400	6	sign 0.0	sign 0.0	ns	ns	ns	6