# THE STATISTICS OF HELICOPTER TOTAL COUNTS OF LARGE UNGULATES IN SOURISH MIXED BUSHVELD, NORTHWEST ARID BUSHVELD AND MOPANE VELD, REPUBLIC OF SOUTH AFRICA.

by

**BRIAN KEVIN REILLY**

Dissertation presented for the
Degree of Doctor of Philosophy at
the University of Stellenbosch

October 2000

Supervisor: Dr. H.J. van Hensbergen

Declaration

I, the undersigned, hereby declare that the work contained in this dissertation is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

*"Continuous census is the yardstick of success or failure in conservation......"*

***ALDO LEOPOLD***
***1933***

## ABSTRACT

The use of helicopters has become almost universally accepted as the method of choice in the enumeration of large ungulates in Southern Africa. In most cases decisions affecting management of these populations are made based on a single count result. In all these instances the within technique variance is ignored, often leading to decisions based on type I or type II statistical errors where the within technique variance is misconstrued as the population change. Many studies have investigated the issue of accuracy of counting methods and a few have quoted precision values for various methods. Very few have, however, investigated power and those extant have approached the problem from a prospective point of view and predicted power values. This study has made use of replicated counts from 12 sites of the original 23 in four vegetation types of the then Transvaal Province. The study sites vary in terms of size and all counts were undertaken with an experienced, trained team in which only four observers were used. A comprehensive *post hoc* analysis of the results of the field surveys shows precision and power to vary widely according to species and vegetation type and concludes that gamecounting results are largely site specific. A decline in observations during the course of four hours of survey is demonstrated and although the exact cause cannot be determined, correction factors have been constructed for two vegetation types. Observers are shown to differ from one another in observation profile during the course of surveys. This study demonstrates, describes and quantifies the existence of several phenomena suspected to exist by experienced game counters, biologists and wildlife managers and makes proposals in terms of improving the data returned from expensive aerial surveys.

## OPSOMMING

In Suider-Afrika word die gebruik van 'n helikopter vir die tel van hoefdiere byna algemeen aanvaar as die metode wat voorkeur geniet. In meeste gevalle word besluitnemings rakende die bestuur van hierdie populasies gebaseer op die resultate van 'n enkele telling. In al die gevalle word tegniekverwante afwykings buite rekening gelaat en dit het die gevolg dat bestuursbesluite gebaseer word op tipe I en tipe II statistiese foute, en dit lei weer op hulle beurt dat tegniek-verwante afwykings verkeerdelik geïnterpreteer word as die rede vir veranderings in die bevolkings. Verskeie studies het al die feitegeskil omtrent die akkuraatheid van telmetodes ondersoek en sommige het herhaalbaarheids-waardes vir die verskillende metodes aangehaal. Baie min het egter statistiese mag ondersoek en die wat dit wel gedoen het, het prospektiewe magsanalise as uitgangspunt gebruik en statistiese magwaardes voorspel om die probleem aan te spreek. Hierdie studie het gebruik gemaak van herhaalde tellings van 12 gebiede uit die oorspronklike 23 in vier veldtipes geleë in die ou Transvaal Provinsie. Die studiegebiede verskil in groottes. Alle tellings is deur 'n bekwaamde opgeleide span gedoen wat slegs vier waarnemers ingesluit het. 'n Omvattende *post hoc* analise van die resultate van die veldopnames dui aan dat herhaalbaarheid en statistiese mag baie varieer met betrekking tot spesies en veldtipes en word die gevolgtrekking gemaak dat wildtellingsresultate grootliks gebiedsgebonde is. ‘n Afname in waarnemings gedurende die verloop van ‘n vier uuropname, is waargeneem en alhoewel die ware oorsaak nie vasgestel kan word nie, is korreksiefaktore bereken vir twee veldtipes. Dit blyk dat waarnemers van mekaar verskil het met betrekking tot hul waarnemingsprofiele gedurende die verloop van die opnames. Hierdie studie dui aan, beskryf en kwantifiseer die bestaan van verskeie verskynsels wat vermoedelik bestaan het by ervare wildtellers, bioloë en wildlewebestuurders en maak voorstelle met betrekking tot die verbetering van data wat tydens duur lugopnames ingesamel word.

## ACKNOWLEDGEMENTS

The data set that forms the backbone of this study has been extracted from a larger data set collected in the period 1987 to 1993. Many people have had an active input into this data set.

The gamecounting team of the then Transvaal Chief Directorate of Nature Conservation constituted of Piet Muller, Dick Carr, Peter Carr, Riaan van Zyl, Mac McKibben and the author undertook the bulk of the fieldwork involved. Ian MacFadyen from the then Gazankulu Nature Conservation Department was also involved as an observer in work undertaken on Letaba Ranch. The enthusiasm of these friends and colleagues in the interest of good data gathering cannot be overemphasized.

All the flying hours represented in this study were undertaken personally by John Vinagre from Capital Air and without whose attention to detail and efforts at precision flying, the data set would have suffered negatively.

Of necessity the analysis was statistically complicated and, at times, frustrating and special thanks to must go to The Hon. Dr. Richard Emslie and Riette Eiselen for all their support and assistance throughout.

Finally, many thanks to my long-suffering wife, Yvonne for all the times spent alone in the interest of science.

# CONTENTS

| | Page |
|---|---|
| **ABSTRACT** | i |
| **ACKNOWLEDGEMENTS** | ii |
| **TABLES** | iv |
| **FIGURES** | vii |
| **CHAPTER 1** | |
| ***INTRODUCTION*** | 1 |
| **CHAPTER 2** | |
| ***MATERIALS AND METHODS*** | |
| ***STUDY AREAS*** | 4 |
| ***METHODS*** | 9 |
| **CHAPTER 3** | |
| ***RESULTS AND DISCUSSION*** | |
| ***PRECISION*** | 20 |
| ***POWER*** | 23 |
| **CHAPTER 4** | |
| ***RESULTS AND DISCUSSION*** | |
| ***TIME BIAS*** | 68 |
| **CHAPTER 5** | |
| ***RESULTS AND DISCUSSION*** | |
| ***OBSERVER BIAS*** | 74 |
| **CHAPTER 6** | |
| ***SUMMARY AND CONCLUSIONS*** | 85 |
| **REFERENCES** | 94 |
| **APPENDIX** | 100 |

**TABLES**

Table 1: Summary precision data for 63 observations during this study. 21

Table 2: Summary statistics of four replicate helicopter counts at Loskop Dam Nature Reserve, showing bootstrapped SD's for n =2, n = 3 and n = 4 as well as standard errors (SE) for differences in means from year 1 to year 2 for various replicates of counts (1,2,3 and 4). 27

Table 3: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of the mean for different replicate options from year 1 to year 2 for calculation of power for kudu at Loskop Dam Nature Reserve. 28

Table 4: Power values to detect population change as a percentage of the mean for various count replicate options in year 1 and year 2 for kudu at 10% and 20% significance at Loskop Dam Nature Reserve. 29

Table 5: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of the mean for different replicate options from year 1 to year 2 for calculation of power for zebra at Loskop Dam Nature Reserve. 32

Table 6: Power values to detect population change as a percentage of the mean for various count replicate options in year 1 and year 2 for zebra at 10% and 20% significance at Loskop Dam Nature Reserve. 33

Table 7: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of the mean for different replicate options from year 1 to year 2 for calculation of power for wildebeestat Loskop Dam Nature Reserve. 36

Table 8: Power values to detect population change as a percentage of the mean forvarious count replicate options in year 1 and year 2 for wildebeest at 10% and 20% significance at Loskop Dam Nature Reserve. 37

Table 9: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of the mean for different replicate options from year 1 to year 2 for calculation of power for impala at Loskop Dam Nature Reserve. 40

Table 10: Power values to detect population change as a percentage of the mean for various count replicate options in year 1 and year 2 for impala at 10%and 20% significance at Loskop Dam Nature Reserve. 41

Table 11: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of the mean for different replicate options from year 1 to year 2 for calculation of power for warthog at Loskop Dam Nature Reserve. 44

Table 12: Power values to detect population change as a percentage of the mean for various count replicate options in year 1 and year 2 for warthog at 10%and 20% significance at Loskop Dam Nature Reserve. 45

Table 13: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of the mean for different replicate options from year 1 to year 2 for calculation of power for sable at Loskop Dam Nature Reserve. 48

Table 14: Power values to detect population change as a percentage of the mean for various count replicate options in year 1 and year 2 for sable at 10%and 20% significance at Loskop Dam Nature Reserve. 49

Table 15: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of the mean for different replicate options from year 1 to year 2 for calculation of power for white rhino at Loskop Dam Nature Reserve. 52

Table 16: Power values to detect population change as a percentage of the mean for various count replicate options in year 1 and year 2 for white rhinoat 10% and 20% significance at Loskop Dam Nature Reserve. 53

Table 17: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of the mean for different replicate options from year 1 to year 2 for calculation of power for mountain reedbuck at Loskop Dam Nature Reserve. 56

Table 18: Power values to detect population change as a percentage of the mean for various count replicate options in year 1 and year 2 for mountain reedbuck at 10% and 20% significance at Loskop Dam Nature Reserve. 57

Table 19: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of the mean for different replicate options from year 1 to year 2 for calculation of power giraffe at Loskop Dam Nature Reserve. 60

Table 20: Power values to detect population change as a percentage of the mean for various count replicate options in year 1 and year 2 for giraffe at 10% and 20% significance at Loskop Dam Nature Reserve. 61

Table 21: Summary power values attained for talpha.1(top) and talpha.2 (bottom) to detect a 15% population change for the 10 properties where kudu were encountered. 64

Table 22: Summary power values attained for talpha.1(top) and talpha.2 (bottom) to detect a 15% population change for the 9 properties where zebra were encountered. 65

Table 23: Summary power values attained for talpha.1(top) and talpha.2 (bottom) to detect a 15% population change for the 9 properties where wildebeest were encountered. 66

Table 24: Summary power values attained for talpha.1(top) and talpha.2 (bottom) to detect a 15% population change for the 12 properties where impala were encountered. 67

Table 25: Quadratic function constants for squareroot of observations versus time interval for *Acacia* and sourish mixed bushveld. 69

Table 26: Correction factors (%) per time interval ( t x 30 minutes) for 4 hours of counting in *Acacia* veld. 71

Table 27: Correction factors (%) per time interval ( t x 30 minutes) for 4 hours of counting in sourish mixed bushveld. 71

Table 28: Summary statistics for observer 1 for observation rates and squareroot of observation rate by time interval for four species and total observations during the course of 76 helicopter counts. 76

Table 29: Summary statistics for observer 2 for observation rates and squareroot of observation rate by time interval for four species and total observations during the course of 76 helicopter counts. 77

Table 30: Summary statistics for observer 3 for observation rates and squareroot of observation rate by time interval for four species and total observations during the course of 76 helicopter counts. 78

Table 31: Summary statistics for observer 4 for observation rates and squareroot of observation rate by time interval for four species and total observations during the course of 76 helicopter counts. 79

**FIGURES**


Page

Figure 1: Locations of major study sites in the Republic of South Africa. 6

Figure 2: Typical vegetation on Loskop Dam Nature Reserve. 7

Figure 3: Typical terrain encountered in the gamecounts of northwest arid bushveld. 7

Figure 4: Typical vegetation and terrain encountered during gamecounts of Letaba Ranch, lowveld mopane veld with a herd of buffalo in view and the counting marker bars of the left hand observer at 175 ft above ground level. 8

Figure 5: Typical vegetation encountered in the sites in northern mopane veld. 9

Figure 6: Example of the flightline pattern used during the total aerial surveys in this study. 10

Figure 7: The sampling distribution of $\bar{x}_1 - \bar{x}_2$ (differences in the means of replicates in year 1 and year 2) under $H_0$ of no difference and $H_a$ of difference of $D$ between means. 13

Figure 8: Hi-lo-close graph of count (population) mean +/- 1 standard error. 23

Figure 9: Power curves for various count replicate options at 10% significance for kudu at Loskop Dam Nature Reserve. 30

Figure 10: Power curves for various count replicate options at 20% significance for kudu at Loskop Dam Nature Reserve. 31

Figure 11: Power curves for various count replicate options at 10% significance for zebra at Loskop Dam Nature Reserve. 34

Figure 11: Power curves for various count replicate options at 20% significance for zebra at Loskop Dam Nature Reserve. 35

Figure 13: Power curves for various count replicate options at 10% significance for wildebeest at Loskop Dam Nature Reserve. 38

Figure 14: Power curves for various count replicate options at 20% significance for wildebeest at Loskop Dam Nature Reserve. 39

Figure 15: Power curves for various count replicate options at 10% significance for impala at Loskop Dam Nature Reserve. 42

Figure 16: Power curves for various count replicate options at 20% significance for kudu at Loskop Dam Nature Reserve. 43

Figure 17: Power curves for various count replicate options at 10% significance for warthog at Loskop Dam Nature Reserve. 46

Figure 18: Power curves for various count replicate options at 20% significance for warthog at Loskop Dam Nature Reserve. 47

Figure 19: Power curves for various count replicate options at 10% significance for sable at Loskop Dam Nature Reserve. 50

Figure 20: Power curves for various count replicate options at 20% significance for sable at Loskop Dam Nature Reserve. 51

Figure 21: Power curves for various count replicate options at 10% significance for white rhino at Loskop Dam Nature Reserve. 54

Figure 22: Power curves for various count replicate options at 20% significance for white rhino at Loskop Dam Nature Reserve. 55

Figure 23: Power curves for various count replicate options at 10% significance for mountain reedbuck at Loskop Dam Nature Reserve. 58

Figure 24: Power curves for various count replicate options at 20% significance for mountain reebuck at Loskop Dam Nature Reserve. 59

Figure 25: Power curves for various count replicate options at 10% significance for giraffe at Loskop Dam Nature Reserve. 62

Figure 26: Power curves for various count replicate options at 20% significance for giraffe at Loskop Dam Nature Reserve. 63

Figure 27: Histogram of observations versus time for all time intervals over all counts in which animals were observed. 69

Figure 28: Quadratic function of squareroot of observations of animal groups versus time interval for *Acacia* veld. 70

Figure 29: Quadratic function of squareroot of observations of animal groups versus time interval for sourish mixed bushveld. 70

Figure 30: Regressions for 4 observers for squareroot of observations versus time for all species over 76 helicopter counts. 80

Figure 31: Regressions for 4 observers for squareroot of observations versus time for impala over 76 helicopter counts. 81

Figure 32: Regressions for 4 observers for squareroot of observations versus time for wildebeest over 76 helicopter counts. 82

Figure 33: Regressions for 4 observers for squareroot of observations versus time for zebra over 76 helicopter counts. 83

Figure 34: Regressions for 4 observers for squareroot of observations versus time for kudu over 76 helicopter counts. 84

# SYMBOLS

Definitions of mathematical symbols used in the text.

$\alpha$ = *Type I error*

$\beta$ = *Type II error*

$D$ = *Difference between means*

$\bar{x}$ = *sample mean*

$\bar{u}$ = *population mean*

$H_0$ = *null hypothesis*

$s$ = *standard deviation*

$n$ = *sample size*

$H_a$ = *alternative hypothesis*

$P$ = *Power*

$\Delta$ = *non-centrality parameter*

*TINV* = *inverse of t-ratio*

$t$ = *t-value*

$t_\phi$ = *non-central t*

*df* = *degrees of freedom*

$l$ = *non - centrality table value constant*

$b_x$ = *quadratic constants*

# CHAPTER 1

## *INTRODUCTION*

The use of aerial surveys as a tool in the management of large ungulates can be traced back as far as 1935 (Cahalane 1938). The use of aircraft and particularly helicopters has grown consistently since the 1950's and today is almost universally applied in enumerating many species of wild ungulates, for example, white tailed deer (Beasom, Leon & Synatzske 1986), mule deer (Bartman, Carpenter, Garrott & Bowden 1986) and elk in Michigan (Otten, Haufler, Winterstein & Bender 1993). Furthermore the method has been applied to many species of African ungulates and results have been recorded by many authors. Van Lavieren & Esser (1979) report results of counts of giant eland *Tragelaphus derbianus*, roan antelope *Hippotragus equinus*, defassa waterbuck *Kobus ellipsiprymnus defassa*, bohor reedbuck *Redunca redunca* and Bubal hartebeest *Alcelaphus buselaphus* in west Africa and several species such as impala *Aepyceros melampus*, topi *Damaliscus lunatus*, sitatunga *Tragelaphus spekii*, eland *Tragelaphus oryx* and waterbuck *Kobus ellipsiprymnus* in Rwanda. The method has been used in both East Africa (Dasmann & Mossman 1962; Jolly 1969 and Melton 1978) and South Africa (Hirst 1969; Goodman 1977; Collinson 1985; Bothma, Peel, Pettit & Grossman 1990; Eiselen 1994 and van Hensbergen, Berry & Juritz 1996).

The use of the technique has moved beyond application in National Parks and Nature Reserves and, particularly in the South African context, is widely applied to provide management information for commercial game ranch undertakings. It provides information in a short time for smaller properties and is less sensitive to habitat diversity and population sizes than many other sampling methods. Visibility from the air is also generally better than from the ground in most bushveld applications.

The helicopter survey has many detractors due to failure to ensure that underlying assumptions have been met (Melton 1978 and Caughley 1974). The essential requirement for skilled observers, poor performance caused by high observer fatigue, difficulty in standardisation and high costs mitigate against the technique (Caughley 1979, Norton-Griffiths 1978, Seber 1992), yet it remains the technique of choice over much of South Africa. Furthermore, these methods are often applied by inexperienced staff unschooled in the underlying statistical principles involved (Adcock pers. comm.)[1]. In general the non-standardisation of approaches to gamecounting lengthens the causal chain of poor precision.

A plethora of publications exists on accuracy of helicopter counts (Rice & Harder 1977, Beasom 1979, Payne 1981, de Young 1985, Beasom, Leon & Synatzske 1986, Seber 1992 and Bothma et al.1990) and the effect of various factors such as height and speed on accuracy. Other investigations quantify observer bias

---

[1] K. Adcock, P.O.Box 1212, HILTON, 3245.

( Pennycuick & Western 1972, Norton-Griffiths 1978, Melton 1978, Graham & Bell 1989) but there are few references on precision and power of these applications. A review of statistical power levels in 14 research domains by Lipsey (1990) makes no reference to wildlife management in this regard.

Unless counts, or for that matter, any monitoring actions are replicated thus allowing estimation of variance, any resulting management decision made with unknown within-technique variation could lead to a decision subject to large Type I or Type II error. Replication allows the assessment of the risks involved in making decisions based on these counts.

Doubt in the value of these surveys arises in erroneous experimental design and lack of concern for sensitivity. Value in this case refers to the likelihood that what is detected from the gamecount is in fact the effect of interest (population change). Sensitivity refers to the likelihood that an effect if present will be detected. A sensitive design is one yielding data for which the central test of statistical significance has a high statistical power (Lipsey 1990). Where experimental or monitoring designs lack sensitivity they cannot accomplish their central purpose – detecting population change. In the context of wildlife population management this change is usually from one year to the next.

Within method variation may exceed the magnitude of population change to be measured and thus make the resulting estimate valueless. At best, large ungulate counts are subjected to a high degree of standardisation, on the assumption that high precision will be achieved, an assumption which has not been verified and which may very often be violated and compounded by poor observer performance (Adcock pers. comm.). Obviously the high cost of helicopter aerial game counting operations mitigates against the replication of counts (Collinson 1985).

Power analyses are not widely known or applied to wildlife management in South Africa with the exception of Emslie & le Roux(*in prep*) on forest antelope, Emslie, Fourie & Reilly (1994) on aerial counts of cycads, Reilly and Emslie (1998) on ungulates. The concept has been discussed in relation to population decline by Reed & Blaustein (1995) and to amphibian population trends by Hayes & Steidl (1997). It has also been applied in environmental management and fisheries (Conquest 1983, Peterman 1990, Conquest 1993, Mapstone 1995). This is in contrast with the literature on concepts such as accuracy of gamecounting. Hinds (1984) refers to power analysis in monitoring long-term trends in terrrestrial ecosystems. The use of power analysis is however well documented in the behavioural sciences (Cohen 1988), medicine (Freiman, Chalmers, Smith & Kuebler 1978) and psychiatry (Rothpearl, Mohs & Davis 1981). Further, power analysis is widely used in market research and quality control where the technique is referred to as process analysis (Kraemer 1985) and is often used to determine sample sizes. Researchers are generally preoccupied with $\alpha$ or the probability of a Type I error (Lipsey 1990), often ignoring the probability of a type II error. Cohen (1988) defines the power of a statistical test of a null hypothesis ($H_0$) as the probability of rejecting the null hypothesis when it is in fact false and denotes it as $1-\beta$.

In the period 1991 to 1994 an opportunity arose to replicate counts on several properties in the then Transvaal as part of the game counting programme. The process began in 1991 when 4 replicate counts were conducted of the northern shore of Loskop Dam Nature Reserve as a pilot investigation into the precision of the 4 man helicopter counts used by the then Transvaal Directorate of Nature Conservation. In 1993 3 replicate counts were accepted as the basis for cooperative agreements between the Directorate of Nature Conservation and private landowners surrounding Atherstone Nature Reserve in the north- western Transvaal and landowners around the Vhembe Nature Reserve in the northern Transvaal. Finally, 4 replicates counts were conducted of the Letaba Ranch Nature Reserve run by the Gazankulu Government in order to estimate the methods ability to show change in the ungulate populations. In all 23 properties were counted either 3 or 4 times and the data from 12 of these properties forms the basis of this study.

These true replications originating under field monitoring conditions allow us to obtain estimates of precision necessary for power analysis.

# CHAPTER 2

## *MATERIALS AND METHODS*

### STUDY AREAS

The study areas are indicated in figure 1.

Loskop Dam Nature Reserve

Loskop Dam Nature Reserve is 24 800 ha in area and situated in the western Mpumalanga Province 180 km northeast of Pretoria. The area has an annual rainfall of 600 mm and consists of 18 distinct vegetation communities (Theron 1978). The topography ranges from flat grassland plains to wooded gorges and can generally be described as sourish mixed bushveld. A photograph illustrating the vegetation of the area appears as figure 2.

The study was conducted (quadruple counts – see fieldwork) over the 8 500 ha section of the reserve north of the dam. This portion is a closed area because it is bounded on the south and east by the Dam and the north and west by a game-proof fence.

Atherstone cooperative Reserve

The area in question is located 50 km west of the town of Thabazimbi in the northern Province. The properties surrounding Atherstone Nature Reserve all fall into the veldtype known as northwestern arid bushveld and the vegetation of this area is described by Pauw (1988) as dominated by *Grewia flava – Acacia erubescens* short tree savanna interspersed by *Acacia* short tree savanna and *Acacia tenuispina* shrub veld on the floodplains. A photograph illustrating the vegetation of the area appears as figure 3. The topography is flat and featureless throughout. Triple counts (see fieldwork) were conducted on consecutive days on the following properties:

Dieplaagte ( 1500ha)
Groengoud ( 1000ha)
Laagwater ( 4800ha)
Grootvlei ( 600ha)
Elandskloof ( 4000ha)
Onrus ( 2200ha)

Vhembe cooperative Reserve

The vegetation of the area is dominated by *Colophospermum mopane* and can be divided into four dominant communities viz. Riverine communities of the southern bank of the Limpopo river which made up only a small percentage of the properties surveyed, alluvial floodplain community, basalt community and the sandveld community. In general a mixed bushveld dominated by scrub mopane with the exception of the riverine community and riverine forest which was only present on some properties. A photograph illustrating the vegetation of the area appears as figure 4. Topography is generally flat with several shallow gorges.

The counts (triple – see fieldwork) were conducted on the following properties: -
Shroda (4100ha)
Samaria 1 (3100ha)
Samaria 3 (1400ha)
Greefswald (3500ha)

<u>Letaba Ranch</u>

Letaba Ranch is situated in the northern lowveld of the eastern part of northern Province adjacent to the Kruger National Park just north of the town of Phalaborwa. The area is 33 500ha in extent and is generally considered to be *Colophospermum mopane* veld. The vegetation has been described by several authors and is generally classified into two major veldtypes, the Letaba River rugged veld adjacent to the Letaba River and the *Colophospermum mopane* savanna covering the southern areas of the reserve (Pauw 1987, Gertenbach 1983, Gertenbach 1987, Turner 1989 & Turner 1991). A photograph illustrating the vegetation of the area appears as figure 5. The topography is generally flat and a 10 000ha section of the south central part of the reserve was counted four times (see fieldwork). This was the only study site that was not bounded entirely and as such game movements could occur into and out of the area overnight.

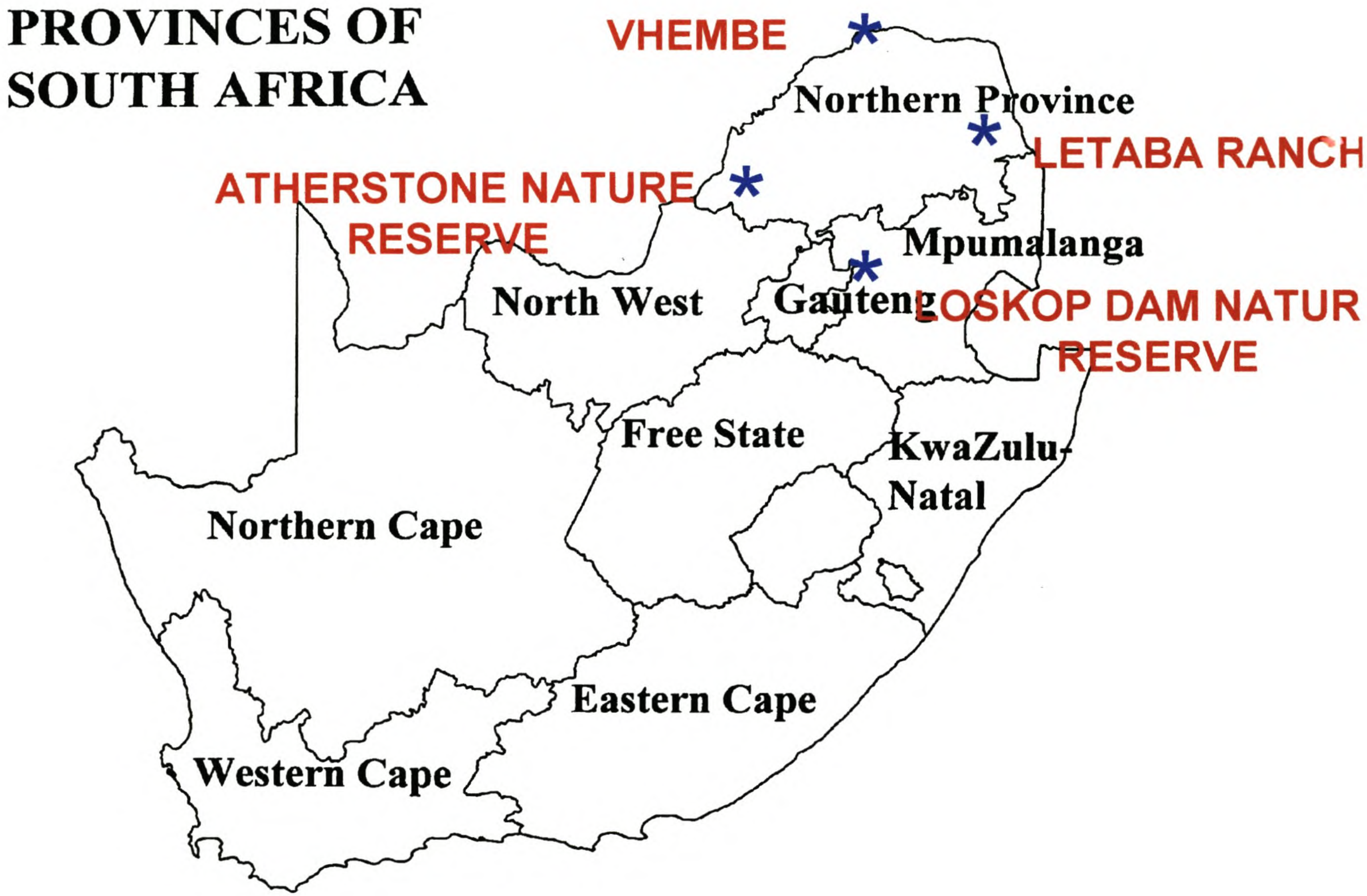


Figure 1: - Locations of major study sites in the Republic of South Africa.

Figure 2: Typical vegetation on Loskop Dam Nature Reserve.

Figure 3: Typical terrain encountered in the gamecounts of properties surrounding the Atherstone cooperative reserve, northwest arid bushveld.

Figure 4: Typical vegetation and terrain encountered during gamecounts of Letaba Ranch, lowveld mopane veld with a herd of buffalo in view and the counting marker bars of the left hand observer at 175 ft above ground level.

Figure 5: Typical vegetation encountered in the sites in northern mopane veld.

## *METHODS*

### Fieldwork

A four-seat Bell Jet Ranger III helicopter (with a pilot, navigator and two experienced observers) was used. Counting marker bars were fitted and set to delineate a 330m wide strip at a height of 53m above ground level. Height was regulated using a radar altimeter and counts were done with the rear doors removed. All counts were done during July after leaf drop and replicates were conducted on consecutive days at the same time of day. Speed was constant at 96 kilometers per hour. Navigation was accomplished by heading and counter heading and tracked by the navigator on a 1 $km^2$ grid overlay of the 1:50 000 topocadastral map. Figure 6 illustrates the flight lines used in the counts of Loskop Dam Nature Reserve. All replicate counts took place on consecutive days along the same flightlines and were GPS assisted.

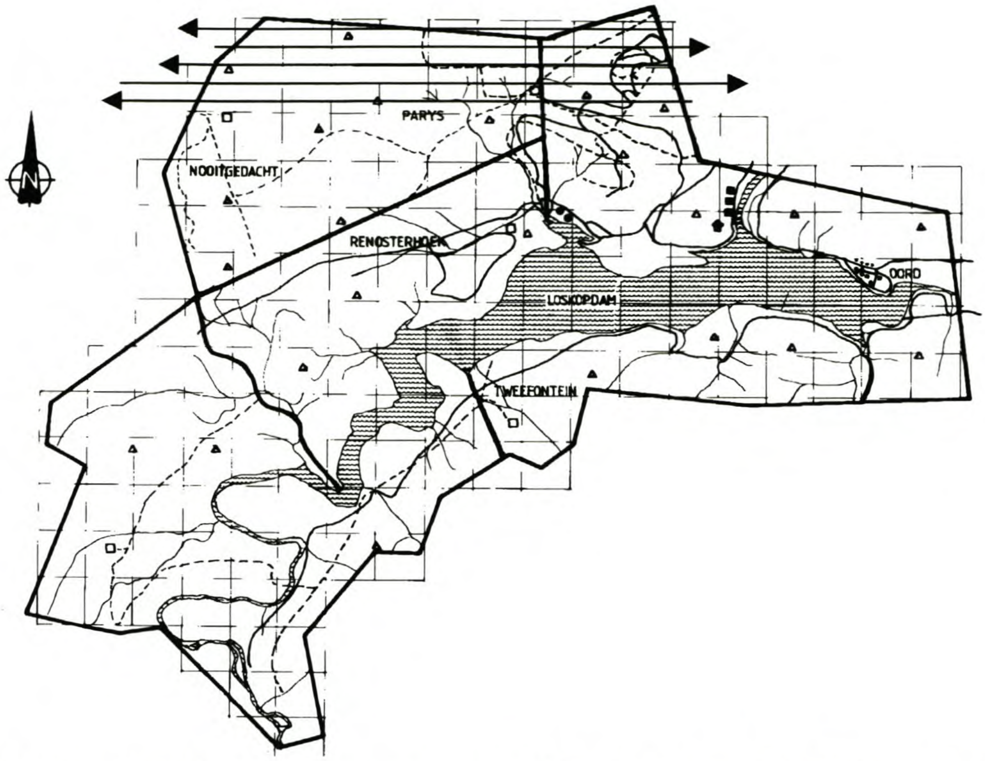


Figure 6: Example of the flightline pattern used during the total aerial surveys in this study.

Data were recorded onto handheld recorders and later transcribed to data sheets using the grid numbers of the overlay. All animals seen were counted and, where necessary, herds were flushed to ensure accurate enumeration. The navigator marked the positions of herds crossing out of strips, on the map, to avoid overcounting.

## Statistical analyses

### *Precision*

Each aerial survey is an attempt to completely enumerate the population. We have seen in chapter one that there is good evidence that this is rarely achieved. Each survey produces a count of the population, which is some fraction, hopefully large, of the population. In practice individual counts differ for a variety of reasons both due to systematic and random errors. The extent to which repeated counts differ can be stated in terms of the precision of a count. If precision is high then repeated counts will all have similar values. Precision is most commonly stated in terms of a variance or standard deviation or may be scaled and presented in the form of a coefficient of variation. In this study, coefficients of variation are used to present information on relative precision since the absolute sizes of populations differ greatly both between species and sites.

When repeated survey counts of a population are taken these counts will vary between occasions as a result of a variety of factors. It is of interest to us to know on average how much variation we can expect in these counts. The usual way of stating this variation is in terms of its variance or its standard deviation. The standard deviation can be considered as a weighted average of the amount by which any individual observation deviates from the average of all observations. For the purpose of this study this is converted to a percentage by dividing the standard deviation by the mean giving the coefficient of variation.

Precision of the counts is expressed as a coefficient of variation (scaled measure of dispersion that allows for comparison between sites), i.e.

$$\frac{s}{\bar{x}} \times (100)$$

Where *s is* the sample standard deviation and $\bar{x}$ the mean of the replicate counts. These values are expressed as a percentage in the results.

### *Power*

Theoretically power refers to the ability of a particular statistical test to determine between alternative hypotheses. A test with low power will be unable (or rarely able) to discriminate between hypotheses even if the null hypothesis is false. In the present context of monitoring wildlife populations the factor of interest is the question of whether or not there has been a change in the population. A test of low power will be unable to detect a change even if there has been one. (It should be noted that the opposite hypothesis of attempting to demonstrate no change in large populations of free roaming wild animals is of little or no relevance since in large populations births and deaths cause populations to change by small amounts on a daily basis).

In counting wildlife populations for the purpose of management two types of errors are possible as a result of the random variation in the census process. We may fail to detect a change in the population which has really occurred (statistically a type II error) or on the other hand we may come to the conclusion that a change in the population has occurred when in fact it has stayed the same (a type I error.) Ideally we would like there to be a low chance of either of these errors occurring but in practice the frequency with which these errors occur is often quite high. The frequency of these errors is determined by the investigator and based on the observed data. A test of high power is one where the chance of a type II error is low.

Power is increased under 1 or more of the following scenarios:-

- Increasing sample size (count more, more often)
- Increasing treatment differences (larger population change hence less frequent counts)
- Decrease variance (standardize the operation)
- Increasing alpha to values greater than 0.05 (this is counterfeit and generally not useful)

The logic of the power analysis is to determine what degree of population change (*D*) can be detected significantly from year 1 to year 2. Considering any monitoring result as a sample of reality (the natural phenomena under consideration – in this case population change over time), if the sample shows change, which has not taken place in reality, this is considered a statistical Type I error. This Type I error probability (significance or $\alpha$) plus the confidence is always 100% or 1,00.

Conversely if the sample indicates no change while in fact a change has taken place in reality, this is considered a statistical Type II error. The sum of Power and this Type II or $\beta$ error as probabilities always totals to 100% or a probability of 1,00. Thus if Power is calculated then Type II error ($\beta$) is known under a pre-selected significance or Type I error risk. This allows the efficiency of the technique, in this case the helicopter total counts of large ungulates to be evaluated in terms of its ability in measuring population change as percentage of the mean of a number of replicate counts.

In statistical terms this is explained as follows: - The significance level ($\alpha$ or Type I error) or the probability of rejecting a true null hypothesis is usually arbitrarily set as small as possible in scientific experimentation (Lipsey 1990) i.e. 5% or 1%. It follows that the smaller the value the more rigorous the rejections of the null hypothesis thence, the existence of the phenomenon in question is accepted. Small alpha values often lead to relatively small power values although power values are also dependent on other factors such as the alternative hypothesis (Cohen 1988, Lipsey 1990). The Type II ($\beta$ error) or the probability of failing to reject a false null hypothesis is related to power (power=1-$\beta$), low power thence relating to large values of $\beta$ ( Kraemer & Thiemann 1987, Cohen 1988).

Clearly $\alpha$ and $\beta$ are related as well, small $\alpha$ values imply larger $\beta$ values and vice a versa. The power under any sampling distribution is illustrated by the example figure 7.

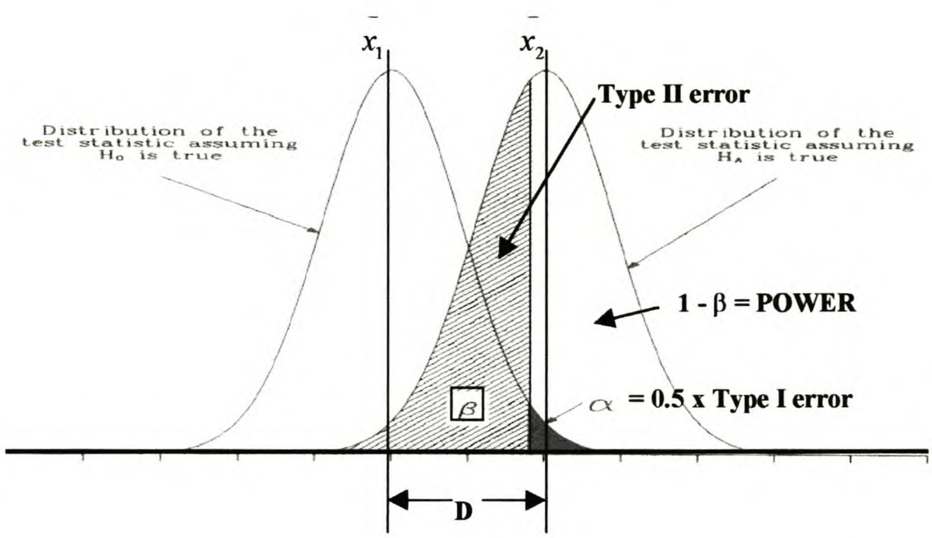


Figure 7: The sampling distribution of $\bar{x}_1 - \bar{x}_2$ (differences in the means of replicates in year 1 and year 2) under $H_0$ of no difference and $H_a$ of difference of *D* between means.

According to Lipsey (1990) *post hoc* power analysis answers one of three questions. Firstly, what number of replicates (*n*) would be needed to detect a difference (*D*) of the magnitude observed in the data for pre-selected values of $\alpha$ and $\beta$. $\frac{D}{s}$ is also referred to as the effect size, where *s* is the pooled sample standard deviation and: -

$$s = \sqrt{\frac{s_1^2 + s_2^2}{n_1 + n_2 - 2}}$$

where (in the case of replicated helicopter counts): -

$s_1$ and $s_2$ are sample standard deviations in year 1 and year 2 and
$n_1$ and $n_2$ the number of replicates in year 1 and year 2.

In other words, how many replicates would be needed to detect a difference of *D* in the number of animals from one year to the next. Secondly, what is the smallest difference (*D)* that can be detected for a given number of replicates (*n*), again, with pre-selected values of $\alpha$ and $\beta$, and finally what is the statistical power (1- $\beta$) of the test procedure for given values of *n, D* and $\alpha$?

In this study analyses will centre on the latter two questions given the fixed sample size of three or four replicates {replicates (*n)* = sample size}.

*Randomisation and variance estimation*

Each of the surveys can be considered as an independent sample from the population of all possible surveys for that site. To estimate the variance of these counts the standard estimator of variance could be used but this gives rise to problems since we need to know the estimate of variance for (in most cases) samples of 2, 3 and 4 surveys. This is easily calculated for 4 surveys directly from the data but for 2 and 3 surveys the question of which surveys to include in the calculation is important. Since each survey is different, a different estimate of variance will be obtained for each possible combination of 2 or 3 observations. In order to overcome this problem the estimate of the variance was obtained by bootstrapping (Efron 1974).

Samples (4000) were generated randomly with replacement from 2, 3 and 4 actual values. From each of these samples a variance was calculated. The mean of these variances is an estimate of the population variance.

*Power calculation*

In order to determine the power to detect a change of *D* in the population size, the assumption is made that the sample variance in year 1 is equal to the sample variance in year 2. This assumption is necessary for the use in this study of a *t* – distribution for 2 independent samples. This assumption is tenable since counts are performed in the same site at the same time of year using a standardized method.

The purpose of the power analysis is to determine what degree of population change (*D*) can be detected significantly from year 1 to year 2.

Let *s* denote the standard deviation of the replicated counts in year 1 (and hence year 2 – assumption as stated above) and let $\bar{x}_1$ be the mean in year 1 and $\bar{x}_2$ the mean in year 2. The number of replicates in year 1 is $n_1$ and in year 2 the number of replicates is $n_2$ .

The null hypothesis is:-

$$H_0: \quad \mu_1 = \mu_2$$

$$i.e. \quad \mu_1 - \mu_2 = 0$$

Where $\mu_1$ is the true population size in year 1 and $\mu_2$ is the true population size in year 2.

One of the alternative hypotheses is that the mean in year 1 is larger than the mean in year 2, i.e. there is a decrease in population size from year 1 to year 2.

$$H_a: \mu_1 - \mu_2 > 0$$

Clearly the true population means are unknown. Only the sample values $\bar{x}_1$ and $\bar{x}_2$ with $s_1$ and $s_2$, sample standard deviations are known. Under the null-hypothesis ($H_0$) $\bar{x}_1 \overset{D}{\cong} N(\mu_1, \delta^2)$ and $\bar{x}_2 \overset{D}{\cong} N(\mu_2, \delta^2)$ (both $\bar{x}_1$ and $\bar{x}_2$ are normally distributed) where $\delta^2$ is the population variance (see assumption)(Zar 1984). $\delta^2$ is estimated by $s^2$ (the bootstrap estimate). Alternately $\bar{x}_1 - \bar{x}_2 \overset{D}{\cong} N(\mu_1 - \mu_2, \delta^2)$.

Because $n_1$ and $n_2$ are small and δ is unknown, $\bar{x}_1$ and $\bar{x}_2$ have a *t*-distribution with $n_1 + n_2 - 2$ degrees of freedom.

Hence

$$P(\bar{x}_1 - \bar{x}_2 > D) = \alpha$$

If the null hypothesis is true, then the probability (*P*) is calculated: -

$$P\left(\frac{\bar{x}_1 - \bar{x}_2}{s\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}} > t_{n_1+n_2-2;\alpha}\right) = \alpha$$

$$\text{i.e. } P(t > t_{n_1+n_2-2;\alpha}) = \alpha \quad \text{where } \frac{\bar{x}_1 - \bar{x}_2}{s\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}} = t$$

and $t_{n_1+n_2-2;\alpha}$ is the critical value of the t-distribution with $n_1+n_2-2$ degrees of freedom. Hence, the variable $t$ is assumed to have a t-distribution with $n_1+n_2-2$ degrees of freedom.

We wish to determine for which value of *D*, the $P(\bar{x}_1 - \bar{x}_2 > D) = \alpha$

i.e. for which value of *D* will we reject the null hypothesis when in fact $H_0$ is true.

$$P(\text{Reject } H_0 \mid H_0 \text{ is true}) = \alpha$$

$$P(\text{Reject } H_0 \mid H_a \text{ is true}) = 1 - \beta$$

$H_a$ is true if a difference of $\Delta x$ has occurred in the relative population size ( $\mu_1 - \mu_2$ = difference $\Delta$).

i.e.

$$P\left(t - \frac{\Delta\bar{x}_1}{s\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}} > t_{n_1+n_2-2;\alpha}\right)$$

$$\text{i.e. } P\left(t > \frac{\Delta\bar{x}_1 + t_{n_1+n_2-2;\alpha}\cdot s\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}}{s\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}}\right)$$

= 1 - β

= Power

Similarly, in order to detect an increase in size from year 1 to year 2 the following is calculated:

$$P\left( t > \frac{\Delta^{*}\overline{x}_1 - t_{n_1+n_2-2;\alpha} \cdot s\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}}{s\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}} \right) \text{ where } \Delta^{*} > 1.$$

Unfortunately the standard (central or location fixed) *t*-distribution (as in the above formulae) cannot be used in this case and the non-central (location free) *t*-distribution is used (Pearson & Harley 1972). The term non-central is applied to distributions of *t* where the single normal variable (numerator or *x* in the *t* –ratio) no longer has a zero expectation.

i.e. the *t* – ratio = $\frac{x}{y}$ where *x* is normally distributed and *y* has a chi-square distribution (df =n). When *x* does not have a normal distribution the distribution of *t* is non-central and therefore the central *t* value is corrected with the Δ term as computed below.

The non-central (location free) *t*-distribution is computed as follows: -

For $\alpha = 0.05, \quad (significance) \quad 1-\beta = 0.95(power)$

$$y = -\frac{t_{\phi}}{\sqrt{2\,df}}\left(1 + \frac{(-t\phi)}{2\,df}\right)^{-\frac{1}{2}}$$

Where degrees of freedom = $n_1 + n_2 - 2$

And $t_\phi = TINV(0.025, df)$

*TINV* = table value for one tailed significance (0.025) and *df* = degrees of freedom

*l* = table value for given *y* and *df* (Pearson and Harley 1972)

then

$$\Delta = -\left[ -t_\phi - l\left(1 + \frac{(-t_\phi)}{2df}\right)^{\frac{1}{2}} \right]$$

$\Delta$ = non-centrality parameter (skewness of *t* – distribution)

And standardized difference = $\Delta.\left(\frac{1}{n_1} + \frac{1}{n_2}\right)^{\frac{1}{2}}$

*Time and observer bias*

During the course of the study all observations were logged in 30-minute time intervals. In Chapter 4 these data are transformed using a squareroot function (data are Poisson distributed and are transformed to a normal distribution). Data (observations over time) are analysed using a one-way analysis of variance (ANOVA) accompanied by Scheffe *post hoc* multiple range tests to identify sources of variation between cells (Zar 1984). In cases where significance is demonstrated the most suitable curve is fitted to the scatterplot (transformed data) in an effort to quantify any bias evident over time.

Between observer bias is analysed in Chapter 5 where the number of observations made by the observer for the most commonly encountered species in a specific time interval (observation window) is converted to an observation rate for each observer. These rates are then plotted against time interval and linear regressions fitted. To demonstrate significant difference between observers an analysis of covariance (ANCOVA) is applied with the transformed observation (squareroot) rate as dependant variable, observer as fixed factor and time as covariant.

Data analysis was accomplished using Microsoft Excel to summarise data and SPSS for all other analyses.

# CHAPTER 3

## *RESULTS AND DISCUSSION*

### *PRECISION*

Results

Estimates of precision derived from bootstrap replications are presented in table 1 as standard errors of the mean and as coefficients of variation. The means of these results are presented in figure 8. It can be seen that there is considerable variation in the estimates of C.V., they range from a low value of less than 5,3% to a high in excess of 70% for some species (figure 8).

For the purpose of discussion in the following review of results by species and area-habitat type the C.V. is used as a measure of precision.

*Kudu*

Ten estimates of precision were obtained for kudu ranging from 5,3 to 54,2% with a median of 14,6% (N = 10). Single observations were obtained for lowveld mopane veld and the sourish mixed bushveld (29,6 and 5,3% respectively). The results for the northern mopane veld were particularly poor with a high of 70,9%, while a median of five observations in northwestern arid bushveld showed a precision of 12,5%.

*Zebra*

Six estimates of precision were obtained for zebra with C.V.'s ranging from 4,9 to 61,9%. Single observations for lowveld mopane veld, sourish mixed bushveld and northwestern arid bushveld were 18,6; 7,2 and 11,3% respectively. The median of three observations for northern mopane veld is 9,8%.

*Wildebeest*

Similarly, in the case of wildebeest, seven C.V.'s obtained range from a low of 3,8 to a high of 70,9% with a median of 8,2%. The C.V.'s for lowveld mopane veld, sourish mixed bushveld and northwestern arid bushveld are 6,8; 8,2 and 9,0 respectively while a median of 19,1 was obtained for the northern mopane veld.

*Impala*

Eleven estimates of precision were obtained for impala with C.V.'s ranging from the high of 70,9 to 7,7% with a median of 14,3%. Single values for lowveld mopane veld and sourish mixed bushveld are 16,9 and 9,0% respectively. The median C.V. for northern mopane veld is 9,5% and that for northwestern arid bushveld 9,7%.

*Giraffe*

There were only four estimates of precision obtained for giraffe with C.V.'s of 30,1; 31,3; 19,0 and 0 for lowveld mopane veld, sourish mixed bushveld and the last two for northern mopane veld respectively. This computes to a median of 24,6%.

Several other species were present and their results appear in table 1.

Discussion

Beasom (1979) reports variations in replicated helicopter counts in Texas, ranging from 0,9% to 32,3%, while Le Resche and Rausch (1974) report coefficients of variation ranging from 16% to 41% in fixed wing counts of moose and they also report significantly lower CV's in some seasons (spring, $p < 0.05$). Hirst (1969) recorded variability of 12,8% to 32,2% on strip counts of blesbok on Rietvlei Nature Reserve. Beasom (1979) indicates a significant negative correlation between CV and mean estimated deer population and area size. Rice and Harder (1977) comment on the high precision attained using helicopters for mark-recapture counts in Ohio and reports a CV of 7%. McCullough (1994), in documenting herd composition counts of black tailed deer, describes large variances, consequently questioning the value of the data in decision making. Generally results obtained appear consistent in range with those of other authors and are mainly unpredictable.

The means of the C.V. indicate that, in most cases, the precision is inadequate for decision making on an annual basis, making the use of single pass surveys doubtful as a decision support tool in ungulate management goal achievement.

Table 1: Summary precision data for 61 observations during this study.

| STUDY SITE | SPECIES | COUNT REPLICATES 1 | 2 | 3 | 4 | MEAN | BOOTSTRAPPED SD | SE | CV |
|---|---|---|---|---|---|---|---|---|---|
| .ETABA | *KUDU* | **25** | **48** | **57** | **35** | 41.3 | 12.2 | 6.1 | 29.6 |
| RANCH | *ZEBRA* | **76** | **60** | **54** | **46** | 59.0 | 11.0 | 5.5 | 18.6 |
| MOPANIEVELD | *WILDEBEEST* | **67** | **62** | **59** | **70** | 64.5 | 4.4 | 2.2 | 6.8 |
| | *IMPALA* | **633** | **727** | **615** | **446** | 605.3 | 102.4 | 51.2 | 16.9 |
| | *GIRAFFE* | **25** | **48** | **57** | **35** | 41.3 | 12.4 | 6.2 | 30.1 |
| .OSKOP DAM | *KUDU* | **263** | **274** | **260** | **237** | 258.5 | 13.8 | 6.9 | 5.3 |
| MIXED BUSHVELD | *ZEBRA* | **262** | **236** | **243** | **214** | 238.8 | 17.2 | 8.6 | 7.2 |
| | *WILDEBEEST* | **160** | **192** | **200** | **192** | 186.0 | 15.2 | 7.6 | 8.2 |
| | *IMPALA* | **285** | **346** | **291** | **345** | 316.8 | 28.6 | 14.3 | 9.0 |
| | *GIRAFFE* | **33** | **14** | **19** | **26** | 23.0 | 7.2 | 3.6 | 31.3 |
| | *WARTHOG* | **35** | **37** | **46** | **37** | 38.8 | 4.2 | 2.1 | 10.8 |
| | *SABLE* | **43** | **41** | **45** | **36** | 41.3 | 3.4 | 1.7 | 8.2 |
| | *WHITE RHINO* | **32** | **33** | **25** | **30** | 30.0 | 3.2 | 1.6 | 10.7 |
| | *MT.REEDBUCK* | **163** | **149** | **170** | **141** | 155.8 | 11.4 | 5.7 | 7.3 |

Table 1 continued:-

| STUDY SITE | SPECIES | COUNT REPLICATES 1 | 2 | 3 | 4 | MEAN | BOOTSTRAPPED SD | SE | CV |
|---|---|---|---|---|---|---|---|---|---|
| VHEMBE | *KUDU* | **3** | **13** | **7** | | 7.7 | 4.2 | 2.4 | 54.2 |
| MOPANIEVELD | *KUDU* | **26** | **30** | **50** | | 35.3 | 10.4 | 6.0 | 29.4 |
| | *KUDU* | **28** | **26** | **21** | | 25.0 | 2.9 | 1.7 | 11.8 |
| | *ZEBRA* | **13** | **3** | **5** | | 7.0 | 4.3 | 2.5 | 61.9 |
| | *ZEBRA* | **55** | **55** | **61** | | 57.0 | 2.8 | 1.6 | 4.9 |
| | *ZEBRA* | **24** | **25** | **20** | | 23.0 | 2.3 | 1.3 | 9.8 |
| | *WILDEBEEST* | **23** | **0** | **21** | | 14.7 | 10.4 | 6.0 | 70.9 |
| | *WILDEBEEST* | **94** | **106** | **100** | | 100.0 | 4.8 | 2.8 | 4.8 |
| | *WILDEBEEST* | **32** | **76** | **54** | | 54.0 | 18.0 | 10.4 | 33.4 |
| | *WILDEBEEST* | **70** | **64** | **69** | | 67.7 | 2.6 | 1.5 | 3.8 |
| | *IMPALA* | **120** | **85** | **122** | | 109.0 | 17.1 | 9.9 | 15.7 |
| | *IMPALA* | **210** | **160** | **178** | | 182.7 | 20.4 | 11.8 | 11.2 |
| | *IMPALA* | **122** | **114** | **137** | | 124.3 | 9.5 | 5.5 | 7.7 |
| | *IMPALA* | **175** | **288** | **372** | | 278.3 | 81.9 | 47.3 | 29.4 |
| | *GIRAFFE* | **22** | **18** | **21** | | 20.3 | 1.7 | 1.0 | 8.5 |
| | *GIRAFFE* | **4** | **4** | **4** | | 4.0 | 0.0 | 0.0 | 0.0 |
| | *WARTHOG* | **5** | **3** | **2** | | 3.3 | 1.2 | 0.7 | 36.4 |
| | *WARTHOG* | **21** | **26** | **11** | | 19.3 | 6.2 | 3.6 | 32.3 |
| | *ELAND* | **3** | **7** | **3** | | 4.3 | 1.9 | 1.1 | 44.0 |
| | *ELAND* | **5** | **11** | **10** | | 8.7 | 2.6 | 1.5 | 30.0 |
| | *ELAND* | **5** | **3** | **2** | | 3.3 | 1.2 | 0.7 | 36.4 |
| | *HARTEBEEST* | **22** | **15** | **26** | | 21.0 | 6.2 | 3.6 | 29.7 |
| | *GEMSBOK* | **26** | **27** | **28** | | 27.0 | 0.9 | 0.5 | 3.2 |
| | *WATERBUCK* | **5** | **14** | **16** | | 11.7 | 4.8 | 2.8 | 41.6 |
| | *WATERBUCK* | **27** | **15** | **15** | | 19.0 | 5.7 | 3.3 | 30.1 |
| | *WATERBUCK* | **12** | **10** | **12** | | 11.3 | 0.9 | 0.5 | 7.6 |
| ATHERSTONE | *KUDU* | **132** | **116** | **108** | | 118.7 | 9.9 | 5.7 | 8.3 |
| NW ARID | *KUDU* | **22** | **26** | **33** | | 27.0 | 4.5 | 2.6 | 16.7 |
| BUSHVELD | *KUDU* | **19** | **33** | **24** | | 25.3 | 5.7 | 3.3 | 22.6 |
| | *KUDU* | **34** | **33** | **28** | | 31.7 | 2.6 | 1.5 | 8.2 |
| | *KUDU* | **9** | **7** | **9** | | 8.3 | 1.0 | 0.6 | 12.5 |
| | *ZEBRA* | **37** | **39** | **30** | | 35.3 | 4.0 | 2.3 | 11.3 |
| | *WILDEBEEST* | **219** | **185** | **230** | | 211.3 | 19.1 | 11.0 | 9.0 |
| | *IMPALA* | **477** | **477** | **346** | | 433.3 | 62.0 | 35.8 | 14.3 |
| | *IMPALA* | **117** | **78** | **123** | | 106.0 | 19.7 | 11.4 | 18.6 |
| | *IMPALA* | **17** | **16** | **0** | | 11.0 | 7.8 | 4.5 | 70.9 |
| | *IMPALA* | **141** | **179** | **167** | | 162.3 | 15.8 | 9.1 | 9.7 |
| | *IMPALA* | **69** | **82** | **66** | | 72.3 | 6.9 | 4.0 | 9.6 |
| | *WARTHOG* | **87** | **79** | **32** | | 66.0 | 24.9 | 14.4 | 37.8 |
| | *WARTHOG* | **71** | **81** | **49** | | 67.0 | 13.5 | 7.8 | 20.2 |
| | *WARTHOG* | **52** | **29** | **36** | | 39.0 | 9.7 | 5.6 | 24.9 |
| | *WARTHOG* | **54** | **33** | **41** | | 42.7 | 8.7 | 5.0 | 20.3 |
| | *WARTHOG* | **67** | **39** | **27** | | 44.3 | 16.3 | 9.4 | 36.7 |
| | *HARTEBEEST* | **7** | **10** | **32** | | 16.3 | 11.1 | 6.4 | 67.9 |
| | *HARTEBEEST* | **29** | **22** | **30** | | 27.0 | 3.6 | 2.1 | 13.5 |
| | *GEMSBOK* | **79** | **91** | **71** | | 80.3 | 8.3 | 4.8 | 10.3 |
| | *WATERBUCK* | **18** | **23** | **29** | | 23.3 | 4.5 | 2.6 | 19.3 |

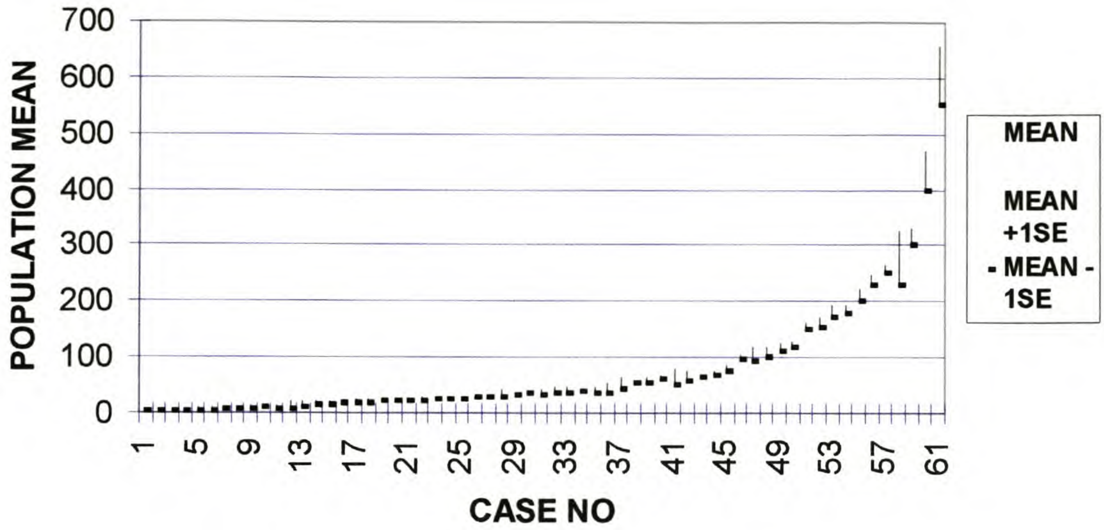


Figure 8: Hi-lo-close graph of count (population) mean +/- 1 standard error.

A regression analysis for all species and vegetation type (site) of the mean count (population) size by the standard error (SE) shows significant correlation ($R^2 = 0,71$, p< 0,074 N = 63). This is an indication that the CV is constant indicating that the technique is robust. Similar regressions by species for those species having several observations show a similar result. For impala, $R^2 = 0,67$, p < 0,002, N = 10; kudu, $R^2 = 0,39$, p < 0,054, N = 9; Warthog, $R^2 = 0,64$, p < 0,018, N = 7; and zebra, $R^2 = 0,86$, p < 0,021, N = 8. In the case of wildebeest however, the result is not significant ($R^2 = 0,17$, p > 0,361, N = 6).

Further regression analysis by vegetation type shows significant coefficients of determination for lowveld mopanie veld (Letaba Ranch) ($R^2 = 0,99$, p < 0,001, N = 4); sourish mixed bushveld (Loskop Dam) ($R^2 = 0,86$, p < 0.001, N = 8); Northern mopanie veld (Vhembe) ($R^2 = 0,72$, p < 0,01, N = 25) and northwest arid bushveld (Atherstone) ($R^2 = 0,81$, p < 0,01, N = 20). The first mentioned of these could be an artefact of small sample size however.

***POWER***

Results

Full analysis of data from all 12 properties dealt with in this study constitutes 265 tables and figures. In the interests of economy only the results from Loskop Dam Nature Reserve (the largest data set) are presented as a representative and discussed in detail. The full suite of results, non-centrality parameters, power and power curves are presented sequentially by study site in Appendix A.

Since the rate of increase of most larger antelope species lies in the range 10 – 20% I investigated the power of the survey method to detect changes in the population of 15%. Also because the cost of a type I error is generally low in South African wildlife management within this range of population change, this was set at talpha.1 (10% significance) and talpha.2 (20% significance) respectively.

This has the advantage of increasing the power of the test.

*Kudu*

At talpha.1, power values for 15% population change range between 60% for the 2-2 option to 89% for the 3-3 option and 97% for the 4-4 option(table 4 and figure 9). Reducing significance levels to talpha.2 shows an increase in the 2-2 option (83%)(figure 10). Table 21 shows power ranges for kudu for all properties counted. Kudu were encountered on 10 different properties and power to detect a 15% population change at talpha.1 ranged from 13 to 89% with a mean power of 42%.

*Zebra*

Table 2 shows that the four counts for zebra range from 214 to 262 with a mean of 239. Table 5 reflects the non-centrality parameters for effect sizes of 5% to 40% of population mean. Power values in table 6 shows that ranges of 41% for the 2-2 option through 68% for the 3-3 option to 83% for the 4-4 option were attained at talpha.1. Again these values improve marginally for the talpha.2 significance level. These results are shown as power curves in figures 11 and 12. Of the 9 properties where zebra were counted power to detect a 15% population change at talpha.1 ranged from 8 to 91% with a mean of 50% (table 22).

*Wildebeest*

Non-centrality parameters for various replicate options for blue wildebeest are presented for effect sizes ranging from 5% to 40% in table 7. Table 8 shows the power values for talpha.1 and talpha.2 respectively. Power values for 15% population change range from 19% to 73% at talpha.1 with the last mentioned highest value at a 4-4 count replicate option and the lowest at a 2-1 option. At talpha.2 the 4-4 option has 86% power. The power values are presented in figures 13 and 14 as power curves for all count replicate options. Power ranges to detect a 15% population change in wildebeest on the 9 properties where they were encountered at talpha.1 started at 8% with a high of 99% (table 23). The mean in this case was 29%.

*Impala*

In the case of impala the non-centrality parameters are reflected in table 9 for the various replicate options and range of effect sizes. A review of the power values (table 10) shows that the power for equal replicate options in year 1 and year 2 ranges from 30% to 66% at talpha.1 with the 4-4 option at the high end of the scale. Once again the decrease of significance to talpha.2 produces an increase in power with the 2-2 replicate option now having 51% power. The resulting plots of the power values are illustrated in figures 15 and 16. Mean power to detect a 15% population change at talpha.1 for the 12 properties harbouring impala was only 18% with a range of 8 to 51%.

*Warthog*

For the 2-2 option, 24% power was attained increasing to 40% for the 3-3 option and to 52% for the 4-4 option, all at talpha.1. Again, as expected the significance drop to talpha.2 brings about increases in power to 69% for the 4-4 option. These results are presented in tables 11 and 12 and the power curves as figures 17 and 18.

*Sable antelope*

Power values to show a 15% population change in the sable population for replicate options range from 19% to 75% for the 2-1 and 4-4 options respectively at talpha.1. As expected the relaxing of the significance to talpha.2 results in a commensurate increase in power values with the 2-1 option at 36% and the 4-4-option power raised to 88%. The non-centrality parameters are given in table 13 and the resulting power values for both talpha.2 and talpha.1 appear in table 14. The power curves are illustrated in figures 19 and 20.

*White rhino*

Table 15 contains the non-centrality parameters for white rhino at Loskop Dam and table 16 the power values for different effect sizes at talpha.2 and talpha.1 significance respectively. At talpha.1 significance 39% power is obtained at a 2-2 replicate option increasing to 65% at the 3-3 option and improving to 81% at the 4-4 option. The values at 3-3 replicates increase to 82% at talpha.2. Figures 21 and 22 present the power curves at the two significance options.

*Mountain reedbuck*

For mountain reedbuck the non-centrality parameters are reflected in table 17 for the various replicate options and range of effect sizes. A review of the power values (table 18) shows that the power for replicate options in year 1 and year 2 ranges from 7% to 13% at talpha.1 significance with the 4-4 option at the high end of the scale. Once again the decrease of significance to talpha.2 produces an increase in power with the 2-1 replicate option now having 15% power and the 4-4 option at 22%. The resulting plots of the power values are illustrated in figures 23 and 24.

*Giraffe*

Table 2 shows that the four counts for giraffe range from 14 to 33 with a mean of 23. Table 19 reflects the non-centrality parameters for effect sizes of 5% to 40% of population mean. Power values in table 20 shows that ranges of 33% for the 2-1 option to 99% for the 4-4 option were attained at talpha.1. Again these values improve marginally for talpha.2 level for lower replicate options (2-1; 59%). The results are shown as power curves in figures 25 and 26.

Discussion

References to the use of statistical power in wildlife management are sparse and those that do exist are mostly references to prospective power analyses in which authors speculate on the ability of estimates of abundance to detect change. Gerrodette (1987) provides a numerical example based on replicated strip transects of aerial counts of sea otters in 1981/82 undertaken by the US Fish and Wildlife Service to calculate precision of the counts. This author presents power curves for rates of increase and number of flights per year and a 5% population change can be detected at significant power using 8 flights at 1 year intervals.

Fabricius, van Hensbergen and Zucchini (1989) show power curves for various significance tests ability to show deviation from sample mean in detecting blesbok/bontebok hybrids. Gerrodette (1987&1993) illustrates the use of the "TRENDS" computer programme in showing the relationship between 5 key parameters, viz. Sampling occasions, rate of change between occasions, CV, significance and power.

Gorman, Primevera and Allison (1995) also show how the "POWPAL" programme can be used to calculate formulae for effect size, statistical power and sample size. Nickerson and Brunell (1995) calculate power for detecting trends in spotlight alligator counts after adjustment of concomitant variables affecting the counts and they conclude that the adjustments improve power.

Several publications were initiated by the monitoring of decline of amphibian populations in the United States and specifically Reed and Blaustein (1995 & 1997) show that statistical power was below that required to conclude that the populations were not declining. Hayes and Steidl (1997) and Thomas (1997) expanded upon these arguments. These authors also concluded that retrospective power analysis on non-significant trends would result in power being below 0,5. Cohen (1988) considers 80% power to be the goal for confidence and this author concurs.

Steidl, Hayes and Schauber (1997) determine power as part of a prospective analysis of potential population changes of 4 bird species in the Pacific northwest of the United States and concluded that power was only adequate to detect 100% changes in these populations. These authors also question the validity of retrospective power analysis and propose the use of confidence intervals in lieu thereof.

No references could be found pertaining to power analyses and large ungulate population estimation. Latterly, two publications, Reilly and Emslie (1998) and Reilly and Haskins (1999) show the results of restrospective power analyses on replicated large ungulate counts. Results of the first mentioned publication follow a similar approach to those in this study using one of these sample site while the second uses power to compare efficiency of two different techniques in detecting change in large ungulate populations. Results in both cases show similar acceptable power levels achieved for most species using both helicopter based total surveys and ground surveys. Johnson (1999) questions the use of hypothesis testing altogether in the wildlife field while Marshal and Boutin (1999) demonstrate power analysis in wolf – moose functional responses.

In this study we have seen the use of retrospective power analysis across a broad range of African large ungulate species in several savanna sites in South Africa. The analysis is based on a commonly applied techniques used to detect "population change" over time. In some cases power attained achieved the goal of 80% (Cohen 1988) for confidence. This analysis which includes estimators of variance can now be used over a broad spectrum of management applications in a prospective manner to increase the cost efficiency of ungulate monitoring in southern Africa.

Table 2: Summary statistics of four replicate helicopter counts at Loskop Dam Nature Reserve, showing bootstrapped SD's for n=2, n=3 and n=4 as well as standard errors (SE) for differences in means from year 1 to year 2 for various replicates of counts (1,2,3,and 4).

| SPECIES | COUNT REPLICATES | | | | MEAN | # STANDARD DEVIATION(n2) | STANDARD DEVIATION(n3) | STANDARD DEVIATION(n4) |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | | | | |
| *KUDU* | **263** | **274** | **260** | **237** | 258.50 | 13.17 | 13.33 | 13.39 |
| *ZEBRA* | **262** | **236** | **243** | **214** | 238.75 | 16.94 | 17.15 | 17.19 |
| *WILDEBEEST* | **160** | **192** | **200** | **192** | 186.00 | 15.19 | 15.50 | 15.52 |
| *IMPALA* | **285** | **346** | **291** | **345** | 316.75 | 29.01 | 28.85 | 28.76 |
| *WARTHOG* | **35** | **37** | **46** | **37** | 38.75 | 4.28 | 4.28 | 4.27 |
| *SABLE* | **43** | **41** | **45** | **36** | 41.25 | 3.38 | 3.33 | 3.33 |
| *WHITE RHINO* | **32** | **33** | **25** | **30** | 30.00 | 3.07 | 3.07 | 3.08 |
| *MT.REEDBUCK* | **163** | **149** | **170** | **141** | 155.75 | 11.25 | 11.36 | 11.34 |
| *GIRAFFE* | **33** | **14** | **19** | **26** | 23.00 | 7.11 | 7.12 | 7.15 |

| SPECIES | SEdiff21* | SEdiff22 | SEdiff23 | SEdiff31 | SEdiff33 | SEdiff41 | SEdiff42 | SEdiff43 | SEdiff44 |
|---|---|---|---|---|---|---|---|---|---|
| *KUDU* | 16.13 | 13.17 | 12.02 | 15.39 | 10.88 | 14.97 | 11.60 | 10.23 | 9.47 |
| *ZEBRA* | 20.75 | 16.94 | 15.47 | 19.80 | 14.00 | 19.22 | 14.89 | 13.13 | 12.16 |
| *WILDEBEEST* | 18.61 | 15.19 | 13.87 | 17.89 | 12.65 | 17.35 | 13.44 | 11.85 | 10.97 |
| *IMPALA* | 35.53 | 29.01 | 26.48 | 33.31 | 23.55 | 32.16 | 24.91 | 21.97 | 20.34 |
| *WARTHOG* | 5.25 | 4.28 | 3.91 | 4.94 | 3.50 | 4.78 | 3.70 | 3.26 | 3.02 |
| *SABLE* | 4.14 | 3.38 | 3.09 | 3.85 | 2.72 | 3.72 | 2.88 | 2.54 | 2.35 |
| *WHITE RHINO* | 3.76 | 3.07 | 2.80 | 3.54 | 2.50 | 3.44 | 2.66 | 2.35 | 2.18 |
| *MT.REEDBUCK* | 13.77 | 11.25 | 10.27 | 13.12 | 9.28 | 12.68 | 9.82 | 8.66 | 8.02 |
| *GIRAFFE* | 8.71 | 7.11 | 6.49 | 8.22 | 5.81 | 8.00 | 6.20 | 5.46 | 5.06 |

* $$SE = s\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}$$

# STANDARD DEVIATION ($S$) = Bootstrapped standard deviation for 2 counts, 3 counts or 4 counts

$n_1$ and $n_2$ = number of counts in year 1 and year 2

Table 3: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of the mean for different replicate options from year 1 to year 2 for calculation of power for kudu at Loskop Dam Nature Reserve.

| **KUDU** | | | **MEAN** | **258.5** | **EFFECT SIZE(%MEAN)** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 12.93 | 25.85 | 38.78 | 51.70 | 64.63 | 77.55 | 90.48 | 103.40 |
| **n1** | **n2** | **df** | **talpha.1*** | **talpha.2** | **NON CENTRALITY PARAMETERS** (Delta #) | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.80 | 1.60 | 2.40 | 3.21 | 4.01 | 4.81 | 5.61 | 6.41 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.98 | 1.96 | 2.94 | 3.93 | 4.91 | 5.89 | 6.87 | 7.85 |
| 2 | 3 | 3 | 2.35 | 1.64 | 1.08 | 2.15 | 3.23 | 4.30 | 5.38 | 6.45 | 7.53 | 8.60 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.84 | 1.68 | 2.52 | 3.36 | 4.20 | 5.04 | 5.88 | 6.72 |
| 3 | 3 | 4 | 2.13 | 1.53 | 1.19 | 2.37 | 3.56 | 4.75 | 5.94 | 7.12 | 8.31 | 9.50 |
| 4 | 1 | 3 | 2.35 | 1.64 | 0.86 | 1.73 | 2.59 | 3.45 | 4.32 | 5.18 | 6.04 | 6.91 |
| 4 | 2 | 4 | 2.13 | 1.53 | 1.11 | 2.23 | 3.34 | 4.46 | 5.57 | 6.69 | 7.80 | 8.92 |
| 4 | 3 | 5 | 2.02 | 1.48 | 1.26 | 2.53 | 3.79 | 5.06 | 6.32 | 7.58 | 8.85 | 10.11 |
| 4 | 4 | 6 | 1.94 | 1.44 | 1.37 | 2.73 | 4.10 | 5.46 | 6.83 | 8.19 | 9.56 | 10.92 |

* talpha.1 = $t_{n_1+n_2-2;\alpha}$ is the critical value of the t-distribution with $n_1 + n_2 - 2$ degrees of freedom and $\alpha$ = 0,1.

n1 and n2 = number of counts in year 1 and year 2

\# $$\Delta = -\left[-t_{\phi} - l\left(1+\frac{(-t_{\phi})}{2df}\right)^{\frac{1}{2}}\right]$$

Table 4: Power values to detect population change as a percentage of the mean for various count replicate options in year 1 and year 2 for kudu at 10% and 20% significance at Loskop Dam Nature Reserve.

talpha.1 KUDU

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.11 | 0.20 | 0.29 | 0.38 | 0.47 | 0.55 | 0.62 | 0.68 |
| **2_2** | 0.17 | 0.37 | 0.60 | 0.79 | 0.91 | 0.97 | 0.99 | 1.00 |
| **2_3** | 0.21 | 0.51 | 0.79 | 0.94 | 0.99 | 1.00 | 1.00 | 1.00 |
| **3_1** | 0.15 | 0.31 | 0.51 | 0.69 | 0.83 | 0.92 | 0.97 | 0.99 |
| **3_3** | 0.26 | 0.62 | 0.89 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 |
| **4_1** | 0.17 | 0.38 | 0.63 | 0.83 | 0.94 | 0.98 | 1.00 | 1.00 |
| **4_2** | 0.24 | 0.58 | 0.86 | 0.97 | 1.00 | 1.00 | 1.00 | 1.00 |
| **4_3** | 0.29 | 0.70 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| **4_4** | 0.34 | 0.78 | 0.97 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.23 | 0.38 | 0.54 | 0.68 | 0.78 | 0.86 | 0.92 | 0.95 |
| **2_2** | 0.31 | 0.60 | 0.83 | 0.95 | 0.99 | 1.00 | 1.00 | 1.00 |
| **2_3** | 0.36 | 0.71 | 0.92 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 |
| **3_1** | 0.27 | 0.52 | 0.75 | 0.90 | 0.97 | 0.99 | 1.00 | 1.00 |
| **3_3** | 0.42 | 0.80 | 0.97 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| **4_1** | 0.29 | 0.58 | 0.82 | 0.95 | 0.99 | 1.00 | 1.00 | 1.00 |
| **4_2** | 0.39 | 0.76 | 0.95 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| **4_3** | 0.45 | 0.85 | 0.98 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| **4_4** | 0.50 | 0.89 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

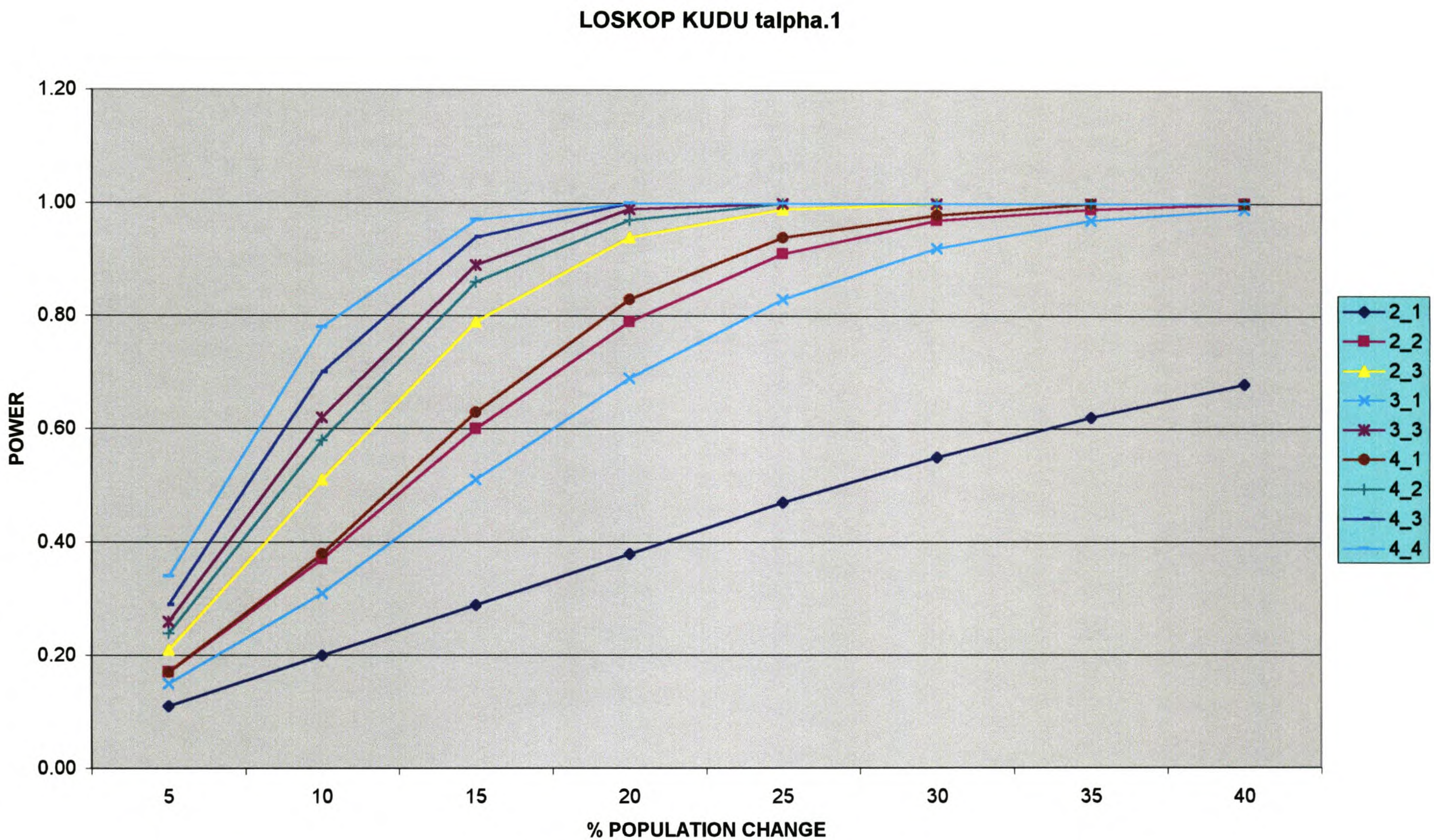


Figure 9: Power curves for various count replicate options at 10% significance for kudu at Loskop Dam Nature Reserve

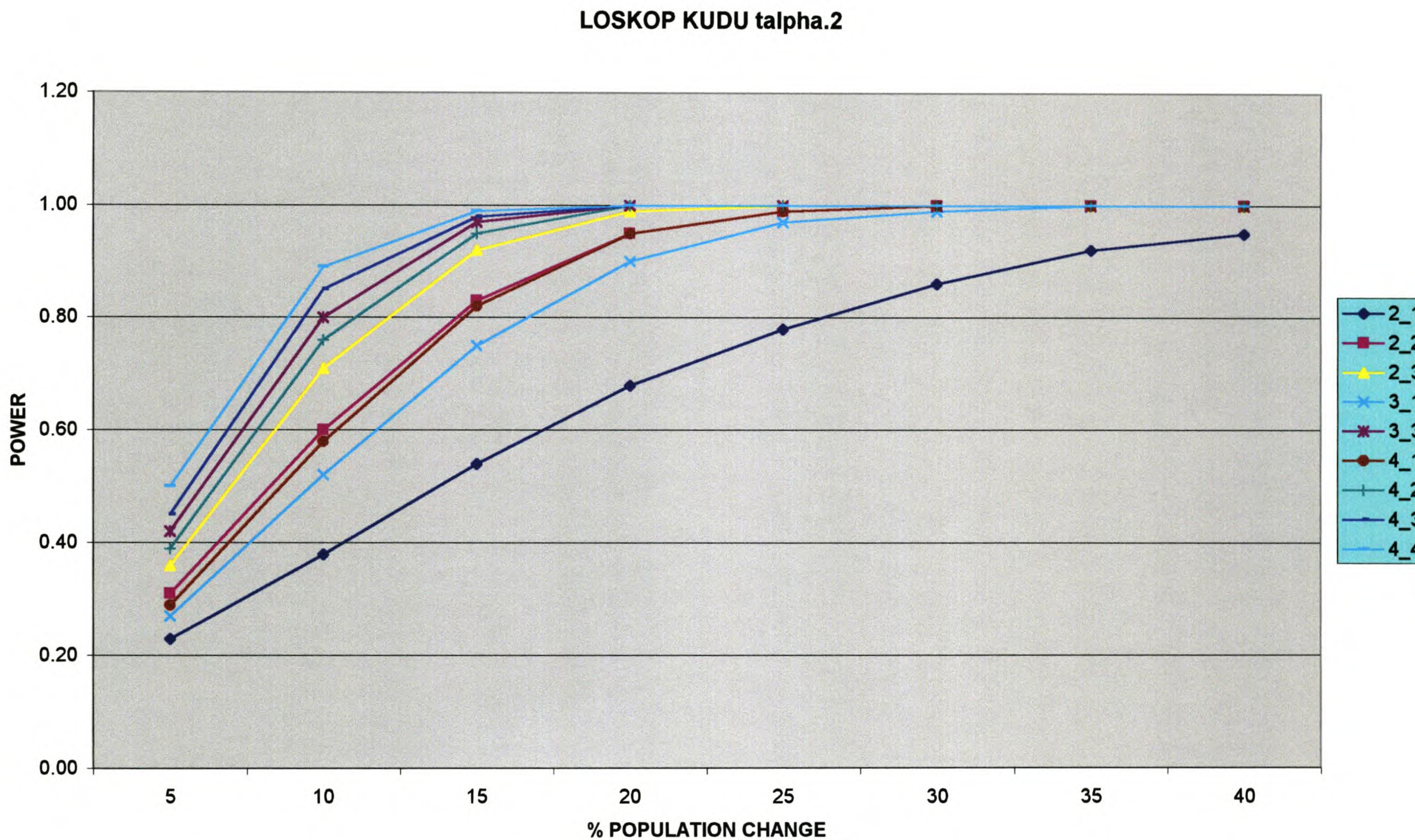


Figure 10: Power curves for various count replicate options at 20% significance for kudu at Loskop Dam Nature Reserve.

Table 5: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of the mean for different replicate options from year 1 to year 2 for calculation of power for zebra at Loskop Dam Nature Reserve.

| ZEBRA | | | MEAN | 238.75 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 11.94 | 23.88 | 35.81 | 47.75 | 59.69 | 71.63 | 83.56 | 95.50 |
| **n1** | **n2** | **df** | **talpha.1** | **talpha.2** | **NON CENTRALITY PARAMETERS** | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.58 | 1.15 | 1.73 | 2.30 | 2.88 | 3.45 | 4.03 | 4.60 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.70 | 1.41 | 2.11 | 2.82 | 3.52 | 4.23 | 4.93 | 5.64 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.77 | 1.54 | 2.32 | 3.09 | 3.86 | 4.63 | 5.40 | 6.17 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.60 | 1.21 | 1.81 | 2.41 | 3.01 | 3.62 | 4.22 | 4.82 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.85 | 1.71 | 2.56 | 3.41 | 4.26 | 5.12 | 5.97 | 6.82 |
| 4 | 1 | 3 | 2.35 | 1.64 | 0.62 | 1.24 | 1.86 | 2.48 | 3.10 | 3.73 | 4.35 | 4.97 |
| 4 | 2 | 4 | 2.13 | 1.53 | 0.80 | 1.60 | 2.40 | 3.21 | 4.01 | 4.81 | 5.61 | 6.41 |
| 4 | 3 | 5 | 2.02 | 1.48 | 0.91 | 1.82 | 2.73 | 3.64 | 4.54 | 5.45 | 6.36 | 7.27 |
| 4 | 4 | 6 | 1.94 | 1.44 | 0.98 | 1.96 | 2.95 | 3.93 | 4.91 | 5.89 | 6.87 | 7.85 |

* talpha.1 = $t_{n_1+n_2-2;\alpha}$ is the critical value of the t-distribution with $n_1 + n_2 - 2$ degrees of freedom and $\alpha$ = 0,1.

n1 and n2 = number of counts in year 1 and year 2

\# 
$$\Delta = -\left[ -t_{\phi} - l\left(1 + \frac{(-t_{\phi})}{2df}\right)^{\frac{1}{2}} \right]$$

Table 6: Power values to detect population change as a percentage of the mean for various count replicate options in year 1 and year 2 for zebra at 10% and 20% significance at Loskop Dam Nature Reserve.

talpha.1 ZEBRA

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.09 | 0.15 | 0.22 | 0.28 | 0.35 | 0.41 | 0.47 | 0.53 |
| **2_2** | 0.13 | 0.25 | 0.41 | 0.58 | 0.72 | 0.84 | 0.91 | 0.96 |
| **2_3** | 0.15 | 0.33 | 0.56 | 0.76 | 0.89 | 0.96 | 0.99 | 1 |
| **3_1** | 0.11 | 0.21 | 0.34 | 0.48 | 0.62 | 0.74 | 0.83 | 0.9 |
| **3_3** | 0.18 | 0.41 | 0.68 | 0.87 | 0.96 | 0.99 | 1 | 1 |
| **4_1** | 0.13 | 0.25 | 0.42 | 0.6 | 0.76 | 0.87 | 0.94 | 0.98 |
| **4_2** | 0.17 | 0.38 | 0.63 | 0.84 | 0.95 | 0.99 | 1 | 1 |
| **4_3** | 0.2 | 0.47 | 0.76 | 0.93 | 0.99 | 1 | 1 | 1 |
| **4_4** | 0.22 | 0.54 | 0.83 | 0.96 | 1 | 1 | 1 | 1 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.19 | 0.29 | 0.41 | 0.52 | 0.63 | 0.71 | 0.79 | 0.84 |
| **2_2** | 0.24 | 0.44 | 0.64 | 0.81 | 0.92 | 0.97 | 0.99 | 1 |
| **2_3** | 0.27 | 0.51 | 0.75 | 0.91 | 0.97 | 0.99 | 1 | 1 |
| **3_1** | 0.21 | 0.38 | 0.56 | 0.72 | 0.85 | 0.93 | 0.97 | 0.99 |
| **3_3** | 0.30 | 0.6 | 0.84 | 0.96 | 0.99 | 1 | 1 | 1 |
| **4_1** | 0.23 | 0.41 | 0.62 | 0.79 | 0.91 | 0.97 | 0.99 | 1 |
| **4_2** | 0.29 | 0.56 | 0.8 | 0.94 | 0.99 | 1 | 1 | 1 |
| **4_3** | 0.33 | 0.65 | 0.89 | 0.98 | 1 | 1 | 1 | 1 |
| **4_4** | 0.36 | 0.7 | 0.93 | 0.99 | 1 | 1 | 1 | 1 |

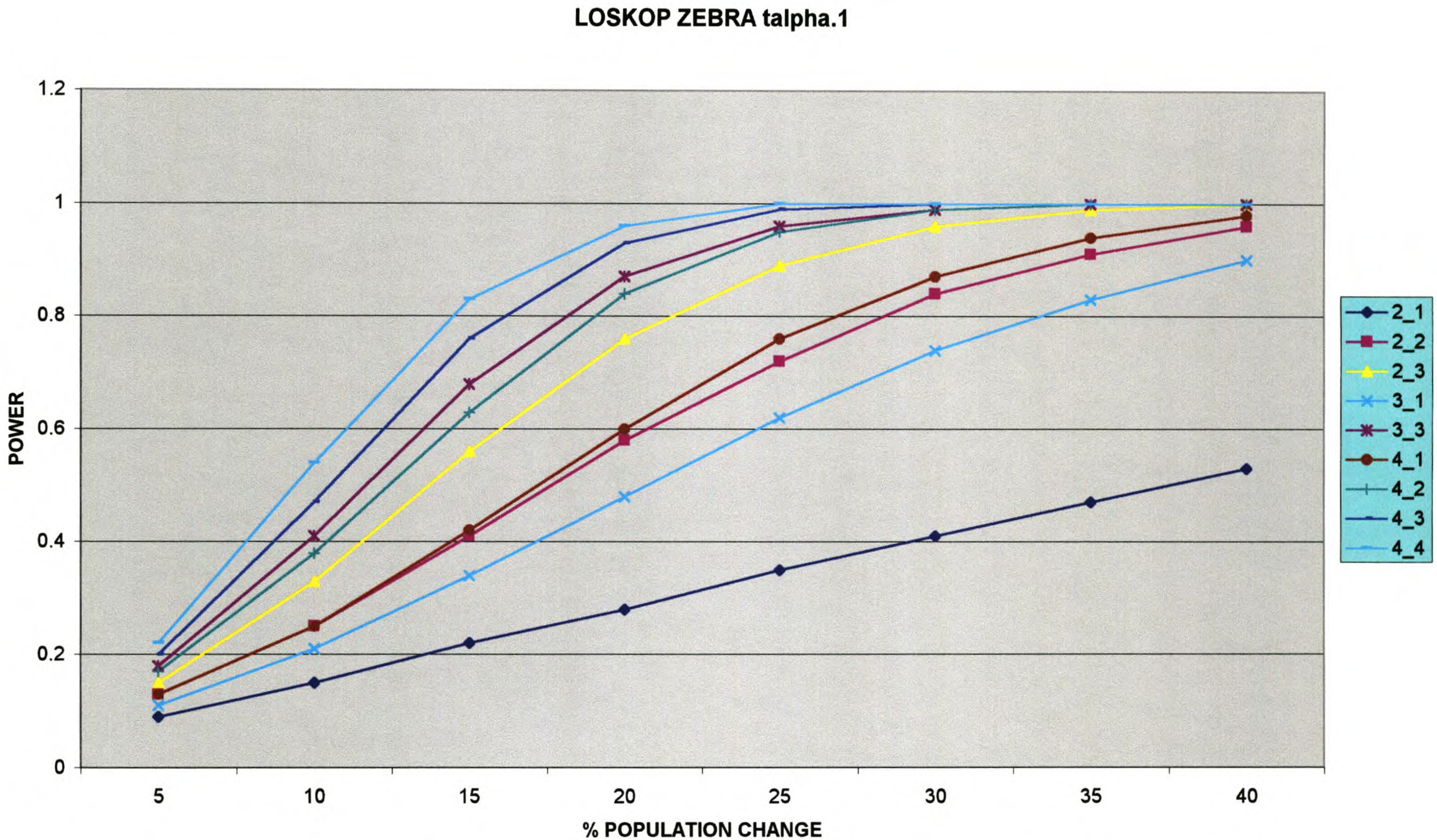


Figure 11: Power curves for various count replicate options at 10% significance for zebra at Loskop Dam Nature Reserve.

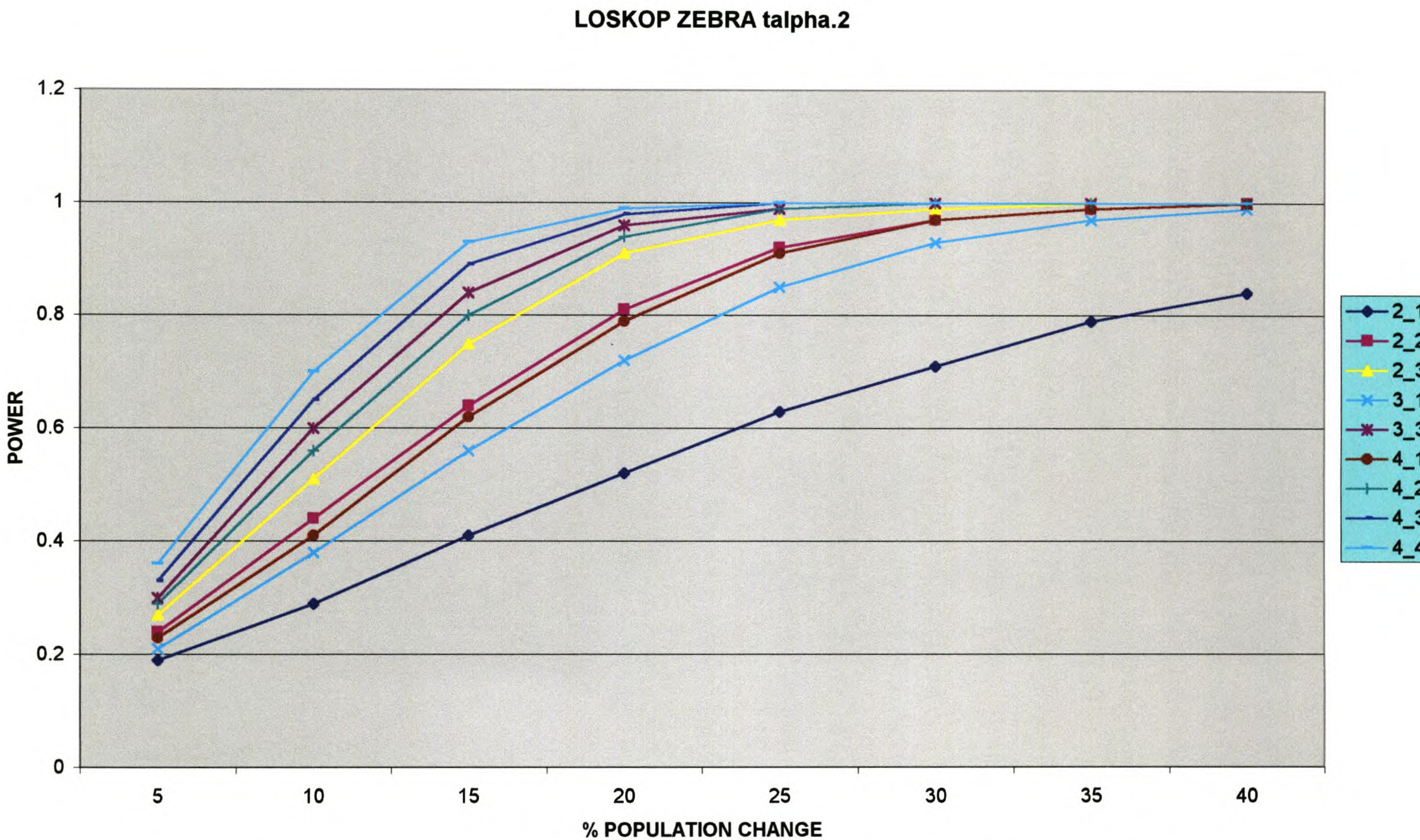


Figure 12: Power curves for various count replicate options at 20% significance for zebra at Loskop Dam Nature Reserve.

Table 7: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of the mean for different replicate options from year 1 to year 2 for calculation of power for wildebeest at Loskop Dam Nature Reserve.

| WILDEBEEST | | MEAN | 186 | | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 9.30 | 18.60 | 27.90 | 37.20 | 46.50 | 55.80 | 65.10 | 74.40 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.50 | 1.00 | 1.50 | 2.00 | 2.50 | 3.00 | 3.50 | 4.00 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.61 | 1.22 | 1.84 | 2.45 | 3.06 | 3.67 | 4.28 | 4.90 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.67 | 1.34 | 2.01 | 2.68 | 3.35 | 4.02 | 4.69 | 5.36 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.52 | 1.04 | 1.56 | 2.08 | 2.60 | 3.12 | 3.64 | 4.16 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.74 | 1.47 | 2.21 | 2.94 | 3.68 | 4.41 | 5.15 | 5.88 |
| 4 | 1 | 3 | 2.35 | 1.64 | 0.54 | 1.07 | 1.61 | 2.14 | 2.68 | 3.22 | 3.75 | 4.29 |
| 4 | 2 | 4 | 2.13 | 1.53 | 0.69 | 1.38 | 2.08 | 2.77 | 3.46 | 4.15 | 4.84 | 5.54 |
| 4 | 3 | 5 | 2.02 | 1.48 | 0.78 | 1.57 | 2.35 | 3.14 | 3.92 | 4.71 | 5.49 | 6.28 |
| 4 | 4 | 6 | 1.94 | 1.44 | 0.85 | 1.70 | 2.54 | 3.39 | 4.24 | 5.09 | 5.93 | 6.78 |

Table 8: Power values to detect population change as a percentage of the mean for various count replicate options in year 1 and year 2 for wildebeest at 10% and 20% significance at Loskop Dam Nature Reserve.

talpha.1 WILDEBEEST

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.09 | 0.13 | 0.19 | 0.25 | 0.3 | 0.36 | 0.42 | 0.47 |
| **2_2** | 0.11 | 0.21 | 0.35 | 0.49 | 0.63 | 0.75 | 0.84 | 0.91 |
| **2_3** | 0.13 | 0.28 | 0.46 | 0.66 | 0.81 | 0.91 | 0.96 | 0.99 |
| **3_1** | 0.10 | 0.18 | 0.28 | 0.4 | 0.53 | 0.64 | 0.74 | 0.83 |
| **3_3** | 0.15 | 0.34 | 0.57 | 0.78 | 0.91 | 0.97 | 0.99 | 1 |
| **4_1** | 0.11 | 0.21 | 0.35 | 0.5 | 0.66 | 0.78 | 0.88 | 0.94 |
| **4_2** | 0.14 | 0.31 | 0.53 | 0.74 | 0.88 | 0.96 | 0.99 | 1 |
| **4_3** | 0.17 | 0.39 | 0.64 | 0.85 | 0.95 | 0.99 | 1 | 1 |
| **4_4** | 0.19 | 0.45 | 0.73 | 0.91 | 0.98 | 1 | 1 | 1 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.17 | 0.26 | 0.36 | 0.47 | 0.56 | 0.65 | 0.72 | 0.78 |
| **2_2** | 0.22 | 0.38 | 0.57 | 0.73 | 0.85 | 0.93 | 0.97 | 0.99 |
| **2_3** | 0.24 | 0.45 | 0.67 | 0.84 | 0.94 | 0.98 | 1 | 1 |
| **3_1** | 0.20 | 0.33 | 0.48 | 0.64 | 0.77 | 0.86 | 0.93 | 0.97 |
| **3_3** | 0.27 | 0.51 | 0.75 | 0.91 | 0.98 | 1 | 1 | 1 |
| **4_1** | 0.21 | 0.36 | 0.54 | 0.71 | 0.84 | 0.92 | 0.97 | 0.99 |
| **4_2** | 0.25 | 0.48 | 0.72 | 0.88 | 0.96 | 0.99 | 1 | 1 |
| **4_3** | 0.28 | 0.56 | 0.8 | 0.94 | 0.99 | 1 | 1 | 1 |
| **4_4** | 0.31 | 0.62 | 0.86 | 0.97 | 1 | 1 | 1 | 1 |

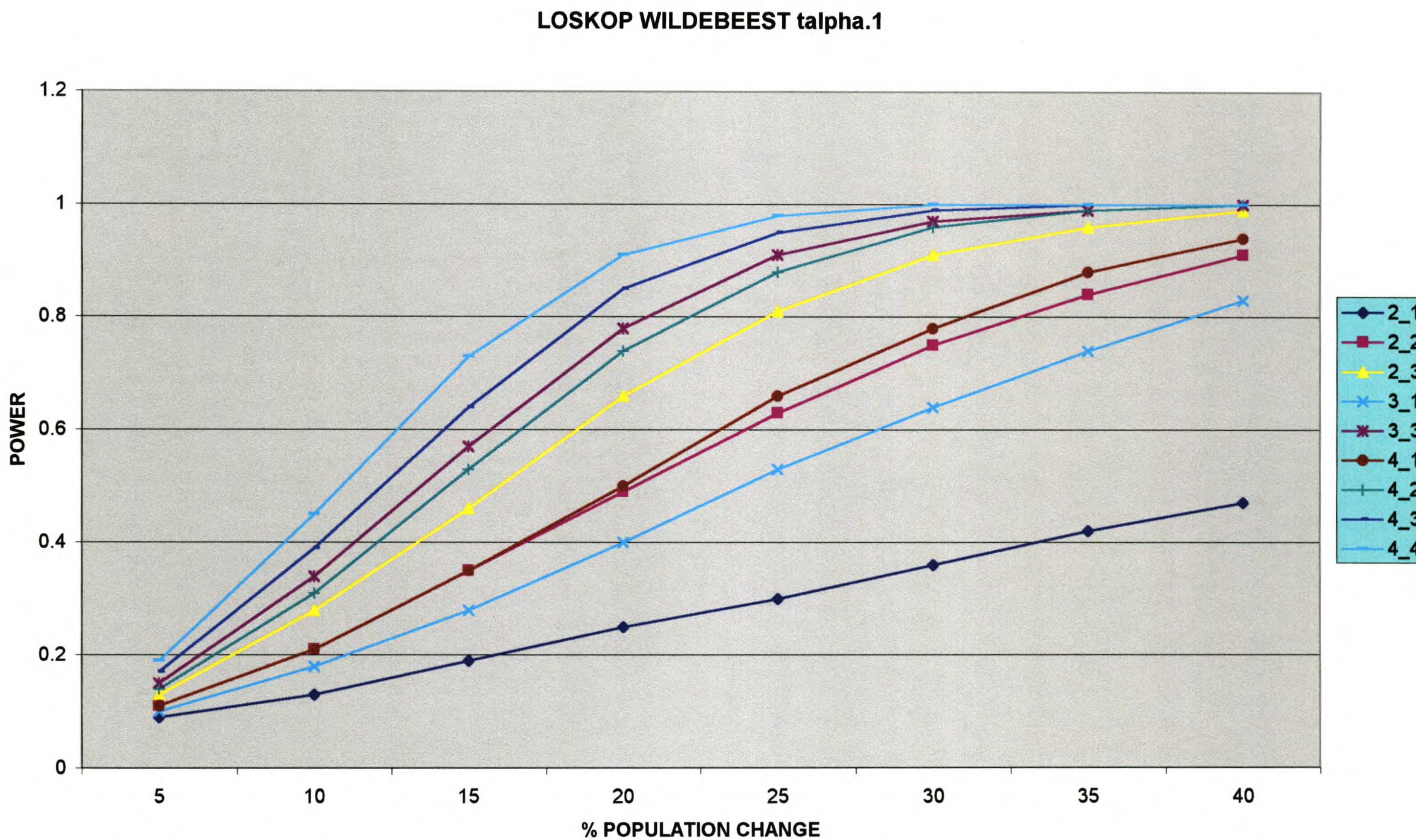


Figure 13: Power curves for various count replicate options at 10% significance for wildebeest at Loskop Dam Nature Reserve.

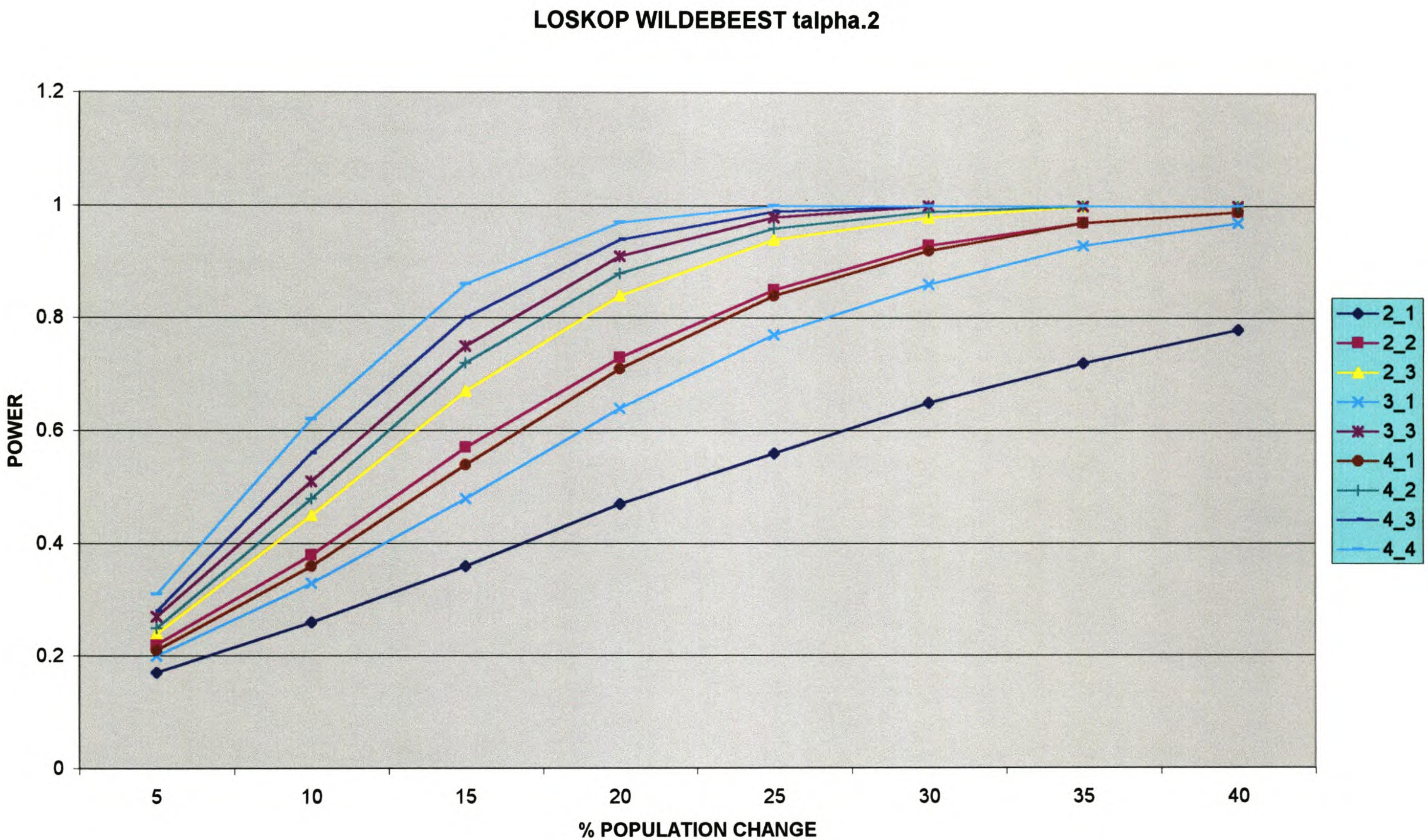


Figure 14: Power curves for various count replicate options at 20% significance for wildebeest at Loskop Dam Nature Reserve.

Table 9: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of the mean for different replicate options from year 1 to year 2 for calculation of power for impala at Loskop Dam Nature Reserve.

| IMPALA | | MEAN | 316.75 | | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 15.84 | 31.68 | 47.51 | 63.35 | 79.19 | 95.03 | 110.86 | 126.70 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.45 | 0.89 | 1.34 | 1.78 | 2.23 | 2.67 | 3.12 | 3.57 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.55 | 1.09 | 1.64 | 2.18 | 2.73 | 3.28 | 3.82 | 4.37 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.60 | 1.20 | 1.79 | 2.39 | 2.99 | 3.59 | 4.19 | 4.78 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.48 | 0.95 | 1.43 | 1.90 | 2.38 | 2.85 | 3.33 | 3.80 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.67 | 1.34 | 2.02 | 2.69 | 3.36 | 4.03 | 4.71 | 5.38 |
| 4 | 1 | 3 | 2.35 | 1.64 | 0.49 | 0.99 | 1.48 | 1.97 | 2.46 | 2.96 | 3.45 | 3.94 |
| 4 | 2 | 4 | 2.13 | 1.53 | 0.64 | 1.27 | 1.91 | 2.54 | 3.18 | 3.81 | 4.45 | 5.09 |
| 4 | 3 | 5 | 2.02 | 1.48 | 0.72 | 1.44 | 2.16 | 2.88 | 3.60 | 4.33 | 5.05 | 5.77 |
| 4 | 4 | 6 | 1.94 | 1.44 | 0.78 | 1.56 | 2.34 | 3.11 | 3.89 | 4.67 | 5.45 | 6.23 |

Table 10: Power values to detect population change as a percentage of the mean for various count replicate options in year 1 and year 2 for impala at 10% and 20% significance at Loskop Dam Nature Reserve.

talpha.1 IMPALA

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.08 | 0.12 | 0.17 | 0.22 | 0.27 | 0.32 | 0.37 | 0.42 |
| **2_2** | 0.11 | 0.19 | 0.3 | 0.43 | 0.56 | 0.68 | 0.77 | 0.85 |
| **2_3** | 0.12 | 0.24 | 0.4 | 0.58 | 0.73 | 0.85 | 0.93 | 0.97 |
| **3_1** | 0.10 | 0.17 | 0.26 | 0.36 | 0.47 | 0.58 | 0.69 | 0.77 |
| **3_3** | 0.14 | 0.3 | 0.51 | 0.71 | 0.86 | 0.95 | 0.98 | 1 |
| **4_1** | 0.11 | 0.19 | 0.31 | 0.45 | 0.6 | 0.73 | 0.83 | 0.9 |
| **4_2** | 0.13 | 0.28 | 0.48 | 0.67 | 0.83 | 0.93 | 0.97 | 0.99 |
| **4_3** | 0.15 | 0.34 | 0.58 | 0.79 | 0.92 | 0.98 | 1 | 1 |
| **4_4** | 0.17 | 0.4 | 0.66 | 0.86 | 0.96 | 0.99 | 1 | 1 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.16 | 0.24 | 0.33 | 0.42 | 0.51 | 0.59 | 0.66 | 0.73 |
| **2_2** | 0.20 | 0.34 | 0.51 | 0.66 | 0.79 | 0.89 | 0.94 | 0.98 |
| **2_3** | 0.22 | 0.4 | 0.6 | 0.77 | 0.89 | 0.96 | 0.99 | 1 |
| **3_1** | 0.19 | 0.3 | 0.44 | 0.58 | 0.71 | 0.82 | 0.89 | 0.94 |
| **3_3** | 0.25 | 0.47 | 0.7 | 0.87 | 0.95 | 0.99 | 1 | 1 |
| **4_1** | 0.2 | 0.33 | 0.49 | 0.65 | 0.79 | 0.89 | 0.95 | 0.98 |
| **4_2** | 0.24 | 0.44 | 0.66 | 0.84 | 0.94 | 0.98 | 1 | 1 |
| **4_3** | 0.27 | 0.51 | 0.75 | 0.91 | 0.98 | 1 | 1 | 1 |
| **4_4** | 0.29 | 0.57 | 0.81 | 0.94 | 0.99 | 1 | 1 | 1 |

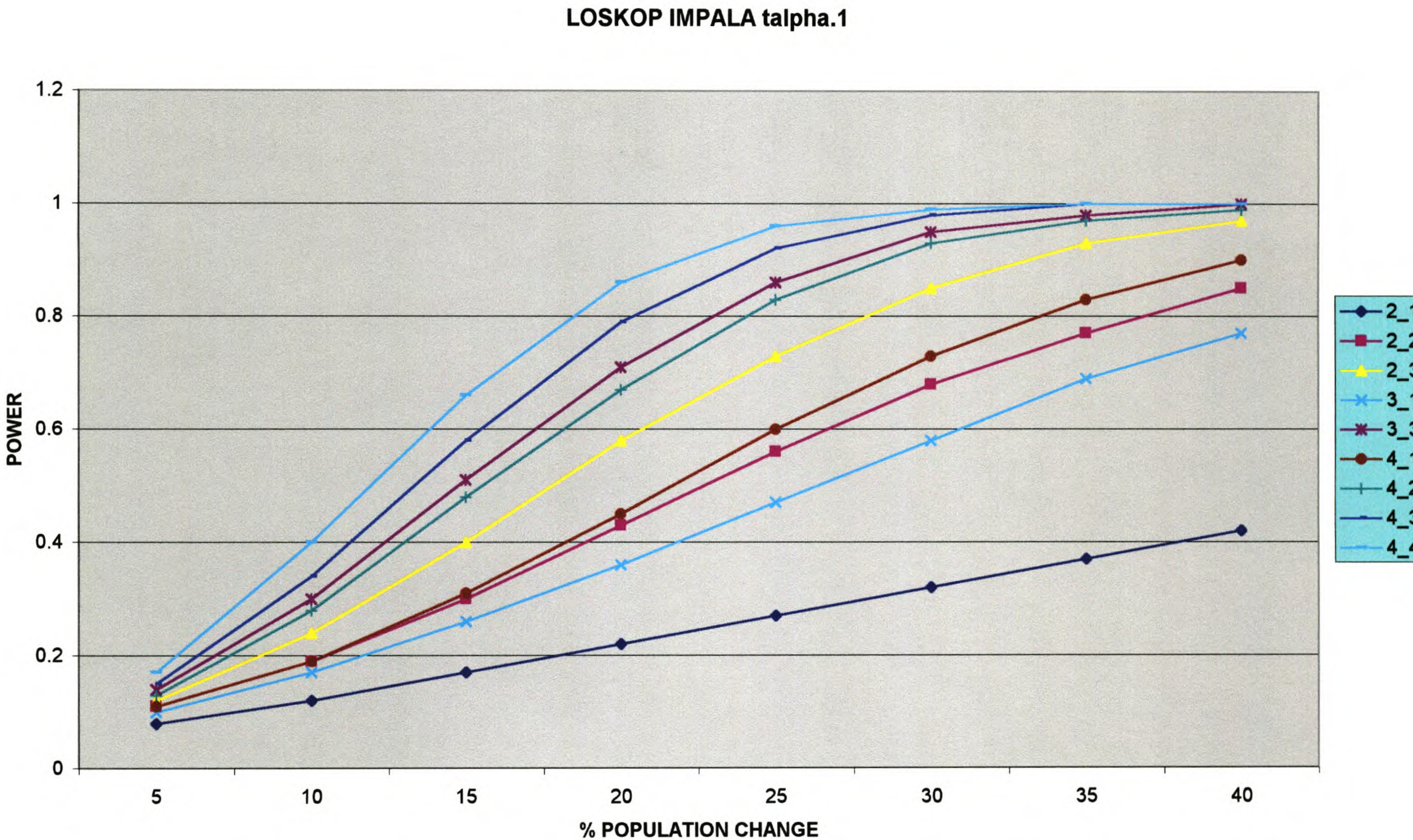


Figure 15: Power curves for various count replicate options at 10% significance for impala at Loskop Dam Nature Reserve.

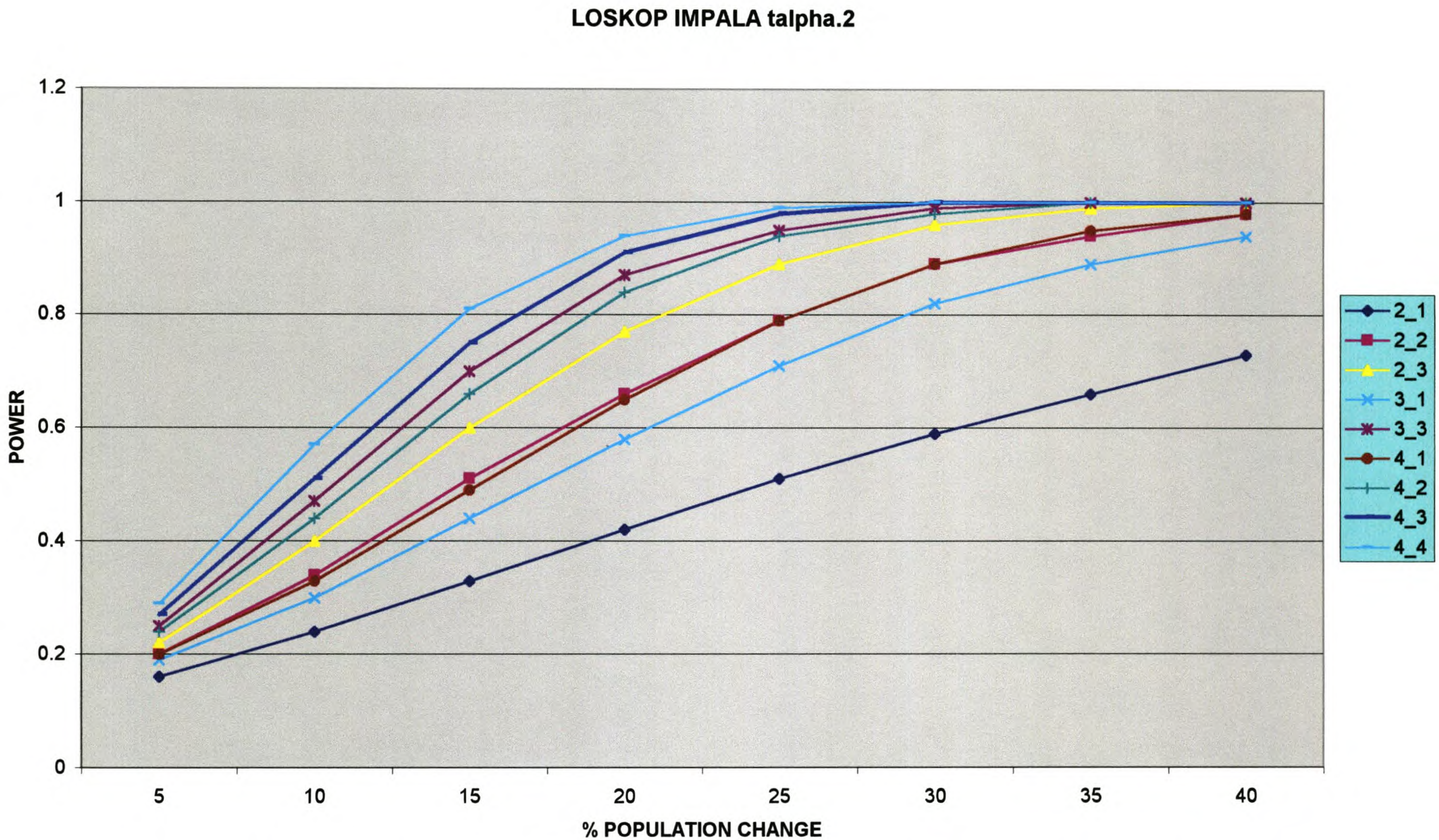


Figure 16: Power curves for various count replicate options at 20% significance for impala at Loskop Dam Nature Reserve.

Table 11: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of the mean for different replicate options from year 1 to year 2 for calculation of power for warthog at Loskop Dam Nature Reserve.

| WARTHOG | | | MEAN | 38.75 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 1.94 | 3.88 | 5.81 | 7.75 | 9.69 | 11.63 | 13.56 | 15.50 |
| **n1** | **n2** | **df** | **talpha.1** | **talpha.2** | **NON CENTRALITY PARAMETERS** | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.37 | 0.74 | 1.11 | 1.48 | 1.85 | 2.22 | 2.58 | 2.95 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.45 | 0.90 | 1.36 | 1.81 | 2.26 | 2.71 | 3.17 | 3.62 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.50 | 0.99 | 1.49 | 1.98 | 2.48 | 2.97 | 3.47 | 3.96 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.39 | 0.78 | 1.18 | 1.57 | 1.96 | 2.35 | 2.74 | 3.14 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.55 | 1.11 | 1.66 | 2.22 | 2.77 | 3.33 | 3.88 | 4.43 |
| 4 | 1 | 3 | 2.35 | 1.64 | 0.41 | 0.81 | 1.22 | 1.62 | 2.03 | 2.43 | 2.84 | 3.24 |
| 4 | 2 | 4 | 2.13 | 1.53 | 0.52 | 1.05 | 1.57 | 2.09 | 2.62 | 3.14 | 3.66 | 4.19 |
| 4 | 3 | 5 | 2.02 | 1.48 | 0.59 | 1.19 | 1.78 | 2.37 | 2.97 | 3.56 | 4.15 | 4.75 |
| 4 | 4 | 6 | 1.94 | 1.44 | 0.64 | 1.28 | 1.92 | 2.56 | 3.21 | 3.85 | 4.49 | 5.13 |

Table 12: Power values to detect population change as a percentage of the mean for various count replicate options in year 1 and year 2 for warthog at 10% and 20% significance at Loskop Dam Nature Reserve.

talpha.1 WARTHOG

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| 2_1 | 0.08 | 0.11 | 0.15 | 0.19 | 0.23 | 0.27 | 0.31 | 0.36 |
| 2_2 | 0.09 | 0.16 | 0.24 | 0.34 | 0.45 | 0.55 | 0.65 | 0.74 |
| 2_3 | 0.11 | 0.19 | 0.32 | 0.46 | 0.6 | 0.73 | 0.83 | 0.9 |
| 3_1 | 0.09 | 0.14 | 0.21 | 0.29 | 0.37 | 0.47 | 0.56 | 0.65 |
| 3_3 | 0.12 | 0.24 | 0.4 | 0.58 | 0.74 | 0.86 | 0.93 | 0.97 |
| 4_1 | 0.09 | 0.16 | 0.25 | 0.35 | 0.47 | 0.59 | 0.7 | 0.79 |
| 4_2 | 0.11 | 0.22 | 0.37 | 0.53 | 0.7 | 0.82 | 0.91 | 0.96 |
| 4_3 | 0.13 | 0.27 | 0.46 | 0.65 | 0.81 | 0.92 | 0.97 | 0.99 |
| 4_4 | 0.14 | 0.31 | 0.52 | 0.73 | 0.88 | 0.96 | 0.99 | 1 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| 2_1 | 0.15 | 0.21 | 0.29 | 0.36 | 0.44 | 0.51 | 0.57 | 0.64 |
| 2_2 | 0.18 | 0.29 | 0.42 | 0.56 | 0.68 | 0.79 | 0.87 | 0.93 |
| 2_3 | 0.20 | 0.33 | 0.5 | 0.66 | 0.79 | 0.89 | 0.95 | 0.98 |
| 3_1 | 0.17 | 0.26 | 0.37 | 0.49 | 0.6 | 0.71 | 0.8 | 0.87 |
| 3_3 | 0.22 | 0.39 | 0.58 | 0.76 | 0.88 | 0.95 | 0.98 | 1 |
| 4_1 | 0.18 | 0.28 | 0.41 | 0.54 | 0.67 | 0.78 | 0.87 | 0.93 |
| 4_2 | 0.21 | 0.37 | 0.55 | 0.72 | 0.85 | 0.93 | 0.97 | 0.99 |
| 4_3 | 0.23 | 0.42 | 0.63 | 0.81 | 0.92 | 0.97 | 0.99 | 1 |
| 4_4 | 0.25 | 0.46 | 0.69 | 0.86 | 0.95 | 0.99 | 1 | 1 |

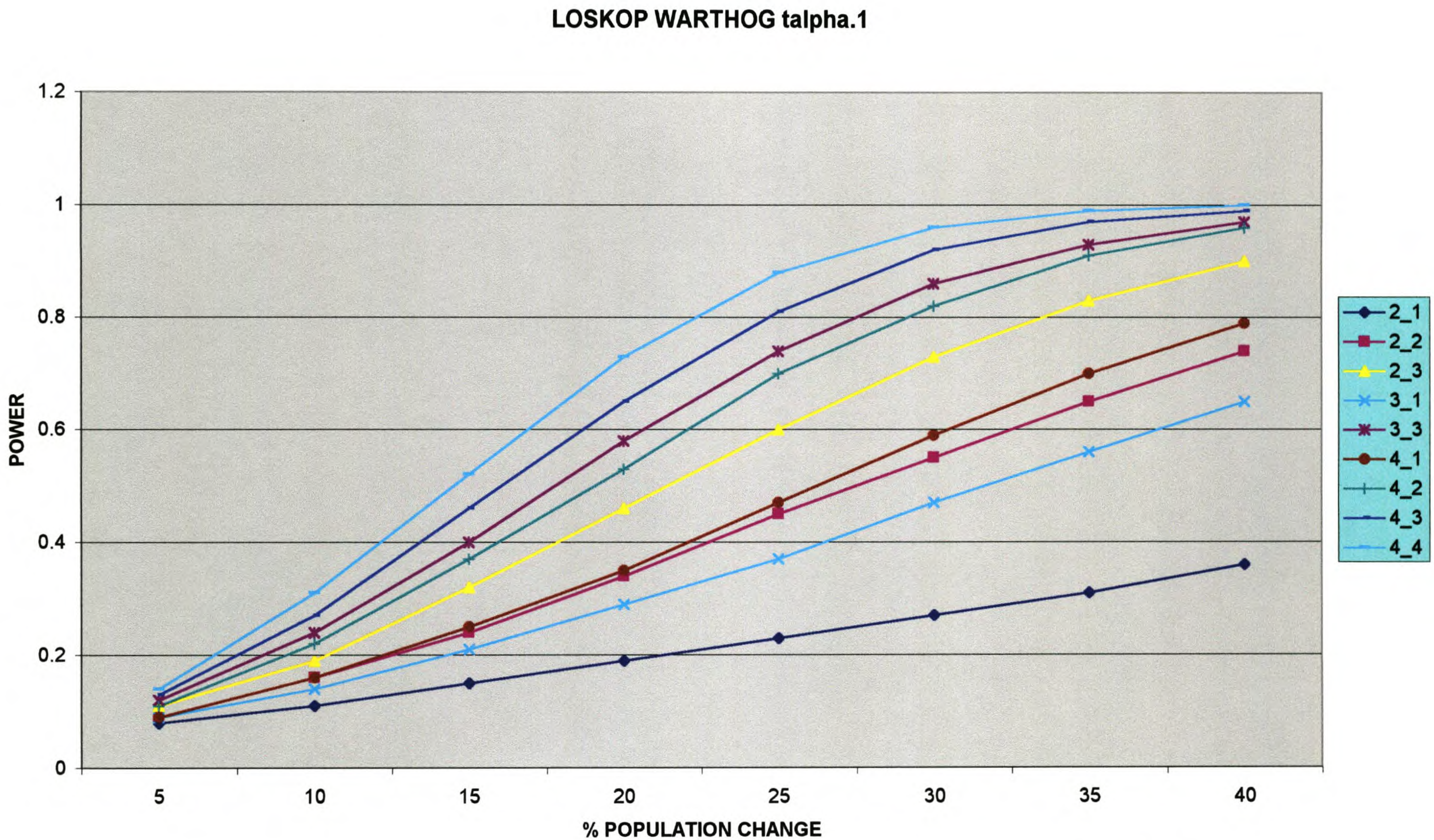


Figure 17: Power curves for various count replicate options at 10% significance for warthog at Loskop Dam Nature Reserve.

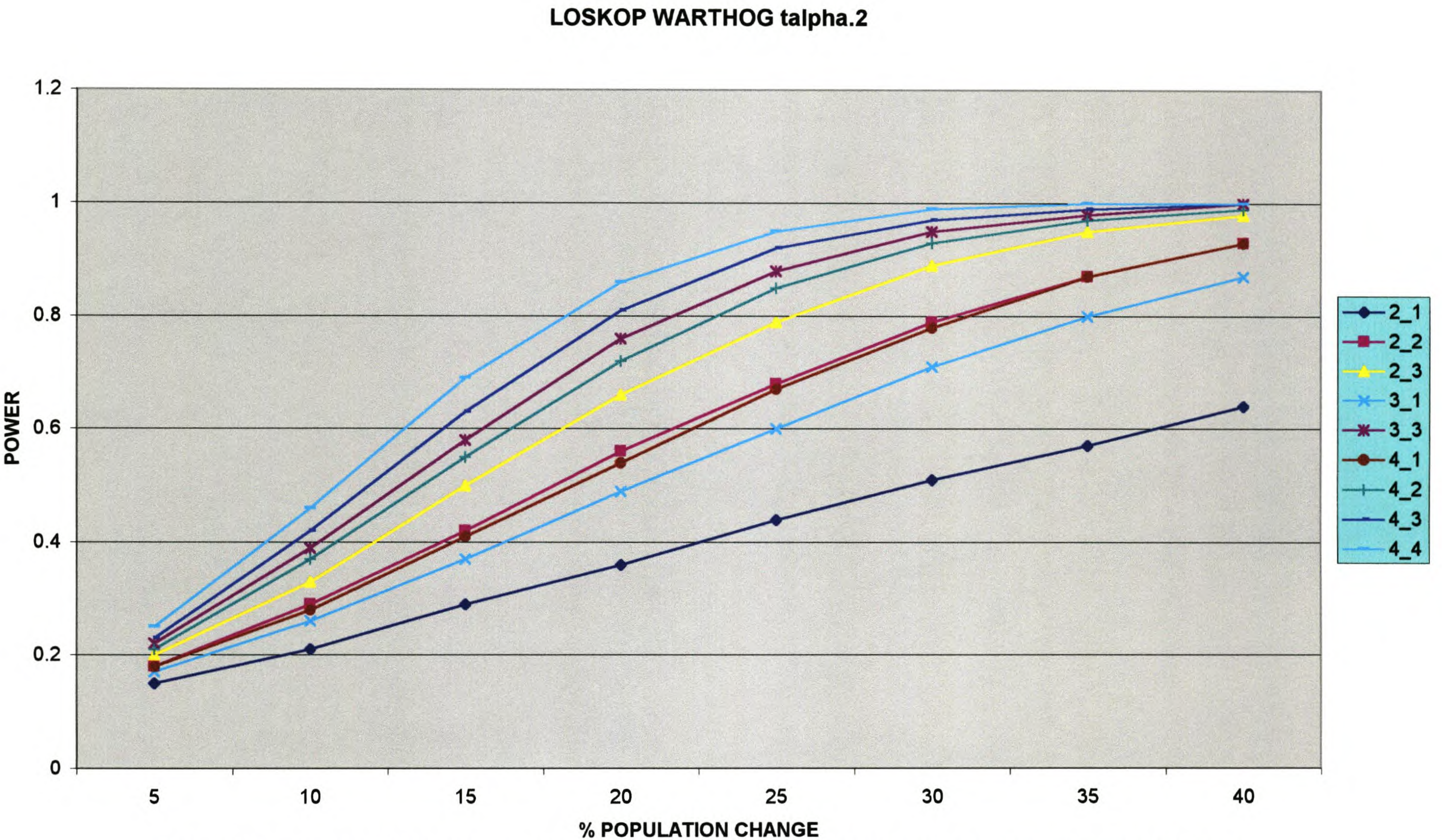


Figure 18: Power curves for various count replicate options at 20% significance for warthog at loskop Dam Nature Reserve.

Table 13: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of the mean for different replicate options from year 1 to year 2 for calculation of power for sable at Loskop Dam Nature Reserve.

| SABLE | | MEAN | 41.25 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | 2.06 | 4.13 | 6.19 | 8.25 | 10.31 | 12.38 | 14.44 | 16.50 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.50 | 1.00 | 1.49 | 1.99 | 2.49 | 2.99 | 3.49 | 3.99 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.61 | 1.22 | 1.83 | 2.44 | 3.05 | 3.66 | 4.27 | 4.88 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.67 | 1.34 | 2.01 | 2.67 | 3.34 | 4.01 | 4.68 | 5.35 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.54 | 1.07 | 1.61 | 2.15 | 2.68 | 3.22 | 3.75 | 4.29 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.76 | 1.52 | 2.28 | 3.03 | 3.79 | 4.55 | 5.31 | 6.07 |
| 4 | 1 | 3 | 2.35 | 1.64 | 0.55 | 1.11 | 1.66 | 2.22 | 2.77 | 3.33 | 3.88 | 4.44 |
| 4 | 2 | 4 | 2.13 | 1.53 | 0.72 | 1.43 | 2.15 | 2.86 | 3.58 | 4.30 | 5.01 | 5.73 |
| 4 | 3 | 5 | 2.02 | 1.48 | 0.81 | 1.62 | 2.44 | 3.25 | 4.06 | 4.87 | 5.68 | 6.49 |
| 4 | 4 | 6 | 1.94 | 1.44 | 0.88 | 1.75 | 2.63 | 3.51 | 4.38 | 5.26 | 6.14 | 7.01 |

Table 14: Power values to detect population change as a percentage of the mean for various count replicate options in year 1 and year 2 for sable at 10% and 20% significance at Loskop Dam Nature Reserve.

talpha.1 SABLE

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.09 | 0.13 | 0.19 | 0.25 | 0.3 | 0.36 | 0.42 | 0.47 |
| **2_2** | 0.11 | 0.21 | 0.34 | 0.49 | 0.63 | 0.75 | 0.84 | 0.91 |
| **2_3** | 0.13 | 0.28 | 0.46 | 0.65 | 0.81 | 0.91 | 0.96 | 0.99 |
| **3_1** | 0.10 | 0.19 | 0.29 | 0.42 | 0.55 | 0.66 | 0.76 | 0.84 |
| **3_3** | 0.16 | 0.35 | 0.59 | 0.8 | 0.92 | 0.98 | 1 | 1 |
| **4_1** | 0.11 | 0.22 | 0.36 | 0.53 | 0.68 | 0.81 | 0.89 | 0.95 |
| **4_2** | 0.15 | 0.33 | 0.55 | 0.76 | 0.9 | 0.97 | 0.99 | 1 |
| **4_3** | 0.17 | 0.4 | 0.67 | 0.87 | 0.96 | 0.99 | 1 | 1 |
| **4_4** | 0.2 | 0.46 | 0.75 | 0.93 | 0.99 | 1 | 1 | 1 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.17 | 0.26 | 0.36 | 0.46 | 0.56 | 0.64 | 0.72 | 0.78 |
| **2_2** | 0.22 | 0.38 | 0.56 | 0.73 | 0.85 | 0.93 | 0.97 | 0.99 |
| **2_3** | 0.24 | 0.45 | 0.67 | 0.84 | 0.94 | 0.98 | 1 | 1 |
| **3_1** | 0.20 | 0.34 | 0.5 | 0.66 | 0.78 | 0.88 | 0.94 | 0.97 |
| **3_3** | 0.28 | 0.53 | 0.77 | 0.92 | 0.98 | 1 | 1 | 1 |
| **4_1** | 0.21 | 0.37 | 0.56 | 0.73 | 0.86 | 0.94 | 0.98 | 0.99 |
| **4_2** | 0.26 | 0.5 | 0.74 | 0.9 | 0.97 | 0.99 | 1 | 1 |
| **4_3** | 0.29 | 0.58 | 0.83 | 0.95 | 0.99 | 1 | 1 | 1 |
| **4_4** | 0.32 | 0.63 | 0.88 | 0.98 | 1 | 1 | 1 | 1 |

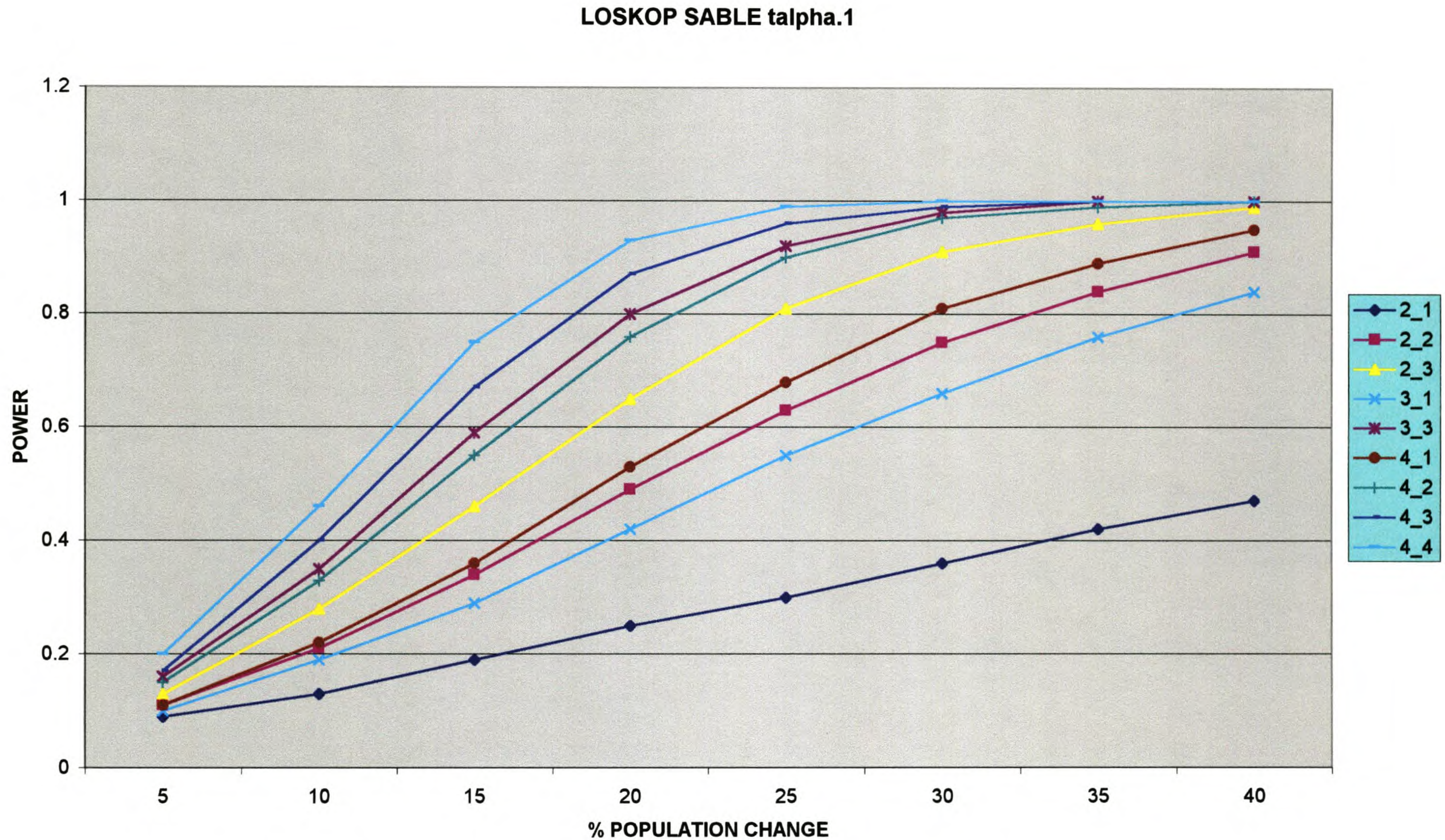


Figure 19: Power curves for various count replicate options at 10% significance for sable at Loskop Dam Nature Reserve.

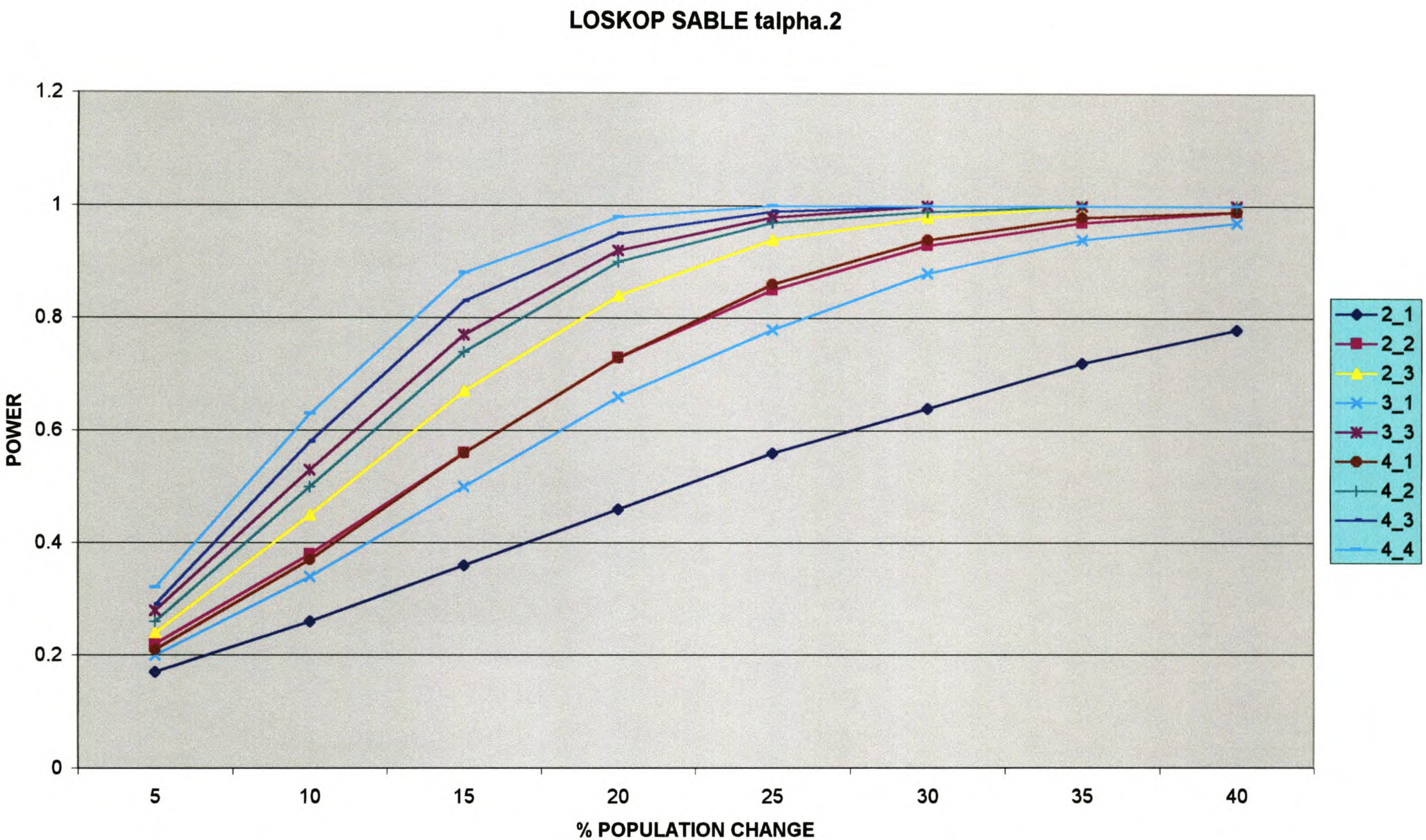


Figure 20: Power curves for various count replicate options at 20% significance for sable at Loskop Dam Nature Reserve.

Table 15: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of the mean for different replicate options from year 1 to year 2 for calculation of power for white rhino at Loskop Dam Nature Reserve.

| WHITE RHINO | | MEAN | 41.25 | | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 2.06 | 4.13 | 6.19 | 8.25 | 10.31 | 12.38 | 14.44 | 16.50 |
| **n1** | **n2** | **df** | **talpha.1** | **talpha.2** | **NON CENTRALITY PARAMETERS** | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.55 | 1.10 | 1.65 | 2.19 | 2.74 | 3.29 | 3.84 | 4.39 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.67 | 1.34 | 2.02 | 2.69 | 3.36 | 4.03 | 4.70 | 5.38 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.74 | 1.47 | 2.21 | 2.94 | 3.68 | 4.42 | 5.15 | 5.89 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.58 | 1.17 | 1.75 | 2.33 | 2.91 | 3.50 | 4.08 | 4.66 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.82 | 1.65 | 2.47 | 3.30 | 4.12 | 4.94 | 5.77 | 6.59 |
| 4 | 1 | 3 | 2.35 | 1.64 | 0.60 | 1.20 | 1.80 | 2.40 | 3.00 | 3.60 | 4.20 | 4.80 |
| 4 | 2 | 4 | 2.13 | 1.53 | 0.77 | 1.55 | 2.32 | 3.10 | 3.87 | 4.64 | 5.42 | 6.19 |
| 4 | 3 | 5 | 2.02 | 1.48 | 0.88 | 1.76 | 2.63 | 3.51 | 4.39 | 5.27 | 6.14 | 7.02 |
| 4 | 4 | 6 | 1.94 | 1.44 | 0.95 | 1.90 | 2.84 | 3.79 | 4.74 | 5.69 | 6.64 | 7.58 |

Table 16: Power values to detect population change as a percentage of the mean for various count replicate options in year 1 and year 2 for white rhino at 10% and 20% significance at Loskop Dam Nature Reserve.

talpha.1 WHITE RHINO

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.09 | 0.15 | 0.21 | 0.27 | 0.33 | 0.39 | 0.45 | 0.51 |
| **2_2** | 0.12 | 0.24 | 0.39 | 0.55 | 0.69 | 0.81 | 0.89 | 0.94 |
| **2_3** | 0.15 | 0.31 | 0.52 | 0.72 | 0.87 | 0.95 | 0.98 | 1 |
| **3_1** | 0.11 | 0.2 | 0.33 | 0.46 | 0.6 | 0.72 | 0.81 | 0.89 |
| **3_3** | 0.17 | 0.39 | 0.65 | 0.85 | 0.95 | 0.99 | 1 | 1 |
| **4_1** | 0.12 | 0.24 | 0.4 | 0.58 | 0.74 | 0.85 | 0.93 | 0.97 |
| **4_2** | 0.16 | 0.36 | 0.61 | 0.81 | 0.93 | 0.98 | 1 | 1 |
| **4_3** | 0.19 | 0.45 | 0.73 | 0.91 | 0.98 | 1 | 1 | 1 |
| **4_4** | 0.21 | 0.52 | 0.81 | 0.95 | 0.99 | 1 | 1 | 1 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.18 | 0.28 | 0.39 | 0.5 | 0.6 | 0.69 | 0.76 | 0.82 |
| **2_2** | 0.23 | 0.42 | 0.62 | 0.79 | 0.9 | 0.96 | 0.99 | 1 |
| **2_3** | 0.26 | 0.49 | 0.73 | 0.88 | 0.96 | 0.99 | 1 | 1 |
| **3_1** | 0.21 | 0.37 | 0.54 | 0.7 | 0.83 | 0.91 | 0.96 | 0.98 |
| **3_3** | 0.29 | 0.58 | 0.82 | 0.95 | 0.99 | 1 | 1 | 1 |
| **4_1** | 0.22 | 0.4 | 0.6 | 0.77 | 0.89 | 0.96 | 0.99 | 1 |
| **4_2** | 0.28 | 0.54 | 0.78 | 0.93 | 0.98 | 1 | 1 | 1 |
| **4_3** | 0.32 | 0.63 | 0.87 | 0.97 | 1 | 1 | 1 | 1 |
| **4_4** | 0.35 | 0.69 | 0.91 | 0.99 | 1 | 1 | 1 | 1 |

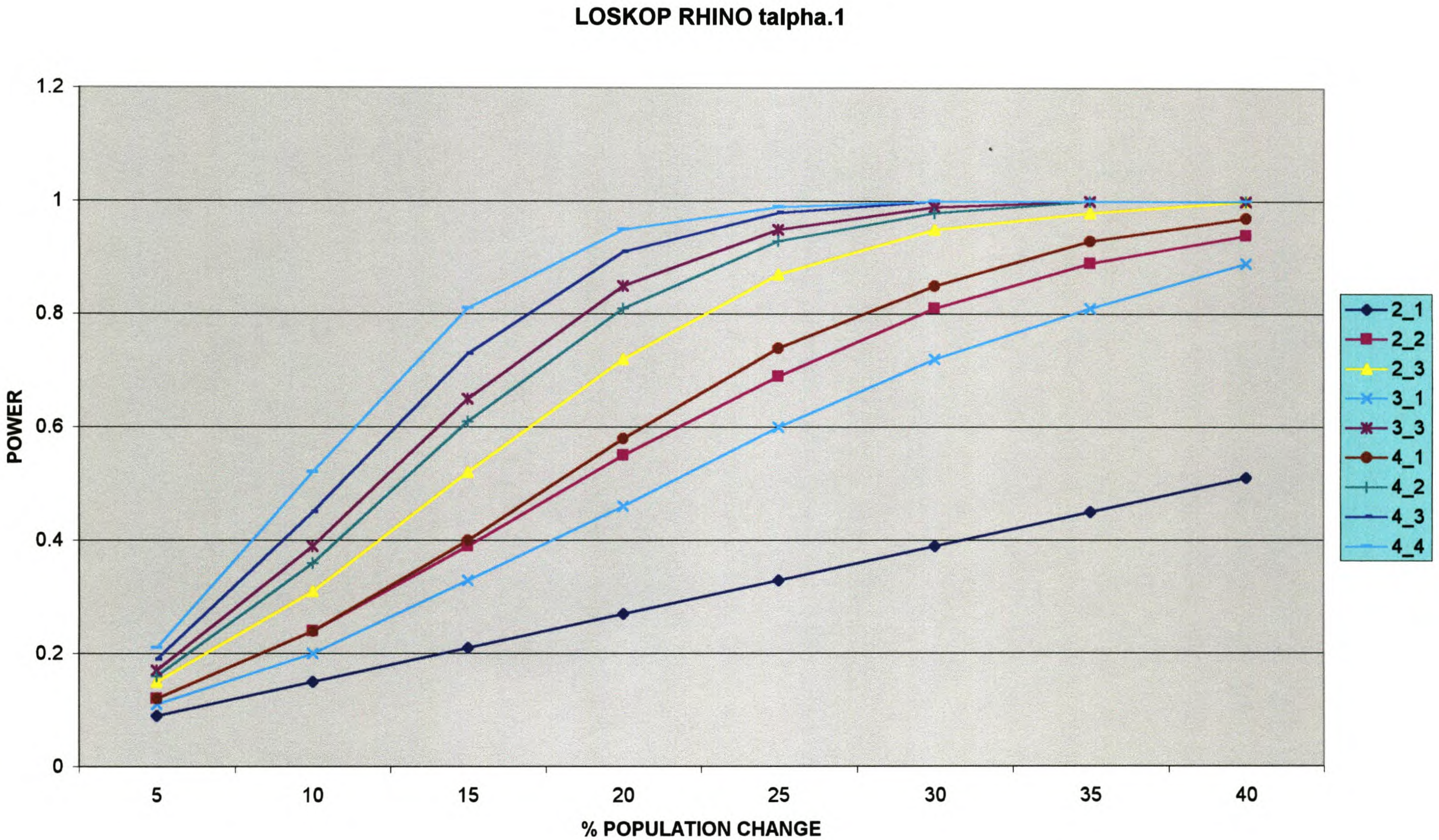


Figure 21: Power curves for various count replicate options at 10% significance for white rhino at Loskop Dam Nature Reserve.

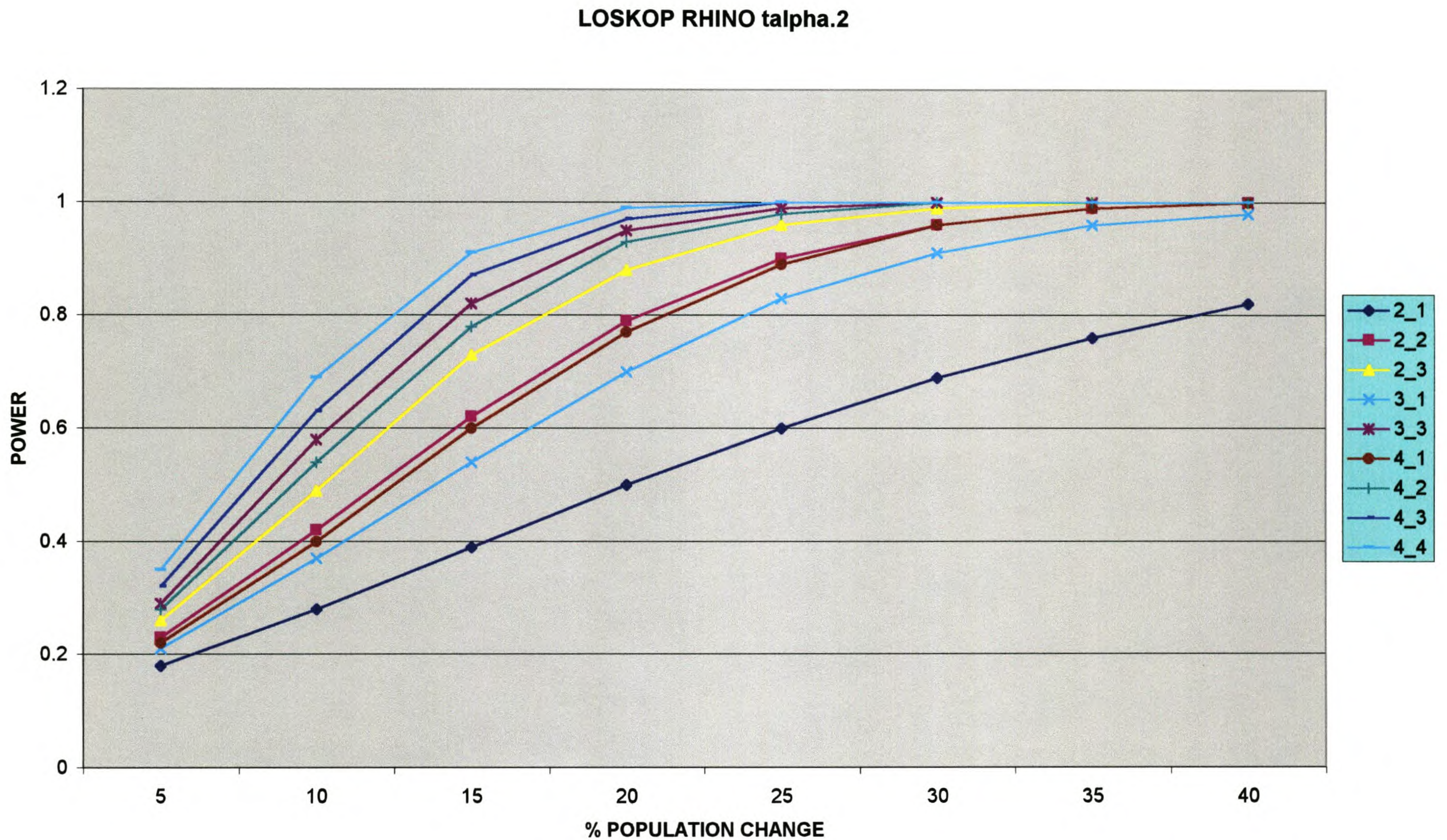


Figure 22: Power curves for various count replicate options at 20% significance for white rhino at Loskop Dam Nature Reserve.

Table 17: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of the mean for different replicate options from year 1 to year 2 for calculation of power for mt. reedbuck at Loskop Dam Nature Reserve.

| MT.REEDBUCK | | | MEAN | 30 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 1.50 | 3.00 | 4.50 | 6.00 | 7.50 | 9.00 | 10.50 | 12.00 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.11 | 0.22 | 0.33 | 0.44 | 0.54 | 0.65 | 0.76 | 0.87 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.13 | 0.27 | 0.40 | 0.53 | 0.67 | 0.80 | 0.93 | 1.07 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.15 | 0.29 | 0.44 | 0.58 | 0.73 | 0.88 | 1.02 | 1.17 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.11 | 0.23 | 0.34 | 0.46 | 0.57 | 0.69 | 0.80 | 0.91 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.16 | 0.32 | 0.48 | 0.65 | 0.81 | 0.97 | 1.13 | 1.29 |
| 4 | 1 | 3 | 2.35 | 1.64 | 0.12 | 0.24 | 0.35 | 0.47 | 0.59 | 0.71 | 0.83 | 0.95 |
| 4 | 2 | 4 | 2.13 | 1.53 | 0.15 | 0.31 | 0.46 | 0.61 | 0.76 | 0.92 | 1.07 | 1.22 |
| 4 | 3 | 5 | 2.02 | 1.48 | 0.17 | 0.35 | 0.52 | 0.69 | 0.87 | 1.04 | 1.21 | 1.39 |
| 4 | 4 | 6 | 1.94 | 1.44 | 0.19 | 0.37 | 0.56 | 0.75 | 0.94 | 1.12 | 1.31 | 1.50 |

Table 18: Power values to detect population change as a percentage of the mean for various count replicate options in year 1 and year 2 for mt.reedbuck at 10% and 20% significance at Loskop Dam Nature Reserve.

talpha.1 MT.REEDBUCK

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.06 | 0.06 | 0.07 | 0.08 | 0.09 | 0.1 | 0.11 | 0.12 |
| **2_2** | 0.06 | 0.07 | 0.09 | 0.1 | 0.12 | 0.14 | 0.16 | 0.19 |
| **2_3** | 0.06 | 0.08 | 0.1 | 0.12 | 0.14 | 0.17 | 0.2 | 0.23 |
| **3_1** | 0.06 | 0.07 | 0.08 | 0.09 | 0.11 | 0.12 | 0.14 | 0.16 |
| **3_3** | 0.07 | 0.08 | 0.11 | 0.14 | 0.17 | 0.2 | 0.24 | 0.29 |
| **4_1** | 0.06 | 0.07 | 0.09 | 0.1 | 0.12 | 0.14 | 0.16 | 0.19 |
| **4_2** | 0.06 | 0.08 | 0.1 | 0.13 | 0.16 | 0.19 | 0.23 | 0.27 |
| **4_3** | 0.07 | 0.09 | 0.12 | 0.15 | 0.19 | 0.23 | 0.27 | 0.33 |
| **4_4** | 0.07 | 0.09 | 0.13 | 0.16 | 0.21 | 0.26 | 0.32 | 0.38 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.11 | 0.13 | 0.15 | 0.16 | 0.18 | 0.2 | 0.22 | 0.24 |
| **2_2** | 0.12 | 0.15 | 0.17 | 0.2 | 0.23 | 0.26 | 0.3 | 0.34 |
| **2_3** | 0.12 | 0.15 | 0.18 | 0.22 | 0.26 | 0.3 | 0.34 | 0.39 |
| **3_1** | 0.12 | 0.14 | 0.16 | 0.18 | 0.21 | 0.24 | 0.26 | 0.29 |
| **3_3** | 0.13 | 0.16 | 0.2 | 0.24 | 0.29 | 0.34 | 0.39 | 0.45 |
| **4_1** | 0.12 | 0.14 | 0.16 | 0.19 | 0.22 | 0.25 | 0.29 | 0.32 |
| **4_2** | 0.13 | 0.16 | 0.19 | 0.23 | 0.28 | 0.32 | 0.37 | 0.43 |
| **4_3** | 0.13 | 0.17 | 0.21 | 0.26 | 0.31 | 0.37 | 0.43 | 0.5 |
| **4_4** | 0.13 | 0.17 | 0.22 | 0.28 | 0.34 | 0.41 | 0.47 | 0.54 |

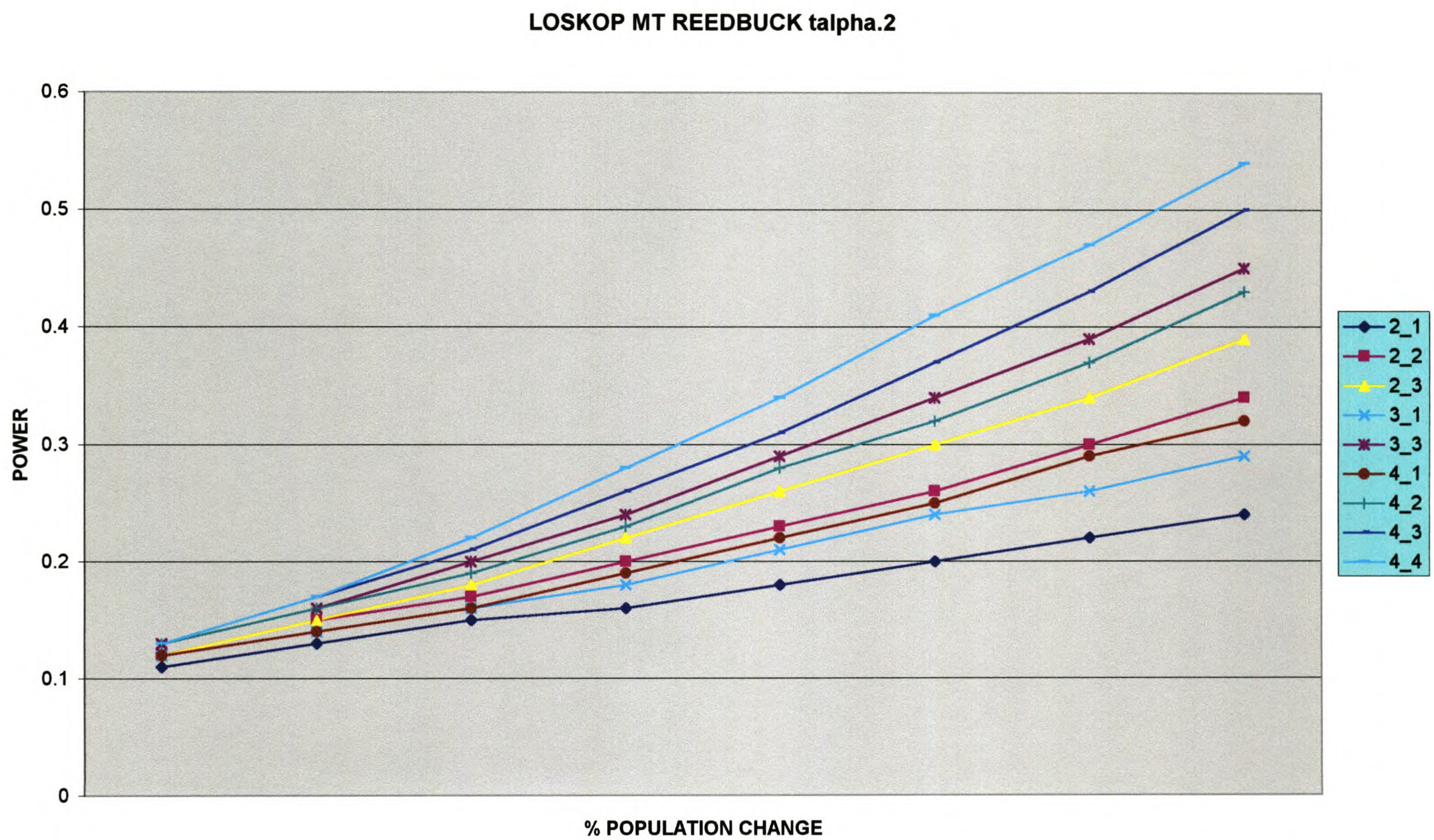


Figure 23: Power curves for various count replicate options at 20% significance for mt. reedbuck at Loskop Dam Nature Reserve.

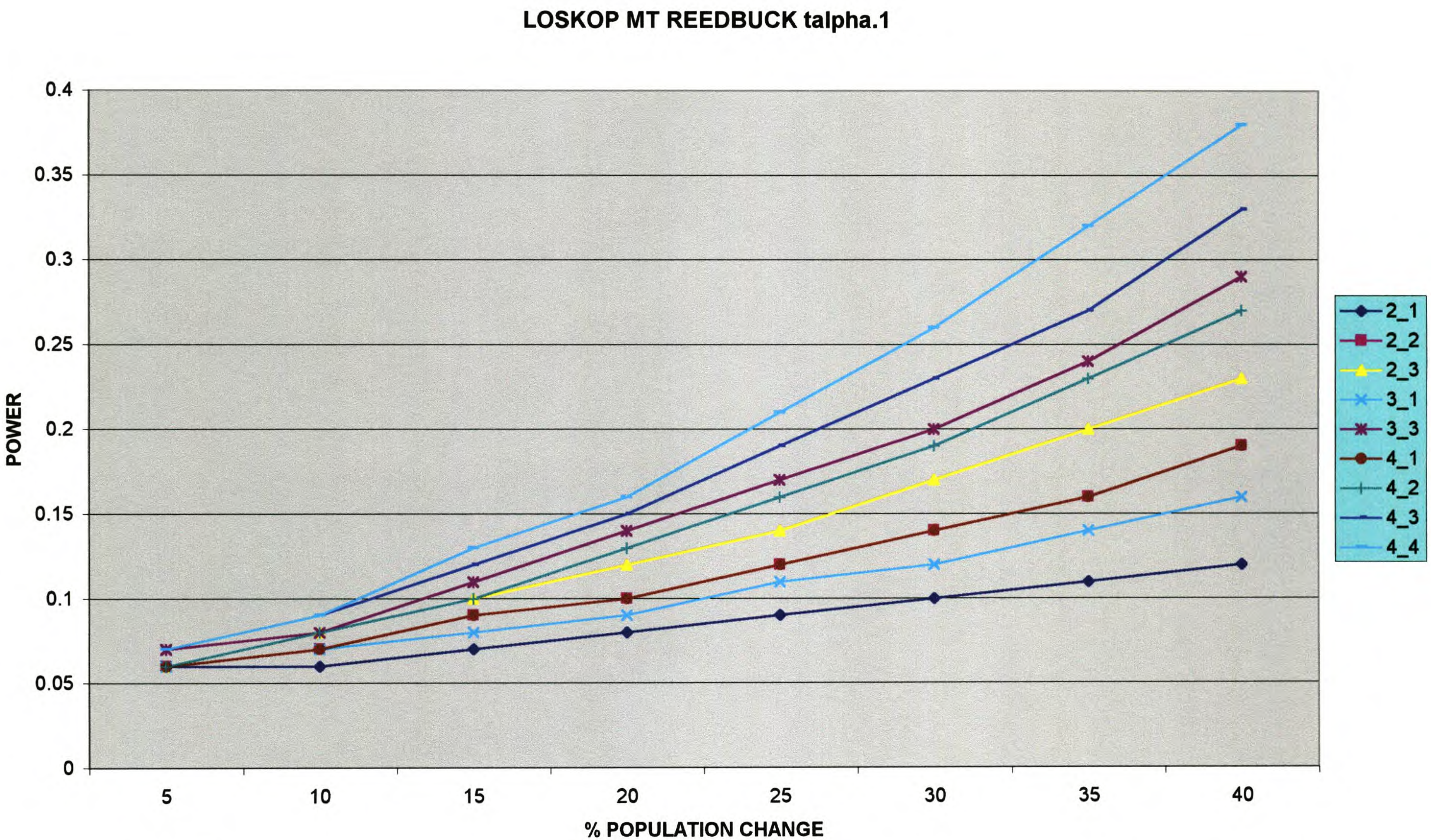


Figure 24: Power curves for various count replicate options at 10% significance for mt. reedbuck at Loskop Dam Nature Reserve.

Table 19: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of the mean for different replicate options from year 1 to year 2 for calculation of power for giraffe at Loskop Dam Nature Reserve.

| GIRAFFE | | MEAN | 155.75 | | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 7.79 | 15.58 | 23.36 | 31.15 | 38.94 | 46.73 | 54.51 | 62.30 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.89 | 1.79 | 2.68 | 3.58 | 4.47 | 5.37 | 6.26 | 7.15 |
| 2 | 2 | 2 | 2.92 | 1.87 | 1.10 | 2.19 | 3.29 | 4.38 | 5.48 | 6.57 | 7.67 | 8.76 |
| 2 | 3 | 3 | 2.35 | 1.64 | 1.20 | 2.40 | 3.60 | 4.80 | 6.00 | 7.20 | 8.40 | 9.60 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.95 | 1.89 | 2.84 | 3.79 | 4.74 | 5.68 | 6.63 | 7.58 |
| 3 | 3 | 4 | 2.13 | 1.53 | 1.34 | 2.68 | 4.02 | 5.36 | 6.70 | 8.04 | 9.38 | 10.71 |
| 4 | 1 | 3 | 2.35 | 1.64 | 0.97 | 1.95 | 2.92 | 3.89 | 4.87 | 5.84 | 6.82 | 7.79 |
| 4 | 2 | 4 | 2.13 | 1.53 | 1.26 | 2.51 | 3.77 | 5.03 | 6.28 | 7.54 | 8.80 | 10.06 |
| 4 | 3 | 5 | 2.02 | 1.48 | 1.43 | 2.85 | 4.28 | 5.70 | 7.13 | 8.55 | 9.98 | 11.40 |
| 4 | 4 | 6 | 1.94 | 1.44 | 1.54 | 3.08 | 4.62 | 6.16 | 7.70 | 9.24 | 10.78 | 12.32 |

Table 20: Power values to detect population change as percentage of the mean for various count replicate options in year 1 and year 2 for giraffe at 10% and 20% significance at Loskop Dam Nature Reserve.

talpha.1 GIRAFFE

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.12 | 0.22 | 0.33 | 0.42 | 0.52 | 0.6 | 0.67 | 0.74 |
| **2_2** | 0.19 | 0.43 | 0.68 | 0.85 | 0.95 | 0.99 | 1 | 1 |
| **2_3** | 0.24 | 0.58 | 0.85 | 0.97 | 1 | 1 | 1 | 1 |
| **3_1** | 0.17 | 0.36 | 0.58 | 0.77 | 0.89 | 0.96 | 0.99 | 1 |
| **3_3** | 0.3 | 0.71 | 0.95 | 1 | 1 | 1 | 1 | 1 |
| **4_1** | 0.19 | 0.45 | 0.72 | 0.9 | 0.97 | 1 | 1 | 1 |
| **4_2** | 0.28 | 0.66 | 0.92 | 0.99 | 1 | 1 | 1 | 1 |
| **4_3** | 0.34 | 0.79 | 0.98 | 1 | 1 | 1 | 1 | 1 |
| **4_4** | 0.39 | 0.86 | 0.99 | 1 | 1 | 1 | 1 | 1 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.24 | 0.42 | 0.59 | 0.73 | 0.83 | 0.9 | 0.95 | 0.97 |
| **2_2** | 0.35 | 0.67 | 0.89 | 0.98 | 1 | 1 | 1 | 1 |
| **2_3** | 0.4 | 0.77 | 0.96 | 1 | 1 | 1 | 1 | 1 |
| **3_1** | 0.3 | 0.58 | 0.82 | 0.94 | 0.99 | 1 | 1 | 1 |
| **3_3** | 0.47 | 0.86 | 0.99 | 1 | 1 | 1 | 1 | 1 |
| **4_1** | 0.33 | 0.65 | 0.88 | 0.98 | 1 | 1 | 1 | 1 |
| **4_2** | 0.44 | 0.83 | 0.98 | 1 | 1 | 1 | 1 | 1 |
| **4_3** | 0.51 | 0.9 | 1 | 1 | 1 | 1 | 1 | 1 |
| **4_4** | 0.56 | 0.94 | 1 | 1 | 1 | 1 | 1 | 1 |

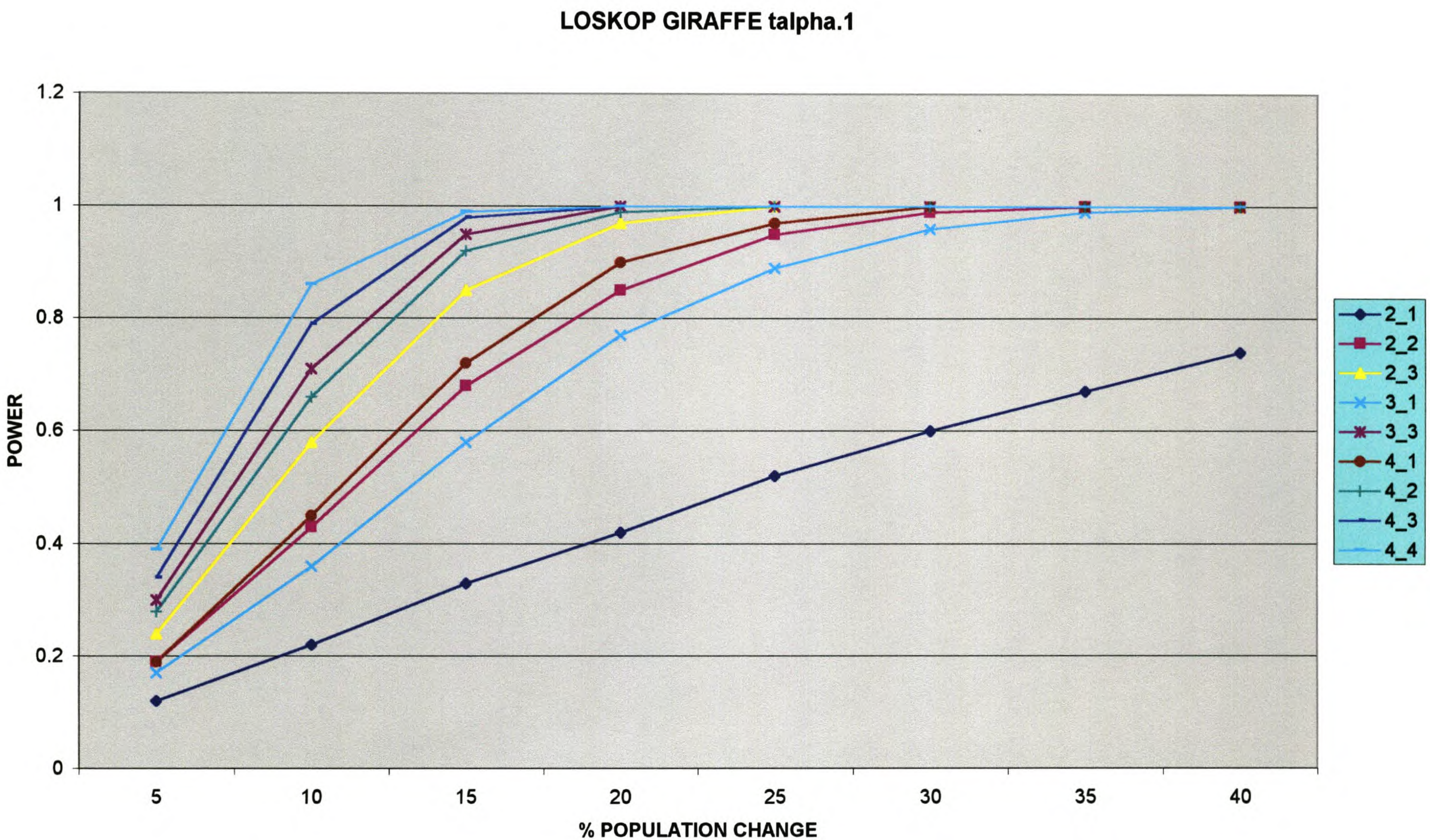


Figure 25: Power curves for various count replicate options at 10% significance for giraffe at Loskop Dam Nature Reserve.

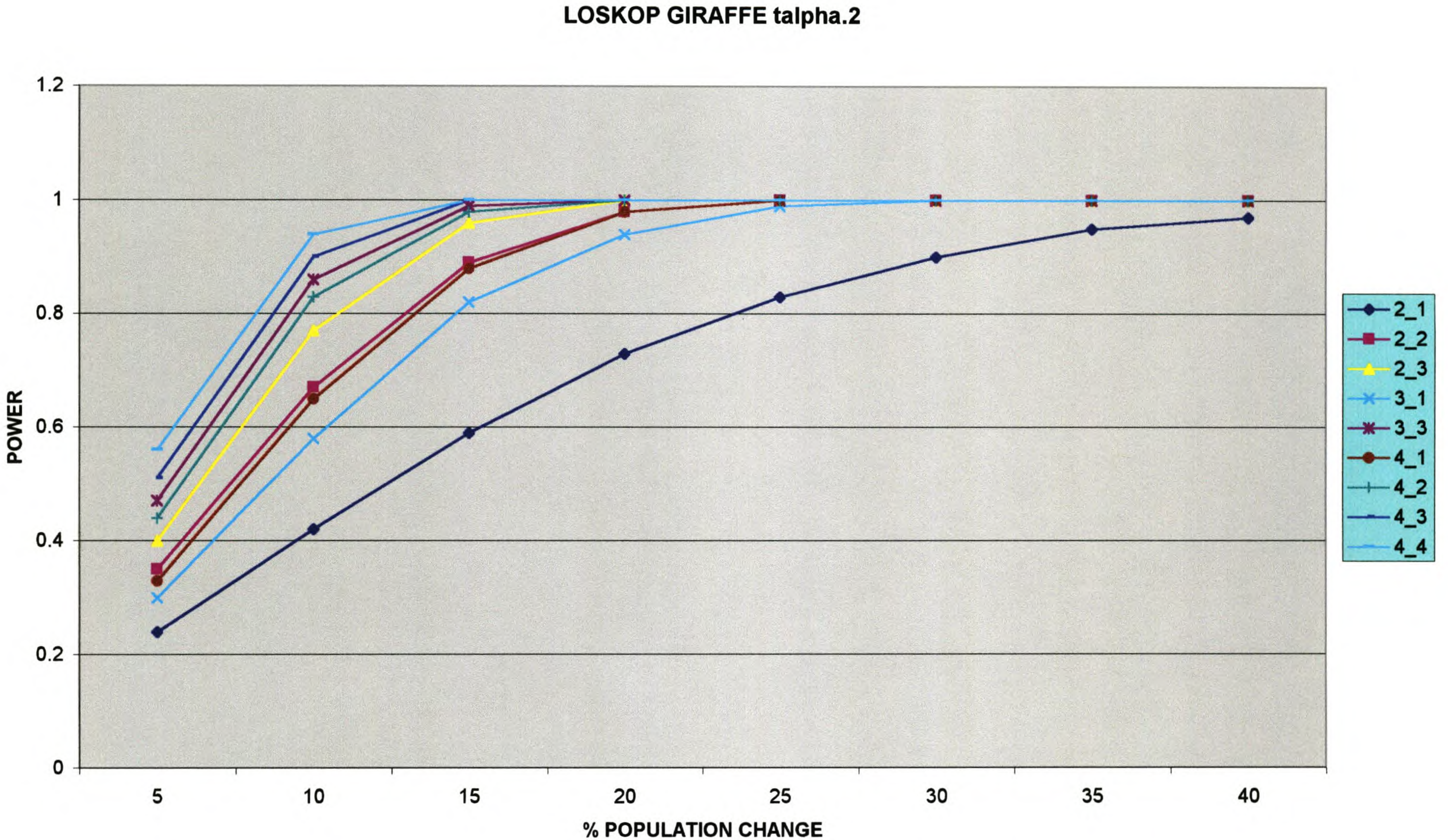


Figure 26: Power curves for various count replicate options at 20% significance for giraffe at Loskop Dam Nature Reserve.

Table 21: Summary of power values attained for talpha.1 (top) and talpha.2 (bottom) to detect a 15% population change for the 10 properties where kudu where encountered.

| | LOSKOP DAM NR | LETABA RANCH | DIEPLAAGTE | ELANDSKLOOF | GROENGOUD | GROOTVLEI | LAAGWATER | ONRUS | GREEFSWALD | SCHRODA |
|---|---|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.29 | 0.08 | 0.25 | 0.18 | 0.14 | 0.09 | 0.19 | 0.08 | 0.07 | 0.14 |
| **2_2** | 0.60 | 0.1 | 0.50 | 0.33 | 0.22 | 0.12 | 0.34 | 0.10 | 0.07 | 0.22 |
| **2_3** | 0.79 | 0.12 | 0.67 | 0.44 | 0.29 | 0.14 | 0.46 | 0.11 | 0.08 | 0.29 |
| **3_1** | 0.51 | 0.09 | 0.42 | 0.28 | 0.24 | 0.11 | 0.28 | 0.09 | 0.07 | 0.19 |
| **3_3** | 0.89 | 0.14 | 0.80 | 0.56 | 0.48 | 0.17 | 0.57 | 0.13 | 0.09 | 0.36 |
| **4_1** | 0.63 | 0.1 | | | | | | | | |
| **4_2** | 0.86 | 0.13 | | | | | | | | |
| **4_3** | 0.94 | 0.15 | | | | | | | | |
| **4_4** | 0.97 | 0.16 | | | | | | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.54 | 0.16 | 0.47 | 0.35 | 0.27 | 0.18 | 0.36 | 0.16 | 0.13 | 0.27 |
| **2_2** | 0.83 | 0.20 | 0.74 | 0.54 | 0.40 | 0.23 | 0.56 | 0.19 | 0.15 | 0.40 |
| **2_3** | 0.92 | 0.22 | 0.85 | 0.64 | 0.47 | 0.25 | 0.66 | 0.21 | 0.16 | 0.46 |
| **3_1** | 0.75 | 0.18 | 0.66 | 0.48 | 0.42 | 0.21 | 0.48 | 0.18 | 0.14 | 0.34 |
| **3_3** | 0.97 | 0.24 | 0.92 | 0.75 | 0.66 | 0.29 | 0.75 | 0.24 | 0.17 | 0.54 |
| **4_1** | 0.82 | 0.19 | | | | | | | | |
| **4_2** | 0.95 | 0.24 | | | | | | | | |
| **4_3** | 0.98 | 0.26 | | | | | | | | |
| **4_4** | 0.99 | 0.28 | | | | | | | | |

Table 22: Summary of power values attained for talpha.1 (top) and talpha.2 (bottom) to detect a 15% population change for the 9 properties where zebra where encountered.

| | LOSKOP DAM NR | LETABA RANCH | DIEPLAAGTE | ELANDSKLOOF | ONRUS | GREEFSWALD | SAMARIA1 | SAMARIA3 | SCHRODA |
|---|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.22 | 0.1 | 0.19 | 0.15 | 0.30 | 0.06 | 0.16 | 0.20 | 0.17 |
| **2_2** | 0.41 | 0.14 | 0.35 | 0.24 | 0.61 | 0.07 | 0.28 | 0.36 | 0.29 |
| **2_3** | 0.56 | 0.17 | 0.48 | 0.31 | 0.79 | 0.08 | 0.38 | 0.49 | 0.39 |
| **3_1** | 0.34 | 0.13 | 0.30 | 0.21 | 0.53 | 0.07 | 0.25 | 0.30 | 0.25 |
| **3_3** | **0.68** | **0.21** | **0.60** | **0.40** | **0.91** | **0.08** | **0.49** | **0.60** | **0.49** |
| **4_1** | 0.42 | 0.14 | | | | | | | |
| **4_2** | 0.63 | 0.19 | | | | | | | |
| **4_3** | 0.76 | 0.23 | | | | | | | |
| **4_4** | 0.83 | 0.26 | | | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.41 | 0.2 | 0.37 | 0.28 | 0.55 | 0.13 | 0.32 | 0.38 | 0.33 |
| **2_2** | 0.64 | 0.26 | 0.58 | 0.42 | 0.84 | 0.14 | 0.48 | 0.59 | 0.50 |
| **2_3** | 0.75 | 0.3 | 0.68 | 0.49 | 0.93 | 0.15 | 0.57 | 0.69 | 0.59 |
| **3_1** | 0.56 | 0.24 | 0.50 | 0.37 | 0.77 | 0.13 | 0.43 | 0.50 | 0.43 |
| **3_3** | **0.84** | **0.35** | **0.78** | **0.58** | **0.98** | **0.16** | **0.68** | **0.78** | **0.68** |
| **4_1** | 0.62 | 0.25 | | | | | | | |
| **4_2** | 0.8 | 0.33 | | | | | | | |
| **4_3** | 0.89 | 0.38 | | | | | | | |
| **4_4** | 0.93 | 0.41 | | | | | | | |

Table 23: Summary of power values attained for talpha.1 (top) and talpha.2 (bottom) to detect a 15% population change for the 9 properties where wildebeest where encountered.

| | LOSKOP DAM NR | LETABA RANCH | DIEPLAAGTE | ELANDSKLOOF | ONRUS | GREEFSWALD | SAMARIA1 | SAMARIA3 | SCHRODA |
|---|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.19 | 0.23 | 0.11 | 0.17 | 0.30 | 0.06 | 0.08 | 0.11 | 0.38 |
| **2_2** | 0.35 | 0.44 | 0.16 | 0.30 | 0.62 | 0.07 | 0.09 | 0.16 | 0.78 |
| **2_3** | 0.46 | 0.6 | 0.19 | 0.41 | 0.80 | 0.07 | 0.11 | 0.19 | 0.93 |
| **3_1** | 0.28 | 0.37 | 0.14 | 0.26 | 0.54 | 0.07 | 0.09 | 0.14 | 0.69 |
| **3_3** | **0.57** | **0.74** | **0.23** | **0.51** | **0.92** | **0.08** | **0.12** | **0.23** | **0.99** |
| **4_1** | 0.35 | 0.47 | | | | | | | |
| **4_2** | 0.53 | 0.69 | | | | | | | |
| **4_3** | 0.64 | 0.81 | | | | | | | |
| **4_4** | 0.73 | 0.88 | | | | | | | |
| **2_1** | 0.36 | 0.43 | 0.21 | 0.33 | 0.55 | 0.12 | 0.15 | 0.21 | 0.67 |
| **2_2** | 0.57 | 0.68 | 0.29 | 0.51 | 0.85 | 0.13 | 0.18 | 0.29 | 0.95 |
| **2_3** | 0.67 | 0.79 | 0.33 | 0.60 | 0.93 | 0.14 | 0.20 | 0.33 | 0.99 |
| **3_1** | 0.48 | 0.6 | 0.26 | 0.44 | 0.78 | 0.13 | 0.17 | 0.26 | 0.90 |
| **3_3** | **0.75** | **0.88** | **0.38** | **0.70** | **0.98** | **0.15** | **0.22** | **0.38** | **1.00** |
| **4_1** | 0.54 | 0.67 | | | | | | | |
| **4_2** | 0.72 | 0.85 | | | | | | | |
| **4_3** | 0.8 | 0.92 | | | | | | | |
| **4_4** | 0.86 | 0.95 | | | | | | | |

Table 24: Summary of power values attained for talpha.1 (top) and talpha.2 (bottom) to detect a 15% population change for the 12 properties where impala where encountered.

| | LOSKOP DAM NR | LETABA RANCH | DIEPLAAGTE | ELANDSKLOOF | GROENGOUD | GROOTVLEI | LAAGWATER | ONRUS | GREEFSWALD | SAMARIA1 | SAMARIA3 | SCHRODA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.17 | 0.11 | 0.14 | 0.12 | 0.13 | 0.06 | 0.16 | 0.14 | 0.11 | 0.20 | 0.13 | 0.08 |
| **2_2** | 0.3 | 0.16 | 0.22 | 0.18 | 0.19 | 0.07 | 0.28 | 0.24 | 0.17 | 0.38 | 0.21 | 0.10 |
| **2_3** | 0.4 | 0.19 | 0.28 | 0.23 | 0.25 | 0.07 | 0.37 | 0.31 | 0.21 | 0.51 | 0.27 | 0.12 |
| **3_1** | 0.26 | 0.14 | 0.19 | 0.16 | 0.21 | 0.07 | 0.23 | 0.20 | 0.15 | 0.31 | 0.19 | 0.09 |
| **3_3** | 0.51 | 0.23 | 0.35 | 0.29 | 0.40 | 0.08 | 0.46 | 0.39 | 0.26 | 0.63 | 0.35 | 0.13 |
| **4_1** | 0.31 | 0.16 | | | | | | | | | | |
| **4_2** | 0.48 | 0.22 | | | | | | | | | | |
| **4_3** | 0.58 | 0.26 | | | | | | | | | | |
| **4_4** | 0.66 | 0.3 | | | | | | | | | | |

| | LOSKOP DAM NR | LETABA RANCH | DIEPLAAGTE | ELANDSKLOOF | GROENGOUD | GROOTVLEI | LAAGWATER | ONRUS | GREEFSWALD | SAMARIA1 | SAMARIA3 | SCHRODA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.33 | 0.21 | 0.27 | 0.24 | 0.25 | 0.12 | 0.32 | 0.28 | 0.23 | 0.39 | 0.26 | 0.16 |
| **2_2** | 0.51 | 0.29 | 0.39 | 0.33 | 0.35 | 0.13 | 0.48 | 0.42 | 0.31 | 0.61 | 0.38 | 0.20 |
| **2_3** | 0.6 | 0.33 | 0.46 | 0.39 | 0.41 | 0.14 | 0.56 | 0.49 | 0.36 | 0.72 | 0.44 | 0.22 |
| **3_1** | 0.44 | 0.26 | 0.34 | 0.29 | 0.37 | 0.13 | 0.41 | 0.36 | 0.27 | 0.53 | 0.34 | 0.18 |
| **3_3** | 0.7 | 0.38 | 0.53 | 0.45 | 0.59 | 0.15 | 0.65 | 0.57 | 0.42 | 0.81 | 0.53 | 0.24 |
| **4_1** | 0.49 | 0.28 | | | | | | | | | | |
| **4_2** | 0.66 | 0.36 | | | | | | | | | | |
| **4_3** | 0.75 | 0.42 | | | | | | | | | | |
| **4_4** | 0.81 | 0.46 | | | | | | | | | | |

# CHAPTER 4

## *RESULTS AND DISCUSSION*

### *TIME BIAS*

During the course of this study all observations of animals or groups of animals were logged into 30-minute intervals. The majority of counts undertaken during the period 1987 to 1994 were of 4 hours or less duration. The observations were thus logged into 8 time intervals with a large sample size (n = 13 295). The purpose of this analysis was to determine if the number of observations decline significantly during the course of a count. Data were analyzed according to the major veldtypes represented during these surveys (northern mopane veld, lowveld mopane veld, *Acacia* veld, northwestern arid bushveld and sourish mixed bushveld).

If all observations are combined and plotted against time interval, the resulting data is Poisson distributed (figure 27). These data are normalized by a square root transformation of the number of observations (Fowler, Cohen & Jarvis 1998). This transformation is not essential as statistical techniques such as ANOVA's are dependent on the assumption that errors are normally distributed (Fowler, Cohen & Jarvis 1998). Secondly, and particularly in the case of Poisson distributions, the single parameter $\lambda$ which determines the distribution is equal to both the mean and the variance. The data transformation tends to remove this dependency of the variance on the mean (Fowler, Cohen & Jarvis 1998). Post transformation shows that the null hypothesis of normality could not be rejected ( mean = 5.11; SD = 2.01; n = 509). In this case n is the number of time intervals containing an observation.

A one-way ANOVA of the transformed data shows no significant difference for each of the time intervals and a *post hoc* Scheffe multiple range test shows no significant difference between any of the cells (p – value > 0.05). A univariate ANOVA between the mean number of observations in each time interval and the midpoint of each time interval is significant ($R^2$ = 0.74). If the data are analyzed (ANOVA) according to vegetation type then significant differences between time intervals is evident for *Acacia* veld and for sourish mixed bushveld.

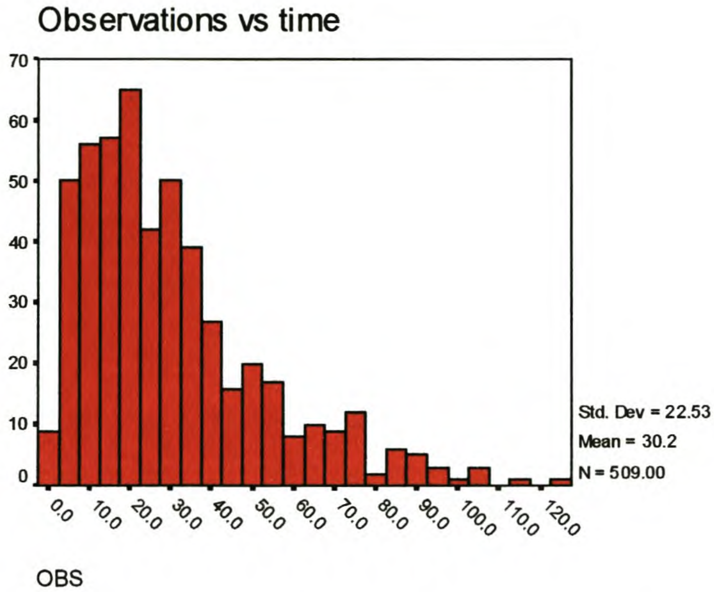


Figure 27: Histogram of observations versus time for all time intervals over all counts in which animals were observed.

These two data sets were subjected to regression analysis of the respective scatterplots with the squareroot of observations as the dependant variable and an attempt made to fit a curve to the data. In both cases the quadratic function best fitted the data with the *Acacia* ($R^2 = 0.37$) (figure 28) and sourish mixed bush ($R^2 = 0.47$) (figure 29) yielding constants shown in table 25. The Scheffe multiple range showed significant differences ( $p< 0,05$) between time intervals 1,2 and 3 and the rest of the time intervals. Although these relationships are not very significant of 91 separate counts logged over time, 85 showed decline over time and a Chi-square meta-analysis is significant ($\chi^2$ =70,33; df = 1; $p<0.01$).

Table 25 : Quadratic function constants for squareroot of obsevations versus time interval for *Acacia* and sourish mixed bushveld.

| VELDTYPE | CONSTANTS | | |
|---|---|---|---|
| | $b_0$ | $b_1$ | $b_2$ |
| *Acacia* veld | 7,16 | - 0,099 | - 0,059 |
| Sourish mixed bushveld | 4,55 | 0,14 | - 0,042 |

These constants allow the computation of correction factors for each 30 minute time interval for up to 4 hours of aerial counting(Tables 26 & 27).

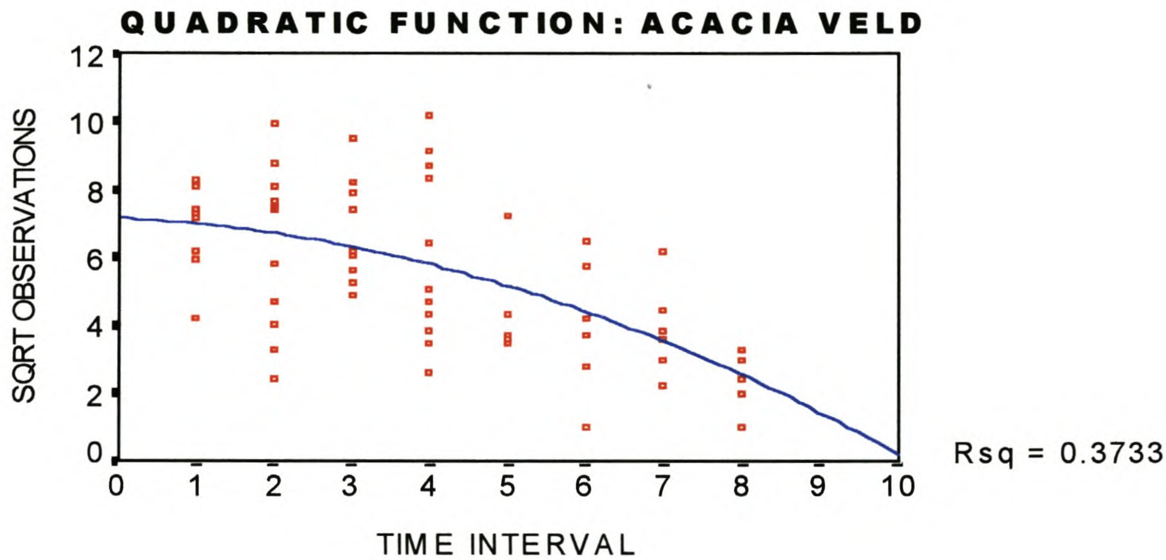


Figure 28: Quadratic function of squareroot of observations of animal groups versus time interval for *Acacia* veld.


Figure 29: Quadratic function of squareroot of observations of animal groups versus time interval for sourish mixed bushveld.

Table 26: Correction factors (%) per time interval ( t x 30 minutes) for 4 hours of counting in *Acacia* veld.

| TIME INTERVAL | SQRT OBSERVATIONS | *ACACIA* VELD OBSERVATIONS | CORRECTION FACTOR(%) | % ANIMALS MISSED |
|---|---|---|---|---|
| 1 | 7.00 | 49.04 | | |
| 2 | 6.73 | 45.25 | 1.08 | 7.71 |
| 3 | 6.33 | 40.11 | 1.22 | 18.19 |
| 4 | 5.82 | 33.90 | 1.45 | 30.87 |
| 5 | 5.19 | 26.96 | 1.82 | 45.01 |
| 6 | 4.45 | 19.76 | 2.48 | 59.71 |
| 7 | 3.58 | 12.81 | 3.83 | 73.87 |
| 8 | 2.60 | 6.74 | 7.28 | 86.26 |

Table 27: Correction factors (%) per time interval ( t x 30 minutes) for 4 hours of counting in sourish mixed bushveld.

| TIME INTERVAL | SQRT OBSERVATIONS | SOURISH MIXED BUSH OBSERVATIONS | CORRECTION FACTOR(%) | % ANIMALS MISSED |
|---|---|---|---|---|
| 1 | 4.65 | 21.60 | | |
| 2 | 4.66 | 21.73 | 0.99 | -0.60 |
| 3 | 4.59 | 21.09 | 1.02 | 2.40 |
| 4 | 4.44 | 19.70 | 1.10 | 8.83 |
| 5 | 4.20 | 17.64 | 1.22 | 18.35 |
| 6 | 3.88 | 15.04 | 1.44 | 30.39 |
| 7 | 3.47 | 12.05 | 1.79 | 44.20 |
| 8 | 2.98 | 8.89 | 2.43 | 58.84 |

Many authors recognize the existence of bias in aerial surveys of large ungulates (Seber 1992). Most of the sources of bias are attributed to sightability of individual animals or groups of animals (Seber 1992) and many methods are used to establish correction factors to compensate for this phenomenon. The development of line methods through standard strip transects (Seber 1973) to modified strip transects (Eberhardt 1976) with their restrictive and, at times, unlikely assumptions (Hirst 1969; Robinette et al. 1974; Burnham, Anderson & Laacke 1980) led finally to the population based line transect method of Burnham *et al.* 1980). These methods are statistically robust and incorporate site specific sightability attributes by deriving population densities from actual data and the resulting probability density function.

This method has undergone an evolution (Buckland, Anderson, Burnham & Laacke 1993) and several authors have investigated bias relating to the method (Burnham, Anderson & Laacke 1985). The evolution of the method has culminated in the application of the "distance" method to aerial counting (Van Hensbergen *et al.* 1996) where population estimation recognizes differential sightability by aerial observers. It has long been suspected that the number of sightings of animals may also be biased over time due to the combined effect of changing sightability profiles during the course of a count, the behaviour of the animals and/or observer fatigue.

The use of correction factors in game counting is well documented (Seber 1992). A great deal of scientific effort has been expended in investigating correction factors for aerial counts under the premise that results will almost always be negatively biased (Jolly 1969; Marsh & Sinclair 1989 and Seber 1992). Many authors have investigated visibility bias as the basis of the assumed negative bias in aerial counts ( Broome 1985; Bayliss & Giles 1985 and Jackson 1985) and Hill, Barnes & Wilson (1985) have proposed a methodology for reducing time of day effects. Methods for reducing visibility bias revolve by-and-large around the probability of sighting animals (Caughley & Grice 1982; Rivest, Potvin, Crepeau & Daigle 1995). The decline of number of animals seen during the course of a survey (visibility bias) is undoubtedly the product of several factors, time of day, changing light characteristics and changing behaviour patterns. No authors, however, point out observer fatigue as a potential factor in this bias.

Results of total aerial counts are used as indices of relative density in southern Africa context under the assumption that bias is constant. According to Conroy et al. (1988) this underlying assumption is unlikely to be met.

Correction factors applied to counting results are most often attempts to achieve greater accuracy and many such factors have been proposed based on sighting probability of animals (Samuel & Pollock 1981; Caughley & Grice 1982 and Crete et al. 1986) and corrections based on sub-sampling the data (Rivest et al. 1990 and Rivest et al. 1995). Many authors are of the opinion that correction factors are site specific (Pollock & Kendall 1987; Graham & Bell 1989; Marsh & Sinclair 1989 and Seber 1992).

The correction factors based on the models fitted in the present study are not in any way related to the accuracy of the method but demonstrate the existence of declining observations as a function of time. This is due to changing visibility which the present author contends is in part due to observer fatigue. Computed correction factors (table 23 ) enable corrected estimates to be computed according to the time length of the operation for southern African veldtypes, *Acacia* veld and sourish mixed bushveld. These corrections can only be applied on assumption of random distribution of animals or animal groups.

# CHAPTER 5

## *OBSERVER BIAS*

## *RESULTS*

In the previous chapter the effect of time on the number of observations by observers has been investigated and although the result was significant for only two of the four vegetation types in the analysis, a general negative relationship was evidenced.

The period of this study (7 years) and the number of operations involved in making the 13 295 observations under discussion, added to the experience of the author and other observers, provide an opportunity to investigate the individual observation profiles of the four most experienced observers. Each of them had a minimum of 100 operational hours' experience preceding this programme. During its course they completed 76 separate counting operations for which data were logged in 30-minute intervals. The results present a unique opportunity to compare these observers using their time/ observation profile.

Results are presented by observer and by species. Species included in the analysis are those most often encountered viz. impala, wildebeest, zebra and kudu. Summary statistics are presented for observer 1 in table 28. They show observations as well as observation rates per time interval for actual observations and for the squareroot of observations. Summaries for observers 2, 3 and 4 appear in tables 29, 30 and 31. The transformed observation rate forms the basis of the correlations of observations and time interval as well as the statistical comparison between observers.

Regression analyses for squareroot of observations versus time for all species shows that correlations exist ($R^2$ = 0.89, 0.85, 0.22 and 0.25 for observers 1, 2, 3 and 4 respectively). It is important to note at this stage that the within observer correlation is not of significance, but rather the subsequent proof of a difference in between observer profiles. These regressions are plotted in figure 29. An analysis of covariance (ANCOVA) with time as covariate shows the differences between observers to be significant (adjusted $R^2$ = 0.77 and p = 0.001).

In the case of impala linear regressions for observers 1, 2, 3 and 4 show $R^2$ values of 0.90, 0.85, 0.21 and 0.22 respectively. Once again the ANCOVA proves significant (adjusted $R^2$ = 0.75 and p = 0.001). These regressions are illustrated in figure 30.

For wildebeest observer 1 shows a correlation between squareroot of observation rate and time ($R^2 = 0.88$) while other observers also show correlation to a lesser degree (observer 2, $R^2 = 0.85$; observer 3, $R^2 = 0.22$; and observer 4, $R^2 = 0.12$). The ANCOVA again proves significant (adjusted $R^2 = 0.71$ and p = 0.001). Figure 31 plots these regressions.

The results for zebra show negative correlations for observers 1 and 2 (observer 1, $R^2 = 0.47$ and observer 2, $R^2 = 0.04$) whilst those for observers 3 and 4 are positive (observer 3, $R^2 = 0.49$; and observer 4, $R^2 = 0.63$). Analysis of covariance is significant (adjusted $R^2 = 0.41$ and $p < 0.037$). The plots appear as figure 32.

***DISCUSSION***

Finally, correlations between each of the four observer's squareroot of observations and time interval for kudu are as follows:- Observer 1, $R^2 = 0.15$; observer 2, $R^2 = 0.72$, observer 3, $R^2 = 0.49$; and observer 4, $R^2 = 0.40$. ANCOVA shows these regressions to differ significantly (adjusted $R^2 = 0.52$ and $p < 0.013$).

Authors on the subject all agree that any survey of this nature, aerial or otherwise irrespective of the specific method employed, contains counting errors (Collinson 1985, Seber 1992 and Eiselen 1994). The counting error is the sum of several different errors relating to sampling, visibility, species counted (behaviour) and observer bias (Caughley & Grice 1982, Seber 1992). Although several authors either allude to the fact, or conclude that observers see differently (Caughley & Grice 1982) and that observer error is present (Bell, Grimsdell, van Lavieren & Sayer 1973) and that conclusions of one observer are not comparable to those of another observer (Jolly 1969), very few references either quantify or investigate the role of the observer in counting error. These results demonstrate that observers do differ in profile although a general negative tendency in number of observations over time does occur (Chapter 4).

These results lead us to conclude that each observer has a unique observation profile and ideally this profile should be established over time so as to create a set of correction factors for each observer. Current tendencies in the industry are to scrape together observers to undertake surveys irrespective of their individual capabilities and this may be one of the largest contributory factors to some of the high variation in results attained. At the very least one would expect a high degree of standardization of observers in monitoring programmes.

Table 28: Summary statistics for observer 1 for observation rates and squareroot of observation rate by time interval for four species and total observations during the course of 76 helicopter counts.

| | SPECIES | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TIME | IMPALA | | | WILDEBEEST | | | ZEBRA | | | KUDU | | | TOTAL | | |
| INTERVAL | OBS | N | RATE | OBS | N | RATE | OBS | N | RATE | OBS | N | RATE | OBS | N | RATE |
| 1 | 143 | 45 | 3.18 | 54 | 45 | 1.20 | 40 | 45 | 0.89 | 60 | 45 | 1.33 | 297 | 45 | 6.60 |
| 2 | 124 | 45 | 2.76 | 57 | 45 | 1.27 | 42 | 45 | 0.93 | 82 | 45 | 1.82 | 305 | 45 | 6.78 |
| 3 | 124 | 45 | 2.76 | 65 | 45 | 1.44 | 38 | 45 | 0.84 | 92 | 45 | 2.04 | 319 | 45 | 7.09 |
| 4 | 125 | 45 | 2.78 | 49 | 45 | 1.09 | 53 | 45 | 1.18 | 85 | 45 | 1.89 | 312 | 45 | 6.93 |
| 5 | 91 | 40 | 2.28 | 29 | 40 | 0.73 | 45 | 40 | 1.13 | 57 | 40 | 1.43 | 222 | 40 | 5.55 |
| 6 | 70 | 25 | 2.80 | 15 | 25 | 0.60 | 29 | 25 | 1.16 | 77 | 25 | 3.08 | 191 | 25 | 7.64 |
| 7 | 61 | 18 | 3.39 | 13 | 18 | 0.72 | 10 | 18 | 0.56 | 32 | 18 | 1.78 | 116 | 18 | 6.44 |
| 8 | 50 | 18 | 2.78 | 3 | 18 | 0.17 | 1 | 18 | 0.06 | 25 | 18 | 1.39 | 79 | 18 | 4.39 |
| TOTAL | 788 | 281 | 2.84 | 285 | 281 | 0.90 | 258 | 281 | 0.84 | 510 | 281 | 1.85 | 1841 | 281 | 6.43 |

| TIME | IMPALA | | | WILDEBEEST | | | ZEBRA | | | KUDU | | | TOTAL | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| INTERVAL | OBS | N | RATE | OBS | N | RATE | OBS | N | RATE | OBS | N | RATE | OBS | N | RATE |
| 1 | 143 | 6.71 | 21.32 | 54 | 6.71 | 8.05 | 40 | 6.71 | 5.96 | 60 | 6.71 | 8.94 | 297 | 6.71 | 99.00 |
| 2 | 124 | 6.71 | 18.48 | 57 | 6.71 | 8.50 | 42 | 6.71 | 6.26 | 82 | 6.71 | 12.22 | 305 | 6.71 | 45.47 |
| 3 | 124 | 6.71 | 18.48 | 65 | 6.71 | 9.69 | 38 | 6.71 | 5.66 | 92 | 6.71 | 13.71 | 319 | 6.71 | 47.55 |
| 4 | 125 | 6.71 | 18.63 | 49 | 6.71 | 7.30 | 53 | 6.71 | 7.90 | 85 | 6.71 | 12.67 | 312 | 6.71 | 46.51 |
| 5 | 91 | 6.32 | 14.39 | 29 | 6.32 | 4.59 | 45 | 6.32 | 7.12 | 57 | 6.32 | 9.01 | 222 | 6.32 | 35.10 |
| 6 | 70 | 5.00 | 14.00 | 15 | 5.00 | 3.00 | 29 | 5.00 | 5.80 | 77 | 5.00 | 15.40 | 191 | 5.00 | 38.20 |
| 7 | 61 | 4.24 | 14.38 | 13 | 4.24 | 3.06 | 10 | 4.24 | 2.36 | 32 | 4.24 | 7.54 | 116 | 4.24 | 27.34 |
| 8 | 50 | 4.24 | 11.79 | 3 | 4.24 | 0.71 | 1 | 4.24 | 0.24 | 25 | 4.24 | 5.89 | 79 | 4.24 | 18.62 |
| TOTAL | 788 | 46.64 | 16.43 | 285.00 | 46.64 | 5.61 | 258.00 | 46.64 | 5.16 | 510.00 | 46.64 | 10.68 | 1841.00 | 46.64 | 44.72 |

Table 29: Summary statistics for observer 2 for observation rates and squareroot of observation rate by time interval for four species and total observations during the course of 76 helicopter counts.

| TIME INTERVAL | IMPALA | | | WILDEBEEST | | | ZEBRA | | | KUDU | | | TOTAL | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OBS | N | RATE | OBS | N | RATE | OBS | N | RATE | OBS | N | RATE | OBS | N | RATE |
| 1 | 74 | 32 | 2.31 | 40 | 32 | 1.25 | 8 | 32 | 0.25 | 61 | 32 | 1.91 | 183 | 32 | 5.72 |
| 2 | 74 | 32 | 2.31 | 32 | 32 | 1.00 | 21 | 32 | 0.66 | 63 | 32 | 1.97 | 190 | 32 | 5.94 |
| 3 | 88 | 32 | 2.75 | 25 | 32 | 0.78 | 31 | 32 | 0.97 | 56 | 32 | 1.75 | 200 | 32 | 6.25 |
| 4 | 62 | 32 | 1.94 | 28 | 32 | 0.88 | 34 | 32 | 1.06 | 32 | 32 | 1.00 | 156 | 32 | 4.88 |
| 5 | 55 | 31 | 1.77 | 23 | 31 | 0.74 | 39 | 31 | 1.26 | 55 | 31 | 1.77 | 172 | 31 | 5.55 |
| 6 | 31 | 18 | 1.72 | 17 | 18 | 0.94 | 26 | 18 | 1.44 | 32 | 18 | 1.78 | 106 | 18 | 5.89 |
| 7 | 14 | 11 | 1.27 | 4 | 11 | 0.36 | 5 | 11 | 0.45 | 10 | 11 | 0.91 | 33 | 11 | 3.00 |
| 8 | 9 | 11 | 0.82 | 2 | 11 | 0.18 | 0 | 11 | 0.00 | 11 | 11 | 1.00 | 22 | 11 | 2.00 |
| TOTAL | 407 | 199 | 1.86 | 171 | 199 | 0.77 | 164 | 199 | 0.76 | 320 | 199 | 1.51 | 1062 | 199 | 4.90 |

| TIME INTERVAL | IMPALA | | | WILDEBEEST | | | ZEBRA | | | KUDU | | | TOTAL | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OBS | N | RATE | OBS | N | RATE | OBS | N | RATE | OBS | N | RATE | OBS | N | RATE |
| 1 | 74 | 5.66 | 13.08 | 40 | 5.66 | 7.07 | 8 | 5.66 | 1.41 | 61 | 5.66 | 10.78 | 183 | 5.66 | 32.35 |
| 2 | 74 | 5.66 | 13.08 | 32 | 5.66 | 5.66 | 21 | 5.66 | 3.71 | 63 | 5.66 | 11.14 | 190 | 5.66 | 33.59 |
| 3 | 88 | 5.66 | 15.56 | 25 | 5.66 | 4.42 | 31 | 5.66 | 5.48 | 56 | 5.66 | 9.90 | 200 | 5.66 | 35.36 |
| 4 | 62 | 5.66 | 10.96 | 28 | 5.66 | 4.95 | 34 | 5.66 | 6.01 | 32 | 5.66 | 5.66 | 156 | 5.66 | 27.58 |
| 5 | 55 | 5.57 | 9.88 | 23 | 5.57 | 4.13 | 39 | 5.57 | 7.00 | 55 | 5.57 | 9.88 | 172 | 5.57 | 30.89 |
| 6 | 31 | 4.24 | 7.31 | 17 | 4.24 | 4.01 | 26 | 4.24 | 6.13 | 32 | 4.24 | 7.54 | 106 | 4.24 | 24.98 |
| 7 | 14 | 3.32 | 4.22 | 4 | 3.32 | 1.21 | 5 | 3.32 | 1.51 | 10 | 3.32 | 3.02 | 33 | 3.32 | 9.95 |
| 8 | 9 | 3.32 | 2.71 | 2 | 3.32 | 0.60 | 0 | 3.32 | 0.00 | 11 | 3.32 | 3.32 | 22 | 3.32 | 6.63 |
| TOTAL | 407 | 39.07 | 9.60 | 171 | 39.07 | 4.01 | 164 | 39.07 | 3.91 | 320 | 39.07 | 7.65 | 1062 | 39.07 | 25.17 |

Table 30: Summary statistics for observer 2 for observation rates and squareroot of observation rate by time interval for four species and total observations during the course of 76 helicopter counts.

| TIME INTERVAL | SPECIES | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | IMPALA | | | WILDEBEEST | | | ZEBRA | | | KUDU | | | TOTAL | | |
| | OBS | N | RATE | OBS | N | RATE | OBS | N | RATE | OBS | N | RATE | OBS | N | RATE |
| **1** | 29 | 10 | 2.90 | 16 | 10 | 1.60 | 2 | 10 | 0.20 | 26 | 10 | 2.60 | 73 | 10 | 7.30 |
| **2** | 20 | 10 | 2.00 | 5 | 10 | 0.50 | 0 | 10 | 0.00 | 25 | 10 | 2.50 | 50 | 10 | 5.00 |
| **3** | 22 | 10 | 2.20 | 10 | 10 | 1.00 | 4 | 10 | 0.40 | 17 | 10 | 1.70 | 53 | 10 | 5.30 |
| **4** | 22 | 10 | 2.20 | 11 | 10 | 1.10 | 6 | 10 | 0.60 | 29 | 10 | 2.90 | 68 | 10 | 6.80 |
| **5** | 22 | 10 | 2.20 | 7 | 10 | 0.70 | 4 | 10 | 0.40 | 10 | 10 | 1.00 | 43 | 10 | 4.30 |
| **6** | 27 | 8 | 3.38 | 13 | 8 | 1.63 | 4 | 8 | 0.50 | 16 | 8 | 2.00 | 60 | 8 | 7.50 |
| **7** | 14 | 8 | 1.75 | 4 | 8 | 0.50 | 4 | 8 | 0.50 | 16 | 8 | 2.00 | 38 | 8 | 4.75 |
| **8** | 15 | 8 | 1.88 | 4 | 8 | 0.50 | 5 | 8 | 0.63 | 6 | 8 | 0.75 | 30 | 8 | 3.75 |
| TOTAL | 171 | 74 | 2.31 | 70 | 74 | 0.94 | 29 | 74 | 0.40 | 145 | 74 | 1.93 | 415 | 74 | 5.59 |

| TIME INTERVAL | SPECIES | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | IMPALA | | | WILDEBEEST | | | ZEBRA | | | KUDU | | | TOTAL | | |
| | OBS | N | RATE | OBS | N | RATE | OBS | N | RATE | OBS | N | RATE | OBS | N | RATE |
| **1** | 29 | 3.16 | 9.17 | 16 | 3.16 | 5.06 | 2 | 3.16 | 0.63 | 26 | 3.16 | 8.22 | 73 | 3.16 | 23.08 |
| **2** | 20 | 3.16 | 6.32 | 5 | 3.16 | 1.58 | 0 | 3.16 | 0.00 | 25 | 3.16 | 7.91 | 50 | 3.16 | 15.81 |
| **3** | 22 | 3.16 | 6.96 | 10 | 3.16 | 3.16 | 4 | 3.16 | 1.26 | 17 | 3.16 | 5.38 | 53 | 3.16 | 16.76 |
| **4** | 22 | 3.16 | 6.96 | 11 | 3.16 | 3.48 | 6 | 3.16 | 1.90 | 29 | 3.16 | 9.17 | 68 | 3.16 | 21.50 |
| **5** | 22 | 3.16 | 6.96 | 7 | 3.16 | 2.21 | 4 | 3.16 | 1.26 | 10 | 3.16 | 3.16 | 43 | 3.16 | 13.60 |
| **6** | 27 | 2.83 | 9.55 | 13 | 2.83 | 4.60 | 4 | 2.83 | 1.41 | 16 | 2.83 | 5.66 | 60 | 2.83 | 21.21 |
| **7** | 14 | 2.83 | 4.95 | 4 | 2.83 | 1.41 | 4 | 2.83 | 1.41 | 16 | 2.83 | 5.66 | 38 | 2.83 | 13.44 |
| **8** | 15 | 2.83 | 5.30 | 4 | 2.83 | 1.41 | 5 | 2.83 | 1.77 | 6 | 2.83 | 2.12 | 30 | 2.83 | 10.61 |
| TOTAL | 171 | 24.3 | 7.02 | 70 | 24.30 | 2.86 | 29 | 24.30 | 1.21 | 145 | 24.30 | 5.91 | 415 | 24.30 | 17 |

Table 31: Summary statistics for observer 4 for observation rates and squareroot of observation rate by time interval for four species and total observations during the course of 76 helicopter counts.

| TIME INTERVAL | IMPALA | | | WILDEBEEST | | | ZEBRA | | | KUDU | | | TOTAL | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OBS | N | RATE | OBS | N | RATE | OBS | N | RATE | OBS | N | RATE | OBS | N | RATE |
| 1 | 23 | 10 | 2.30 | 9 | 10 | 0.90 | 12 | 10 | 1.20 | 10 | 10 | 1.00 | 54 | 10 | 5.40 |
| 2 | 32 | 10 | 3.20 | 12 | 10 | 1.20 | 15 | 10 | 1.50 | 10 | 10 | 1.00 | 69 | 10 | 6.90 |
| 3 | 49 | 10 | 4.90 | 9 | 10 | 0.90 | 11 | 10 | 1.10 | 12 | 10 | 1.20 | 81 | 10 | 8.10 |
| 4 | 25 | 10 | 2.50 | 9 | 10 | 0.90 | 5 | 10 | 0.50 | 16 | 10 | 1.60 | 55 | 10 | 5.50 |
| 5 | 10 | 6 | 1.67 | 0 | 6 | 0.00 | 5 | 6 | 0.83 | 6 | 6 | 1.00 | 21 | 6 | 3.50 |
| 6 | 21 | 6 | 3.50 | 0 | 6 | 0.00 | 2 | 6 | 0.33 | 11 | 6 | 1.83 | 34 | 6 | 5.67 |
| 7 | 17 | 6 | 2.83 | 0 | 6 | 0.00 | 4 | 6 | 0.67 | 16 | 6 | 2.67 | 37 | 6 | 6.17 |
| 8 | 13 | 6 | 2.17 | 2 | 6 | 0.33 | 2 | 6 | 0.33 | 12 | 6 | 2.00 | 29 | 6 | 4.83 |
| TOTAL | 190 | 64 | 2.88 | 41 | 64 | 0.53 | 56 | 64 | 0.81 | 93 | 64 | 1.54 | 380 | 64 | 5.76 |

| TIME INTERVAL | IMPALA | | | WILDEBEEST | | | ZEBRA | | | KUDU | | | TOTAL | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OBS | N | RATE | OBS | N | RATE | OBS | N | RATE | OBS | N | RATE | OBS | N | RATE |
| 1 | 29 | 3.16 | 9.17 | 16 | 3.16 | 5.06 | 2 | 3.16 | 0.63 | 26 | 3.16 | 8.22 | 73 | 3.16 | 23.08 |
| 2 | 20 | 3.16 | 6.32 | 5 | 3.16 | 1.58 | 0 | 3.16 | 0.00 | 25 | 3.16 | 7.91 | 50 | 3.16 | 15.81 |
| 3 | 22 | 3.16 | 6.96 | 10 | 3.16 | 3.16 | 4 | 3.16 | 1.26 | 17 | 3.16 | 5.38 | 53 | 3.16 | 16.76 |
| 4 | 22 | 3.16 | 6.96 | 11 | 3.16 | 3.48 | 6 | 3.16 | 1.90 | 29 | 3.16 | 9.17 | 68 | 3.16 | 21.50 |
| 5 | 22 | 2.45 | 8.98 | 7 | 2.45 | 2.86 | 4 | 2.45 | 1.63 | 10 | 2.45 | 4.08 | 43 | 2.45 | 17.55 |
| 6 | 27 | 2.45 | 11.02 | 13 | 2.45 | 5.31 | 4 | 2.45 | 1.63 | 16 | 2.45 | 6.53 | 60 | 2.45 | 24.49 |
| 7 | 14 | 2.45 | 5.72 | 4 | 2.45 | 1.63 | 4 | 2.45 | 1.63 | 16 | 2.45 | 6.53 | 38 | 2.45 | 15.51 |
| 8 | 15 | 2.45 | 6.12 | 4 | 2.45 | 1.63 | 5 | 2.45 | 2.04 | 6 | 2.45 | 2.45 | 30 | 2.45 | 12.25 |
| TOTAL | 171 | 22.447 | 7.66 | 70 | 22.45 | 3.09 | 29 | 22.45 | 1.34 | 145 | 22.45 | 6.28 | 415 | 22.45 | 18 |

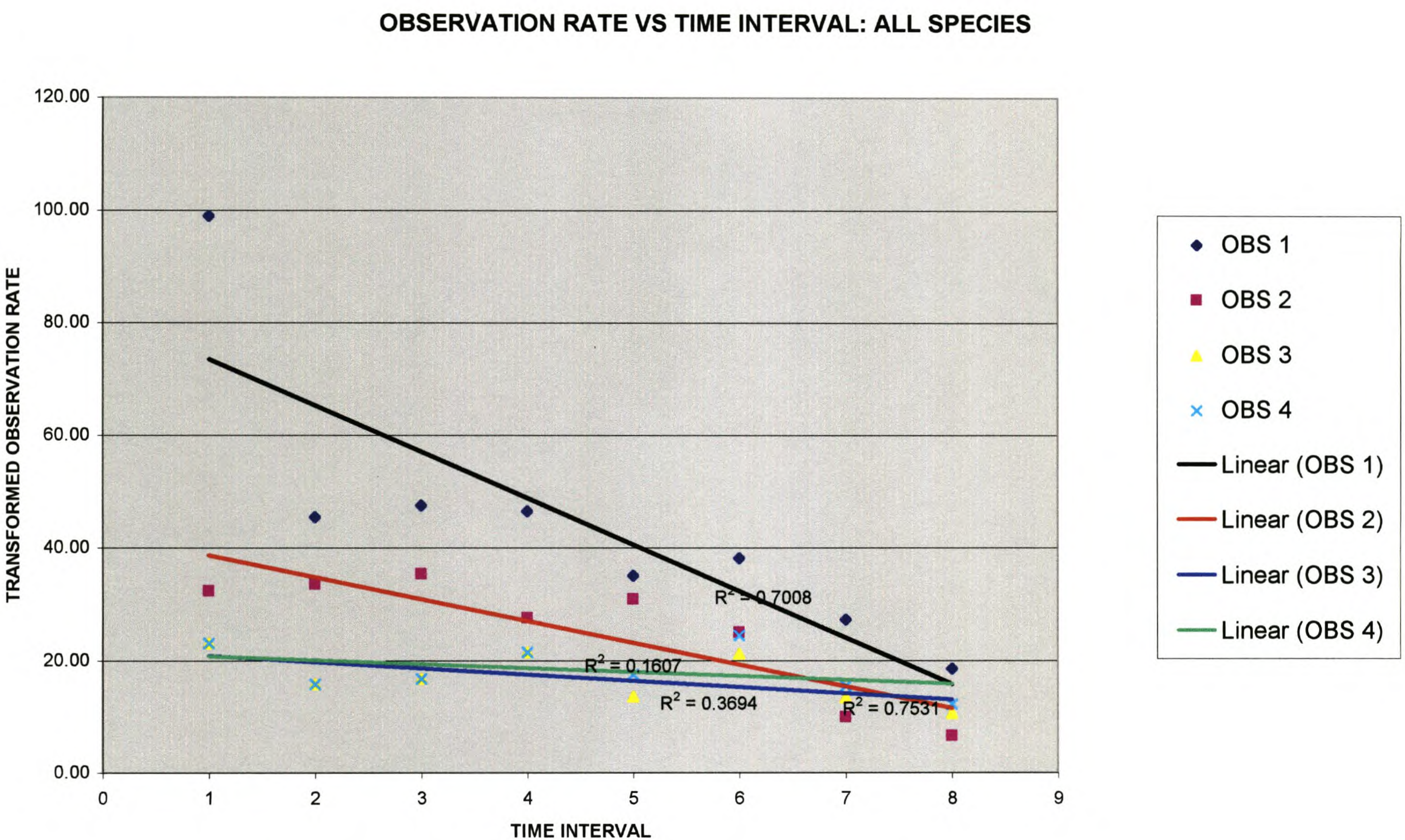


Figure 30: Regressions for 4 observers for squareroot of observations versus time for all species over 76 helicopter counts.

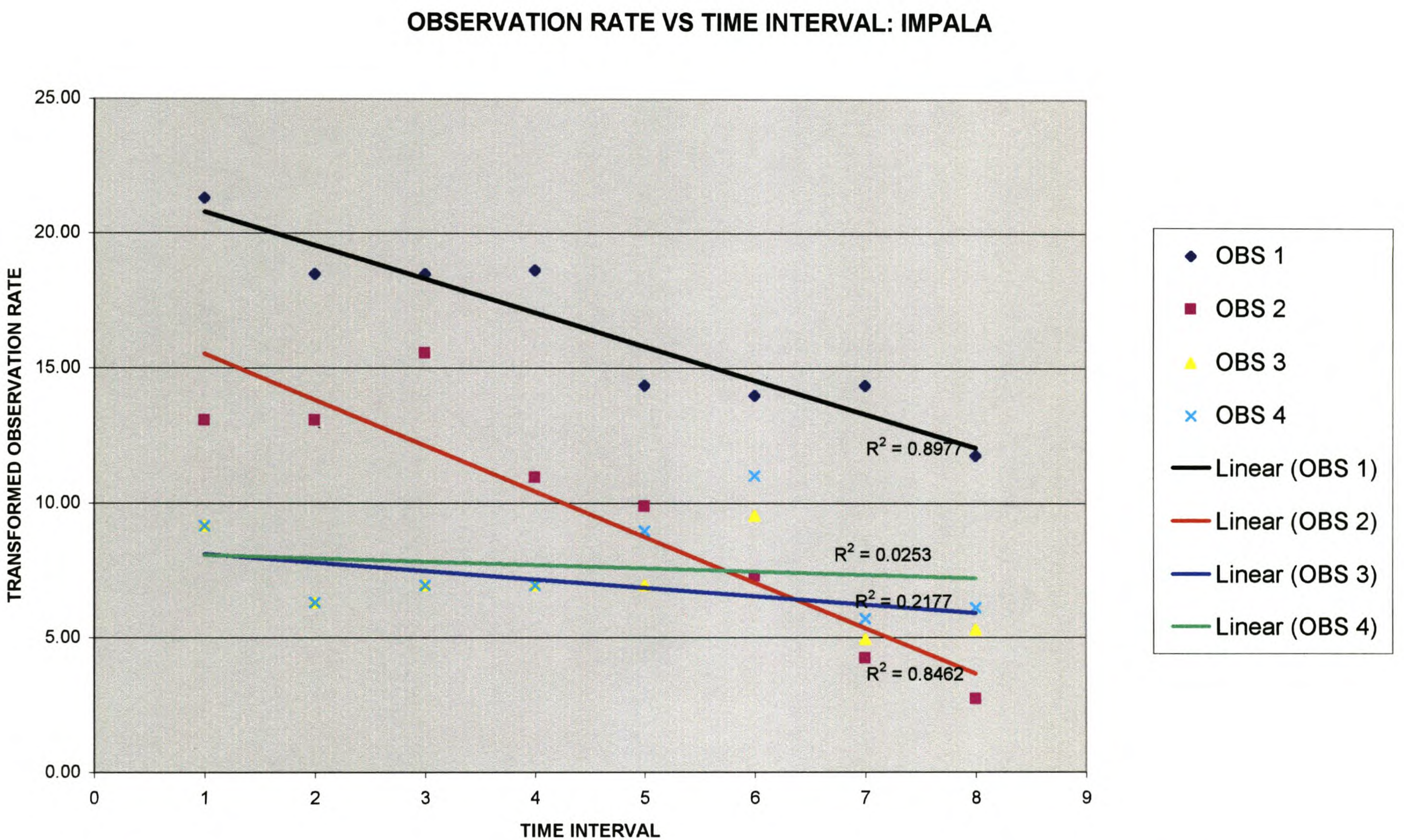


Figure 31: Regressions for 4 observers for squareroot of observations versus time for impala over 76 helicopter counts.

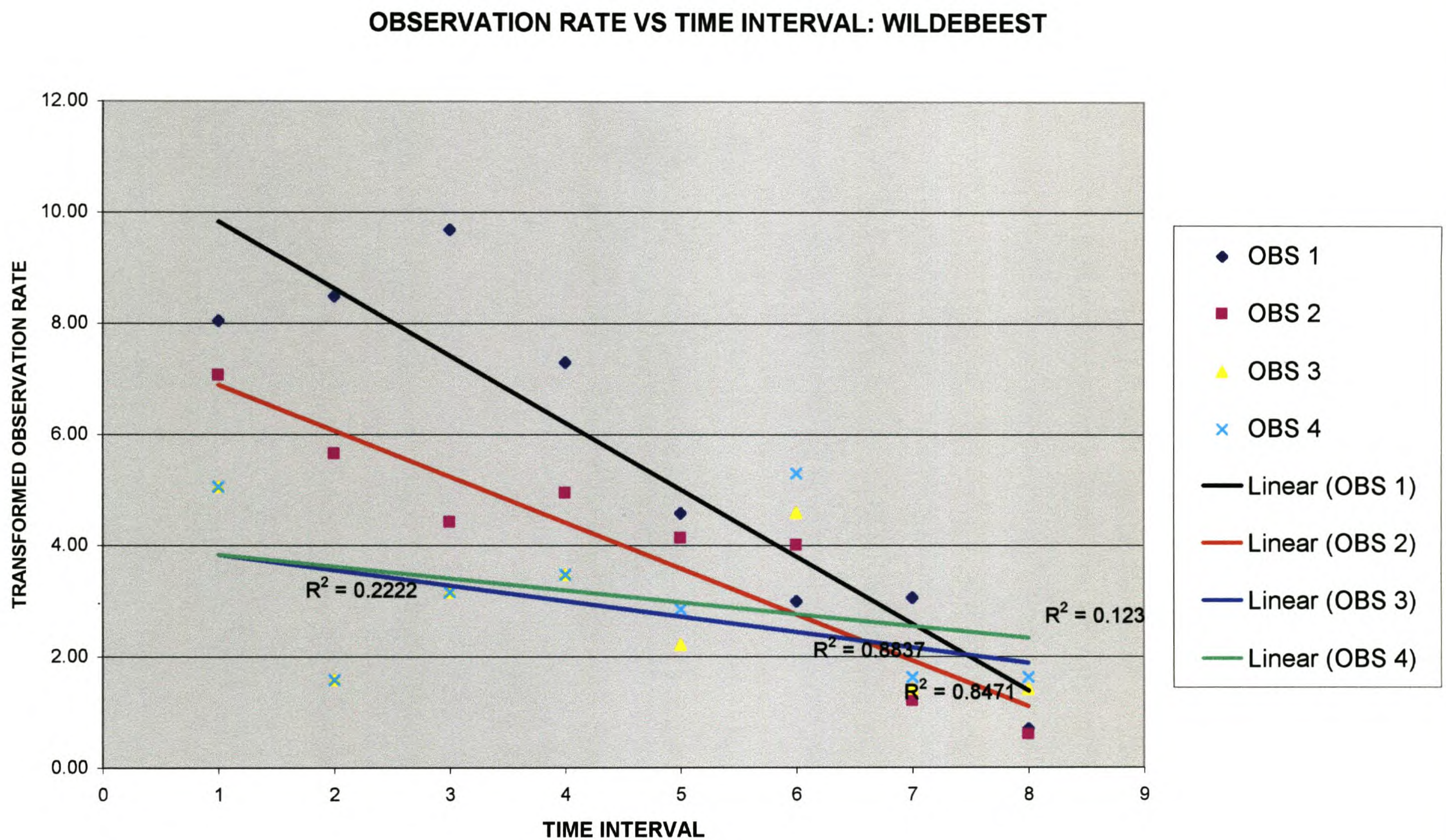


Figure 32: Regressions for 4 observers for squareroot of observations versus time for wildebeest over 76 helicopter counts.

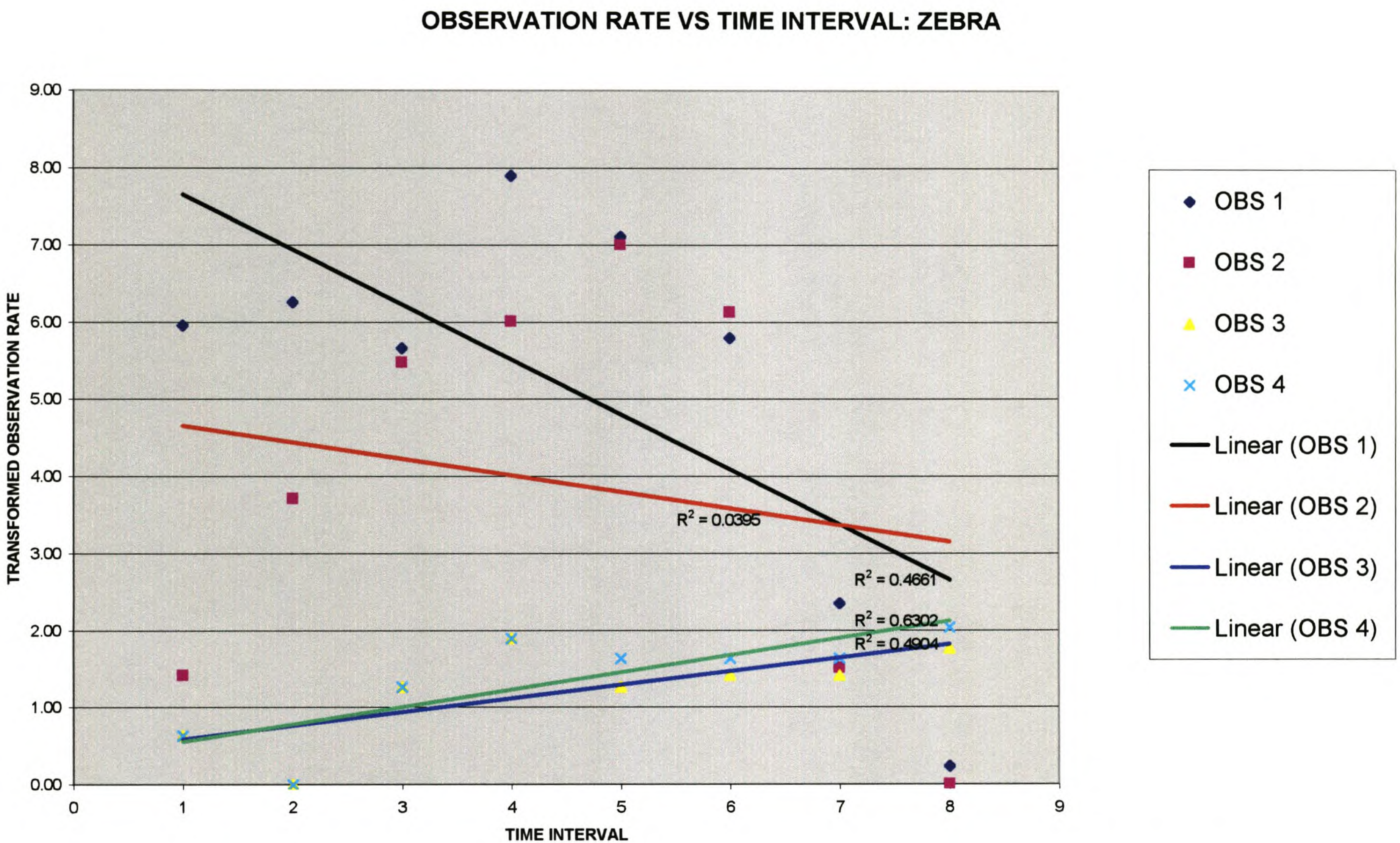


Figure 33: Regressions for 4 observers of squareroot of observations versus time for zebra over 76 helicopter counts.

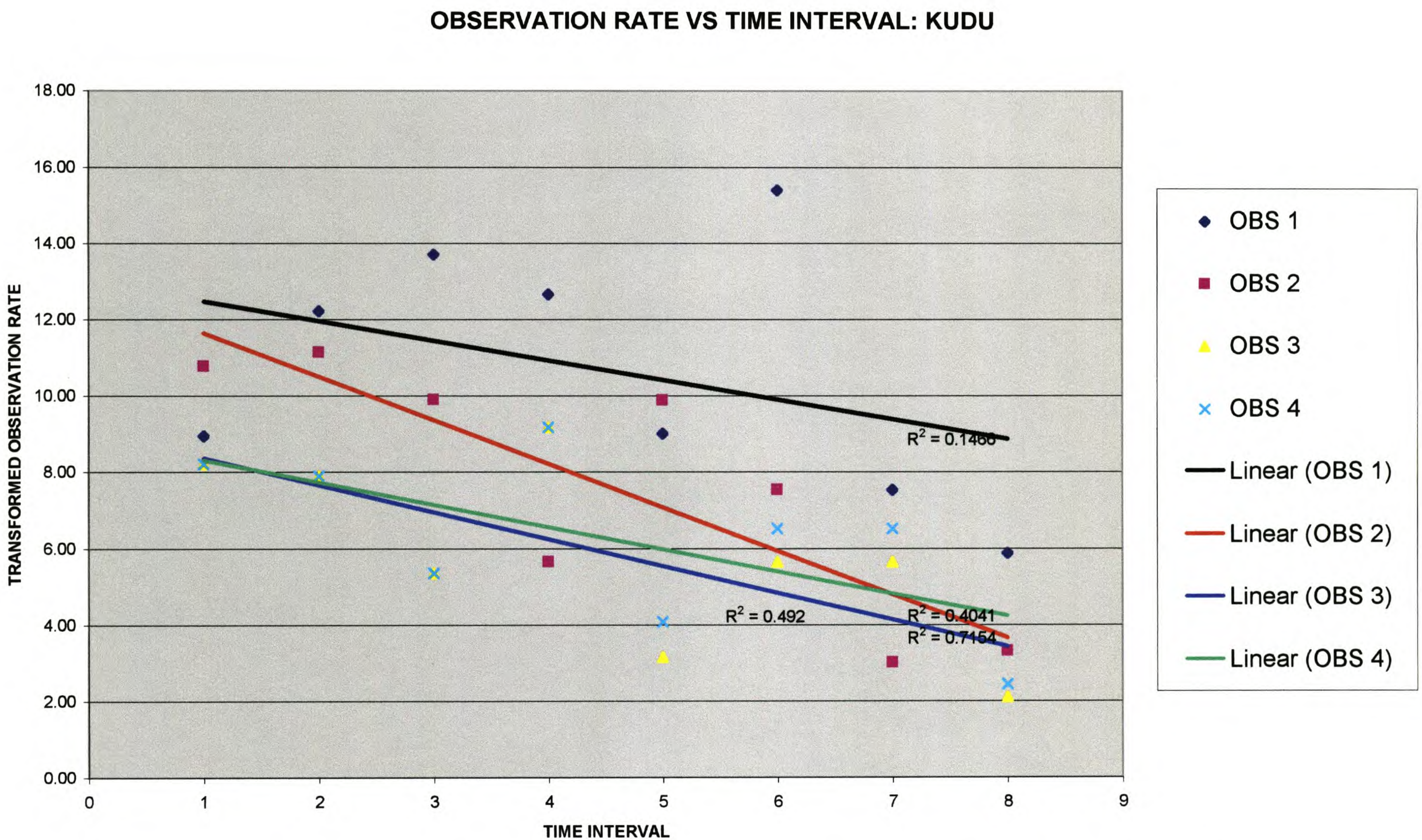


Figure 34: Regressions for 4 observers for squareroot of observations versus time for kudu over 76 helicopter counts.

# CHAPTER 6

## *SUMMARY AND CONCLUSIONS*

The purpose of counting is twofold in the African context. Many research undertakings require enumeration of species and these counts must conform to the empirical requirements of the research. More commonly however, game counts are undertaken as part of a "monitoring" programme that is designed to measure goal achievement in management. The term monitoring has become an omnibus term and even though managers are aware that these results must be referred back to stated management goals, they still persist in undertaking single monitoring actions. In terms of definitions, Hellawell *in* Goldsmith (1991) puts forward the following: -

> Intermittent (regular or irregular) surveillance carried out in order to ascertain the extent of compliance with a predetermined standard or the degree of deviation from an expected norm.

Thompson, White and Gowan (1998) put forward the following definition of monitoring: -

> Monitoring, in its most general sense, implies a repeated assessment of status of some quantity, attribute, or task within a defined area over a specified time period.

I have used the following definition as a basis for monitoring in South Africa: -

> Monitoring is the repetitive empirical testing of natural phenomena under the null hypothesis of no significant difference over time between baseline and follow-up surveys of a natural system or pattern, in measurable and independent variables, that are sensitive to known or unknown factors impacting such system or patterns.

All of the above definitions are essentially within the gambit of what is known as an operational audit. The operational audit is essentially used to judge the quality of operations and make operational improvements in any undertaking (Reider 1994). An underlying principle of auditing is however, that sampling procedures answer to rigorous statistical requirements in particular error probabilities (Reider 1994).

It is well established that the aerial count has become almost universally accepted as the method of choice for the operational monitoring of wild ungulate populations for management purposes in extensive game management areas. In this study a four-man helicopter total count was used for that purpose on several

Provincial Nature reserves and private game ranches in the then Transvaal province of the Republic of South Africa. Collinson (1985) predicted the proliferation of aerial methods in the region.

These actions formed the backbone of the management decision making support of the management of these ungulate populations. In many of these sites replicate counts were undertaken with a view to investigating the methods ability to show change in ungulate populations.

Summary of important results

Precision from the field data was shown to vary but median values for the more common species were all below 16,5%. The study has successfully demonstrated the use of a *post hoc* power analysis with the inclusion of randomization with replacement and a *Monte Carlo* variance estimation (bootstrap) and the use of the non-central *t*-distribution in the significance tests.

Power values demonstrated from this comprehensive field data set vary widely. Summary data for the more common species frequently encountered during the survey viz. kudu, zebra, wildebeest and impala show this. In the case of kudu power values to show a 15% population change (% of mean) using 3 counts in year 1 and 3 counts in year 2 and at talpha.1 show a range of 9 to 71% power. In effect this does not exceed the minimum power requirements of 80% (Cohen 1988). The population change contemplated is no more than annual increment of the population making the method a failure in its fundamental requirement – did the population breed or not? The large range equates to Type II error risks in the range of 29 to 91%. In similar vein under the same pre-selected parameters power values for zebra on 9 different properties ranged between 8 and 71 %. The picture for wildebeest and impala show similar ranges. Thus at talpha.1 and 3 replicates in year 1 and year 2, power never exceeds 80% for these four most commonly encountered species. These results indicate in summary that to achieve 80% power four or more replicate counts are needed or the significance level must be relaxed.

This analysis will allow the formulation of a general model where variance requirements of the counting method can be estimated. This can be related to the sensitivity (effect size) of the nature of population change to be measured. This should form a part of the operationalization of the management objectives for any wildlife management undertaking.

Ancillary to the power analysis, the precisions attained under a variety of field conditions, for several commonly managed species are demonstrated. The decline of observations over time is also amply illustrated and described, although the reasons therefore cannot be clearly unraveled. In this regard, I contend that observer fatigue is a major factor. Quadratic models fitted to data from certain veldtypes allow for correction factors to be applied for each 30 minutes of operation of the average short duration operation (up to 4 hours) discussed in this study. Irrespective of cause of decline in observations over time (probably a combination of contrast change and observer fatigue), the phenomenon does exist and can be treated as a probability time function in much the same way as the probability density function in line transects.

Finally between observer bias is demonstrated to exist between individual observers for four of the more commonly encountered species. This emphasizes the importance of observer selection and the standardization of technique.

In conclusion it is possible, from these comprehensive empirical investigations, to synthesize the useful envelope of this method and to make recommendations for its use in the wildlife industry to show population change between time intervals $t_1$ and $t_2$. If the parameters of the method laid down in Chapter 2 are adhered to in detail the following is concluded:

- The method is incapable of consistently detecting small population (10 – 20%) changes at acceptable power and significance under moderate replication(3-3) or high significance(talpha.1).
- The precision and power attained in this limited study is entirely site specific. It is difficult to make any general statements about either.
- The assumption of constant variance from $t_1$ to $t_2$ cannot be validated.
- Operating time for the method should be limited with operations over 2,5 hours being corrected for decline in observations over time.
- Cognizance should be taken of the differing observation profiles of observers in the initial choice of observers for gamecounts.

As far as individual species are concerned the multiple-pass helicopter based method has shown itself to be generally unsuccessful for the commonly encountered species such as kudu, impala, zebra, blue wildebeest and giraffe. These species are those most commonly requiring extensive management in wildlife undertakings. Data were inadequate to successfully conclude success with other species although adequate power was achieved for hartebeest, eland, sable and white rhino in some cases.

These findings are consistent with the general observations of Collinson (1985) regarding the limitations of helicopter-based surveys in Southern Africa. Results, directly support Collinson's (1985) contention that the method has severe limitations where repeatable estimates over time are required unless more than 4 counts are contemplated.

To translate these results into meaningful recommendations for wildlife management operations it is necessary to view the problem and the application of this method to that problem holistically.

Implications of these results for the practical conduct of aerial census operations

In making recommendations for the use of this technique and other aircraft-based counting methods it is necessary to review the requirement for this type of operation in Southern Africa. The nature of monitoring of large ungulates in southern Africa has been affected by several factors, viz. the increasing area of conservation management units, differential capabilities of staff between neighbouring states and south Africa, declining budgets, manpower limitations and other environmental and conservation issues.

Area size provides a basis for review of aerial-based methods in ungulate monitoring and assists in assessing the role and positioning of the method under discussion in ungulate population estimation.

There is a growing demand for monitoring programmes for large ungulates in conservation areas exceeding about 50 000 hectares. These "large" areas have come about as a result of the trans-frontier "peace parks" programme, expansion of existing National Parks, rationalization of Provincial Nature Reserves and the formation of private conservancies. Management of areas of this size are normally the task of professional teams and clearly sampling strategies coupled with aerial based techniques such as line transects (DISTANCE) are effective (van Hensbergen, Berry and Juritz 1996). Recent applications of this technique together with a sampling strategy in Kruger National Park are a case in point.

In the 10 000 to 50 000 hectare category of property the DISTANCE method is very efficient although heterogeneity of vegetation and topography present unique sampling stratification problems. Heterogeneity normally implies variable density of ungulates and multiple pass helicopter total counts combined with stratified area sampling can be useful in these areas. Helicopter based use of DISTANCE may be of particular use here.

Many Provincial Nature Reserves fall into the 5 000 to 10 000 hectare category and have been proclaimed conservation areas primarily because they are marginal for agriculture and as such exhibit some extraordinary topography and vegetation heterogeneity. On these areas multiple pass, helicopter based total counts are particularly useful, specially when population change (effect size) to be detected is increased by counting less frequently. The aerial based line transect methods (DISTANCE) can still be used on areas of this size depending on the topography.

The vast majority of properties under wildlife in southern Africa, particularly South Africa are privately owned and less than 5 000 hectares in extent. Many of these areas are subject to once off, occasional single pass counts. At best single pass counts are conducted regularly on some of these areas and used to establish population trends over time, which then form the basis of management decision making. These trends are of questionable value having no measure of precision or confidence limits.

It is in this last category where an inordinate amount of money is being spent annually by private landowners and conservation agencies in the misguided notion that these results provide adequate basis for decision making. It is also this category that can most benefit from multiple pass, helicopter total counts, which together with retrospective power, tells us more about population change over time. The analyses used in this study are retrospective but the results can be applied to management decision making in a prospective fashion in designing protocols for measurement of large ungulate management goal achievement. Prospective power would be ideal in these cases and could provide guidelines for surveys but site uniqueness and the number of species involved in the Southern African context favours retrospective power calculations as part of pilot surveys. It is also often this category of conservation area that requires the greatest management input in terms of threatened or endangered species.

The problems associated with each of the above management scenarios are exacerbated by declining availability of resources, both manpower and financial for such monitoring.

*Reasons for counting*

It is clear that much more effort must be expended on the setting of management objectives and goals. The operationalization of goals should include requirements from monitoring methods in terms of change necessary for management decision making. If these goals cannot be set in such a way then monitoring becomes monitoring for monitoring's sake.

*Observers*

Training of observers must be an integral part of gamecounting or for that matter any monitoring and time, money and effort spent in training and giving observers an understanding of the methods they employ and the outcomes of their efforts, will enhance the results obtained. A review of the power analysis process will clearly show that desktop analysis (prospective power analysis) as part of the process of designing monitoring protocols is crucial in determining, at least, the approximate significance and power of the methods to be employed.

The decline of observations over time as demonstrated is a serious problem and is probably a function of changing sightability, itself a function of changing contrast as the sun rises in the sky, haze and animal behaviour, particularly activity patterns, and observer fatigue. Much can be done to alleviate fatigue by the implementation of a rest policy of at least 5 minutes in the hour and restricting operating time to approximately 3 hours or less.

The value of simple aerial counts for detecting population change

*The single pass count*

The value of the single pass aerial count as currently applied almost universally throughout the savanna areas of southern Africa must be questioned. The once off application can, in reality only indicate a presence or absence of a species and strung together as a trend the change shown cannot be attributed to either change in reality or within technique variance as there is no estimate of this variance. The number of small populations of large ungulates present on smaller (<5 000ha) properties also decreases the reliability of the technique.

*The multiple pass count*

At this point there is no evidence of variation in precision over time and multiple applications of total aerial surveys will allow the investigation of this phenomenon. Ideally, multiple pass counts conducted at frequent intervals will provide valuable data in constructing population trends over time. These multiple surveys coupled with stated management objectives and goals in terms of population change to be detected is the high road option in management of ungulates on small areas. The use of infrequent multiple pass counts will also serve this purpose but more time will be needed to identify trends. The minimum requirement in the use of aerial based total surveys should be a pilot survey coupled to retrospective power analysis, allowing adjustment of management goal achievement requirement from the surveys.

*Costs*

The most critical factor in survey design is that in most cases agencies and private landowners want to spend the least amount of money on these surveys. If the assessment of expense was coupled to efficiency in showing population change for the least amount of money spent, that would be acceptable. In most cases the relatively large amounts budgeted by managers for aerial surveys are targeted for "cuts" due to ignorance of senior management of the importance of the counts. This is often the case in spite of organizational dependence on income from live sales of ungulates, hunting and ecotourism.

One of the biggest cost factors in aerial based surveys is the cost of "ferrying" aircraft to the area of operation, it can be as much as 50% of the operational cost for some of the smaller reserves. Multiple pass counts less frequently can lead to cost savings in this area.

The majority of managers are fixated with counting every year. Very often the degree of population change to be detected is unrealistically small, and in the case of the method under discussion it will be marginally cheaper to conduct replicate counts at less frequent intervals (2–3 years). This will increase potential effect size, which will allow better power and significance for the variances encountered. This will also provide a measure of variance at each set of counts allowing the monitoring of assumptions of constant variance over time.

The value of distance-based estimators

The work of van Hensbergen *et al.* (1996) shows C.V.'s for the DISTANCE method to be below 10% in most cases for species counted in the northern Cape Province. This method is ideally suited to the intermediate areas (10 000 –50 000 hectares) and larger areas. The method is also robust enough to be applied from fixed-wing aircraft with substantial cost savings over helicopters. The 5 000 to 10 000 hectare area is a grey area where both DISTANCE-based and helicopter-based total surveys are capable of acceptable results depending on topography, population size and habitat heterogeneity. In all likelihood the helicopter based survey combined with the DISTANCE analysis will provide the best option, obviating the need for multiple passes. In cases where a single pass over the area produces too few observations of an important species for DISTANCE to provide a reasonable result then multiple passes using the distance protocol would provide better results. A retrospective power analysis using the variance estimators generated by DISTANCE will be beneficial in constructing sampling protocols. According to White *pers comm*[1], the possibility exists to assume constant sighting functions over time, so pooling data to obtain a sighting function whilst still generating annual density estimates. Clearly some reviews of mark-resight methods are required in the southern African management context.

Power analysis has shown that technique optimization is possible. This circumvents the risk of continually applying techniques as part of a fundamental decision support programme with unsubstantiated trends as the basis of decision support. Ideally population size, effect size and measures of precision can be prospectively estimated and species to be counted grouped accordingly. One of the questions that arise is what to do if minimum power cannot be achieved with a given technique. In this case it replicates can be increased, implying some kind of financial tradeoff – the more spent the better the result. This can be partially achieved with increasing effect size (reevaluation of the management objectives and goals) or counting less frequently. It is however clear from the results obtained that high precision and power in one site does not always equate to similar power levels in another site. It is also a fact that for certain sites and scenarios most established techniques of enumerating wildlife will be left lacking, requiring some more innovative approaches. Finally the increasing value of wildlife on the subcontinent together with the increasing pressure on

---

[1] Gary C. White, Department of Fishery and Wildlife Biology, Colorado State University, Fort Collins, CO 80523

conservation agencies to increase earnings amplify the role of the gamecounts in decision making. Operational auditing dictates that a linkage between value of the resource and the funds spent on the audit need to be equated.

Recommendations

Recommendations are based on what are considered key areas for improvement in counting large ungulates throughout southern Africa and based on the analyses at hand and personal experience in the course of the associated fieldwork.

Both Conservation Agencies and private landowners in setting management objectives and goals for large ungulates must make more effort to operationalize the goals. The goals must be realistic and include the parameters required in their monitoring. The cost components must be added to the equation.

A concerted effort is required in training at several levels.

- ✓ Managers must understand the concept of goal achievement and its measurement.
- ✓ Field ecologists and biologists in Southern Africa are rarely conversant with inferential statistics and the use of power, significance, confidence, sample size, and effect size and error probabilities.
- ✓ Senior management of Conservation Agencies and large private undertakings must budget realistically (in relation to the value of the wildlife assets) for operational audits, mindful of the fact that income generated is directly related to the quality of the surveys. In large organizations this must include the centralization of the operational audit, personnel and budget.
- ✓ Gamecounting teams (observers, navigators and pilots) must be trained in the importance of their work and learn to recognize shortcomings. Screening of observers would assist in this regard.

The aerial based methods do not work for some species of ungulates or in areas of high canopy cover and multiple methods are certain to be required for monitoring on many areas.

Large ungulates are subjected to an annual cycle of counting, live capture and culling. Large cost savings can be made if Agencies have a regional cycle of three years in which counting takes place in year one, live capture year two and culling, if necessary in year three. This will increase effect size in the counts increasing robustness and regionalising monitoring and management effort can lead to substantial cost savings. This will also reduce disturbance to the animals themselves.

Specific recommendations in respect of method:-

- ✓ The DISTANCE method, irrespective of vehicle is the cheapest best method on large areas of more than 10 000 hectares. This can easily be applied using a fixed-wing aircraft and combined with sampling will give adequate results on areas of over 50 000 hectares.
- ✓ In the 5 000 to 10 000 hectare (sample area) area depending on the topography single pass helicopter based total surveys combined with DISTANCE may suffice. Multiple fixed-wing or helicopter based total surveys applied frequently or infrequently or as pilot surveys will also work. Under conditions of extreme heterogeneous vegetation and topography on larger areas last mentioned may have value as stratified random survey blocks.
- ✓ On smaller areas the multiple helicopter based total surveys applied regularly (every 2 or 3 years) will greatly enhance decision support in terms of large ungulates.
- ✓ Aerial based surveys must be supplemented by ground surveys, other methods for certain species, better population dynamics data and population modeling.
- ✓ More attention must be given to other remote data such as catch effort in culling operations and calculation of population sex and age data from culled and captured animals.

In closing, it suffices to say that the results at hand from the four-man, helicopter-based approaches with highly experienced crews using a standardized method are not as successful as hoped. The majority of less rigorous applications where *ad hoc* counts in a non-standardized fashion by inexperienced personnel of aerial techniques over Southern Africa each year must be questioned in terms of their ability to show population change over time.

***REFERENCES***

BARTMANN, R. M.; L. H. CARPENTER; R. A. GARROTT & D. C. BOWDEN. 1986. Accuracy of helicopter counts of mule deer in pinyon-juniper woodland. *Wildl. Soc. Bull. 14(4): 356-363.*

BAYLISS, P. & J. GILES. 1985. Factors affecting the visibility of kangaroos counted during aerial surveys. *J. Wildl. Manage. 49: 686-692.*

BURNHAM, K.P., D.A. ANDERSON & J.L. LAACKE. 1980. Estimation of density from line transect sampling of biological populations. *Wildl. Monogr. No 72, 202 pp.*

BEASOM, S. L. 1979. Precision in helicopter censusing of white-tailed deer. *J. Wildl. Manage. 43(3): 777-780.*

BEASOM, S. L.; F.G. LEON III & D. R. SYNATZSKE.1986. Accuracy and precision of counting white-tailed deer with helicopters at different sampling intensities. *Wildl. Soc. Bull. 14(4): 364-368.*

BOTHMA, J. du P.; M.J.S. PEEL; S. PETTIT & D. GROSSMAN. 1990. Evaluating the accuracy of some commonly used game-counting methods. *S. Afr. J. Wildl. Res. 20(1): 26-32.*

BROOME, L. S. 1985. Sightability as a factor in aerial survey of bird species and communities. *Aust.Wildl. Res. 12: 57-67.*

BUCKLAND, S.T., D.R. ANDERSON, D.R.BURNHAM & J.L. LAACKE. 1992. Distance sampling: Estimating Abundance of biological populations. New York: Chapman and Hall.

CAHALANE, V.H. 1938. The annual northern Yellowstone elk herd count. *Trans. North Am. Wildl. Conf. 3: 388 – 389.*

CAUGHLEY, G. 1974. Bias in aerial survey. *J. Wildl. Manage. 38: 921 – 933.*

CAUGHLEY, G. 1979. Analysis of vertebrate populations. John Wiley & Sons, New York.

CAUGHLEY, G. & D. GRICE. 1982. A correction factor for counting emus from the air, and its applications to counts in Western Australia. *Aust. Wildl. Res. 9: 253-259.*

COHEN, J.C. 1988. Statistical power analysis for the behavioural sciences. Lawrence Erlbaum Associates, New Jersey.

COLLINSON, R.H.F. 1985. Selecting Wildlife Census Techniques. Monogr. 6, Inst. of Nat. Res., University of Natal, Pietermaritzburg.

CONQUEST, L. 1983. Assessing statistical effectiveness of ecological experiments: Utility of the coefficient of variation. *Int. J. Env. Studies. 20: 209 – 221.*

CONQUEST, L. 1993. Statistical approaches to environmental monitoring: Boy, did we teach the wrong thing. *Env. Monitoring & Assessment. 26: 107 – 124.*

CONROY, M.J., J.R. GOLDSBERRY, J.E. HINES & D.B. STOTTS. 1988. Evaluation of aerial transect surveys for wintering American black ducks. *J. Wildl. Manage. 52: 694-703.*

CRETE, M., L.P. RIVEST, H. JOLICOEUR, J.M. BRASSARD & F. MESSIER. 1986. Precision of moose density estimated from helicopter and fixed wing aircraft in southern Quebec. *J. App.Ecol. 23: 751-761.*

DASMANN, R.F. & A.S. MOSSMAN. 1962. Road strip counts for estimating numbers of African ungulates. *J. Wildl. Manage. 26: 101 – 104.*

DeYOUNG, C. A. 1985. Accuracy of helicopter surveys of deer in south Texas. *Wildl. Soc. Bull. 13 (2): 146-149.*

EBERHARDT, L.L. 1976. Transect methods for population studies. *J. Wildl. Manage. 42: 1-31.*

EFRON, B. 1979. Bootstrap methods: another look at the jackknife. *Ann.Stat. 7(1): 1-26.*

EISELEN, R. 1994. Estimating the trends in herbivore numbers in the southern district of the Kruger National Park. *S. Afr. J. Wildl. Res. 24(4): 95-100.*

EMSLIE, R.H., S.P. FOURIE & B.K. REILLY. 1994. A statistical assessment of the utility of replicated aerial strip censusing as a method to monitor a major cycad population. Unpublished report. Ecoscot Consultancy Services. P.O. Box 1212, Hylton, South Africa.

FABRICIUS, C., H.J. VAN HENSBERGEN & W. ZUCHINI. 1989. A discriminant function for identifying hybrid bontebok x blesbok populations. *S. Afr. J. Wildl. Res. 19(2): 61-66.*

FOWLER, J., L. COHEN & P. JARVIS. 1998. Practical statistics for field biology. John Wiley & Sons, New York.

FREIMAN, J.A., T.C. CHALMERS, H. SMITH & R.R. KUEBLER. 1978. The importance of beta, the type II error and sample size in the design and interpretation of the randomized control trial: Survey of 71 "negative" trials. *New England J. of Medicine 299: 690 – 694.*

GERRODETTE, T. 1987. A power analysis for detecting trends. *Ecology, 68(5): 1364 – 1372.*

GERRODETTE, T. 1993. Trends: Software for a power analysis of linear regression. *Wildl. Soc. Bull, 21: 515 – 516.*

GERTENBACH, W.P.D. 1983. Landscapes of the Kruger National Park. *Koedoe 26: 9 – 121.*

GERTENBACH, W.P.D. 1987. Comment on the vegetation of Letaba Ranch. Internal report. Gazankulu Nature Conservation.

GOODMAN, P.S. 1977. An evaluation of three techniques for estimating animal numbers in a wildlife population. Unpub. Mimeographed Rept., Natal Parks Board, Pietermaritzburg.

GOLDSMITH, F.B. 1991. Monitoring for conservation and ecology. Chapman & Hall, London.

GORMAN, B.S., L.H. PRIMAVERA & D.B. ALLISON. 1995. Powpal: A program for estimating effect sizes, statistical power, and sample sizes. *Educational and psychological measurement. 55(5): 773 – 776.*

GRAHAM, A. & R. BELL. 1989. Investigating observer bias in aerial survey by simultaneous double-counts. *J. Wildl. Manage. 53(4): 1009-1010.*

HAYES, J.P. & R.J.STEIDL. 1997. Statistical power analysis and amphibian population trends. *Cons. Biol. 11(1): 273 – 275.*

HILL, G.J.E., A. BARNES & G.R. WILSON. 1985. Time of day and aerial counts of grey kangaroos. *J. Wildl. Manage. 49: 843-849.*

HINDS, W.T. 1984. Towards monitoring of long term trends in terrestrial ecosystems. *Cons. Biol. 11(1): 11 – 18.*

HIRST, S.M. 1969. Road-strip census techniques for wild ungulates in African woodland. *J. Wildl. Manage; 33 (1): 40-48.*

JACKSON, J.A. 1985. An evaluation of aerial survey techniques for red-cockaded woodpeckers. *J. Wildl. Manage. 49: 1083-1088.*

JOLLY, G.M. 1969. The treatment of errors in aerial counts of wildlife populations. *E. Afr. Agr. & For. J., Special Issue, 34: 50-55.*

JOHNSON, D.H. 1999. The insignificance of statistical significance testing. *J. Wildl. Manage. 63(3): 763 - 772.*

KRAEMER, H.C. & S. THIEMANN. 1987. How many subjects? Statistical power analysis in research. Sage, London.

LeRESCHE, R.E. & R.A. RAUSCH. 1974. Accuracy and precision of aerial moose censusing. *J. Wildl. Manage. 38: 175 – 182.*

LIPSEY, M.W. 1990. Design Sensitivity: Statistical Power for Experimental Research. Sage. London.

MAPSTONE, D. 1995. Scalable decision rules for environmental impact studies: Effect size; Type I & Type II errors. *Ecological Applications 5(2): 401 – 410.*

MARSH, H. & D.F. SINCLAIR. 1989. Correcting for visibility bias in strip transect aerial surveys of aquatic fauna. *J. Wildl. Manage. 53: 1017-1024.*

MARSHAL, J.P. & S. BOUTIN. 1999. Power analysis of wolf-moose functional responses. *J. Wildl. Manage. 63(1): 396 – 402.*

McCULLOUGH, D.R. 1994. What do herd composition counts tell us? *Wildlife Society Bulletin 22(2): 295 – 300.*

MELTON, D.A. 1978. Undercounting bias of helicopter census in Umfolozi Game Reserve. *Lammergeyer 26: 1-6.*

NICKERSON, D.M. & A. BRUNELL, 1997. Power analysis for detecting trends in the presence of concomitant variables. *Ecology, 79(4): 1442 – 1447.*

NORTON-GRIFFITHS, M. 1978. Reducing counting bias in aerial census by photography. *E. Afr. Wildl J., 12: 245-248.*

OTTEN, M. R.M.; J. B. HAUFLER; S. R. WINTERSTEIN & L. C. BENDER. 1993. An aerial censusing procedure for elk in Michigan. *Wildl. Soc. Bull. 21(1): 73 - 80.*

PAUW, J.C. 1987. The vegetation of Letaba Ranch. Internal Report. Gazankulu Nature Conservation.

PAUW, J.C. 1988. Riglyne vir die bestuur van die natuurlewe in die bosveldgemeenskappe van die Atherstone Natuurreservaat in die Noordwes-Transvaal. M.Sc. Thesis. University of Pretoria. Pretoria.

PAYNE, N. F. 1981.Accuracy of aerial censusing for beaver colonies in Newfoundland. *J. Wildl. Manage. 45(4): 1014-1016.*

PEARSON, E.S. & H.O. HARTLEY. 1976. *Biometrika tables for statisticians.* Norfolk: Cambridge University Press.

PENNYCUICK, C.J. & D. WESTERN. 1972. An investigation of some sources of bias in aerial transect sampling of large mammal populations. *E. Afr. Wildl. J. 10: 175-191.*

PETERMAN, R.M. 1990. Statistical power analysis can improve fisheries research and management. *Can. J. Fisheries and Aquatic Sci. 47: 2 – 15.*

POLLOCK, K.H. & W.L. KENDALL. 1987. Visibility bias in aerial surveys: A review of estimation procedures. *J. Wildl. Manage. 51:1017-1024.*

REED, J.M. & A.R. BLAUSTEIN. 1995. Assessment of non-declining amphibian populations using power analysis. *Cons. Biol. 9: 1299 – 1300.*

REIDER, H.R. 1994. The complete guide to operational auditing. John Wiley & Sons, New York.

REILLY, B.K. & R.H. EMSLIE. 1998. Power and precision of replicated helicopter surveys in mixed bushveld. *Koedoe. 41(1): 47 – 56.*

REILLY, B.K. & C.I. HASKINS. 1999. Comparative efficiency of two game counting techniques as applied to Suikerbosrand Nature Reserve. *S.Afr. J. Wildl. Res. 29(3): 89 – 97.*

ROBINETTE, W.L. 1970. Game animal survey, Unpublished mimeographed report. World Health Organization.

ROTHPEARL, A.B., R.C. MOHS & K.L. DAVIS. 1981. Statistical power in psychological research. *Psychiatry Research 5: 257 – 266.*

RICE, W.R. & J.D. HARDER, 1977. Application of multiple aerial sampling to mark -recapture census of white-tailed deer. *J. Wildl. Manage. 41: 197 – 206.*

RIVEST, L.P., H. CREPEAU & M. CRETE. 1990. A two phase sampling plan for the estimation of the size of a moose population. *Biometrics 46:163-176.*

RIVEST, L.P.,F. POTVIN, H. CREPEAU & G. DAIGLE. 1995. Statistical methods for aerial surveys using the double count technique for correcting visibility bias. *Biometrics 51:461-470.*

SAMUEL, M.D. & K.H. POLLOCK. 1981. Correction of visibitiy bias in aerial surveys where animals occur in groups. *J. Wildl. Manage. 45: 993-997.*

STEIDL, R.J., J.P. HAYES & E. SCHAUBER. 1997. Statistical power analysis in wildlife research. *J. Wildl. Manage. 61(2): 270-279.*

SEBER, G.A.F. 1982. The estimation of animal abundance and related parameters, 2nd Edition, Charles Griffin, London.

SEBER, G.A.F. 1992. A review of estimating animal abundance II. *Int. Stat. Rev. 60(2): 129-166.*

THERON, 1978. Plantegroei tipes van Loskopdam Natuurreservaat. Unpubl. Ph.D. Thesis, University of Pretoria.

THOMAS, L. 1997. Technological tools. *Bull. Ecol. Soc. Amer. 78: 126 – 139.*

THOMPSON, W.L., G.C. WHITE & C. GOWAN. 1998. Monitoring vertebrate populations. Academic Press, San Diego.

TURNER, B. 1989. Report on the condition of the grass vegetation at Letaba Ranch. Ecofin Consulting Ecologists. Centurion.

TURNER, B. 1991. Report on the condition of the grass vegetation at Letaba Ranch. Ecofin Consulting Ecologists. Centurion.

VAN HENSBERGEN, H.J., M.P.S. BERRY & J. JURITZ. 1996. Helicopter based line transect estimates of African herbivore populations. *S. Afr. J. Wildl. Res. 26(3): 81-87.*

VAN LAVIEREN, L.P. & ESSER, J.D. 1979. Numbers, distribution and habitat preference of large mammals in Bouba Ndjida National Park, Cameroon. *Afr. J. of Ecol. 17: 141-153.*

ZAR, J.H. 1984. Biostatistical analysis. Prentice Hall, New Jersey.

## *APPENDIX*

Results of power analyses of the following properties:

Letaba Ranch: lowveld mopane veld

The following farms adjacent to Atherstone Nature Reserve, northwest arid bushveld: -

Dieplaagte
Elandskloof
Groengoud
Grootvlei
Laagwater
Onrus

The following farms adjacent to Vhembe Nature Reserve, northern mopane veld : -

Greefswald
Shroda
Samaria 1
Samaria 3

Table 32: Summary statistics of four replicate helicopter counts at Letaba Ranch, lowveld mopane veld.

| SPECIES | COUNT REPLICATES | | | | MEAN | STANDARD DEVIATION(n2) | STANDARD DEVIATION(n3) | STANDARD DEVIATION(n4) |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | | | | |
| *KUDU* | **25** | **48** | **57** | **35** | 41.25 | 11.76 | 11.61 | 11.61 |
| *ZEBRA* | **76** | **60** | **54** | **46** | 59 | 11.00 | 10.97 | 10.97 |
| *WILDEBEEST* | **67** | **62** | **59** | **70** | 64.5 | 4.31 | 4.28 | 4.29 |
| *IMPALA* | **633** | **727** | **615** | **446** | 605.25 | 101.32 | 101.27 | 101.58 |
| *GIRAFFE* | **22** | **42** | **51** | **31** | 36.5 | 10.98 | 10.96 | 10.92 |

| SPECIES | SEdiff21 | SEdiff22 | SEdiff23 | SEdiff31 | SEdiff33 | SEdiff41 | SEdiff42 | SEdiff43 | SEdiff44 |
|---|---|---|---|---|---|---|---|---|---|
| *KUDU* | 14.40 | 11.76 | 10.74 | 13.41 | 9.48 | 12.98 | 10.05 | 8.87 | 8.21 |
| *ZEBRA* | 13.47 | 11.00 | 10.04 | 12.67 | 8.96 | 12.26 | 9.50 | 8.38 | 7.76 |
| *WILDEBEEST* | 5.28 | 4.31 | 3.93 | 4.94 | 3.49 | 4.80 | 3.72 | 3.28 | 3.03 |
| *IMPALA* | 124.09 | 101.32 | 92.49 | 116.94 | 82.69 | 113.57 | 87.97 | 77.58 | 71.83 |
| *GIRAFFE* | 13.45 | 10.98 | 10.02 | 12.66 | 8.95 | 12.21 | 9.46 | 8.34 | 7.72 |

Table 33: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for kudu at Letaba Ranch.

| KUDU | | MEAN | 41.25 | | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 2.06 | 4.13 | 6.19 | 8.25 | 10.31 | 12.38 | 14.44 | 16.50 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.14 | 0.29 | 0.43 | 0.57 | 0.72 | 0.86 | 1.00 | 1.15 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.18 | 0.35 | 0.53 | 0.70 | 0.88 | 1.05 | 1.23 | 1.40 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.19 | 0.38 | 0.58 | 0.77 | 0.96 | 1.15 | 1.34 | 1.54 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.15 | 0.31 | 0.46 | 0.62 | 0.77 | 0.92 | 1.08 | 1.23 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.22 | 0.44 | 0.65 | 0.87 | 1.09 | 1.31 | 1.52 | 1.74 |
| 4 | 1 | 3 | 2.35 | 1.64 | 0.16 | 0.32 | 0.48 | 0.64 | 0.79 | 0.95 | 1.11 | 1.27 |
| 4 | 2 | 4 | 2.13 | 1.53 | 0.21 | 0.41 | 0.62 | 0.82 | 1.03 | 1.23 | 1.44 | 1.64 |
| 4 | 3 | 5 | 2.02 | 1.48 | 0.23 | 0.47 | 0.70 | 0.93 | 1.16 | 1.40 | 1.63 | 1.86 |
| 4 | 4 | 6 | 1.94 | 1.44 | 0.25 | 0.50 | 0.75 | 1.00 | 1.26 | 1.51 | 1.76 | 2.01 |

**Table 34**: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for kudu at 10% and 20% significance at Letaba Ranch.

talpha.1 KUDU

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.06 | 0.07 | 0.08 | 0.09 | 0.11 | 0.12 | 0.13 | 0.15 |
| **2_2** | 0.07 | 0.08 | 0.1 | 0.13 | 0.15 | 0.18 | 0.22 | 0.25 |
| **2_3** | 0.07 | 0.09 | 0.12 | 0.15 | 0.19 | 0.23 | 0.28 | 0.33 |
| **3_1** | 0.06 | 0.08 | 0.09 | 0.11 | 0.14 | 0.16 | 0.19 | 0.22 |
| **3_3** | 0.07 | 0.1 | 0.14 | 0.18 | 0.23 | 0.29 | 0.35 | 0.42 |
| **4_1** | 0.06 | 0.08 | 0.1 | 0.13 | 0.15 | 0.19 | 0.22 | 0.26 |
| **4_2** | 0.07 | 0.1 | 0.13 | 0.17 | 0.22 | 0.27 | 0.33 | 0.39 |
| **4_3** | 0.07 | 0.11 | 0.15 | 0.2 | 0.26 | 0.33 | 0.41 | 0.48 |
| **4_4** | 0.08 | 0.12 | 0.16 | 0.23 | 0.3 | 0.38 | 0.47 | 0.55 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.12 | 0.14 | 0.16 | 0.18 | 0.21 | 0.24 | 0.26 | 0.29 |
| **2_2** | 0.13 | 0.16 | 0.20 | 0.24 | 0.29 | 0.33 | 0.38 | 0.43 |
| **2_3** | 0.13 | 0.17 | 0.22 | 0.27 | 0.32 | 0.38 | 0.45 | 0.51 |
| **3_1** | 0.12 | 0.15 | 0.18 | 0.22 | 0.26 | 0.30 | 0.34 | 0.38 |
| **3_3** | 0.14 | 0.19 | 0.24 | 0.31 | 0.38 | 0.46 | 0.53 | 0.61 |
| **4_1** | 0.13 | 0.16 | 0.19 | 0.23 | 0.27 | 0.32 | 0.37 | 0.42 |
| **4_2** | 0.14 | 0.18 | 0.24 | 0.29 | 0.36 | 0.43 | 0.50 | 0.57 |
| **4_3** | 0.14 | 0.20 | 0.26 | 0.33 | 0.41 | 0.50 | 0.58 | 0.66 |
| **4_4** | 0.15 | 0.21 | 0.28 | 0.36 | 0.46 | 0.55 | 0.64 | 0.72 |

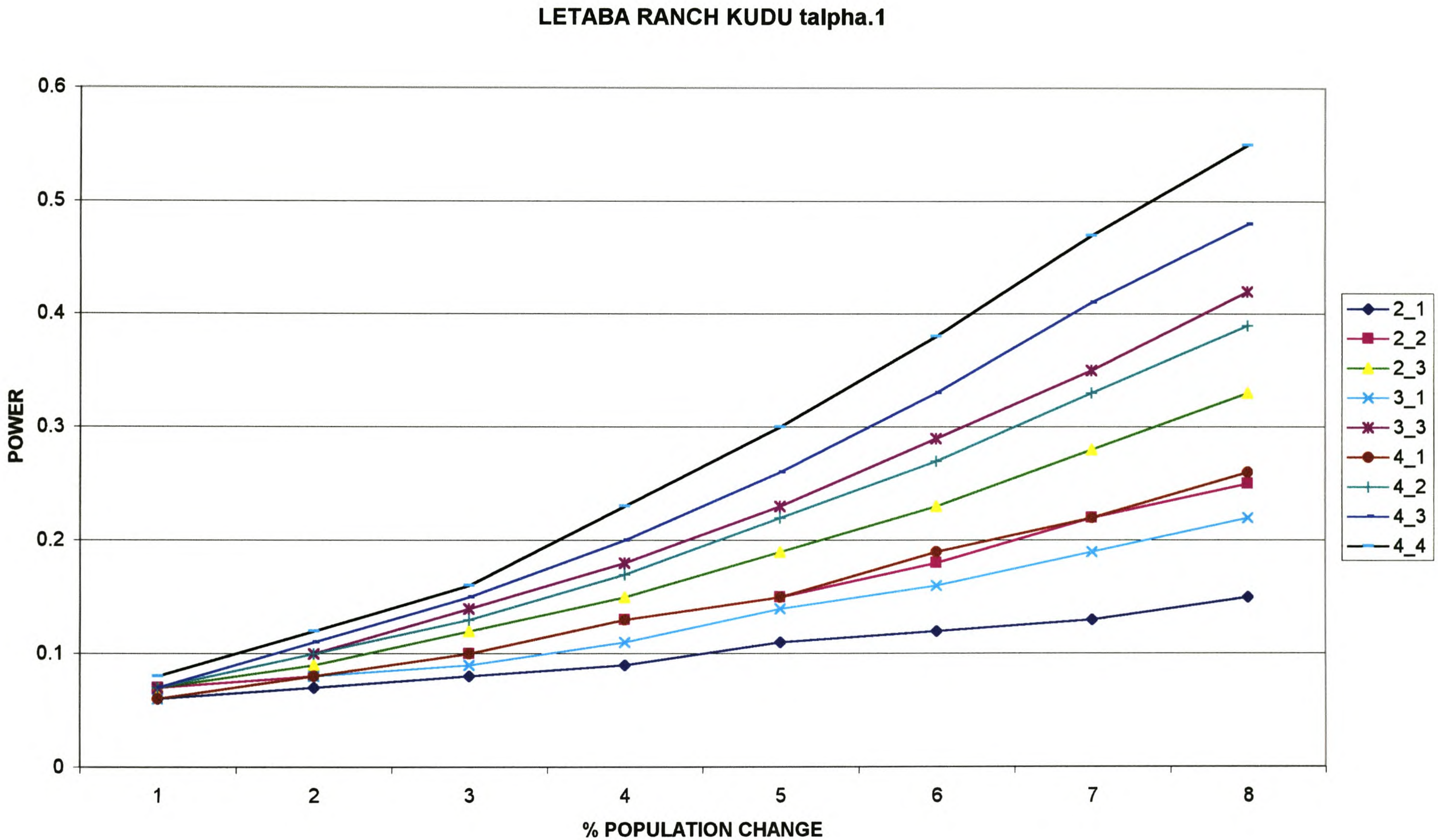


Figure 35: Power curves for various count replicate options at 10% significance for kudu at Letaba Ranch, lowveld mopane veld.

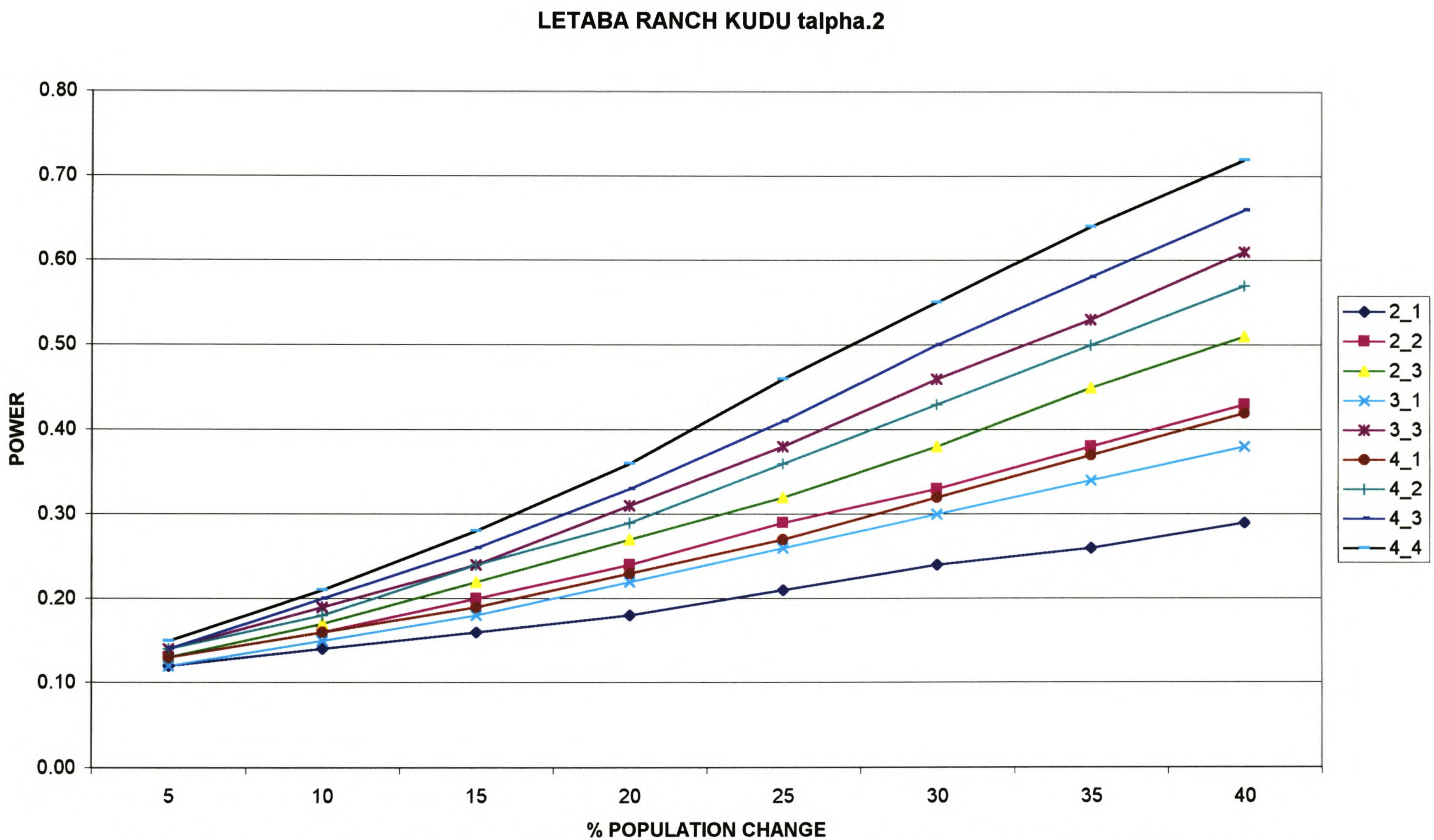

Figure 36: Power curves for various count replicate options at 20% significance for kudu at Letaba Ranch, lowveld mopane veld.

Table 35: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for zebra at Letaba Ranch.

| ZEBRA | | MEAN | 59 | | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 2.95 | 5.90 | 8.85 | 11.80 | 14.75 | 17.70 | 20.65 | 23.60 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.22 | 0.44 | 0.66 | 0.88 | 1.09 | 1.31 | 1.53 | 1.75 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.27 | 0.54 | 0.80 | 1.07 | 1.34 | 1.61 | 1.88 | 2.15 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.29 | 0.59 | 0.88 | 1.18 | 1.47 | 1.76 | 2.06 | 2.35 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.23 | 0.47 | 0.70 | 0.93 | 1.16 | 1.40 | 1.63 | 1.86 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.33 | 0.66 | 0.99 | 1.32 | 1.65 | 1.98 | 2.31 | 2.63 |
| 4 | 1 | 3 | 2.35 | 1.64 | 0.24 | 0.48 | 0.72 | 0.96 | 1.20 | 1.44 | 1.68 | 1.92 |
| 4 | 2 | 4 | 2.13 | 1.53 | 0.31 | 0.62 | 0.93 | 1.24 | 1.55 | 1.86 | 2.17 | 2.48 |
| 4 | 3 | 5 | 2.02 | 1.48 | 0.35 | 0.70 | 1.06 | 1.41 | 1.76 | 2.11 | 2.46 | 2.82 |
| 4 | 4 | 6 | 1.94 | 1.44 | 0.38 | 0.76 | 1.14 | 1.52 | 1.90 | 2.28 | 2.66 | 3.04 |

**Table 36: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for zebra at 10% and 20% significance at Letaba Ranch.**

talpha.1 ZEBRA

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.06 | 0.08 | 0.1 | 0.12 | 0.14 | 0.17 | 0.19 | 0.22 |
| **2_2** | 0.07 | 0.1 | 0.14 | 0.19 | 0.24 | 0.29 | 0.36 | 0.42 |
| **2_3** | 0.08 | 0.12 | 0.17 | 0.24 | 0.31 | 0.39 | 0.48 | 0.56 |
| **3_1** | 0.07 | 0.1 | 0.13 | 0.16 | 0.2 | 0.25 | 0.3 | 0.35 |
| **3_3** | 0.09 | 0.14 | 0.21 | 0.29 | 0.39 | 0.5 | 0.6 | 0.7 |
| **4_1** | 0.07 | 0.1 | 0.14 | 0.19 | 0.24 | 0.3 | 0.37 | 0.44 |
| **4_2** | 0.08 | 0.13 | 0.19 | 0.27 | 0.36 | 0.46 | 0.56 | 0.65 |
| **4_3** | 0.09 | 0.15 | 0.23 | 0.33 | 0.45 | 0.57 | 0.68 | 0.78 |
| **4_4** | 0.1 | 0.17 | 0.26 | 0.38 | 0.52 | 0.65 | 0.76 | 0.85 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.13 | 0.16 | 0.2 | 0.24 | 0.28 | 0.33 | 0.37 | 0.42 |
| **2_2** | 0.15 | 0.2 | 0.26 | 0.34 | 0.42 | 0.5 | 0.58 | 0.66 |
| **2_3** | 0.15 | 0.22 | 0.3 | 0.39 | 0.49 | 0.59 | 0.68 | 0.76 |
| **3_1** | 0.14 | 0.19 | 0.24 | 0.3 | 0.36 | 0.43 | 0.5 | 0.57 |
| **3_3** | 0.16 | 0.25 | 0.35 | 0.46 | 0.58 | 0.69 | 0.78 | 0.85 |
| **4_1** | 0.14 | 0.19 | 0.25 | 0.32 | 0.4 | 0.48 | 0.56 | 0.64 |
| **4_2** | 0.16 | 0.24 | 0.33 | 0.43 | 0.54 | 0.65 | 0.74 | 0.82 |
| **4_3** | 0.17 | 0.26 | 0.38 | 0.5 | 0.63 | 0.74 | 0.83 | 0.9 |
| **4_4** | 0.18 | 0.28 | 0.41 | 0.55 | 0.69 | 0.8 | 0.88 | 0.94 |

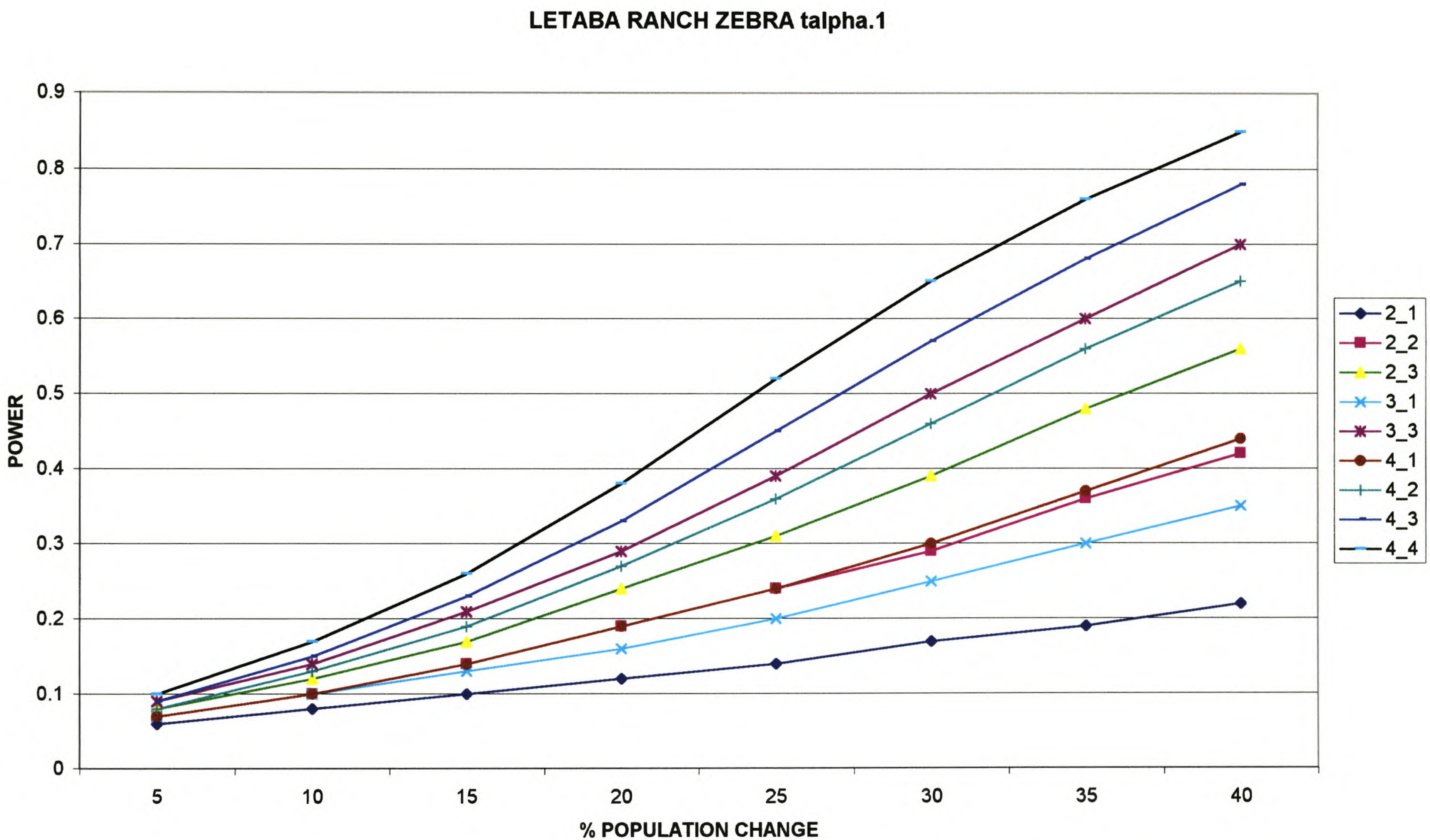


Figure 37: Power curves for various count replicate options at 10% significance for zebra at Letaba Ranch, lowveld mopane veld.

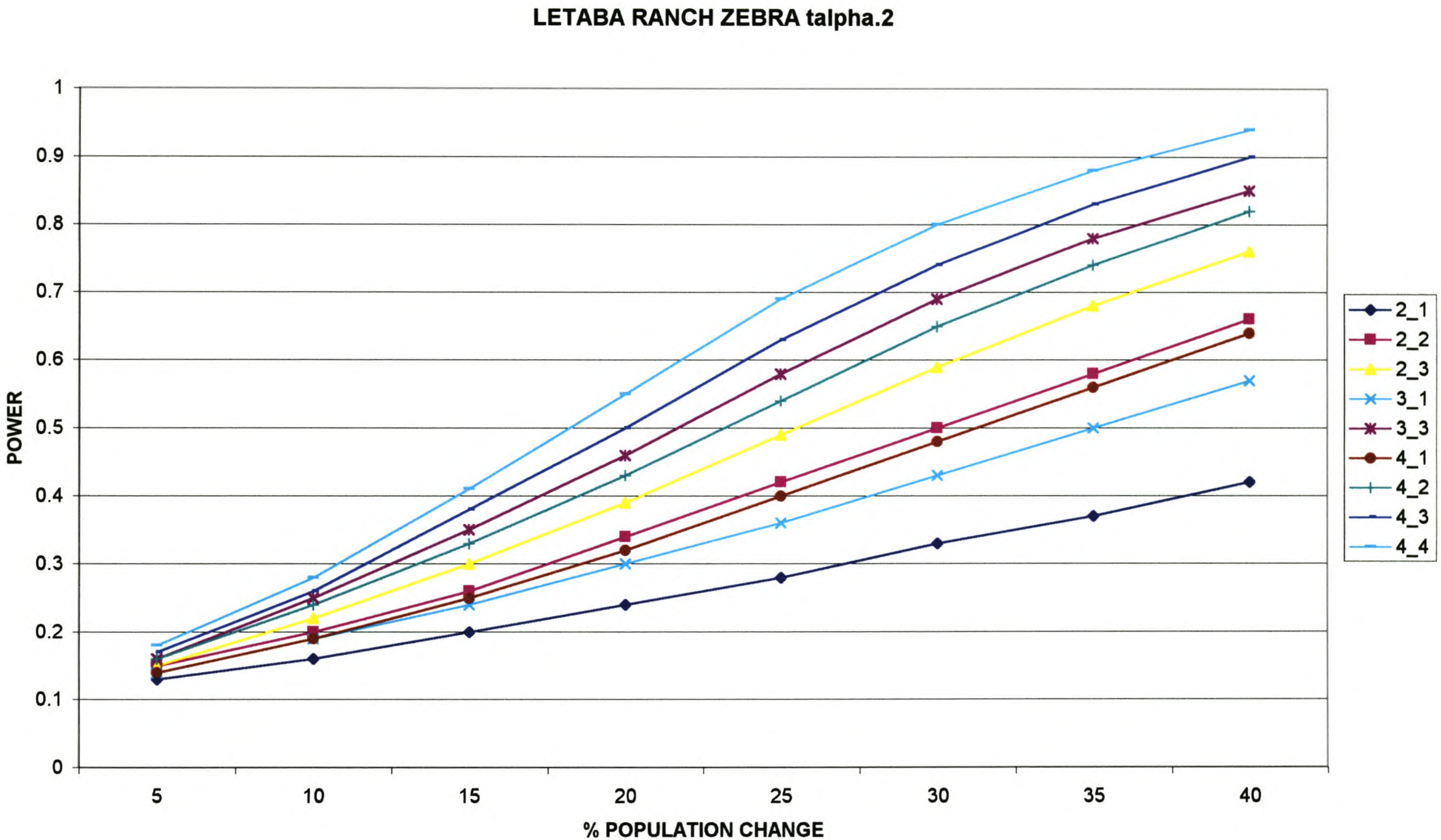


Figure 38: Power curves for various count replicate options at 20% significance for zebra at Letaba Ranch, lowveld mopane veld.

Table 37: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for wildebeest at Letaba Ranch.

| WILDEBEEST | | MEAN | | 64.5 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 3.23 | 6.45 | 9.68 | 12.90 | 16.13 | 19.35 | 22.58 | 25.80 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.61 | 1.22 | 1.83 | 2.44 | 3.05 | 3.67 | 4.28 | 4.89 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.75 | 1.50 | 2.24 | 2.99 | 3.74 | 4.49 | 5.24 | 5.99 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.82 | 1.64 | 2.46 | 3.28 | 4.10 | 4.92 | 5.74 | 6.56 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.65 | 1.31 | 1.96 | 2.61 | 3.26 | 3.92 | 4.57 | 5.22 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.92 | 1.85 | 2.77 | 3.69 | 4.61 | 5.54 | 6.46 | 7.38 |
| 4 | 1 | 3 | 2.35 | 1.64 | 0.67 | 1.34 | 2.02 | 2.69 | 3.36 | 4.03 | 4.71 | 5.38 |
| 4 | 2 | 4 | 2.13 | 1.53 | 0.87 | 1.74 | 2.60 | 3.47 | 4.34 | 5.21 | 6.08 | 6.94 |
| 4 | 3 | 5 | 2.02 | 1.48 | 0.98 | 1.97 | 2.95 | 3.94 | 4.92 | 5.91 | 6.89 | 7.87 |
| 4 | 4 | 6 | 1.94 | 1.44 | 1.06 | 2.13 | 3.19 | 4.25 | 5.32 | 6.38 | 7.44 | 8.51 |

Table 38: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for wildebeest at 10% and 20% significance at Letaba Ranch.

talpha.1 WILDEBEEST

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.1 | 0.16 | 0.23 | 0.3 | 0.37 | 0.43 | 0.5 | 0.56 |
| **2_2** | 0.13 | 0.27 | 0.44 | 0.62 | 0.76 | 0.87 | 0.93 | 0.97 |
| **2_3** | 0.16 | 0.36 | 0.6 | 0.8 | 0.92 | 0.98 | 0.99 | 1 |
| **3_1** | 0.12 | 0.23 | 0.37 | 0.53 | 0.67 | 0.79 | 0.88 | 0.93 |
| **3_3** | 0.19 | 0.46 | 0.74 | 0.91 | 0.98 | 1 | 1 | 1 |
| **4_1** | 0.13 | 0.28 | 0.47 | 0.66 | 0.81 | 0.91 | 0.97 | 0.99 |
| **4_2** | 0.18 | 0.42 | 0.69 | 0.88 | 0.97 | 0.99 | 1 | 1 |
| **4_3** | 0.21 | 0.52 | 0.81 | 0.96 | 0.99 | 1 | 1 | 1 |
| **4_4** | 0.24 | 0.6 | 0.88 | 0.98 | 1 | 1 | 1 | 1 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.19 | 0.31 | 0.43 | 0.55 | 0.65 | 0.74 | 0.81 | 0.87 |
| **2_2** | 0.25 | 0.46 | 0.68 | 0.84 | 0.94 | 0.98 | 0.99 | 1 |
| **2_3** | 0.28 | 0.55 | 0.79 | 0.93 | 0.98 | 1 | 1 | 1 |
| **3_1** | 0.23 | 0.41 | 0.6 | 0.77 | 0.88 | 0.95 | 0.98 | 0.99 |
| **3_3** | 0.32 | 0.64 | 0.88 | 0.98 | 1 | 1 | 1 | 1 |
| **4_1** | 0.24 | 0.45 | 0.67 | 0.84 | 0.94 | 0.98 | 1 | 1 |
| **4_2** | 0.31 | 0.61 | 0.85 | 0.96 | 0.99 | 1 | 1 | 1 |
| **4_3** | 0.35 | 0.7 | 0.92 | 0.99 | 1 | 1 | 1 | 1 |
| **4_4** | 0.38 | 0.76 | 0.95 | 1 | 1 | 1 | 1 | 1 |

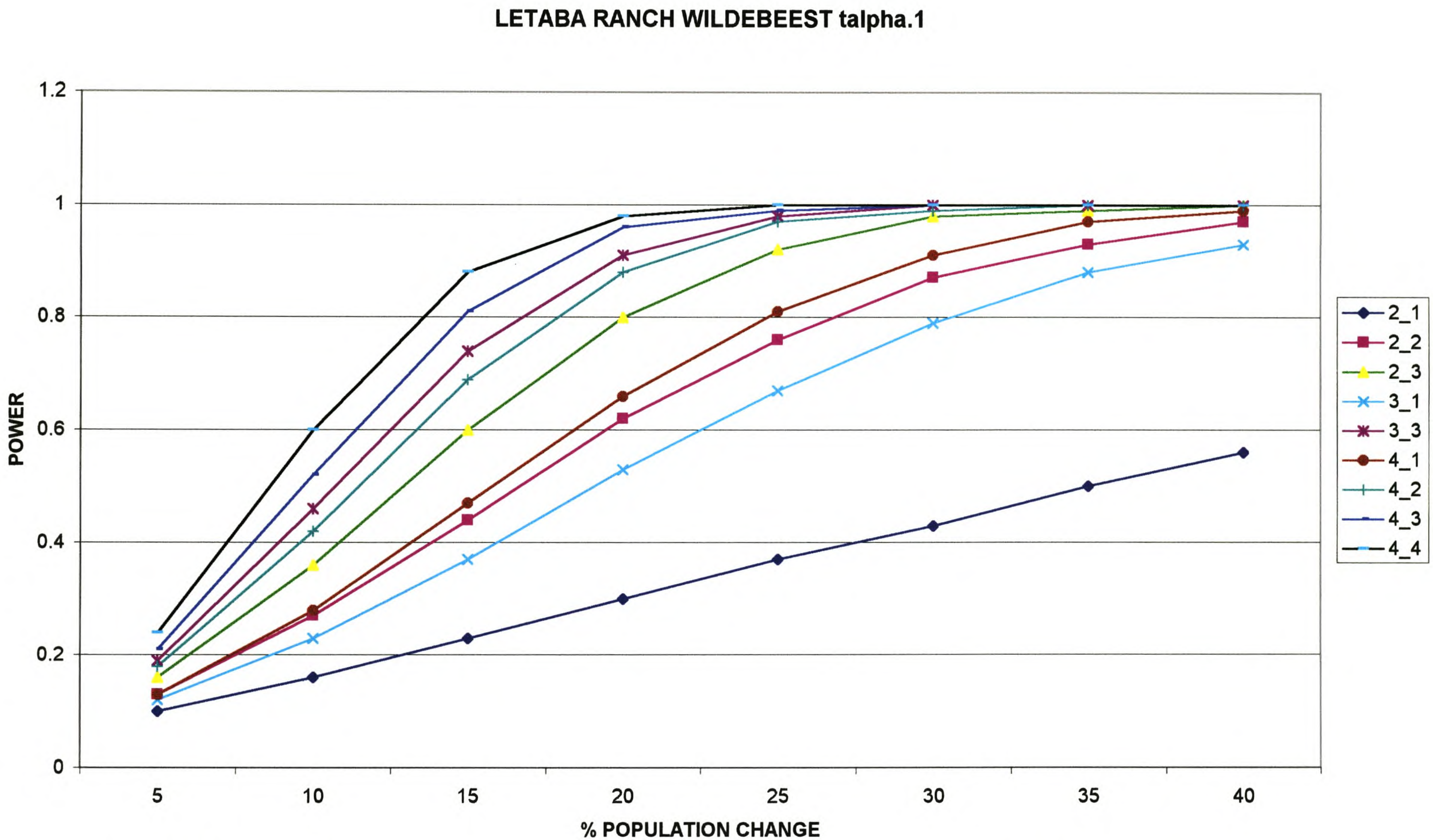


Figure 39: Power curves for various count replicate options at 10% significance for wildebeest at Letaba Ranch, lowveld mopane veld.

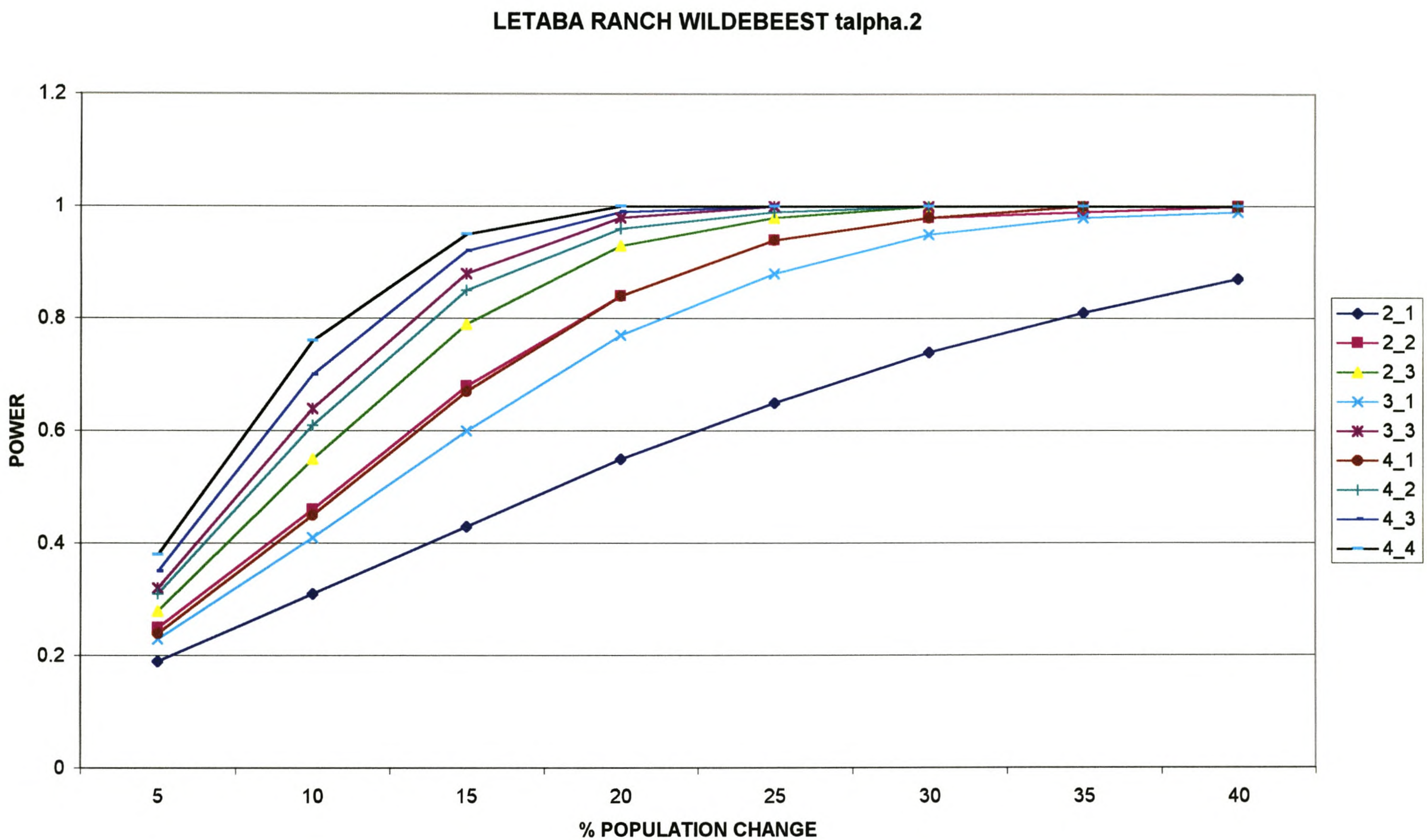


Figure 40: Power curves for various count replicate options at 20% significance for wildebeest at Letaba Ranch, lowveld mopane veld.

Table 39: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for impala at Letaba Ranch.

| **IMPALA** | | **MEAN** | **605.25** | | **EFFECT SIZE(%MEAN)** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | 30.26 | 60.53 | 90.79 | 121.05 | 151.31 | 181.58 | 211.84 | 242.10 |
| **n1** | **n2** | **df** | **talpha.1** | **talpha.2** | **NON CENTRALITY PARAMETERS** | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.24 | 0.49 | 0.73 | 0.98 | 1.22 | 1.46 | 1.71 | 1.95 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.30 | 0.60 | 0.90 | 1.19 | 1.49 | 1.79 | 2.09 | 2.39 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.33 | 0.65 | 0.98 | 1.31 | 1.64 | 1.96 | 2.29 | 2.62 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.26 | 0.52 | 0.78 | 1.04 | 1.29 | 1.55 | 1.81 | 2.07 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.37 | 0.73 | 1.10 | 1.46 | 1.83 | 2.20 | 2.56 | 2.93 |
| 4 | 1 | 3 | 2.35 | 1.64 | 0.27 | 0.53 | 0.80 | 1.07 | 1.33 | 1.60 | 1.87 | 2.13 |
| 4 | 2 | 4 | 2.13 | 1.53 | 0.34 | 0.69 | 1.03 | 1.38 | 1.72 | 2.06 | 2.41 | 2.75 |
| 4 | 3 | 5 | 2.02 | 1.48 | 0.39 | 0.78 | 1.17 | 1.56 | 1.95 | 2.34 | 2.73 | 3.12 |
| 4 | 4 | 6 | 1.94 | 1.44 | 0.42 | 0.84 | 1.26 | 1.69 | 2.11 | 2.53 | 2.95 | 3.37 |

**Table 40: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for impala at 10% and 20% significance at Letaba Ranch.**

talpha.1 IMPALA

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.07 | 0.09 | 0.11 | 0.13 | 0.16 | 0.18 | 0.21 | 0.24 |
| **2_2** | 0.08 | 0.11 | 0.16 | 0.21 | 0.27 | 0.34 | 0.41 | 0.48 |
| **2_3** | 0.08 | 0.13 | 0.19 | 0.27 | 0.36 | 0.45 | 0.55 | 0.64 |
| **3_1** | 0.07 | 0.1 | 0.14 | 0.18 | 0.23 | 0.28 | 0.34 | 0.4 |
| **3_3** | 0.09 | 0.15 | 0.23 | 0.33 | 0.45 | 0.57 | 0.68 | 0.78 |
| **4_1** | 0.08 | 0.11 | 0.16 | 0.21 | 0.27 | 0.35 | 0.42 | 0.5 |
| **4_2** | 0.09 | 0.14 | 0.22 | 0.31 | 0.41 | 0.52 | 0.63 | 0.73 |
| **4_3** | 0.1 | 0.17 | 0.26 | 0.38 | 0.51 | 0.64 | 0.76 | 0.85 |
| **4_4** | 0.1 | 0.19 | 0.3 | 0.44 | 0.59 | 0.72 | 0.83 | 0.91 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.13 | 0.17 | 0.21 | 0.26 | 0.31 | 0.36 | 0.41 | 0.46 |
| **2_2** | 0.15 | 0.21 | 0.29 | 0.37 | 0.46 | 0.55 | 0.64 | 0.72 |
| **2_3** | 0.16 | 0.24 | 0.33 | 0.44 | 0.55 | 0.65 | 0.75 | 0.83 |
| **3_1** | 0.14 | 0.2 | 0.26 | 0.33 | 0.4 | 0.48 | 0.56 | 0.63 |
| **3_3** | 0.17 | 0.27 | 0.38 | 0.51 | 0.64 | 0.75 | 0.84 | 0.91 |
| **4_1** | 0.15 | 0.21 | 0.28 | 0.36 | 0.44 | 0.54 | 0.62 | 0.7 |
| **4_2** | 0.17 | 0.25 | 0.36 | 0.48 | 0.6 | 0.71 | 0.81 | 0.88 |
| **4_3** | 0.18 | 0.28 | 0.42 | 0.56 | 0.69 | 0.8 | 0.89 | 0.94 |
| **4_4** | 0.19 | 0.31 | 0.46 | 0.61 | 0.75 | 0.86 | 0.93 | 0.97 |

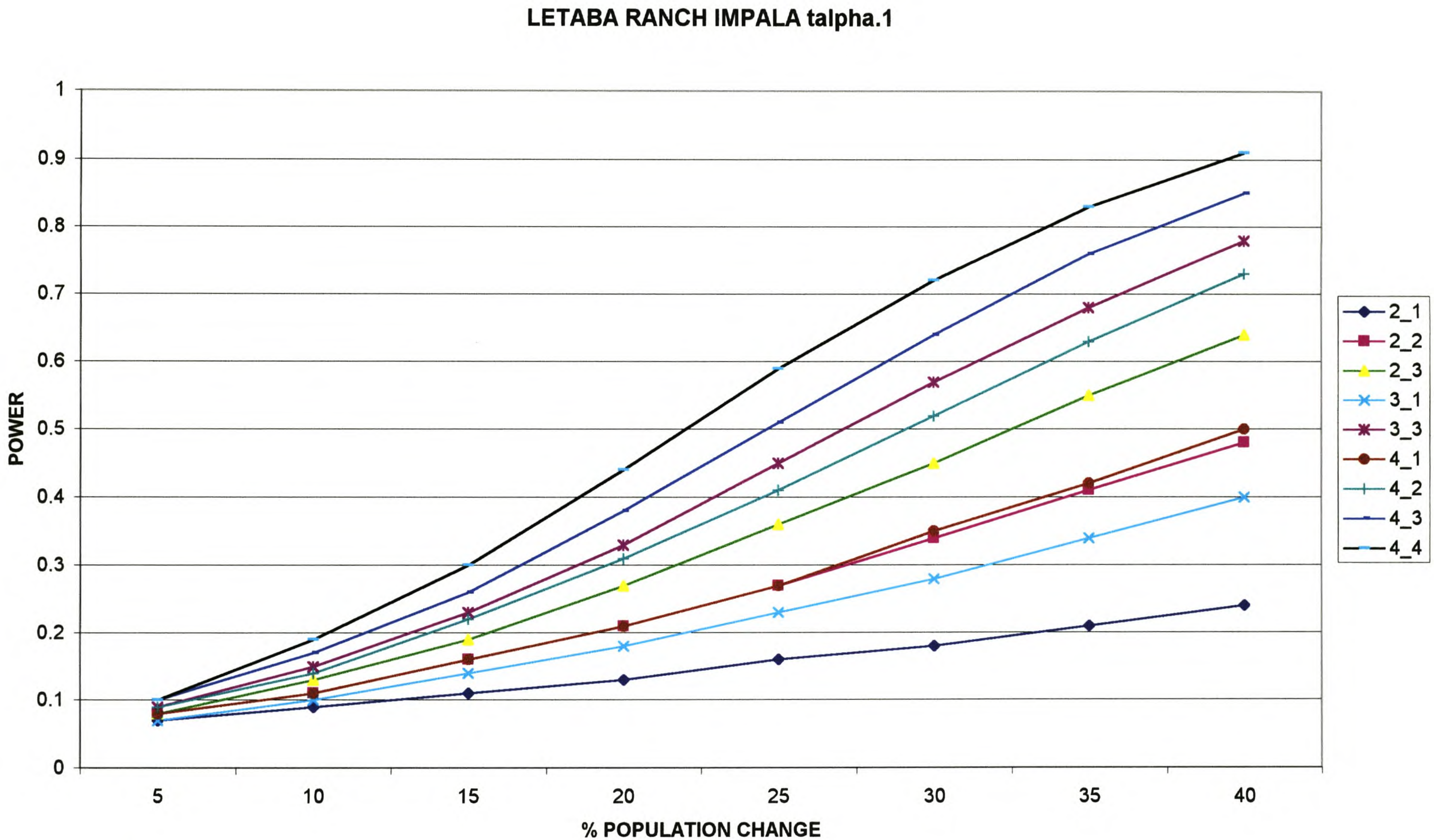


Figure 41: Power curves for various count replicate options at 10% significance for impala at Letaba Ranch, lowveld mopane veld.

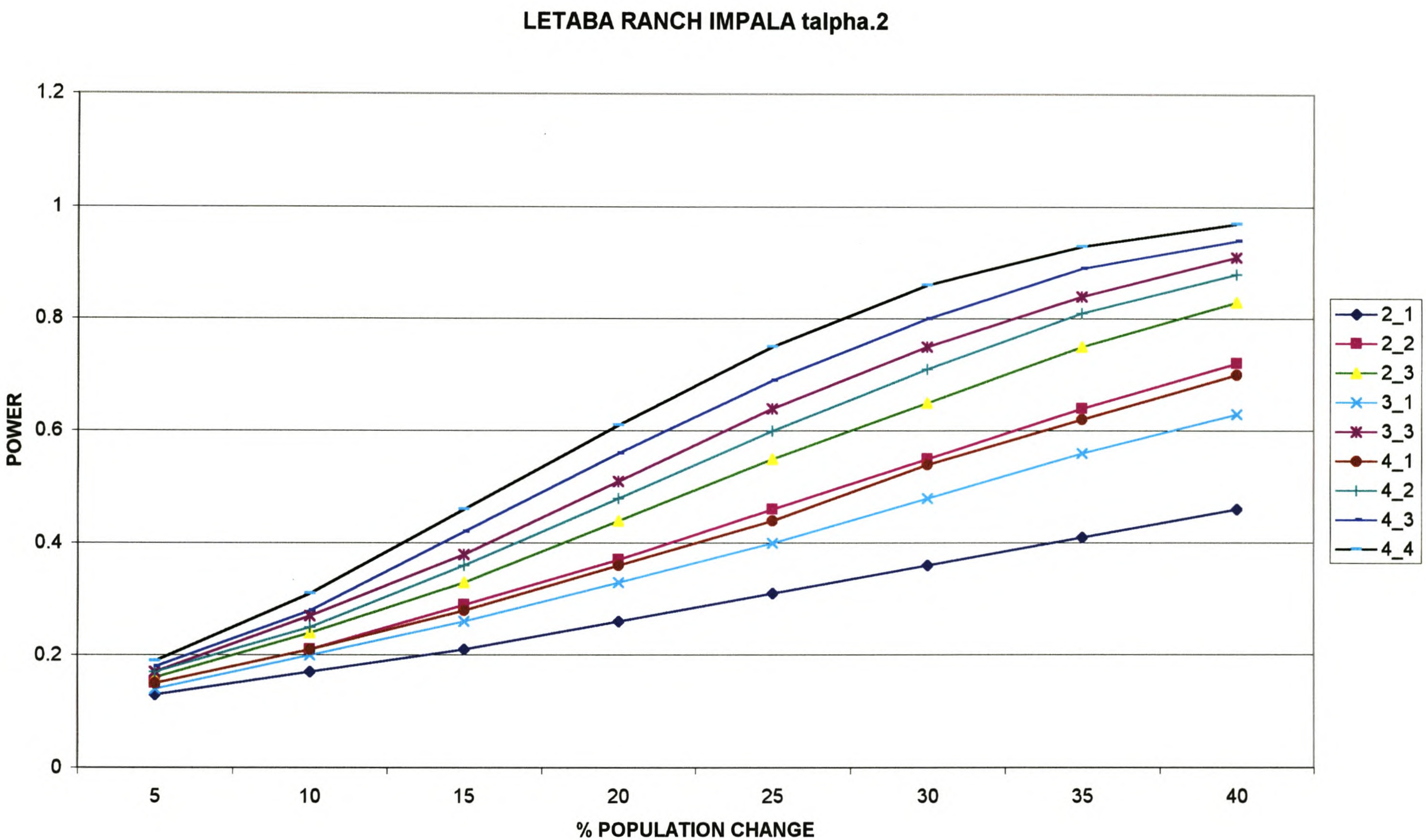


Figure 42: Power curves for various count replicate options at 20% significance for impala at Letaba Ranch, lowveld mopane veld.

Table 41: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for giraffe at Letaba Ranch.

| GIRAFFE | | MEAN | | 36.5 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 1.83 | 3.65 | 5.48 | 7.30 | 9.13 | 10.95 | 12.78 | 14.60 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.01 | 0.03 | 0.04 | 0.06 | 0.07 | 0.09 | 0.10 | 0.12 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.02 | 0.04 | 0.05 | 0.07 | 0.09 | 0.11 | 0.13 | 0.14 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.02 | 0.04 | 0.06 | 0.08 | 0.10 | 0.12 | 0.14 | 0.16 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.02 | 0.03 | 0.05 | 0.06 | 0.08 | 0.09 | 0.11 | 0.12 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.02 | 0.04 | 0.07 | 0.09 | 0.11 | 0.13 | 0.15 | 0.18 |
| 4 | 1 | 3 | 2.35 | 1.64 | 0.02 | 0.03 | 0.05 | 0.06 | 0.08 | 0.10 | 0.11 | 0.13 |
| 4 | 2 | 4 | 2.13 | 1.53 | 0.02 | 0.04 | 0.06 | 0.08 | 0.10 | 0.12 | 0.15 | 0.17 |
| 4 | 3 | 5 | 2.02 | 1.48 | 0.02 | 0.05 | 0.07 | 0.09 | 0.12 | 0.14 | 0.16 | 0.19 |
| 4 | 4 | 6 | 1.94 | 1.44 | 0.03 | 0.05 | 0.08 | 0.10 | 0.13 | 0.15 | 0.18 | 0.20 |

**Table 42: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for giraffe at 10% and 20% significance at Letaba Ranch.**

talpha.1 GIRAFFE

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.06 | 0.06 | 0.06 |
| **2_2** | 0.05 | 0.05 | 0.05 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| **2_3** | 0.05 | 0.05 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| **3_1** | 0.05 | 0.05 | 0.05 | 0.05 | 0.06 | 0.06 | 0.06 | 0.06 |
| **3_3** | 0.05 | 0.05 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.07 |
| **4_1** | 0.05 | 0.05 | 0.05 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| **4_2** | 0.05 | 0.05 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.07 |
| **4_3** | 0.05 | 0.05 | 0.06 | 0.06 | 0.06 | 0.06 | 0.07 | 0.07 |
| **4_4** | 0.05 | 0.06 | 0.06 | 0.06 | 0.06 | 0.07 | 0.07 | 0.07 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.1 | 0.1 | 0.1 | 0.11 | 0.11 | 0.11 | 0.11 | 0.12 |
| **2_2** | 0.10 | 0.11 | 0.11 | 0.11 | 0.11 | 0.12 | 0.12 | 0.12 |
| **2_3** | 0.10 | 0.11 | 0.11 | 0.11 | 0.12 | 0.12 | 0.12 | 0.13 |
| **3_1** | 0.10 | 0.11 | 0.11 | 0.11 | 0.11 | 0.11 | 0.12 | 0.12 |
| **3_3** | 0.10 | 0.11 | 0.11 | 0.12 | 0.12 | 0.12 | 0.13 | 0.13 |
| **4_1** | 0.1 | 0.1 | 0.11 | 0.11 | 0.11 | 0.12 | 0.12 | 0.12 |
| **4_2** | 0.1 | 0.11 | 0.11 | 0.11 | 0.12 | 0.12 | 0.13 | 0.13 |
| **4_3** | 0.1 | 0.11 | 0.11 | 0.11 | 0.12 | 0.12 | 0.13 | 0.13 |
| **4_4** | 0.1 | 0.11 | 0.11 | 0.12 | 0.12 | 0.13 | 0.13 | 0.14 |

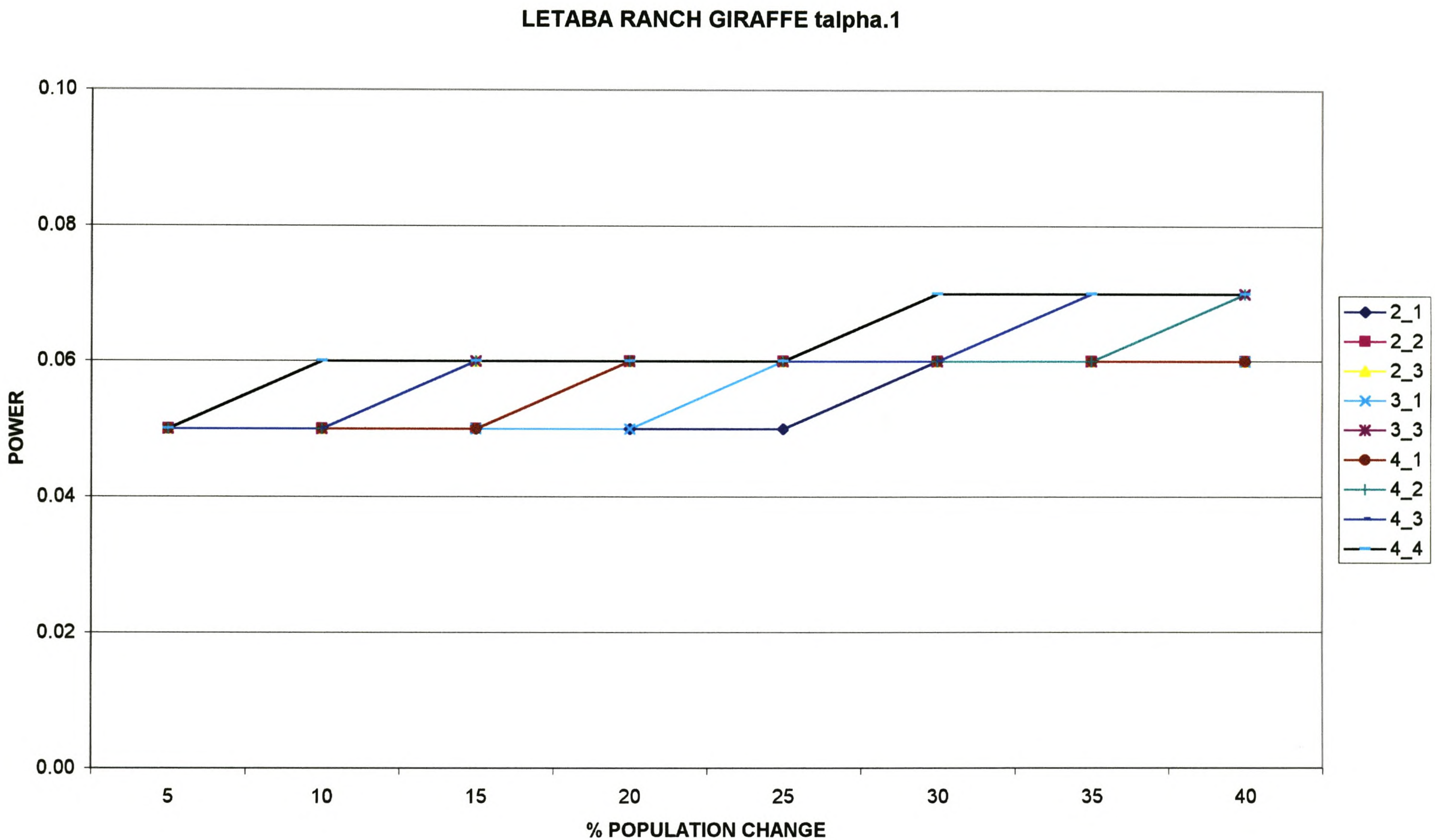


Figure 43: Power curves for various count replicate options at 10% significance for giraffe at Letaba Ranch, lowveld mopane veld.

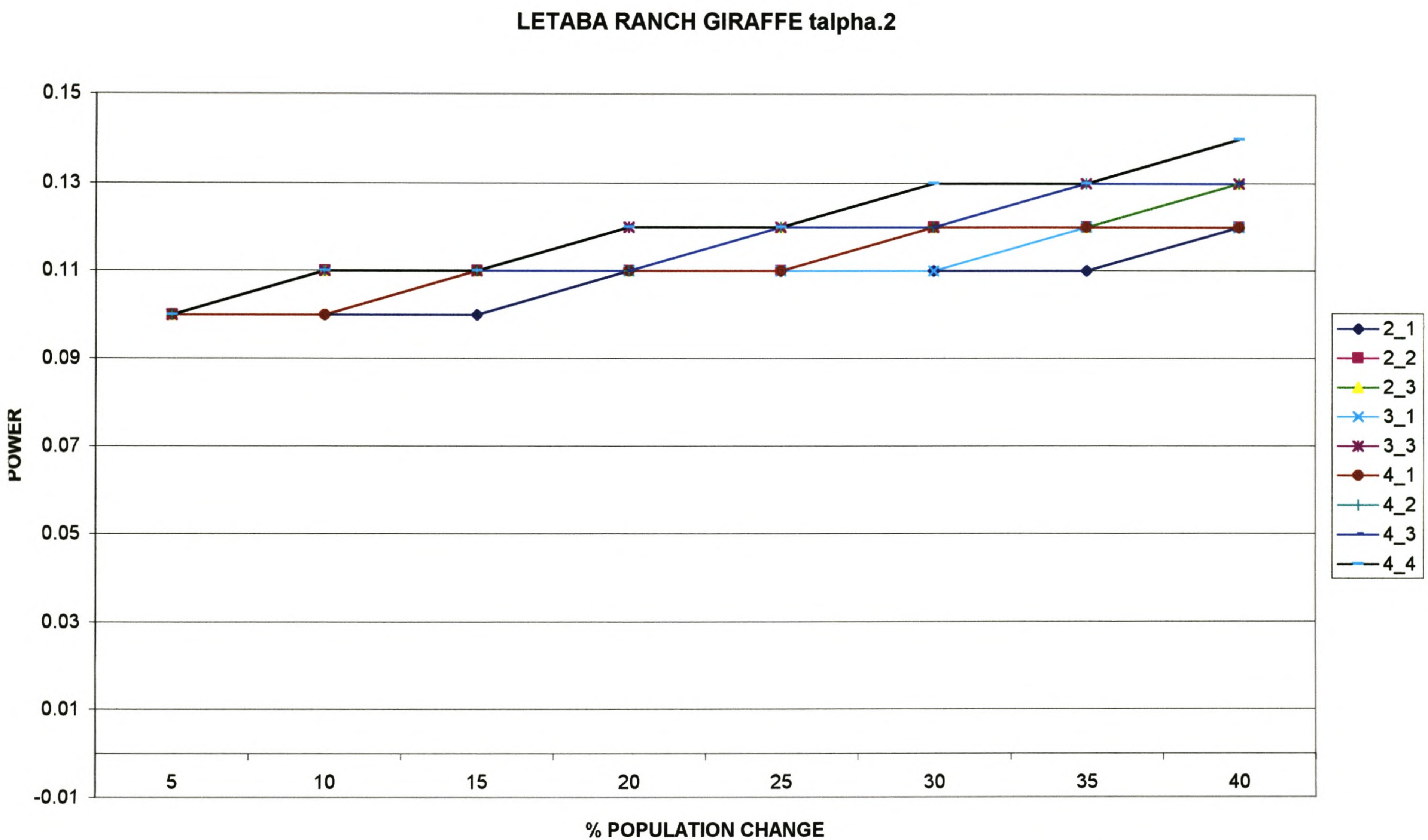


Figure 44: Power curves for various count replicate options at 20% significance for giraffe at Letaba Ranch, lowveld mopane veld.

Table 43: Summary statistics of three replicate helicopter counts of the farm Dieplaagte, northwest arid bushveld.

| SPECIES | COUNT REPLICATES | | | MEAN | STANDARD | STANDARD |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | | DEVIATION(n2) | DEVIATION(n3) |
| *KUDU* | **98** | **86** | **98** | 94.0 | 5.63 | 5.66 |
| *ZEBRA* | **11** | **13** | **11** | 11.7 | 0.94 | 0.94 |
| *WILDEBEEST* | **22** | **31** | **22** | 25.0 | 4.15 | 4.23 |
| *IMPALA* | **70** | **63** | **84** | 72.3 | 8.69 | 8.75 |
| *WARTHOG* | **44** | **42** | **44** | 43.3 | 0.93 | 0.93 |
| *GEMSBOK* | **21** | **20** | **21** | 20.7 | 0.47 | 0.47 |

| SPECIES | SEdiff21 | SEdiff22 | SEdiff23 | SEdiff31 | SEdiff33 |
|---|---|---|---|---|---|
| *KUDU* | 6.90 | 5.63 | 5.14 | 6.54 | 4.62 |
| *ZEBRA* | 1.15 | 0.94 | 0.86 | 1.09 | 0.77 |
| *WILDEBEEST* | 5.08 | 4.15 | 3.79 | 4.88 | 3.45 |
| *IMPALA* | 10.64 | 8.69 | 7.93 | 10.10 | 7.14 |
| *WARTHOG* | 1.14 | 0.93 | 0.85 | 1.07 | 0.76 |
| *GEMSBOK* | 0.58 | 0.47 | 0.43 | 0.54 | 0.38 |

Table 44: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for kudu on the farm Dieplaagte, northwest arid bushveld.

| KUDU | | | MEAN | 94.0 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 4.70 | 9.40 | 14.10 | 18.80 | 23.50 | 28.20 | 32.90 | 37.60 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.68 | 1.36 | 2.04 | 2.73 | 3.41 | 4.09 | 4.77 | 5.45 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.83 | 1.67 | 2.50 | 3.34 | 4.17 | 5.01 | 5.84 | 6.68 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.91 | 1.83 | 2.74 | 3.66 | 4.57 | 5.49 | 6.40 | 7.32 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.72 | 1.44 | 2.16 | 2.88 | 3.60 | 4.31 | 5.03 | 5.75 |
| 3 | 3 | 4 | 2.13 | 1.53 | 1.02 | 2.03 | 3.05 | 4.07 | 5.09 | 6.10 | 7.12 | 8.14 |

**Table 45:** Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for kudu at 10% and 20% significance on the farm Dieplaagte, northwest arid bushveld.

talpha.1 KUDU

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.10 | 0.17 | 0.25 | 0.33 | 0.41 | 0.48 | 0.54 | 0.61 |
| **2_2** | 0.15 | 0.31 | 0.50 | 0.69 | 0.83 | 0.92 | 0.96 | 0.99 |
| **2_3** | 0.18 | 0.41 | 0.67 | 0.86 | 0.96 | 0.99 | 1.00 | 1.00 |
| **3_1** | 0.13 | 0.26 | 0.42 | 0.59 | 0.74 | 0.85 | 0.92 | 0.96 |
| **3_3** | 0.21 | 0.51 | 0.80 | 0.95 | 0.99 | 1.00 | 1.00 | 1.00 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.20 | 0.34 | 0.47 | 0.60 | 0.71 | 0.79 | 0.86 | 0.91 |
| **2_2** | 0.27 | 0.52 | 0.74 | 0.90 | 0.97 | 0.99 | 1.00 | 1.00 |
| **2_3** | 0.31 | 0.61 | 0.85 | 0.96 | 0.99 | 1.00 | 1.00 | 1.00 |
| **3_1** | 0.24 | 0.45 | 0.66 | 0.82 | 0.92 | 0.97 | 0.99 | 1.00 |
| **3_3** | 0.36 | 0.70 | 0.92 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 |

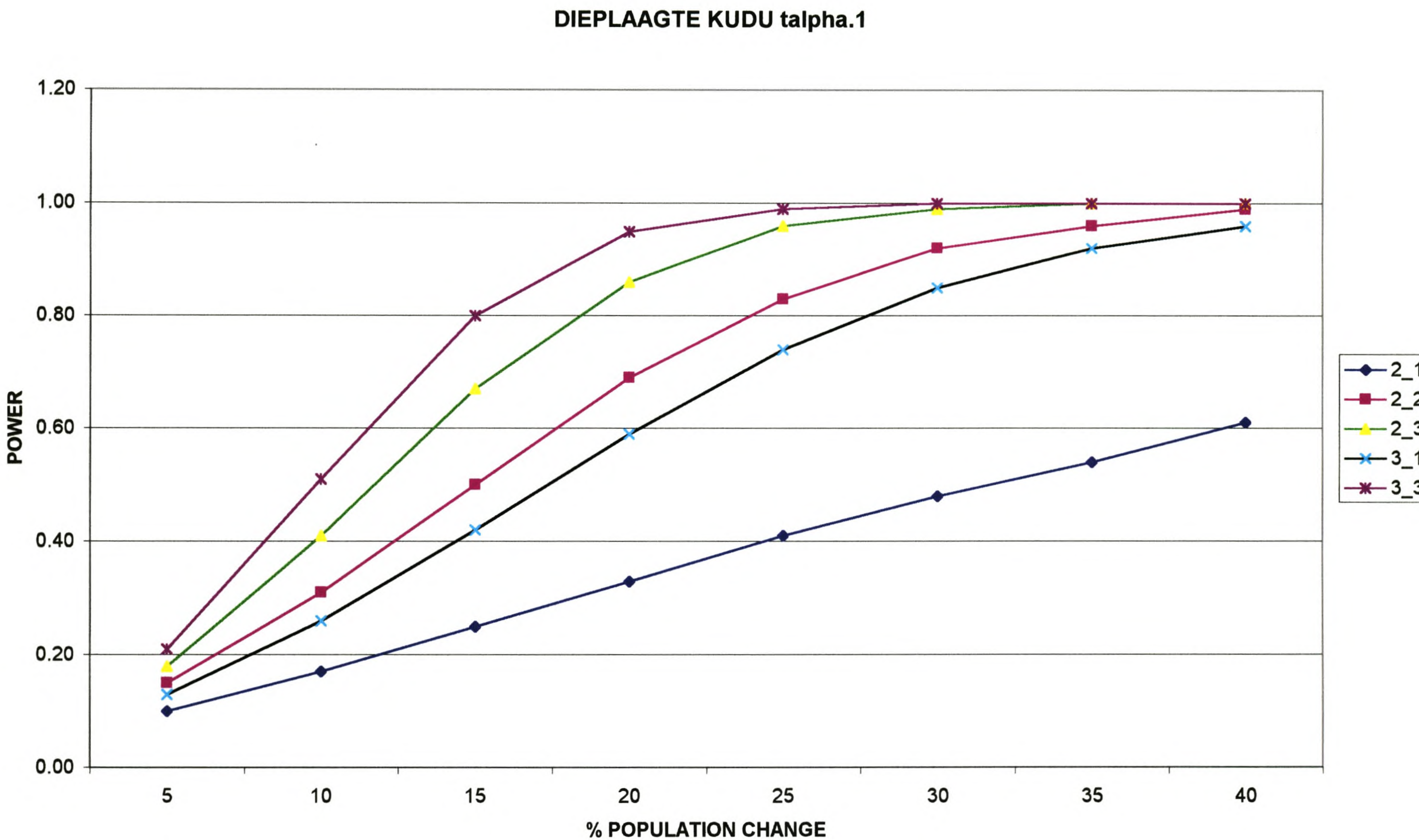


Figure 45: Power curves for various count replicate options at 10% significance for kudu on the farm Dieplaagte, northwest arid bushveld.

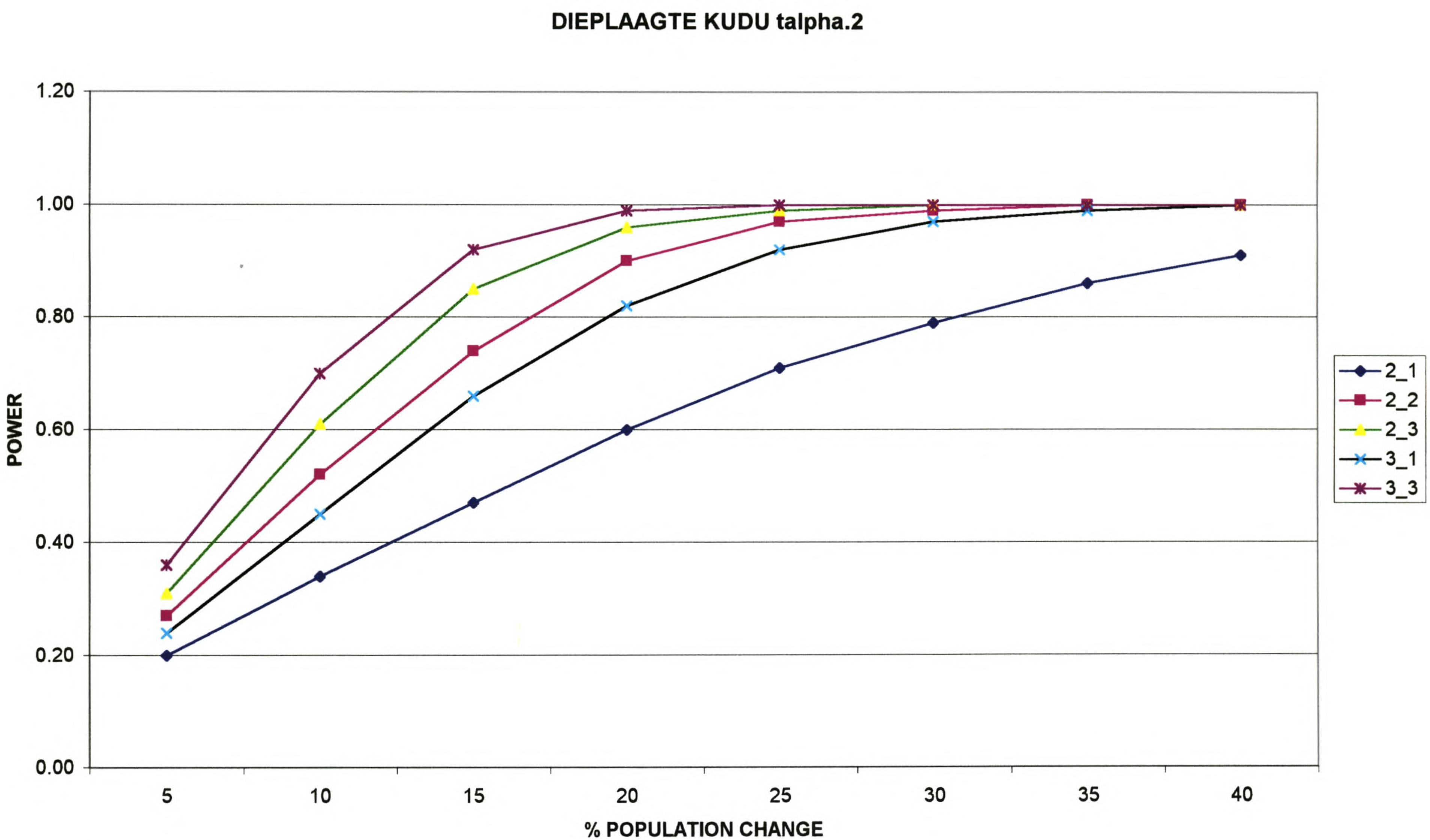


Figure 46: Power curves for various count replicate options at 20% significance for kudu on the farm Dieplaagte, northwest arid bushveld.

Table 46: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for zebra on the farm Dieplaagte, northwest arid bushveld.

| ZEBRA | | MEAN | 11.70 | | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 0.59 | 1.17 | 1.76 | 2.34 | 2.93 | 3.51 | 4.10 | 4.68 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.51 | 1.02 | 1.52 | 2.03 | 2.54 | 3.05 | 3.56 | 4.07 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.62 | 1.24 | 1.87 | 2.49 | 3.11 | 3.73 | 4.36 | 4.98 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.68 | 1.36 | 2.05 | 2.73 | 3.41 | 4.09 | 4.77 | 5.45 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.54 | 1.08 | 1.62 | 2.16 | 2.69 | 3.23 | 3.77 | 4.31 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.76 | 1.52 | 2.29 | 3.05 | 3.81 | 4.57 | 5.34 | 6.10 |

**Table 47: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for zebra at 10% and 20% significance on the farm Dieplaagte, northwest arid bushveld.**

talpha.1 ZEBRA

| | **5** | **10** | **15** | **20** | **25** | **30** | **35** | **40** |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.09 | 0.14 | 0.19 | 0.25 | 0.31 | 0.37 | 0.42 | 0.48 |
| **2_2** | 0.11 | 0.22 | 0.35 | 0.50 | 0.64 | 0.76 | 0.85 | 0.91 |
| **2_3** | 0.14 | 0.28 | 0.48 | 0.67 | 0.82 | 0.92 | 0.97 | 0.99 |
| **3_1** | 0.10 | 0.19 | 0.30 | 0.42 | 0.55 | 0.67 | 0.77 | 0.85 |
| **3_3** | 0.16 | 0.35 | 0.60 | 0.80 | 0.93 | 0.98 | 1.00 | 1.00 |

talpha.2

| | **5** | **10** | **15** | **20** | **25** | **30** | **35** | **40** |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.17 | 0.27 | 0.37 | 0.47 | 0.57 | 0.65 | 0.73 | 0.79 |
| **2_2** | 0.22 | 0.39 | 0.58 | 0.74 | 0.86 | 0.94 | 0.97 | 0.99 |
| **2_3** | 0.24 | 0.45 | 0.68 | 0.85 | 0.94 | 0.98 | 1.00 | 1.00 |
| **3_1** | 0.20 | 0.34 | 0.50 | 0.66 | 0.79 | 0.88 | 0.94 | 0.97 |
| **3_3** | 0.28 | 0.53 | 0.78 | 0.92 | 0.98 | 1.00 | 1.00 | 1.00 |

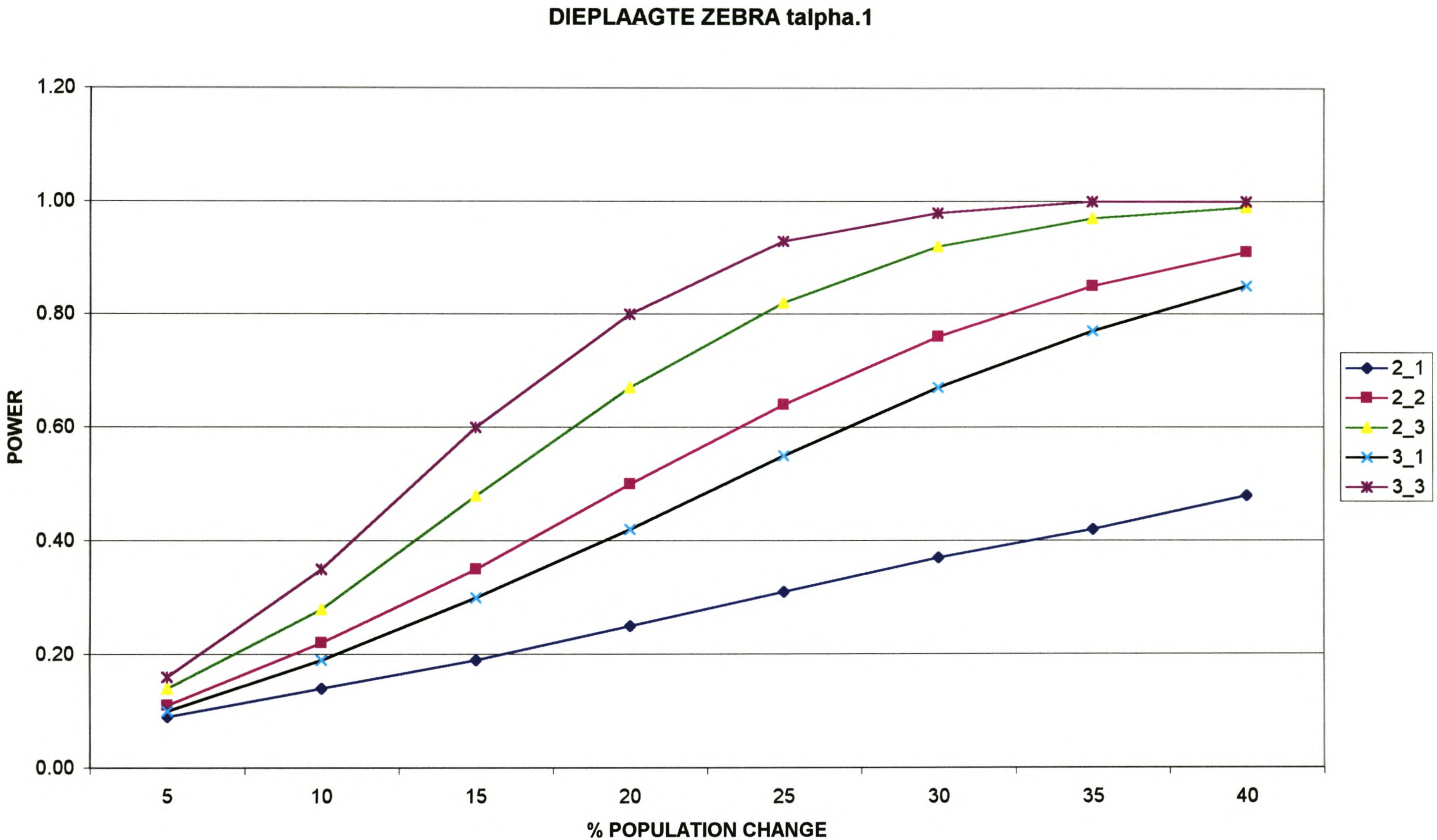


Figure 47: Power curves for various count replicate options at 10% significance for zebra on the farm Dieplaagte, northwest arid bushveld.

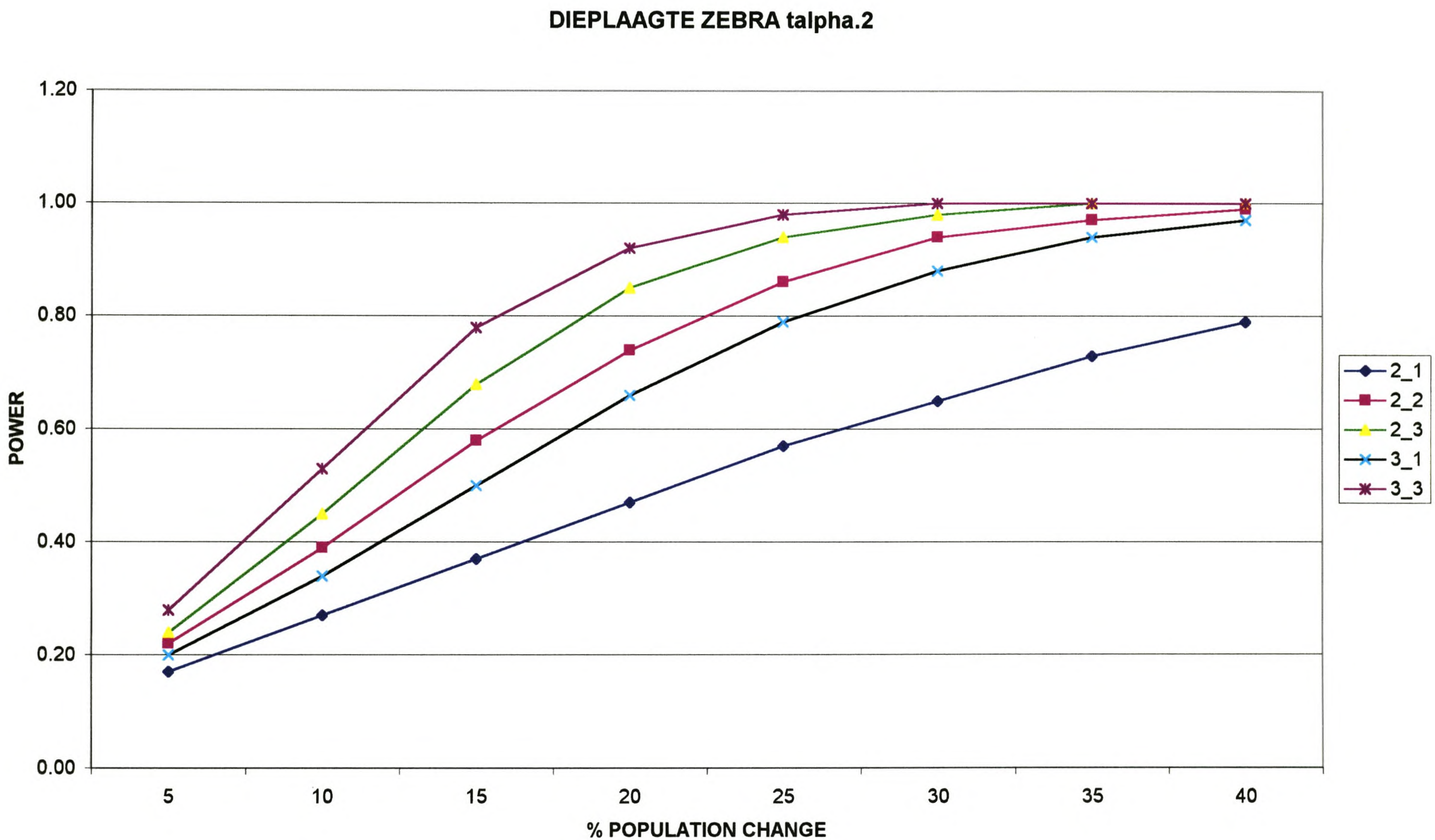


Figure 48: Power curves for various count replicate options at 20% significance for zebra on the farm Dieplaagte, northwest arid bushveld.

Table 48: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for wildebeest on the farm Dieplaagte, northwest arid bushveld.

| WILDEBEEST | | | MEAN | 25.00 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 1.25 | 2.50 | 3.75 | 5.00 | 6.25 | 7.50 | 8.75 | 10.00 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.25 | 0.49 | 0.74 | 0.98 | 1.23 | 1.48 | 1.72 | 1.97 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.30 | 0.60 | 0.90 | 1.20 | 1.51 | 1.81 | 2.11 | 2.41 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.33 | 0.66 | 0.99 | 1.32 | 1.65 | 1.98 | 2.31 | 2.64 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.26 | 0.51 | 0.77 | 1.02 | 1.28 | 1.54 | 1.79 | 2.05 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.36 | 0.72 | 1.09 | 1.45 | 1.81 | 2.17 | 2.53 | 2.90 |

Table 49: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for wildebeest at 10% and 20% significance on the farm Dieplaagte, northwest arid bushveld.

talpha.1 WILDEBEEST

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.07 | 0.09 | 0.11 | 0.13 | 0.16 | 0.19 | 0.21 | 0.24 |
| **2_2** | 0.08 | 0.11 | 0.16 | 0.21 | 0.27 | 0.34 | 0.41 | 0.48 |
| **2_3** | 0.08 | 0.13 | 0.19 | 0.27 | 0.36 | 0.46 | 0.55 | 0.65 |
| **3_1** | 0.07 | 0.10 | 0.14 | 0.18 | 0.23 | 0.28 | 0.34 | 0.40 |
| **3_3** | 0.09 | 0.15 | 0.23 | 0.33 | 0.44 | 0.56 | 0.67 | 0.77 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.13 | 0.17 | 0.21 | 0.26 | 0.31 | 0.36 | 0.41 | 0.46 |
| **2_2** | 0.15 | 0.21 | 0.29 | 0.38 | 0.47 | 0.56 | 0.64 | 0.72 |
| **2_3** | 0.16 | 0.24 | 0.33 | 0.44 | 0.55 | 0.66 | 0.75 | 0.83 |
| **3_1** | 0.14 | 0.19 | 0.26 | 0.32 | 0.40 | 0.48 | 0.55 | 0.63 |
| **3_3** | 0.17 | 0.26 | 0.38 | 0.51 | 0.63 | 0.74 | 0.83 | 0.90 |

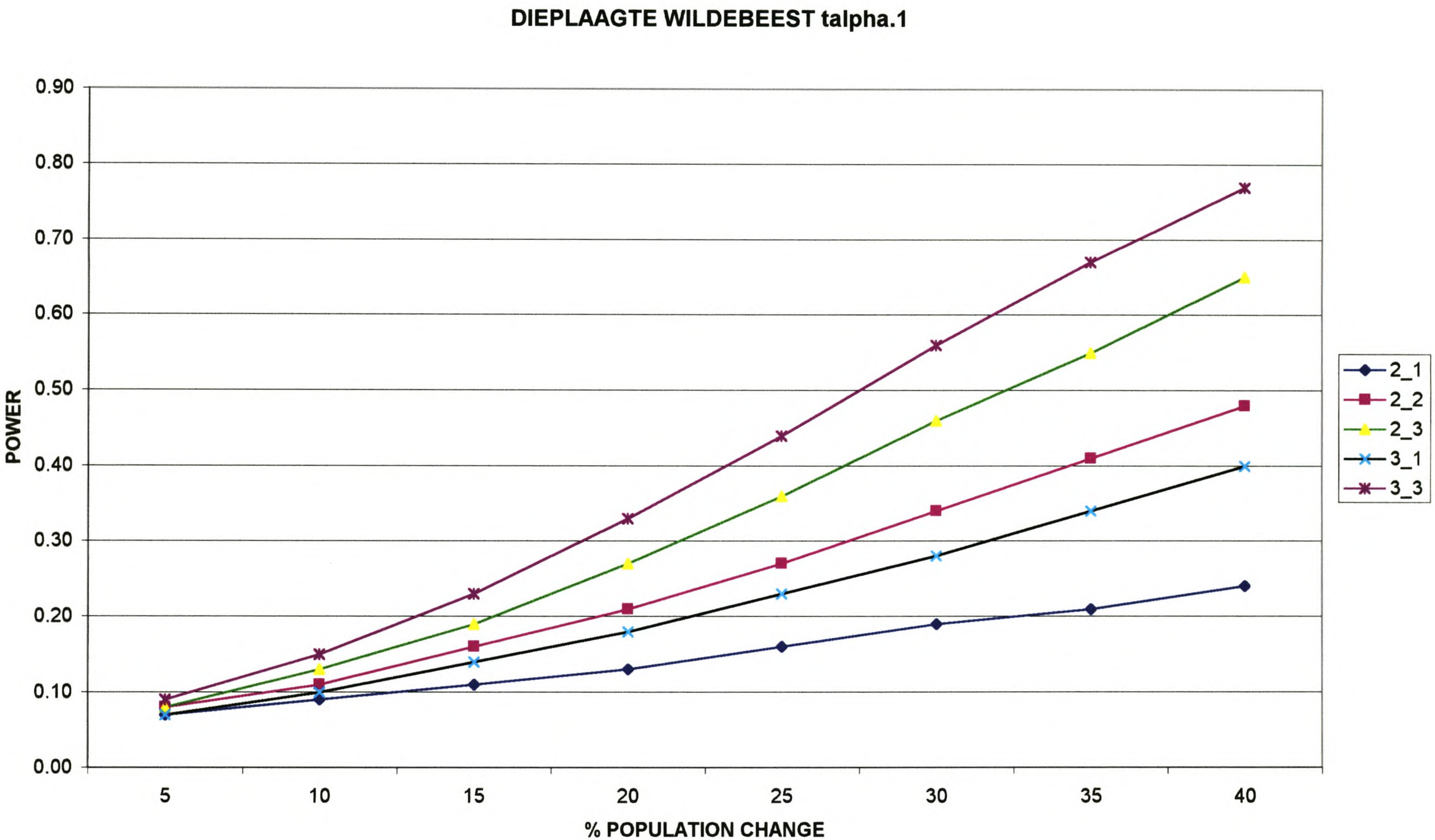


Figure 49: Power curves for various count replicate options at 10% significance for wildebeest on the farm Dieplaagte, northwest arid bushveld.

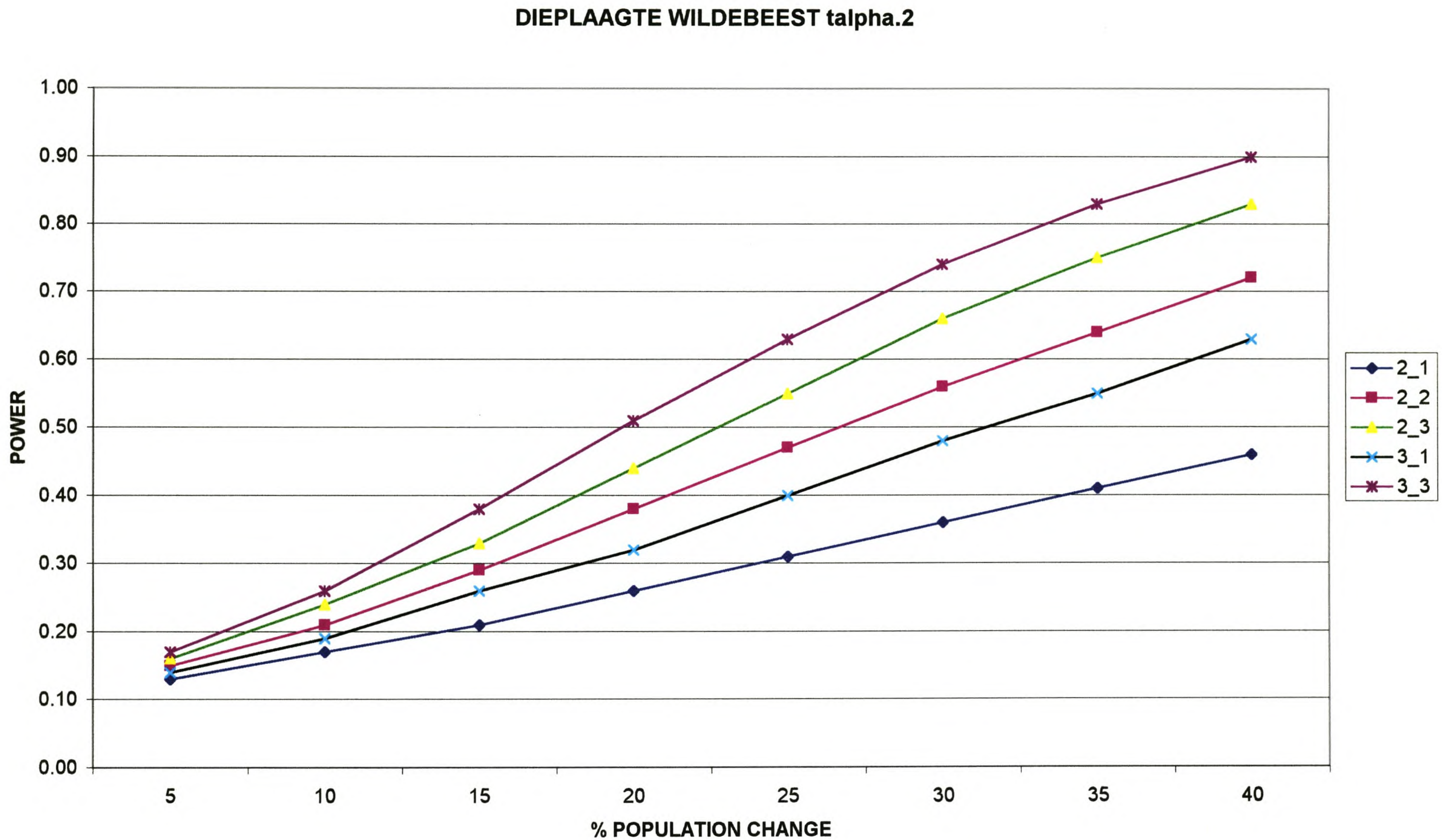


Figure 50: Power curves for various count replicate options at 20% significance for wildebeest on the farm Dieplaagte, northwest arid bushveld.

Table 50: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for impala on the farm Dieplaagte, northwest arid bushveld.

| IMPALA | | MEAN | 72.30 | | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 3.62 | 7.23 | 10.85 | 14.46 | 18.08 | 21.69 | 25.31 | 28.92 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.34 | 0.68 | 1.02 | 1.36 | 1.70 | 2.04 | 2.38 | 2.72 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.42 | 0.83 | 1.25 | 1.66 | 2.08 | 2.50 | 2.91 | 3.33 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.46 | 0.91 | 1.37 | 1.82 | 2.28 | 2.73 | 3.19 | 3.65 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.36 | 0.72 | 1.07 | 1.43 | 1.79 | 2.15 | 2.50 | 2.86 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.51 | 1.01 | 1.52 | 2.02 | 2.53 | 3.04 | 3.54 | 4.05 |

**Table 51: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for impala at 10% and 20% significance on the farm Dieplaagte, northwest arid bushveld.**

talpha.1 IMPALA

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.07 | 0.10 | 0.14 | 0.17 | 0.21 | 0.25 | 0.29 | 0.33 |
| **2_2** | 0.09 | 0.15 | 0.22 | 0.31 | 0.40 | 0.50 | 0.60 | 0.69 |
| **2_3** | 0.10 | 0.18 | 0.28 | 0.41 | 0.54 | 0.67 | 0.78 | 0.86 |
| **3_1** | 0.08 | 0.13 | 0.19 | 0.26 | 0.34 | 0.42 | 0.50 | 0.59 |
| **3_3** | 0.11 | 0.21 | 0.35 | 0.51 | 0.67 | 0.80 | 0.89 | 0.95 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.15 | 0.20 | 0.27 | 0.34 | 0.41 | 0.47 | 0.54 | 0.60 |
| **2_2** | 0.18 | 0.27 | 0.39 | 0.51 | 0.64 | 0.74 | 0.83 | 0.89 |
| **2_3** | 0.19 | 0.31 | 0.46 | 0.61 | 0.74 | 0.85 | 0.92 | 0.96 |
| **3_1** | 0.16 | 0.24 | 0.34 | 0.44 | 0.55 | 0.66 | 0.74 | 0.82 |
| **3_3** | 0.21 | 0.35 | 0.53 | 0.70 | 0.83 | 0.92 | 0.97 | 0.99 |

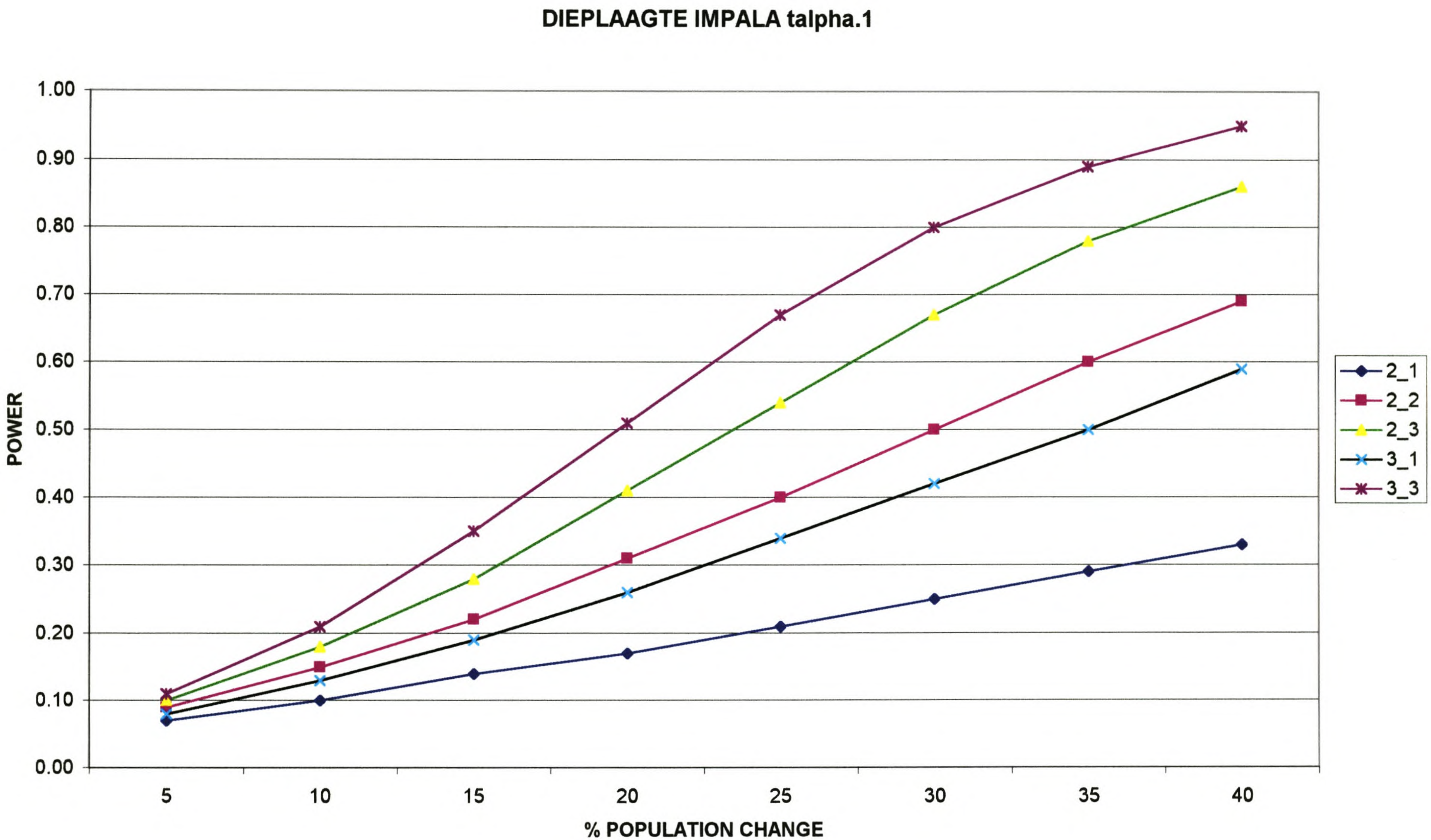


Figure 51: Power curves for various count replicate options at 10% significance for impala on the farm Dieplaagte, northwest arid bushveld.

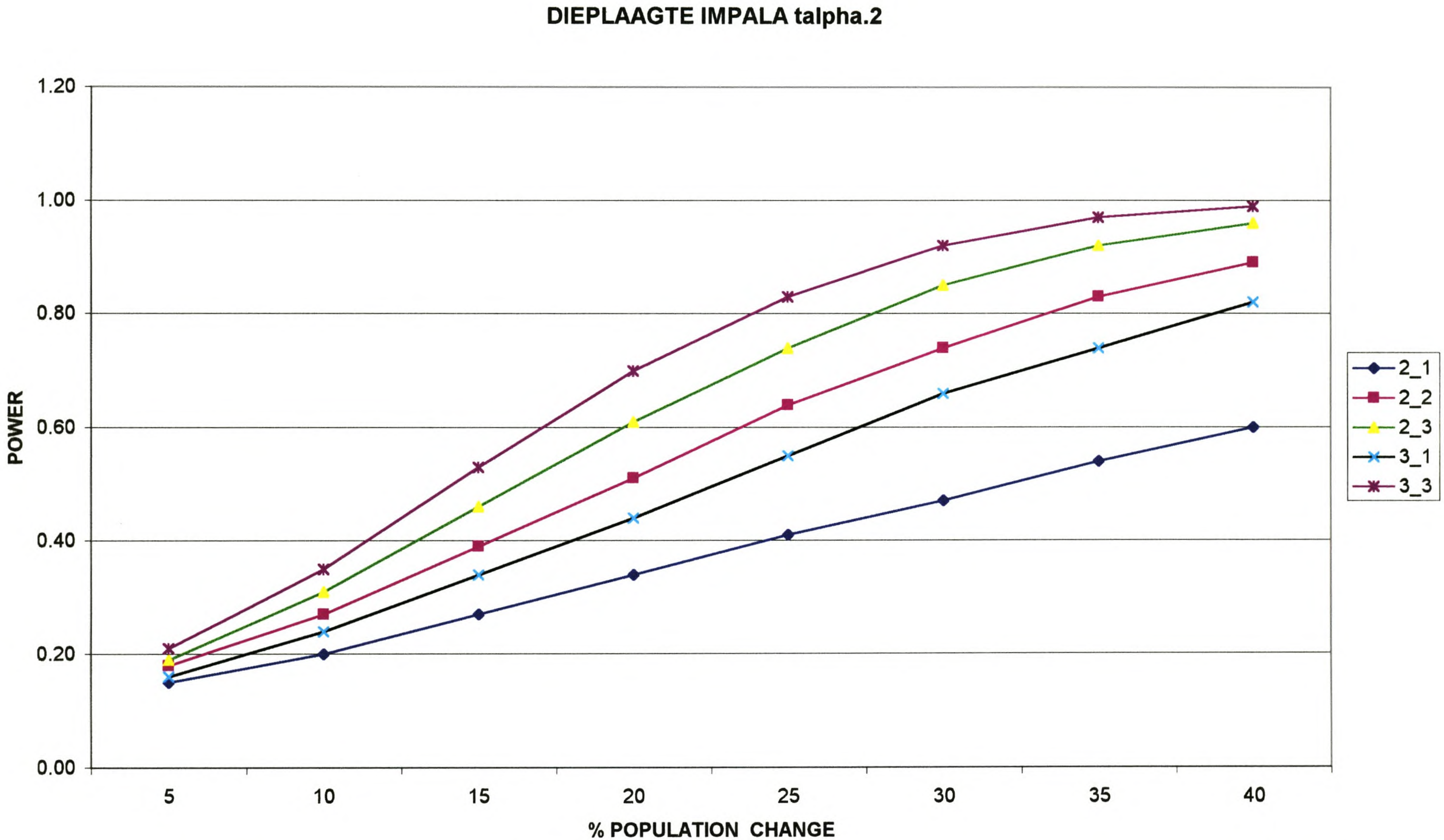


Figure 52: Power curves for various count replicate options at 20% significance for impala on the farm Dieplaagte, northwest arid bushveld.

Table 52: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for warthog on the farm Dieplaagte, northwest arid bushveld.

| WARTHOG | | | MEAN | 43.3 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 2.17 | 4.33 | 6.50 | 8.66 | 10.83 | 12.99 | 15.16 | 17.32 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 1.90 | 3.80 | 5.70 | 7.60 | 9.50 | 11.40 | 13.31 | 15.21 |
| 2 | 2 | 2 | 2.92 | 1.87 | 2.33 | 4.66 | 6.98 | 9.31 | 11.64 | 13.97 | 16.30 | 18.62 |
| 2 | 3 | 3 | 2.35 | 1.64 | 2.55 | 5.10 | 7.65 | 10.20 | 12.75 | 15.30 | 17.85 | 20.40 |
| 3 | 1 | 2 | 2.92 | 1.87 | 2.02 | 4.03 | 6.05 | 8.06 | 10.08 | 12.10 | 14.11 | 16.13 |
| 3 | 3 | 4 | 2.13 | 1.53 | 2.85 | 5.70 | 8.55 | 11.40 | 14.26 | 17.11 | 19.96 | 22.81 |

**Table 53: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for warthog at 10% and 20% significance on the farm Dieplaagte, northwest arid bushveld.**

talpha.1 WARTHOG

| | **5** | **10** | **15** | **20** | **25** | **30** | **35** | **40** |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.24 | 0.45 | 0.63 | 0.77 | 0.86 | 0.93 | 0.96 | 0.98 |
| **2_2** | 0.46 | 0.89 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| **2_3** | 0.62 | 0.98 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| **3_1** | 0.39 | 0.81 | 0.97 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| **3_3** | 0.76 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

talpha.2

| | **5** | **10** | **15** | **20** | **25** | **30** | **35** | **40** |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.45 | 0.76 | 0.92 | 0.98 | 1.00 | 1.00 | 1.00 | 1.00 |
| **2_2** | 0.70 | 0.98 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| **2_3** | 0.81 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| **3_1** | 0.62 | 0.96 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| **3_3** | 0.89 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

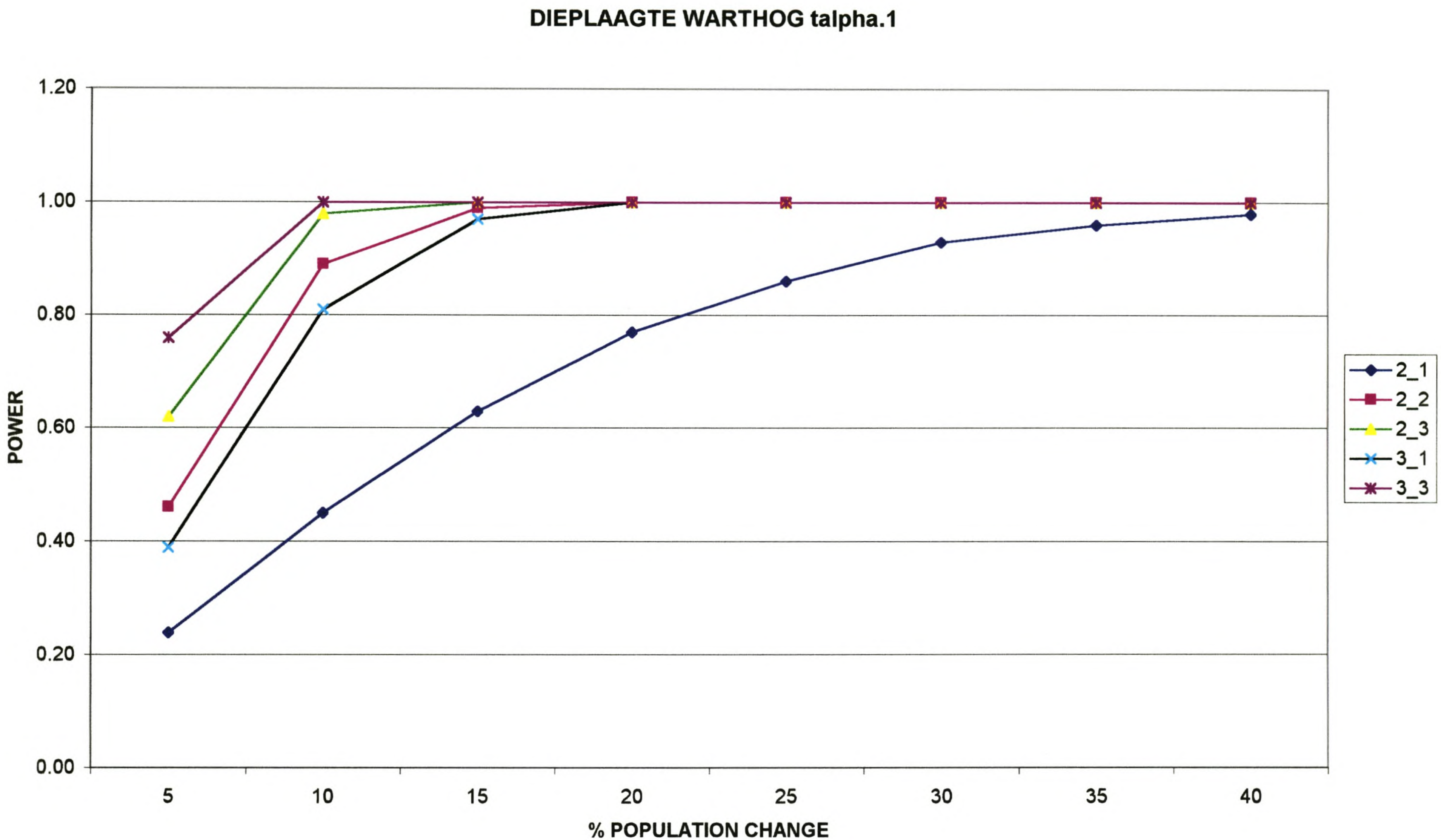


Figure 53: Power curves for various count replicate options at 10% significance for warthog on the farm Dieplaagte, northwest arid bushveld.

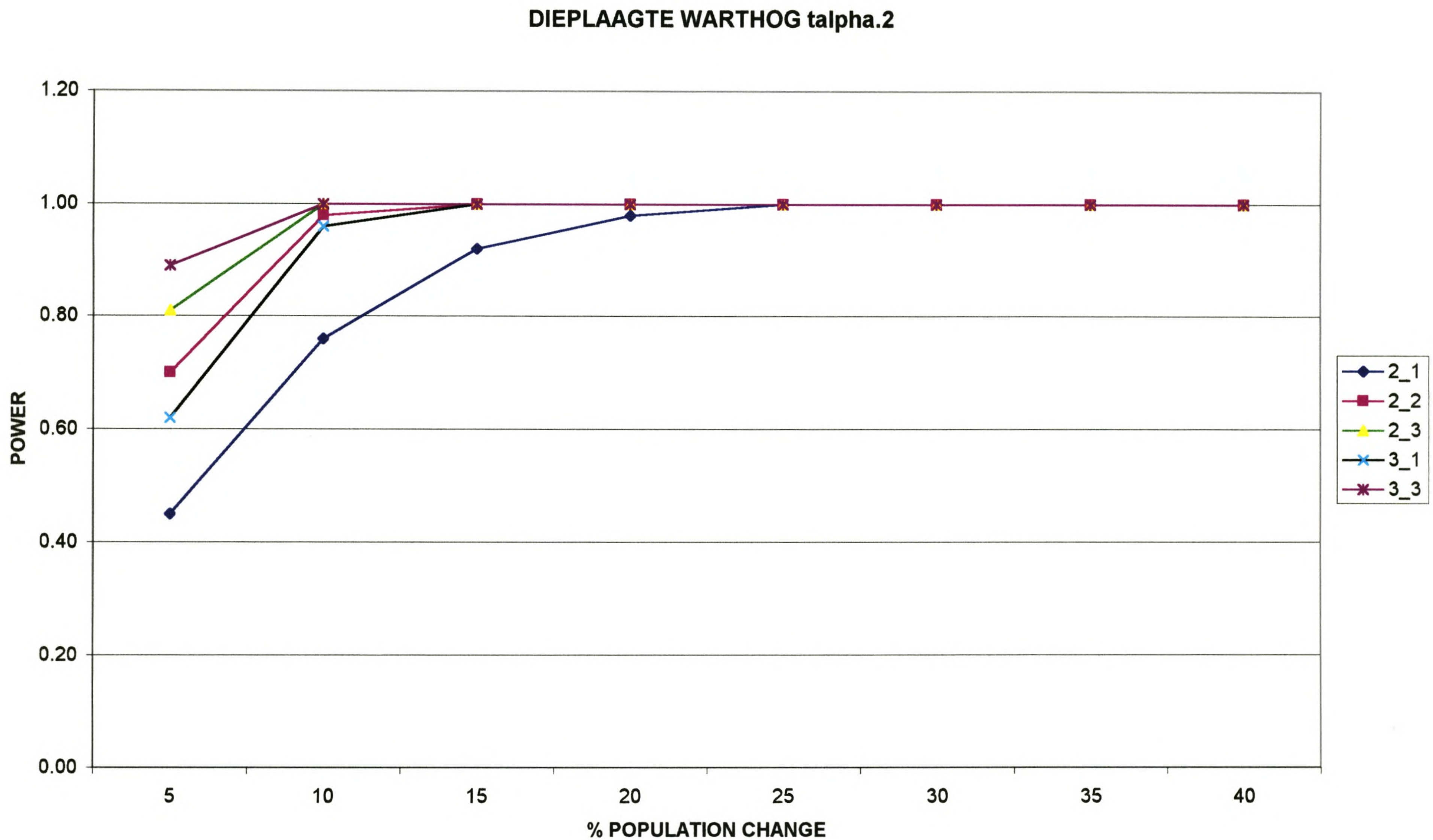


Figure 54: Power curves for various count replicate options at 20% significance for warthog on the farm Dieplaagte, northwest arid bushveld.

Table 54: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for gemsbok on the farm Dieplaagte, northwest arid bushveld.

| GEMSBOK | | | MEAN | 20.70 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 1.04 | 2.07 | 3.11 | 4.14 | 5.18 | 6.21 | 7.25 | 8.28 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 1.80 | 3.60 | 5.39 | 7.19 | 8.99 | 10.79 | 12.59 | 14.38 |
| 2 | 2 | 2 | 2.92 | 1.87 | 2.20 | 4.40 | 6.61 | 8.81 | 11.01 | 13.21 | 15.41 | 17.62 |
| 2 | 3 | 3 | 2.35 | 1.64 | 2.41 | 4.82 | 7.24 | 9.65 | 12.06 | 14.47 | 16.89 | 19.30 |
| 3 | 1 | 2 | 2.92 | 1.87 | 1.91 | 3.81 | 5.72 | 7.63 | 9.54 | 11.44 | 13.35 | 15.26 |
| 3 | 3 | 4 | 2.13 | 1.53 | 2.70 | 5.39 | 8.09 | 10.79 | 13.49 | 16.18 | 18.88 | 21.58 |

**Table 55: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for gemsbok at 10% and 20% significance on the farm Dieplaagte, northwest arid bushveld.**

talpha.1 GEMSBOK

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.22 | 0.43 | 0.60 | 0.74 | 0.84 | 0.91 | 0.95 | 0.98 |
| **2_2** | 0.43 | 0.86 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| **2_3** | 0.58 | 0.97 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| **3_1** | 0.36 | 0.77 | 0.96 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| **3_3** | 0.72 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.43 | 0.73 | 0.90 | 0.97 | 0.99 | 1.00 | 1.00 | 1.00 |
| **2_2** | 0.67 | 0.98 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| **2_3** | 0.78 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| **3_1** | 0.59 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| **3_3** | 0.87 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

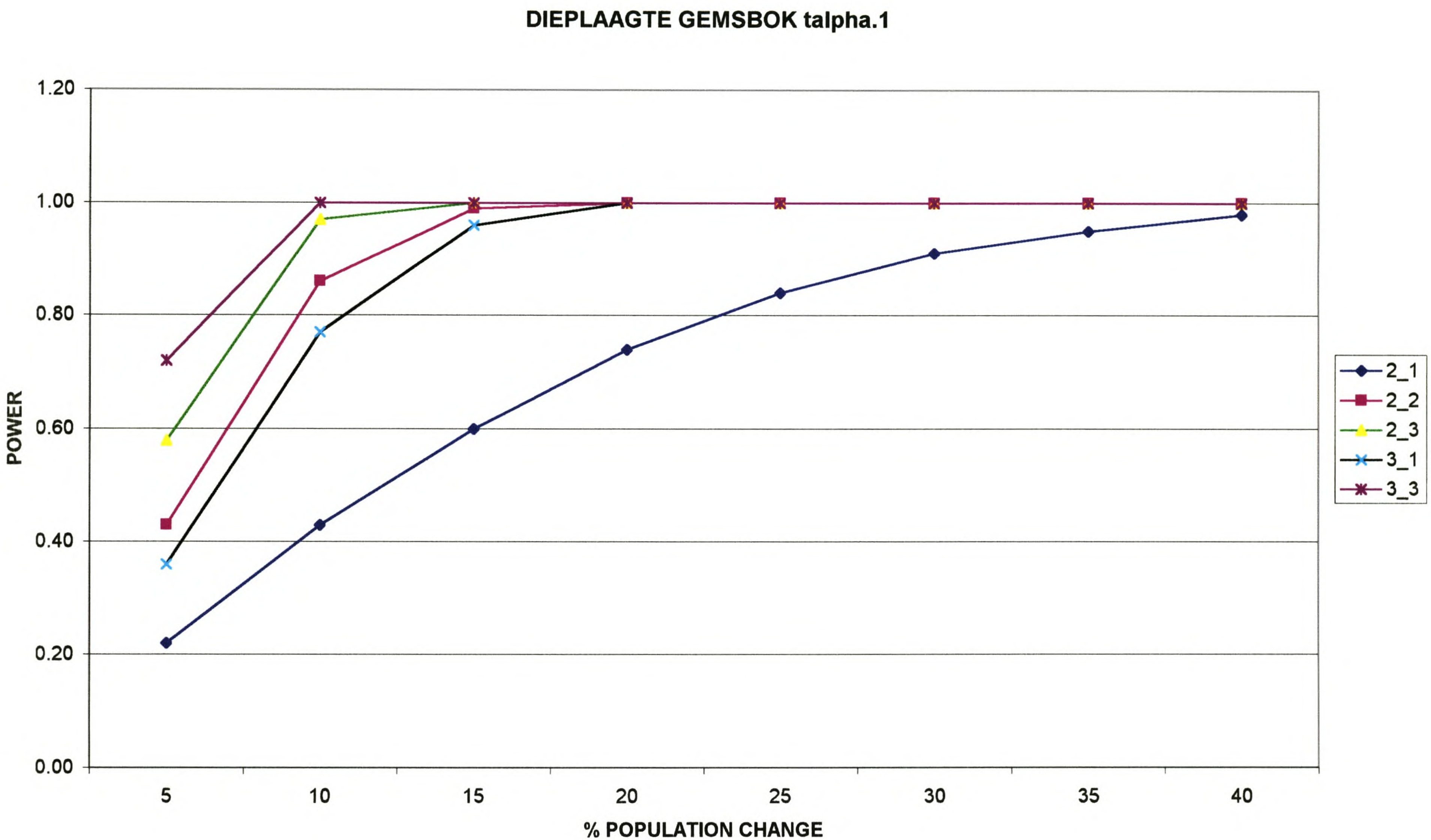


Figure 55: Power curves for various count replicate options at 10% significance for gemsbok on the farm Dieplaagte, northwest arid bushveld.

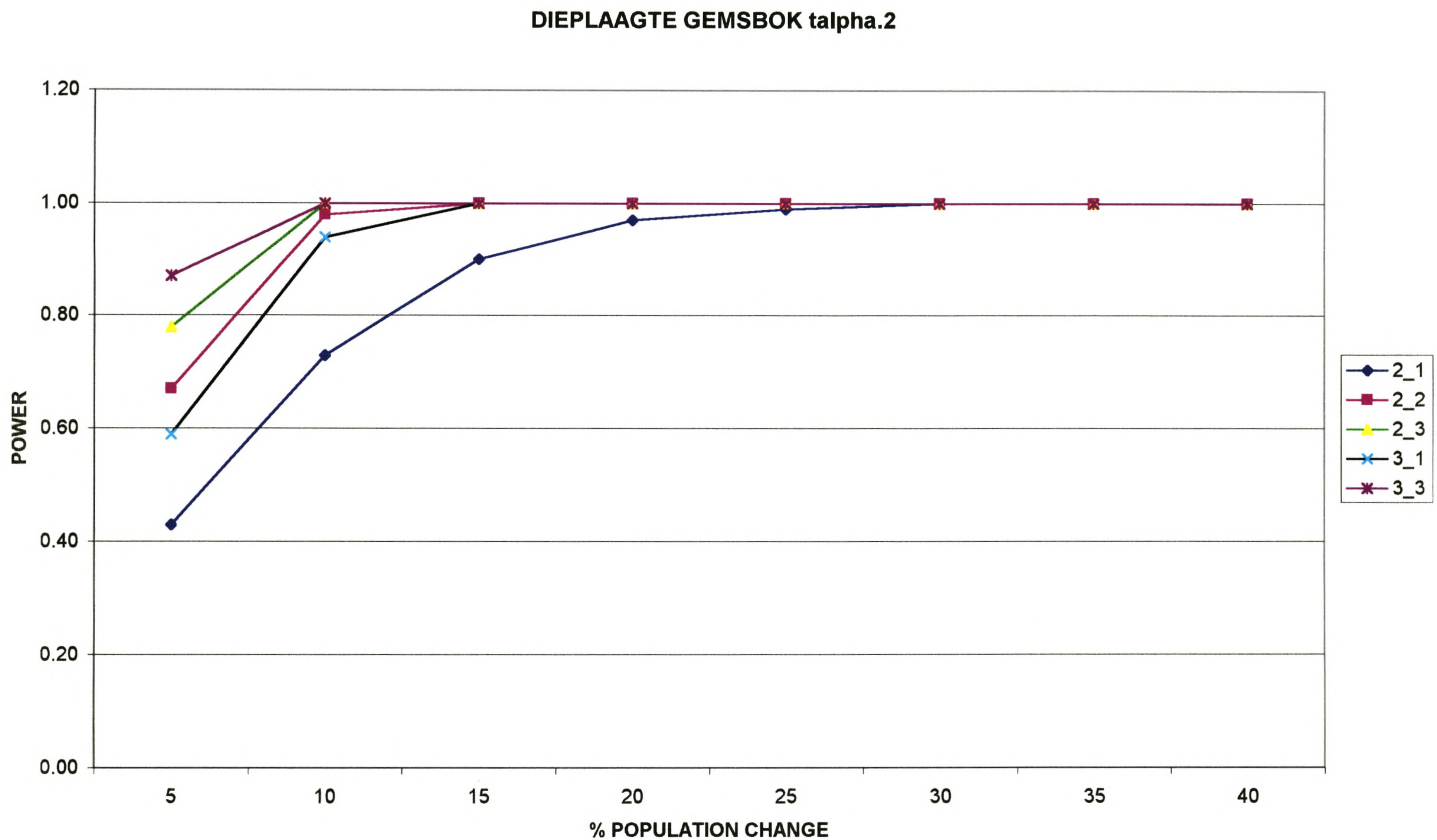


Figure 56 Power curves for various count replicate options at 20% significance for gemsbok on the farm Dieplaagte, northwest arid bushveld.

Table 56: Summary statistics of three replicate helicopter counts of the farm Elandskloof, northwest arid bushveld.

| SPECIES | COUNT REPLICATES | | | MEAN | STANDARD | STANDARD |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | | DEVIATION(n2) | DEVIATION(n3) |
| *KUDU* | **132** | **116** | **108** | 118.7 | 10.12 | 9.99 |
| *ZEBRA* | **37** | **39** | **30** | 35.3 | 3.94 | 3.89 |
| *WILDEBEEST* | **219** | **185** | **230** | 211.3 | 19.17 | 19.16 |
| *IMPALA* | **477** | **346** | **477** | 433.3 | 61.41 | 61.55 |
| *WARTHOG* | **87** | **79** | **32** | 66.0 | 19.78 | 19.95 |
| *GEMSBOK* | **79** | **91** | **71** | 80.3 | 8.26 | 8.21 |
| *OSTRICH* | **40** | **32** | **47** | 39.7 | 6.18 | 6.14 |
| *BLESBOK* | **96** | **77** | **58** | 77.0 | 18.80 | 18.02 |
| *WATERBUCK* | **18** | **23** | **29** | 23.3 | 4.53 | 4.53 |

| SPECIES | SEdiff21 | SEdiff22 | SEdiff23 | SEdiff31 | SEdiff33 |
|---|---|---|---|---|---|
| *KUDU* | 12.39 | 10.12 | 9.24 | 11.54 | 8.16 |
| *ZEBRA* | 4.83 | 3.94 | 3.60 | 4.49 | 3.18 |
| *WILDEBEEST* | 23.48 | 19.17 | 17.50 | 22.12 | 15.64 |
| *IMPALA* | 75.21 | 61.41 | 56.06 | 71.07 | 50.26 |
| *WARTHOG* | 24.23 | 19.78 | 18.06 | 23.04 | 16.29 |
| *SABLE* | 10.12 | 8.26 | 7.54 | 9.48 | 6.70 |
| *WHITE RHINO* | 7.57 | 6.18 | 5.64 | 7.09 | 5.01 |
| *MT.REEDBUCK* | 23.03 | 18.80 | 17.16 | 20.81 | 14.71 |
| *GIRAFFE* | 5.55 | 4.53 | 4.14 | 5.23 | 3.70 |

Table 57: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for kudu on the farm Elandskloof, northwest arid bushveld.

| KUDU | | MEAN | | 118.7 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 5.94 | 11.87 | 17.81 | 23.74 | 29.68 | 35.61 | 41.55 | 47.48 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.48 | 0.96 | 1.44 | 1.92 | 2.39 | 2.87 | 3.35 | 3.83 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.59 | 1.17 | 1.76 | 2.35 | 2.93 | 3.52 | 4.11 | 4.69 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.64 | 1.28 | 1.93 | 2.57 | 3.21 | 3.85 | 4.50 | 5.14 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.51 | 1.03 | 1.54 | 2.06 | 2.57 | 3.09 | 3.60 | 4.12 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.73 | 1.46 | 2.18 | 2.91 | 3.64 | 4.37 | 5.09 | 5.82 |

Table 58: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for kudu at 10% and 20% significance on the farm Elandskloof, northwest arid bushveld.

talpha.1 KUDU

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.09 | 0.13 | 0.18 | 0.24 | 0.29 | 0.35 | 0.40 | 0.45 |
| **2_2** | 0.11 | 0.20 | 0.33 | 0.47 | 0.60 | 0.72 | 0.82 | 0.89 |
| **2_3** | 0.13 | 0.26 | 0.44 | 0.63 | 0.78 | 0.89 | 0.95 | 0.98 |
| **3_1** | 0.10 | 0.18 | 0.28 | 0.40 | 0.52 | 0.64 | 0.74 | 0.82 |
| **3_3** | 0.15 | 0.33 | 0.56 | 0.77 | 0.91 | 0.97 | 0.99 | 1.00 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.17 | 0.26 | 0.35 | 0.45 | 0.54 | 0.62 | 0.70 | 0.76 |
| **2_2** | 0.21 | 0.37 | 0.54 | 0.71 | 0.83 | 0.92 | 0.96 | 0.99 |
| **2_3** | 0.23 | 0.43 | 0.64 | 0.81 | 0.92 | 0.97 | 0.99 | 1.00 |
| **3_1** | 0.19 | 0.33 | 0.48 | 0.63 | 0.76 | 0.86 | 0.92 | 0.96 |
| **3_3** | 0.27 | 0.51 | 0.75 | 0.90 | 0.97 | 0.99 | 1.00 | 1.00 |

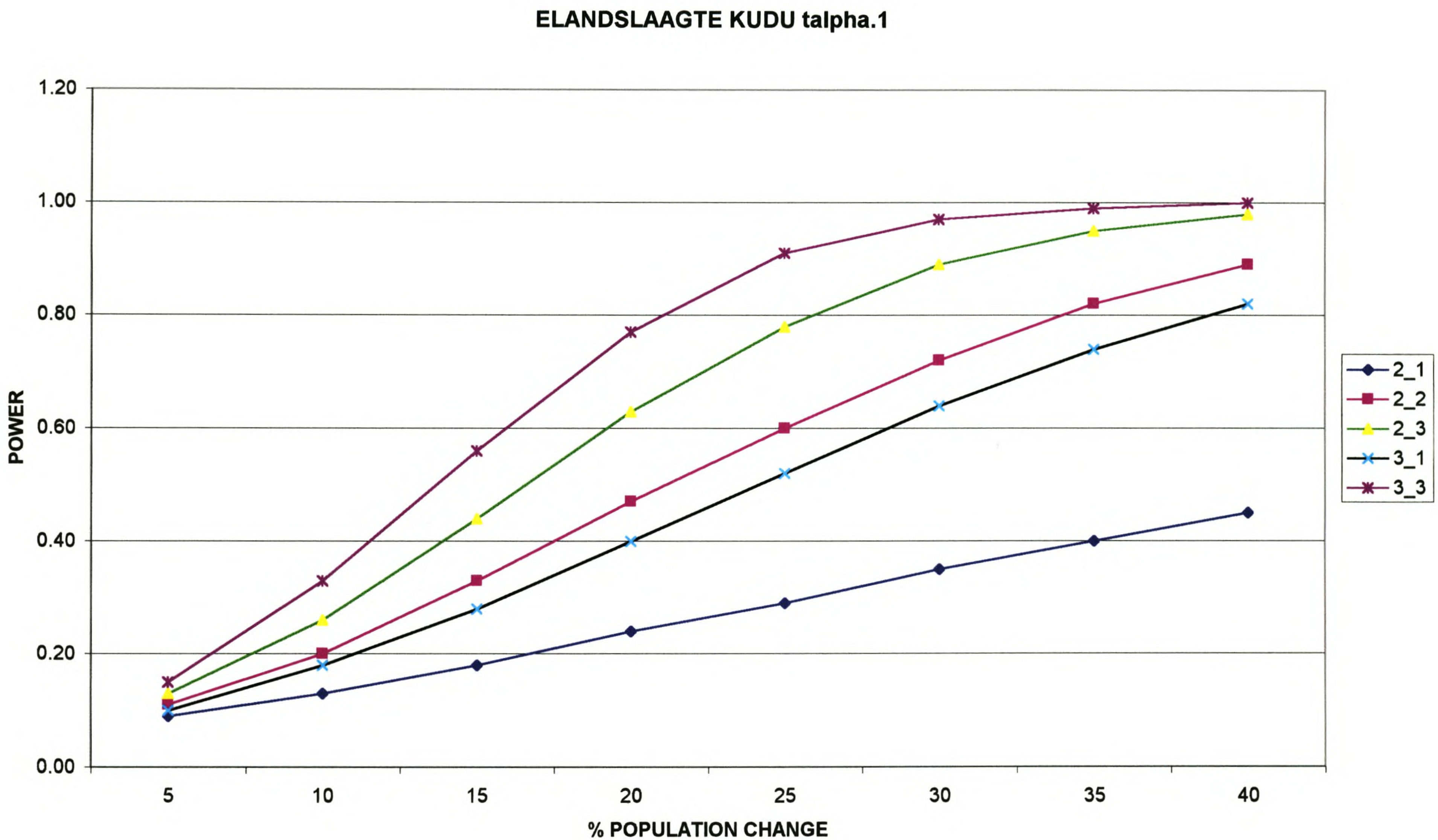


Figure 57: Power curves for various count replicate options at 10% significance for kudu on the farm Elandskloof, northwest arid bushveld.

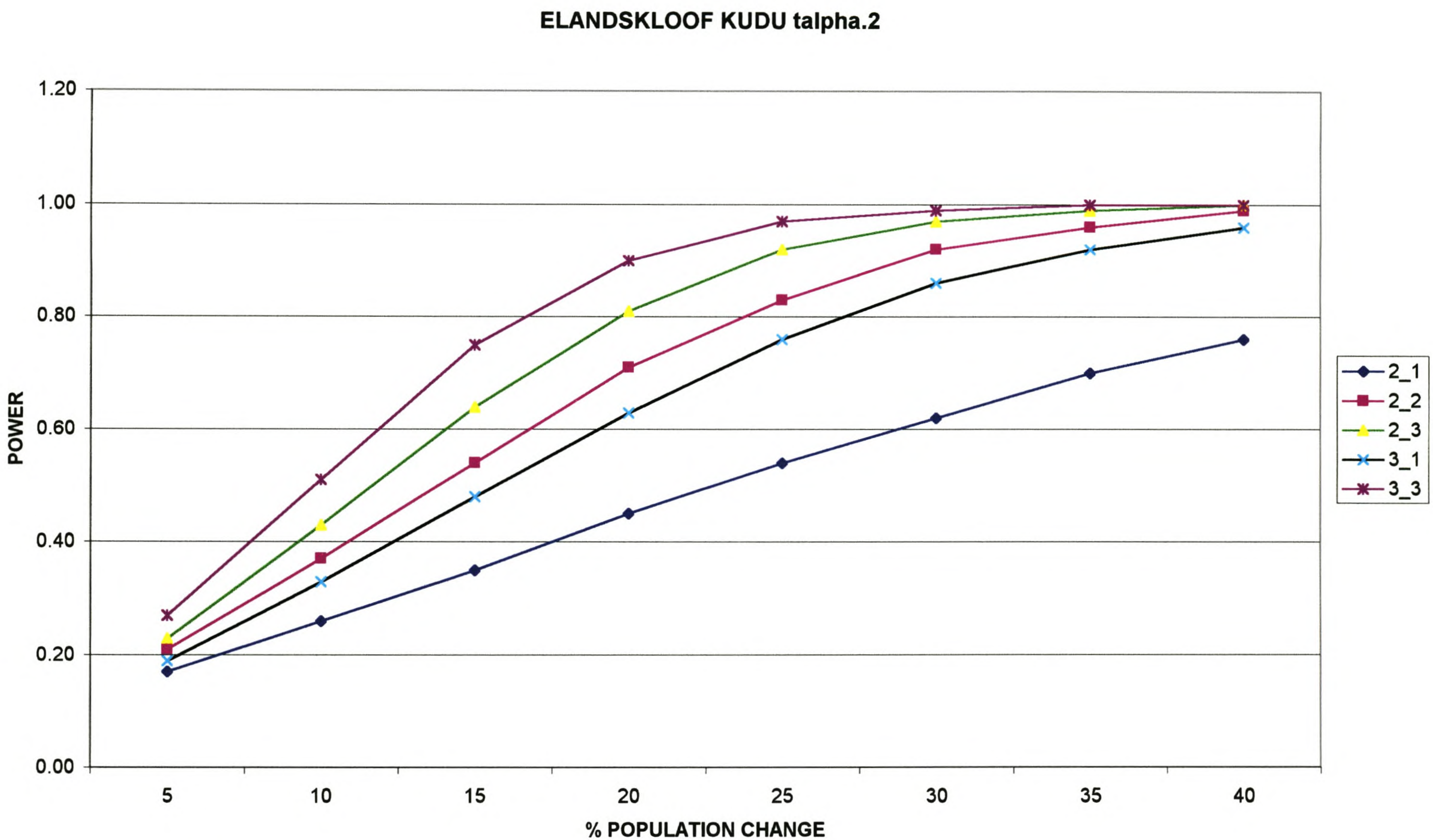


Figure 58: Power curves for various replicate options at 20% significance for kudu on the farm Elandskloof, northwest arid bushveld.

Table 59: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for zebra on the farm Elandskloof, northwest arid bushveld.

| ZEBRA | | MEAN | 35.30 | | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 1.77 | 3.53 | 5.30 | 7.06 | 8.83 | 10.59 | 12.36 | 14.12 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.37 | 0.73 | 1.10 | 1.46 | 1.83 | 2.19 | 2.56 | 2.93 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.45 | 0.90 | 1.34 | 1.79 | 2.24 | 2.69 | 3.14 | 3.58 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.49 | 0.98 | 1.47 | 1.96 | 2.45 | 2.94 | 3.44 | 3.93 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.39 | 0.79 | 1.18 | 1.57 | 1.96 | 2.36 | 2.75 | 3.14 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.56 | 1.11 | 1.67 | 2.22 | 2.78 | 3.33 | 3.89 | 4.45 |

Table 60: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for zebra at 10% and 20% significance on the farm Ealndskloof, northwest arid bushveld.

talpha.1 ZEBRA

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.08 | 0.11 | 0.15 | 0.18 | 0.23 | 0.27 | 0.31 | 0.35 |
| **2_2** | 0.09 | 0.16 | 0.24 | 0.34 | 0.44 | 0.55 | 0.65 | 0.73 |
| **2_3** | 0.11 | 0.19 | 0.31 | 0.45 | 0.59 | 0.72 | 0.83 | 0.90 |
| **3_1** | 0.09 | 0.14 | 0.21 | 0.29 | 0.37 | 0.47 | 0.56 | 0.65 |
| **3_3** | 0.12 | 0.24 | 0.40 | 0.58 | 0.74 | 0.86 | 0.93 | 0.97 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.15 | 0.21 | 0.28 | 0.36 | 0.43 | 0.50 | 0.57 | 0.63 |
| **2_2** | 0.18 | 0.29 | 0.42 | 0.55 | 0.68 | 0.79 | 0.87 | 0.92 |
| **2_3** | 0.20 | 0.33 | 0.49 | 0.65 | 0.79 | 0.88 | 0.95 | 0.98 |
| **3_1** | 0.17 | 0.26 | 0.37 | 0.49 | 0.60 | 0.71 | 0.80 | 0.87 |
| **3_3** | 0.22 | 0.39 | 0.58 | 0.76 | 0.88 | 0.95 | 0.98 | 1.00 |

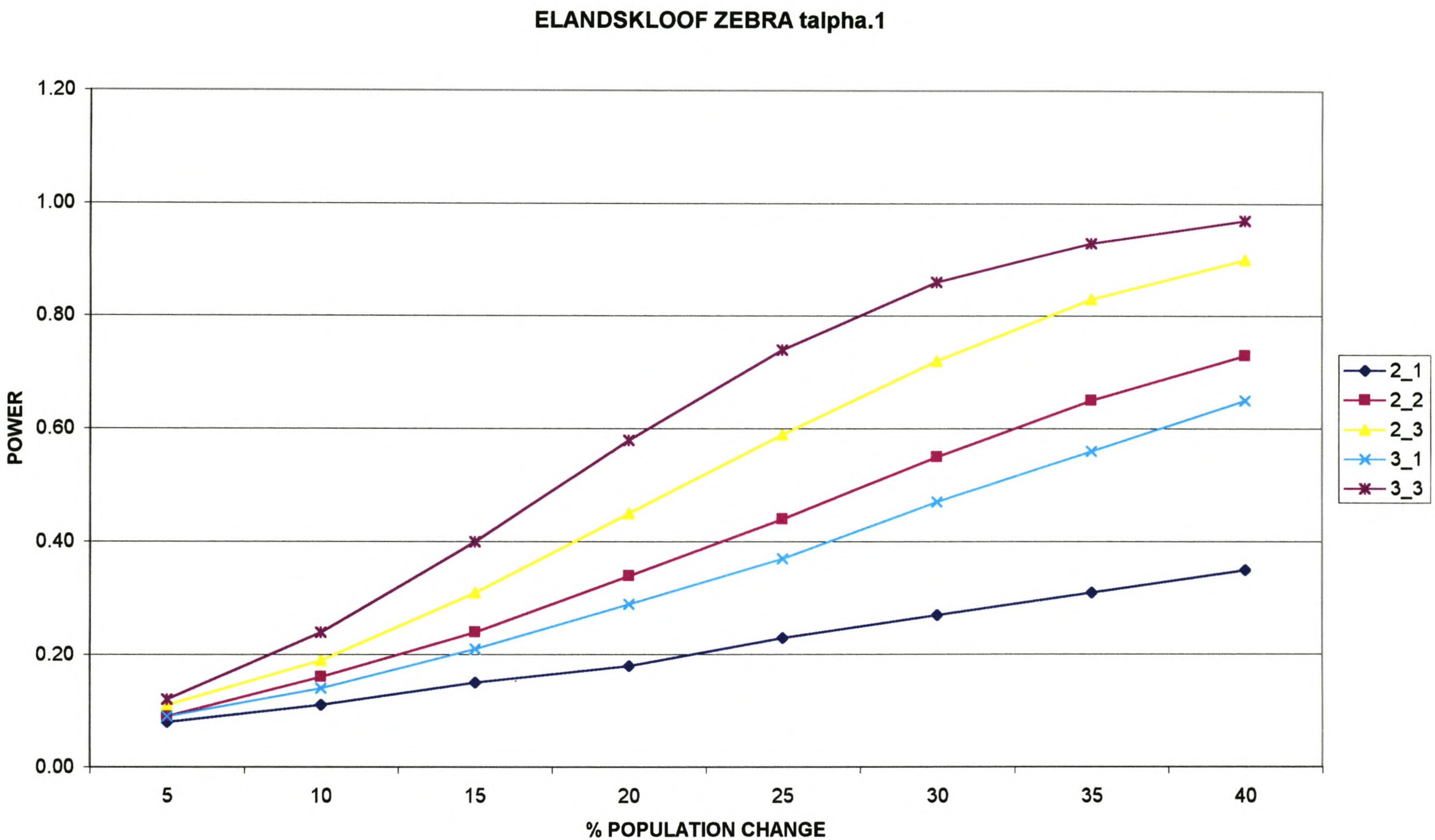


Figure 59: Power curves for various count replicate options at 10% significance for zebra on the farm Elandskloof, northwest arid bushveld.

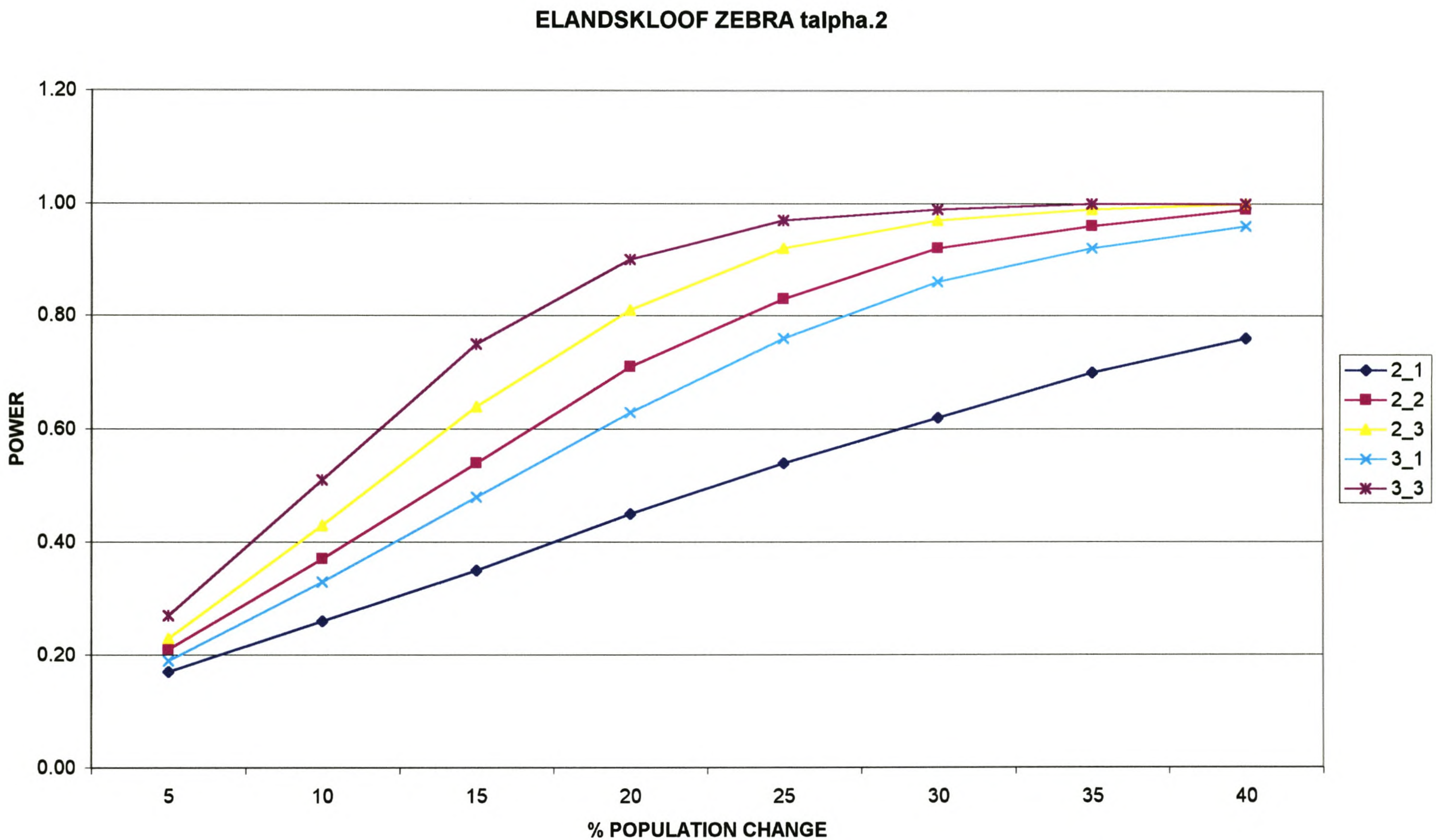


Figure 60: Power curves for various count replicate options at 20% significance for zebra on the farm Elandskloof, northwest arid bushveld.

Table 61: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for wildebeest on the farm Elandskloof, northwest arid bushveld.

| WILDEBEEST | | | MEAN | 211.30 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 10.57 | 21.13 | 31.70 | 42.26 | 52.83 | 63.39 | 73.96 | 84.52 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.45 | 0.90 | 1.35 | 1.80 | 2.25 | 2.70 | 3.15 | 3.60 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.55 | 1.10 | 1.65 | 2.20 | 2.76 | 3.31 | 3.86 | 4.41 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.60 | 1.21 | 1.81 | 2.41 | 3.02 | 3.62 | 4.23 | 4.83 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.48 | 0.96 | 1.43 | 1.91 | 2.39 | 2.87 | 3.34 | 3.82 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.68 | 1.35 | 2.03 | 2.70 | 3.38 | 4.05 | 4.73 | 5.40 |

Table 62: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for wildebeest at 10% and 20% significance on the farm Ealndskloof, northwest arid bushveld.

talpha.1 WILDEBEEST

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.08 | 0.12 | 0.17 | 0.22 | 0.28 | 0.33 | 0.38 | 0.43 |
| **2_2** | 0.11 | 0.19 | 0.30 | 0.43 | 0.56 | 0.68 | 0.78 | 0.86 |
| **2_3** | 0.12 | 0.24 | 0.41 | 0.58 | 0.74 | 0.86 | 0.93 | 0.97 |
| **3_1** | 0.10 | 0.17 | 0.26 | 0.36 | 0.48 | 0.59 | 0.69 | 0.77 |
| **3_3** | 0.14 | 0.30 | 0.51 | 0.72 | 0.87 | 0.95 | 0.98 | 1.00 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.16 | 0.24 | 0.33 | 0.43 | 0.51 | 0.60 | 0.67 | 0.73 |
| **2_2** | 0.20 | 0.35 | 0.51 | 0.67 | 0.80 | 0.89 | 0.95 | 0.98 |
| **2_3** | 0.22 | 0.40 | 0.60 | 0.78 | 0.90 | 0.96 | 0.99 | 1.00 |
| **3_1** | 0.19 | 0.31 | 0.44 | 0.59 | 0.72 | 0.82 | 0.90 | 0.94 |
| **3_3** | 0.25 | 0.47 | 0.70 | 0.87 | 0.96 | 0.99 | 1.00 | 1.00 |

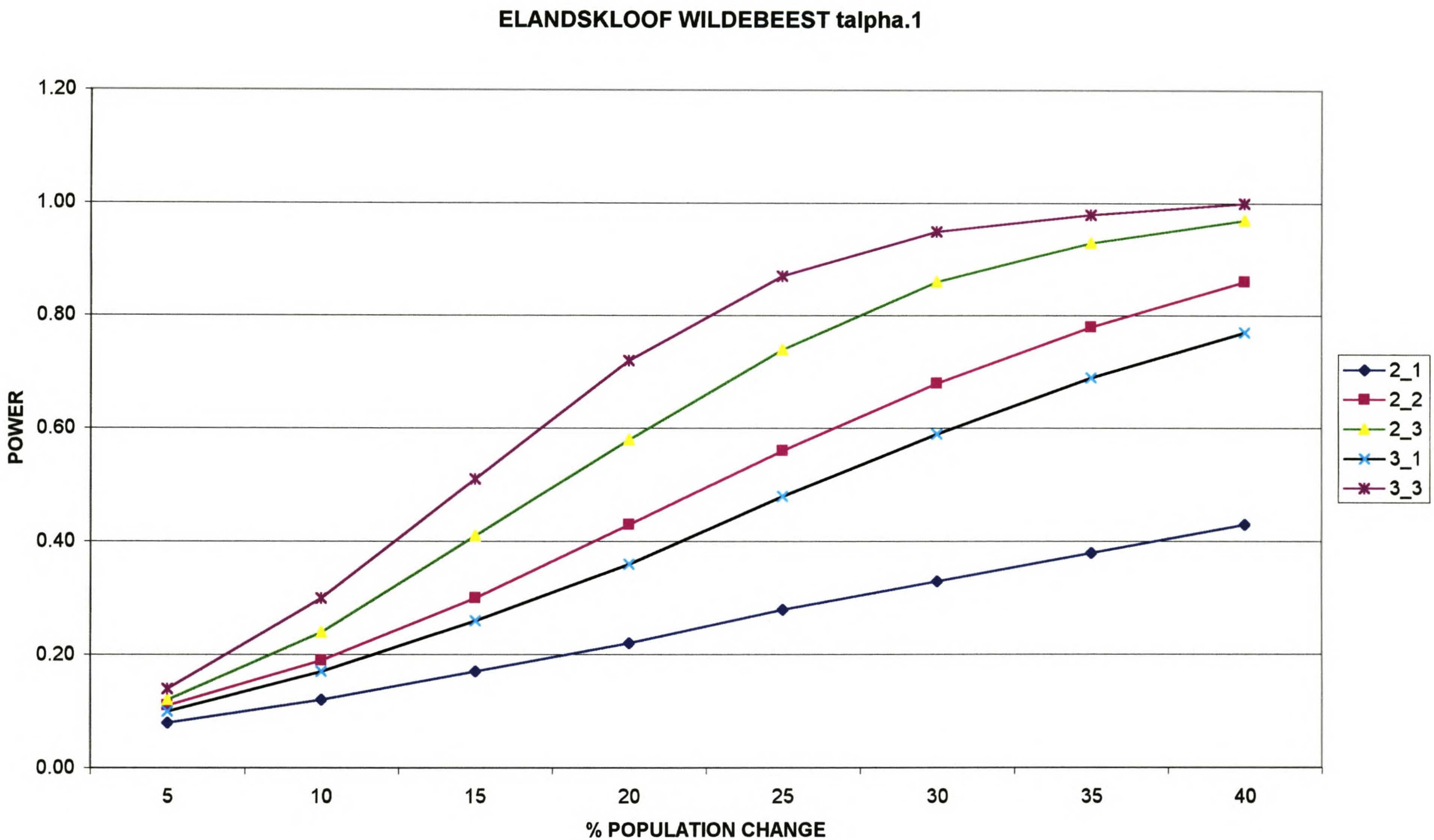


Figure 61: Power curves for various count replicate options at 10% significance for wildebeest on the farm Elandskloof, northwest arid bushveld.

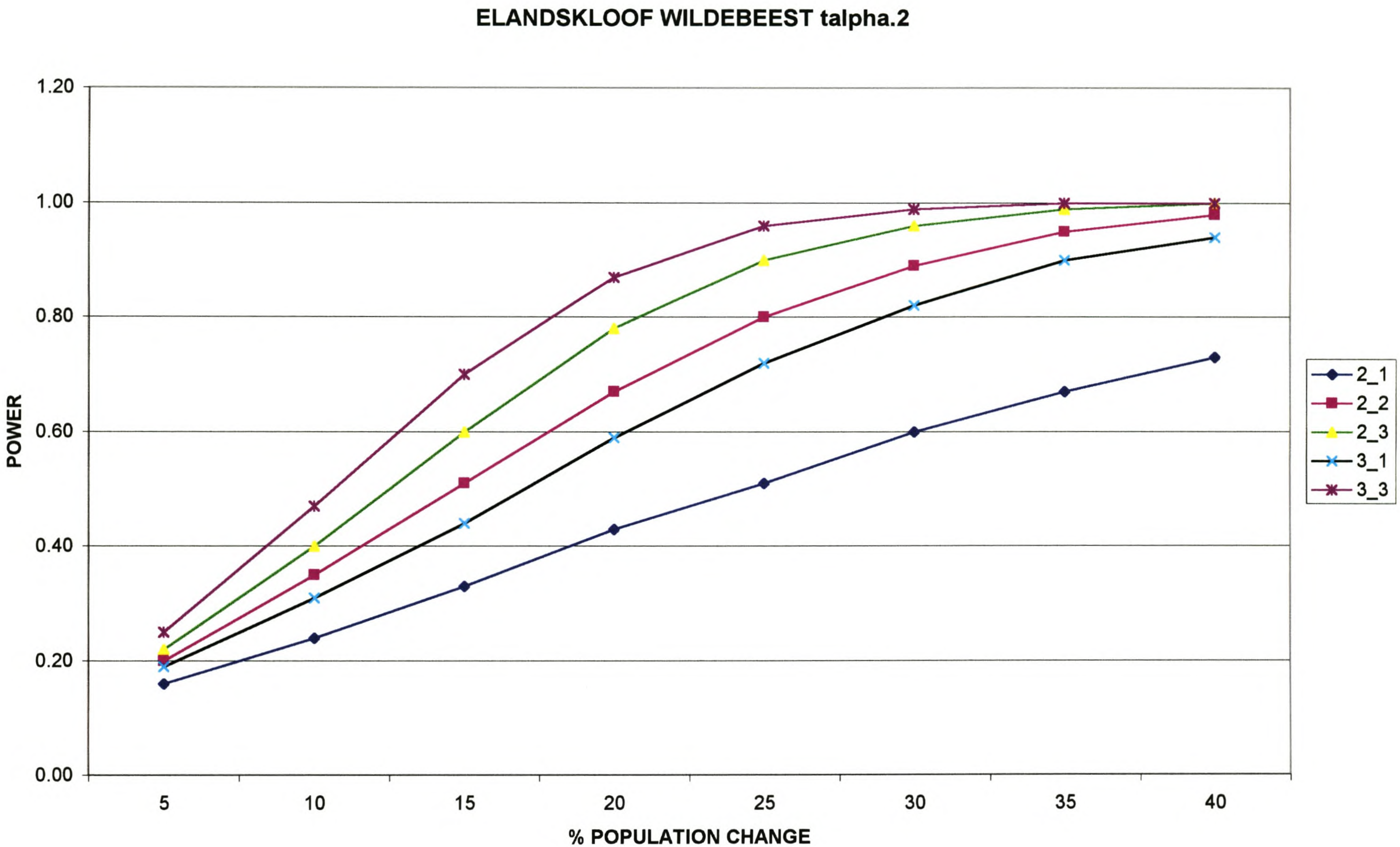


Figure 62: Power curves for various count replicate options at 20% significance for wildewildebeest on the farm Elandskloof, northwest arid bushveld.

Table 63: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for impala on the farm Elandskloof, northwest arid bushveld.

| IMPALA | | MEAN | 433.30 | | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 21.67 | 43.33 | 65.00 | 86.66 | 108.33 | 129.99 | 151.66 | 173.32 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.29 | 0.58 | 0.86 | 1.15 | 1.44 | 1.73 | 2.02 | 2.30 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.35 | 0.71 | 1.06 | 1.41 | 1.76 | 2.12 | 2.47 | 2.82 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.39 | 0.77 | 1.16 | 1.55 | 1.93 | 2.32 | 2.71 | 3.09 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.30 | 0.61 | 0.91 | 1.22 | 1.52 | 1.83 | 2.13 | 2.44 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.43 | 0.86 | 1.29 | 1.72 | 2.16 | 2.59 | 3.02 | 3.45 |

**Table 64**: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for impala at 10% and 20% significance on the farm Ealndskloof, northwest arid bushveld.

talpha.1 IMPALA

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.07 | 0.09 | 0.12 | 0.15 | 0.18 | 0.22 | 0.25 | 0.28 |
| **2_2** | 0.08 | 0.13 | 0.18 | 0.25 | 0.33 | 0.41 | 0.50 | 0.58 |
| **2_3** | 0.09 | 0.15 | 0.23 | 0.33 | 0.44 | 0.56 | 0.66 | 0.76 |
| **3_1** | 0.08 | 0.11 | 0.16 | 0.21 | 0.28 | 0.34 | 0.41 | 0.49 |
| **3_3** | 0.10 | 0.18 | 0.29 | 0.41 | 0.56 | 0.69 | 0.80 | 0.88 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.14 | 0.19 | 0.24 | 0.29 | 0.35 | 0.41 | 0.47 | 0.52 |
| **2_2** | 0.16 | 0.24 | 0.33 | 0.44 | 0.54 | 0.65 | 0.74 | 0.81 |
| **2_3** | 0.17 | 0.27 | 0.39 | 0.52 | 0.64 | 0.75 | 0.84 | 0.91 |
| **3_1** | 0.15 | 0.22 | 0.29 | 0.38 | 0.47 | 0.56 | 0.65 | 0.73 |
| **3_3** | 0.19 | 0.31 | 0.45 | 0.60 | 0.74 | 0.85 | 0.92 | 0.96 |

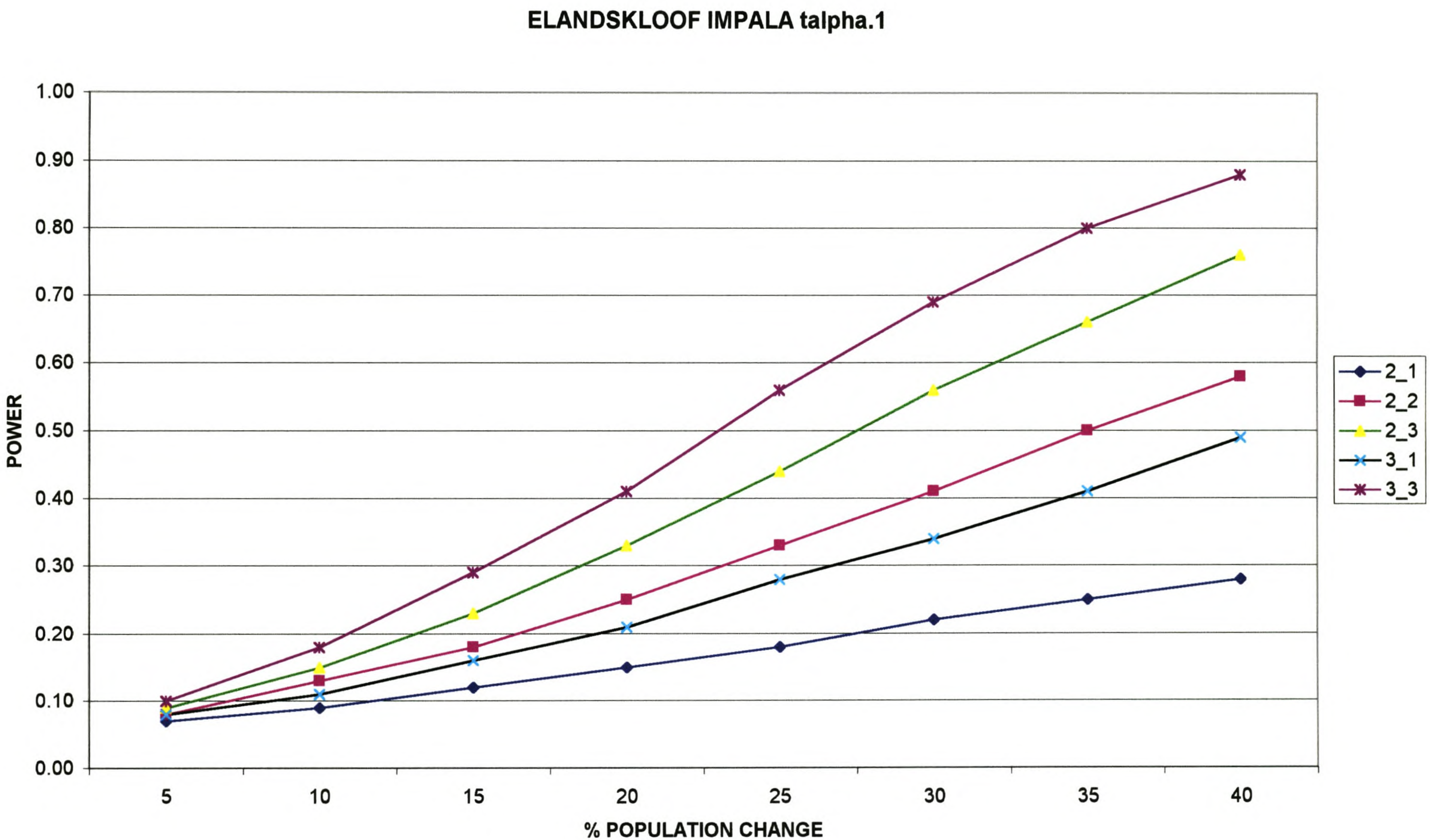


Figure 63: Power curves for various count replicate options at 10% significance for impala on the farm Elandskloof, northwest arid bushveld.

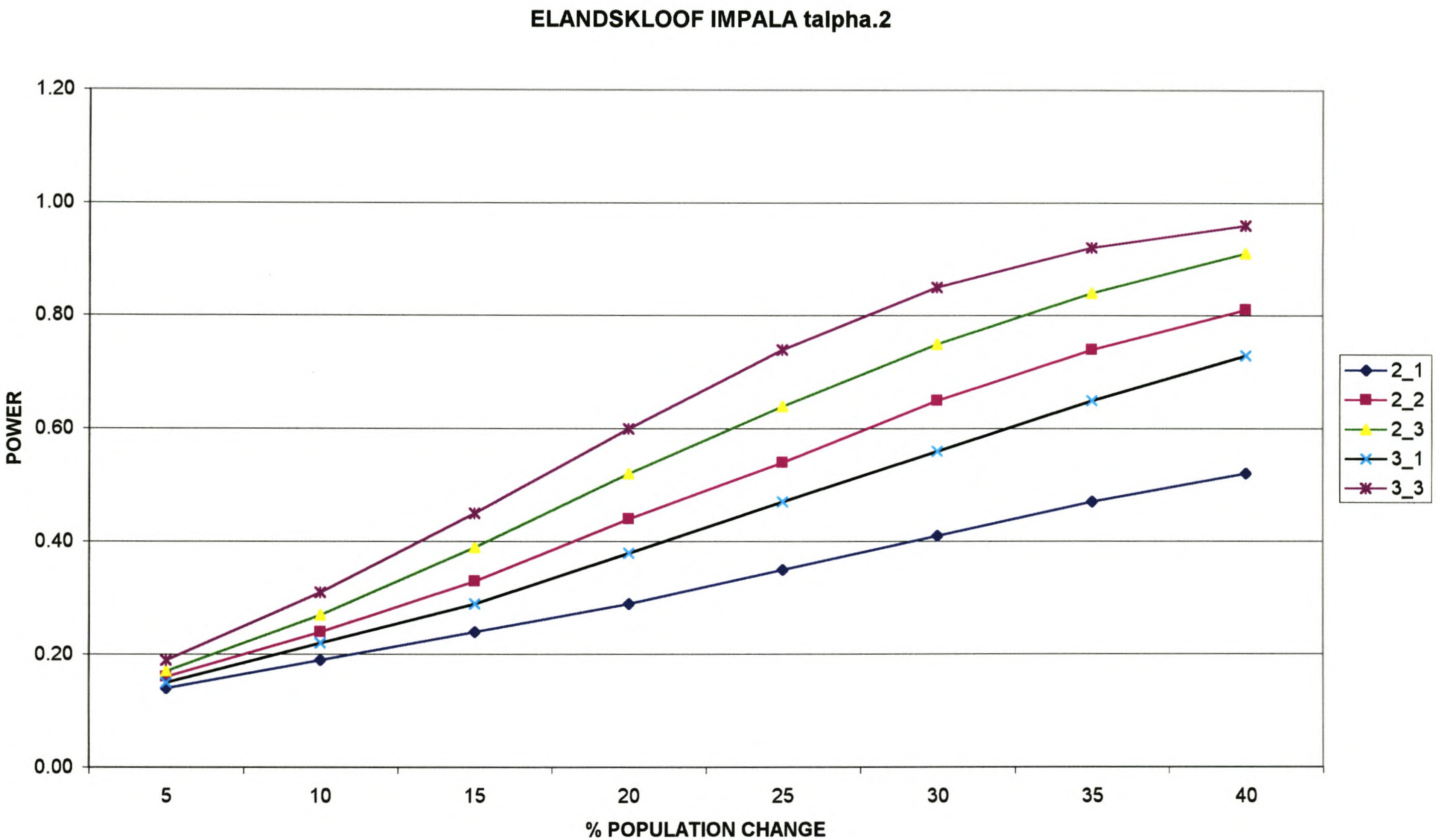


Figure 64: Power curves for various count replicate options at 20% significance for impala on the farm Elandskloof, northwest arid bushveld.

Table 65: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for warthog on the farm Elandskloof, northwest arid bushveld.

| WARTHOG | | | MEAN | 66 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 3.30 | 6.60 | 9.90 | 13.20 | 16.50 | 19.80 | 23.10 | 26.40 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.14 | 0.27 | 0.41 | 0.54 | 0.68 | 0.82 | 0.95 | 1.09 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.17 | 0.33 | 0.50 | 0.67 | 0.83 | 1.00 | 1.17 | 1.33 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.18 | 0.37 | 0.55 | 0.73 | 0.91 | 1.10 | 1.28 | 1.46 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.14 | 0.29 | 0.43 | 0.57 | 0.72 | 0.86 | 1.00 | 1.15 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.20 | 0.41 | 0.61 | 0.81 | 1.01 | 1.22 | 1.42 | 1.62 |

Table 66: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for warthog at 10% and 20% significance on the farm Ealndskloof, northwest arid bushveld.

talpha.1 WARTHOG

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.06 | 0.07 | 0.08 | 0.09 | 0.10 | 0.12 | 0.13 | 0.14 |
| **2_2** | 0.06 | 0.08 | 0.10 | 0.12 | 0.15 | 0.17 | 0.20 | 0.24 |
| **2_3** | 0.07 | 0.09 | 0.11 | 0.14 | 0.18 | 0.22 | 0.26 | 0.31 |
| **3_1** | 0.06 | 0.08 | 0.09 | 0.11 | 0.13 | 0.15 | 0.17 | 0.20 |
| **3_3** | 0.07 | 0.10 | 0.13 | 0.17 | 0.21 | 0.27 | 0.32 | 0.38 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.12 | 0.14 | 0.16 | 0.18 | 0.20 | 0.23 | 0.25 | 0.28 |
| **2_2** | 0.13 | 0.16 | 0.19 | 0.23 | 0.27 | 0.32 | 0.37 | 0.41 |
| **2_3** | 0.13 | 0.17 | 0.21 | 0.26 | 0.31 | 0.37 | 0.43 | 0.49 |
| **3_1** | 0.12 | 0.15 | 0.18 | 0.21 | 0.24 | 0.28 | 0.32 | 0.36 |
| **3_3** | 0.14 | 0.18 | 0.23 | 0.29 | 0.35 | 0.43 | 0.50 | 0.57 |

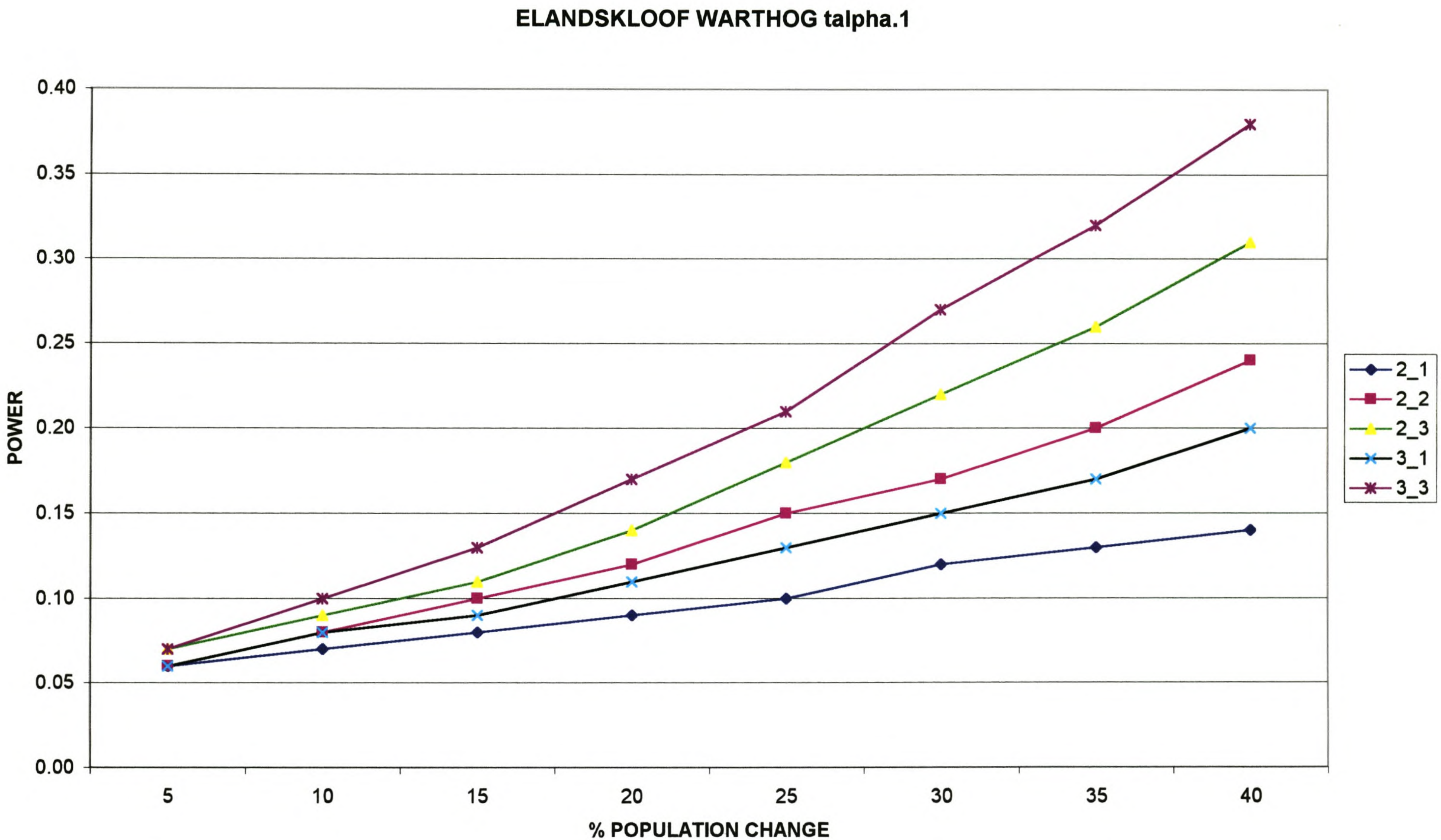


Figure 65: Power curves for various count replicate options at 10% significance for warthog on the farm Elandskloof, northwest arid bushveld.

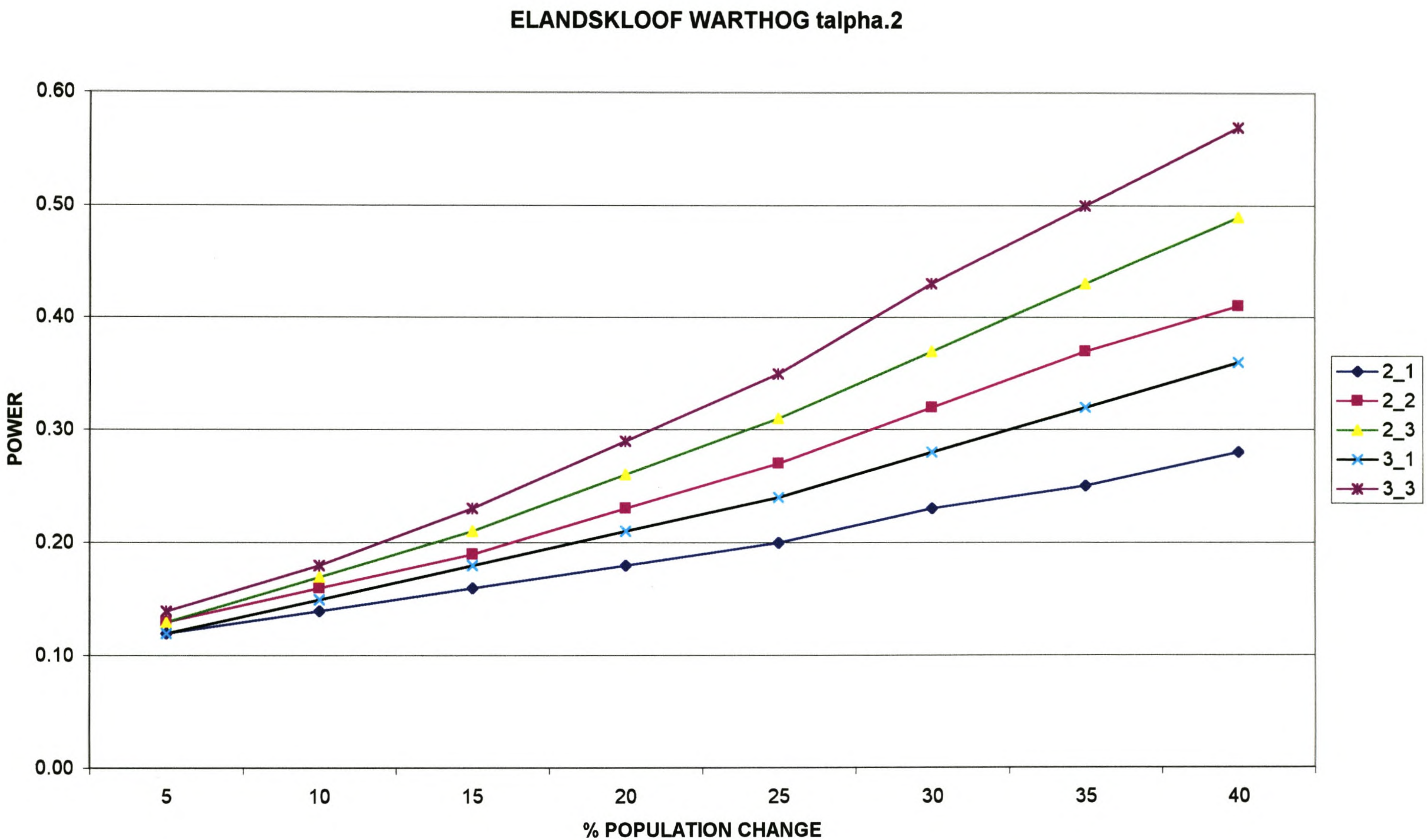


Figure 66: Power curves for various count replicate options at 20% significance for warthog on the farm Elandskloof, northwest arid bushveld.

Table 67: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for gemsbok on the farm Elandskloof, northwest arid bushveld.

| GEMSBOK | | | MEAN | 80.30 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 4.02 | 8.03 | 12.05 | 16.06 | 20.08 | 24.09 | 28.11 | 32.12 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.40 | 0.79 | 1.19 | 1.59 | 1.98 | 2.38 | 2.78 | 3.18 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.49 | 0.97 | 1.46 | 1.94 | 2.43 | 2.92 | 3.40 | 3.89 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.53 | 1.06 | 1.60 | 2.13 | 2.66 | 3.19 | 3.73 | 4.26 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.42 | 0.85 | 1.27 | 1.69 | 2.12 | 2.54 | 2.96 | 3.39 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.60 | 1.20 | 1.80 | 2.40 | 2.99 | 3.59 | 4.19 | 4.79 |

Table 68: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for gemsbok at 10% and 20% significance on the farm Ealndskloof, northwest arid bushveld.

talpha.1 GEMSBOK

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.08 | 0.11 | 0.15 | 0.20 | 0.24 | 0.29 | 0.34 | 0.38 |
| **2_2** | 0.10 | 0.17 | 0.26 | 0.37 | 0.49 | 0.60 | 0.70 | 0.79 |
| **2_3** | 0.11 | 0.21 | 0.35 | 0.50 | 0.65 | 0.78 | 0.87 | 0.93 |
| **3_1** | 0.09 | 0.15 | 0.22 | 0.31 | 0.41 | 0.51 | 0.61 | 0.70 |
| **3_3** | 0.13 | 0.26 | 0.44 | 0.63 | 0.79 | 0.90 | 0.96 | 0.99 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.16 | 0.22 | 0.30 | 0.38 | 0.46 | 0.54 | 0.61 | 0.67 |
| **2_2** | 0.19 | 0.31 | 0.45 | 0.60 | 0.73 | 0.83 | 0.90 | 0.95 |
| **2_3** | 0.21 | 0.36 | 0.54 | 0.70 | 0.83 | 0.92 | 0.97 | 0.99 |
| **3_1** | 0.18 | 0.28 | 0.40 | 0.52 | 0.65 | 0.75 | 0.84 | 0.90 |
| **3_3** | 0.23 | 0.42 | 0.63 | 0.80 | 0.91 | 0.97 | 0.99 | 1.00 |

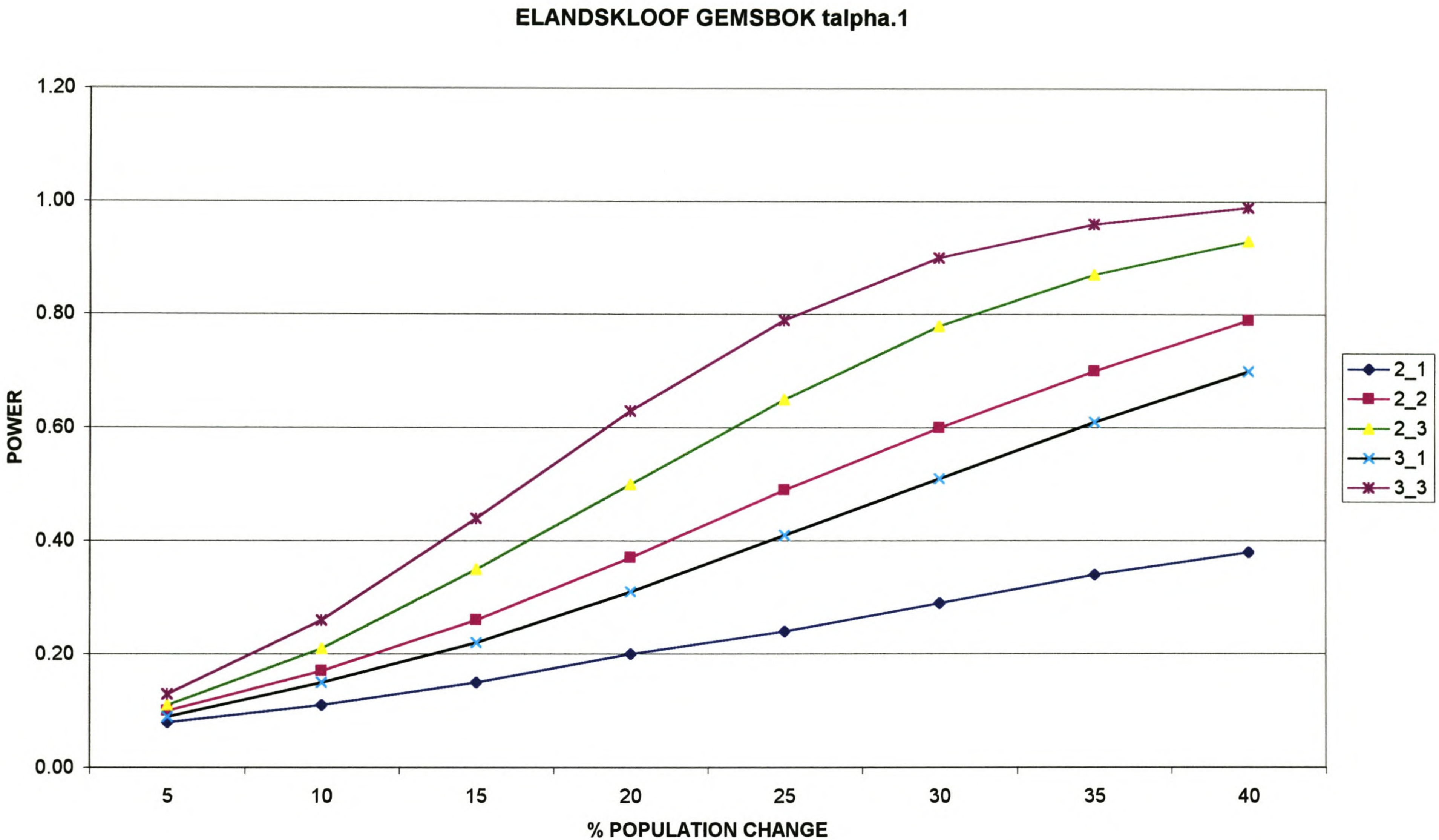


Figure 67: Power curves for various count replicate options at 10% significance for gemsbok on the farm Elandskloof, northwest arid bushveld.

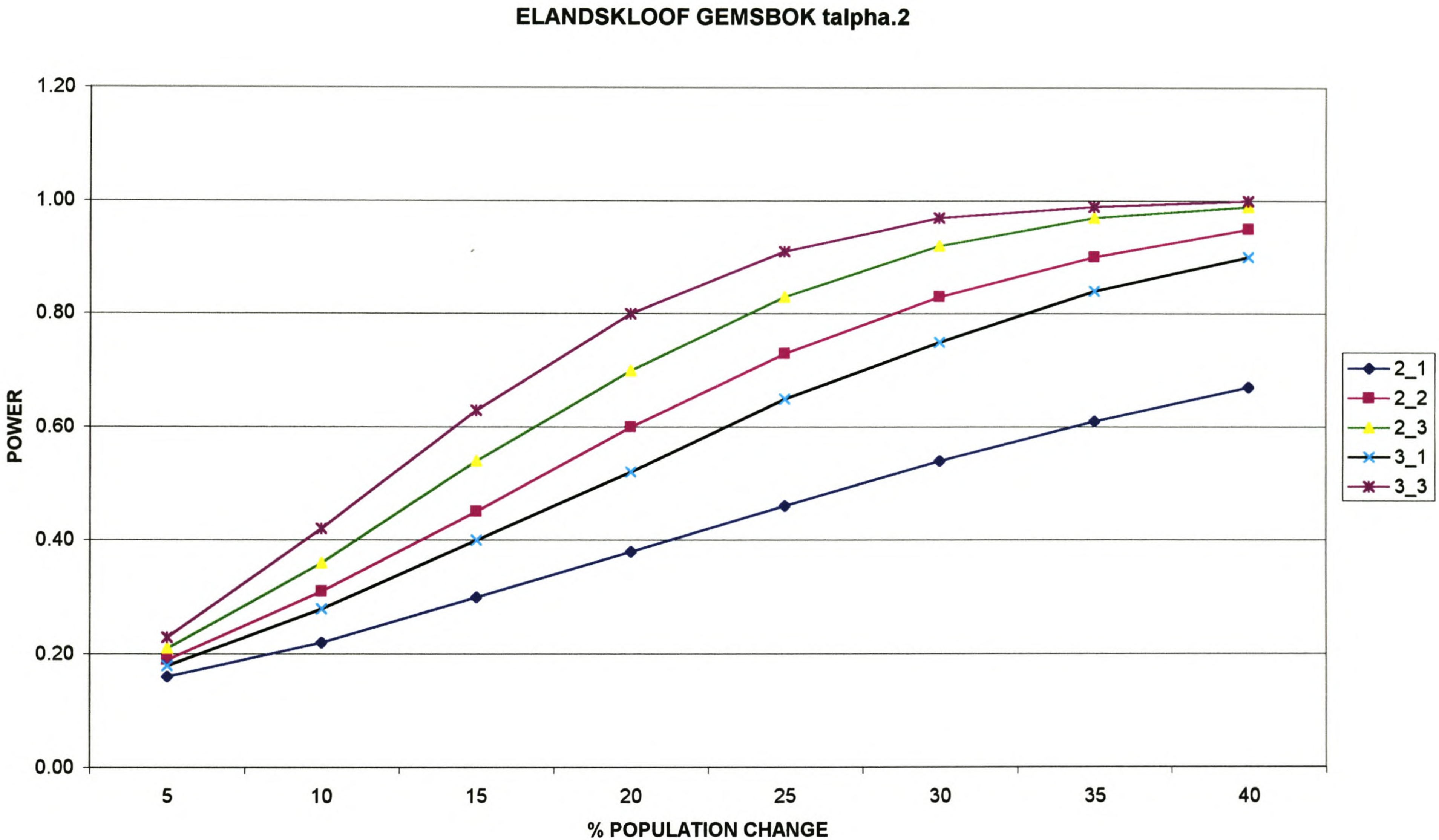


Figure 68: Power curves for various count replicate options at 20% significance for gemsbok on the farm Elandskloof, northwest arid bushveld.

Table 69: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for ostrich on the farm Elandskloof, northwest arid bushveld.

| OSTRICH | | MEAN | 39.70 | | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 1.99 | 3.97 | 5.96 | 7.94 | 9.93 | 11.91 | 13.90 | 15.88 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.26 | 0.52 | 0.79 | 1.05 | 1.31 | 1.57 | 1.84 | 2.10 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.32 | 0.64 | 0.96 | 1.28 | 1.61 | 1.93 | 2.25 | 2.57 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.35 | 0.70 | 1.06 | 1.41 | 1.76 | 2.11 | 2.46 | 2.81 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.28 | 0.56 | 0.84 | 1.12 | 1.40 | 1.68 | 1.96 | 2.24 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.40 | 0.79 | 1.19 | 1.58 | 1.98 | 2.38 | 2.77 | 3.17 |

Table 70: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for ostrich at 10% and 20% significance on the farm Ealndskloof, northwest arid bushveld.

talpha.1 OSTRICH

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.07 | 0.09 | 0.11 | 0.14 | 0.17 | 0.20 | 0.23 | 0.26 |
| **2_2** | 0.08 | 0.12 | 0.17 | 0.23 | 0.29 | 0.37 | 0.44 | 0.52 |
| **2_3** | 0.09 | 0.14 | 0.21 | 0.29 | 0.39 | 0.49 | 0.60 | 0.69 |
| **3_1** | 0.07 | 0.11 | 0.15 | 0.19 | 0.25 | 0.31 | 0.37 | 0.44 |
| **3_3** | 0.10 | 0.16 | 0.26 | 0.37 | 0.50 | 0.62 | 0.74 | 0.83 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.14 | 0.18 | 0.22 | 0.27 | 0.33 | 0.38 | 0.43 | 0.48 |
| **2_2** | 0.16 | 0.22 | 0.31 | 0.40 | 0.50 | 0.59 | 0.68 | 0.76 |
| **2_3** | 0.16 | 0.25 | 0.36 | 0.47 | 0.59 | 0.70 | 0.79 | 0.86 |
| **3_1** | 0.15 | 0.21 | 0.27 | 0.35 | 0.43 | 0.52 | 0.60 | 0.68 |
| **3_3** | 0.18 | 0.28 | 0.42 | 0.55 | 0.69 | 0.80 | 0.88 | 0.94 |

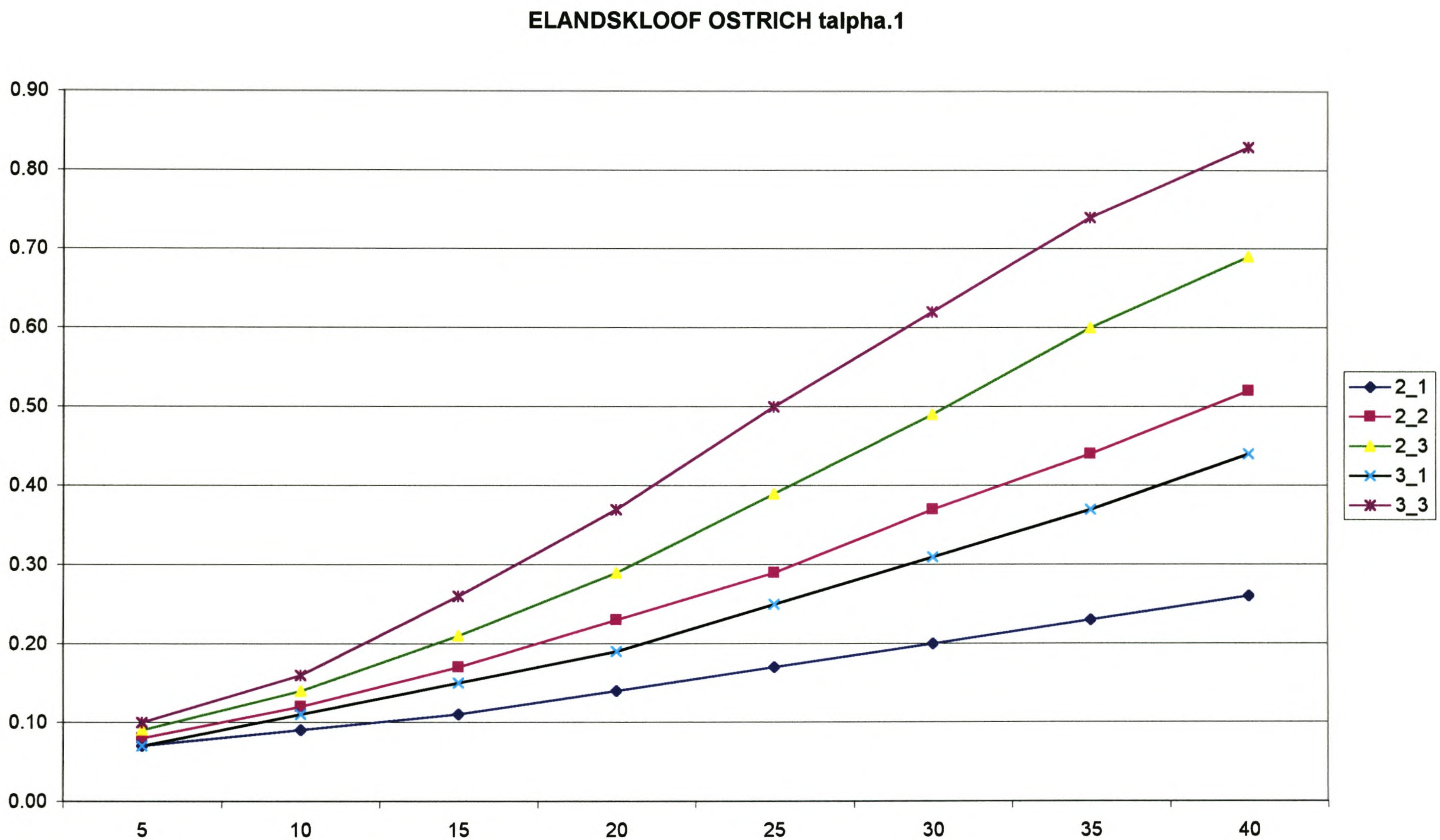


Figure 69: Power curves for various count replicate options at 10% significance for ostrich on the farm Elandskloof, northwest arid bushveld.

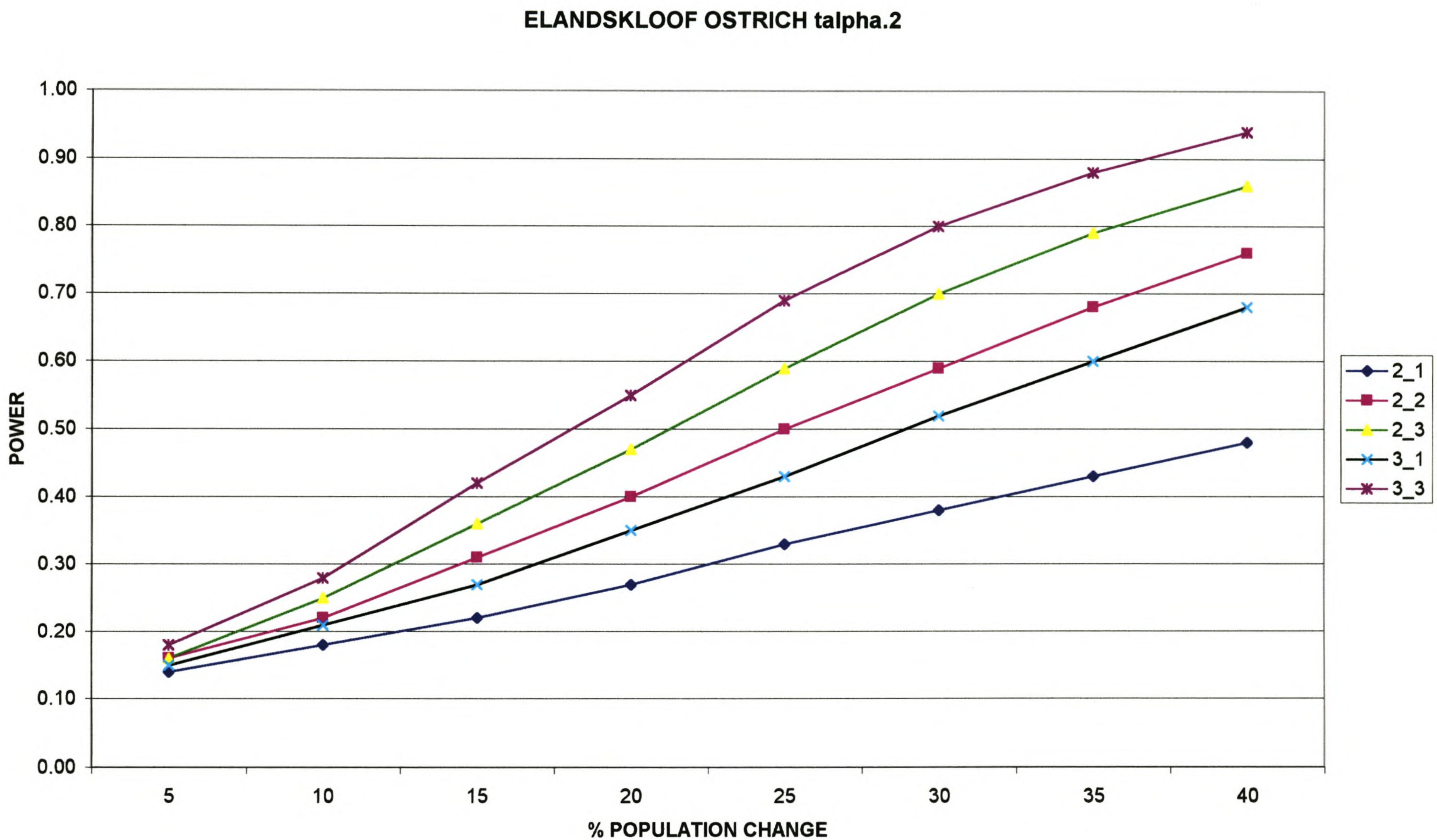


Figure 70: Power curves for various count replicate options at 20% significance for ostrich on the farm Elandskloof, northwest arid bushveld.

Table 71: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for blesbok on the farm Elandskloof, northwest arid bushveld.

| BLESBOK | | | MEAN | 39.7 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 1.99 | 3.97 | 5.96 | 7.94 | 9.93 | 11.91 | 13.90 | 15.88 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.09 | 0.17 | 0.26 | 0.34 | 0.43 | 0.52 | 0.60 | 0.69 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.11 | 0.21 | 0.32 | 0.42 | 0.53 | 0.63 | 0.74 | 0.84 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.12 | 0.23 | 0.35 | 0.46 | 0.58 | 0.69 | 0.81 | 0.93 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.10 | 0.19 | 0.29 | 0.38 | 0.48 | 0.57 | 0.67 | 0.76 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.13 | 0.27 | 0.40 | 0.54 | 0.67 | 0.81 | 0.94 | 1.08 |

Table 72: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for blesbok at 10% and 20% significance on the farm Ealndskloof, northwest arid bushveld.

talpha.1 BLESBOK

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.06 | 0.06 | 0.07 | 0.07 | 0.08 | 0.09 | 0.10 | 0.10 |
| **2_2** | 0.06 | 0.07 | 0.08 | 0.09 | 0.10 | 0.12 | 0.13 | 0.15 |
| **2_3** | 0.06 | 0.07 | 0.09 | 0.10 | 0.12 | 0.14 | 0.16 | 0.18 |
| **3_1** | 0.06 | 0.07 | 0.08 | 0.09 | 0.10 | 0.11 | 0.12 | 0.13 |
| **3_3** | 0.06 | 0.08 | 0.10 | 0.12 | 0.14 | 0.17 | 0.20 | 0.23 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.11 | 0.12 | 0.14 | 0.15 | 0.16 | 0.18 | 0.19 | 0.21 |
| **2_2** | 0.12 | 0.13 | 0.16 | 0.18 | 0.20 | 0.22 | 0.25 | 0.27 |
| **2_3** | 0.12 | 0.14 | 0.16 | 0.19 | 0.22 | 0.25 | 0.28 | 0.32 |
| **3_1** | 0.12 | 0.13 | 0.15 | 0.17 | 0.19 | 0.21 | 0.23 | 0.25 |
| **3_3** | 0.12 | 0.15 | 0.18 | 0.21 | 0.25 | 0.29 | 0.33 | 0.38 |

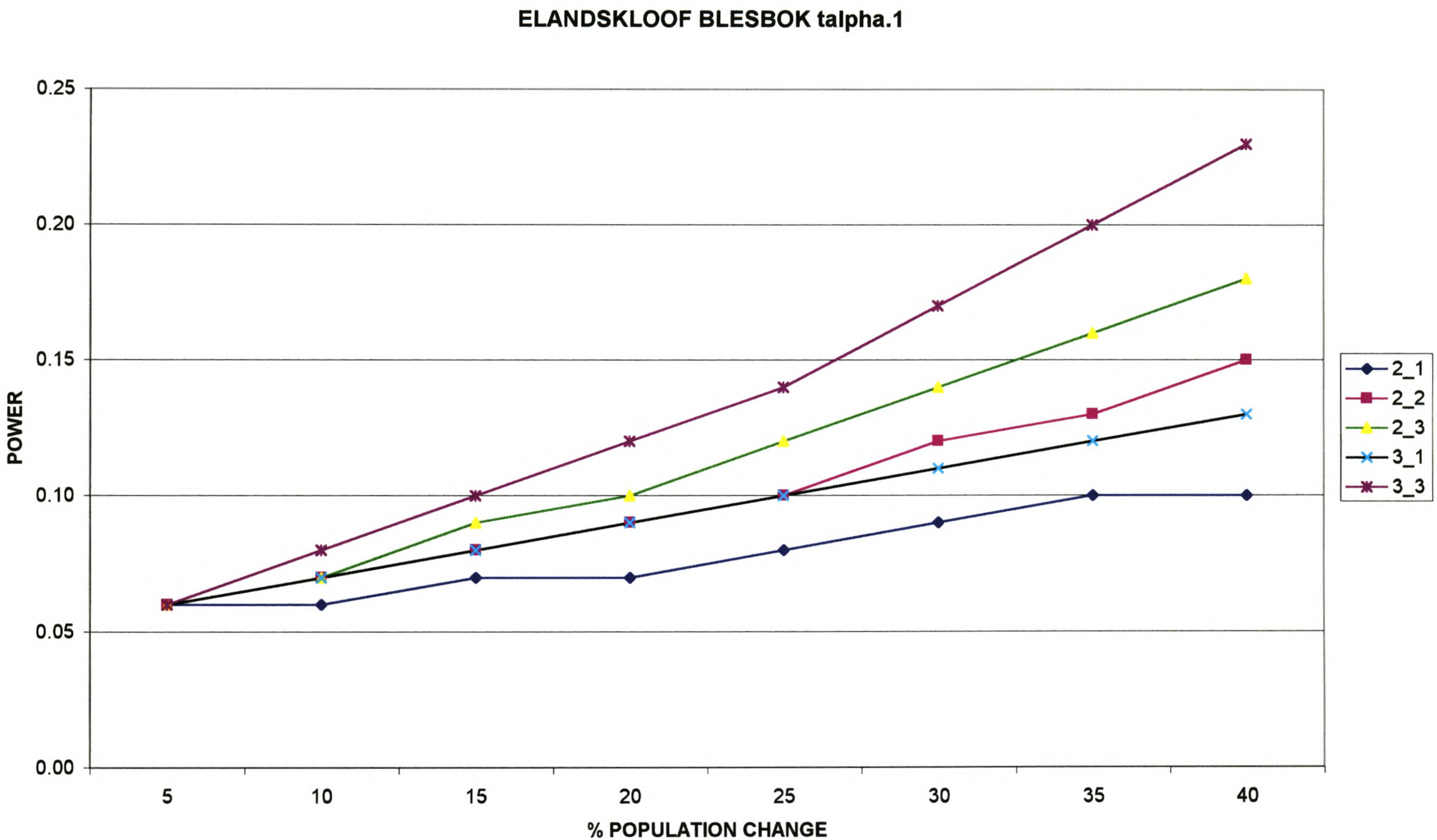


Figure 71: Power curves for various count replicate options at 10% for blesbok on the farm Elandskloof, northwest arid bushveld.

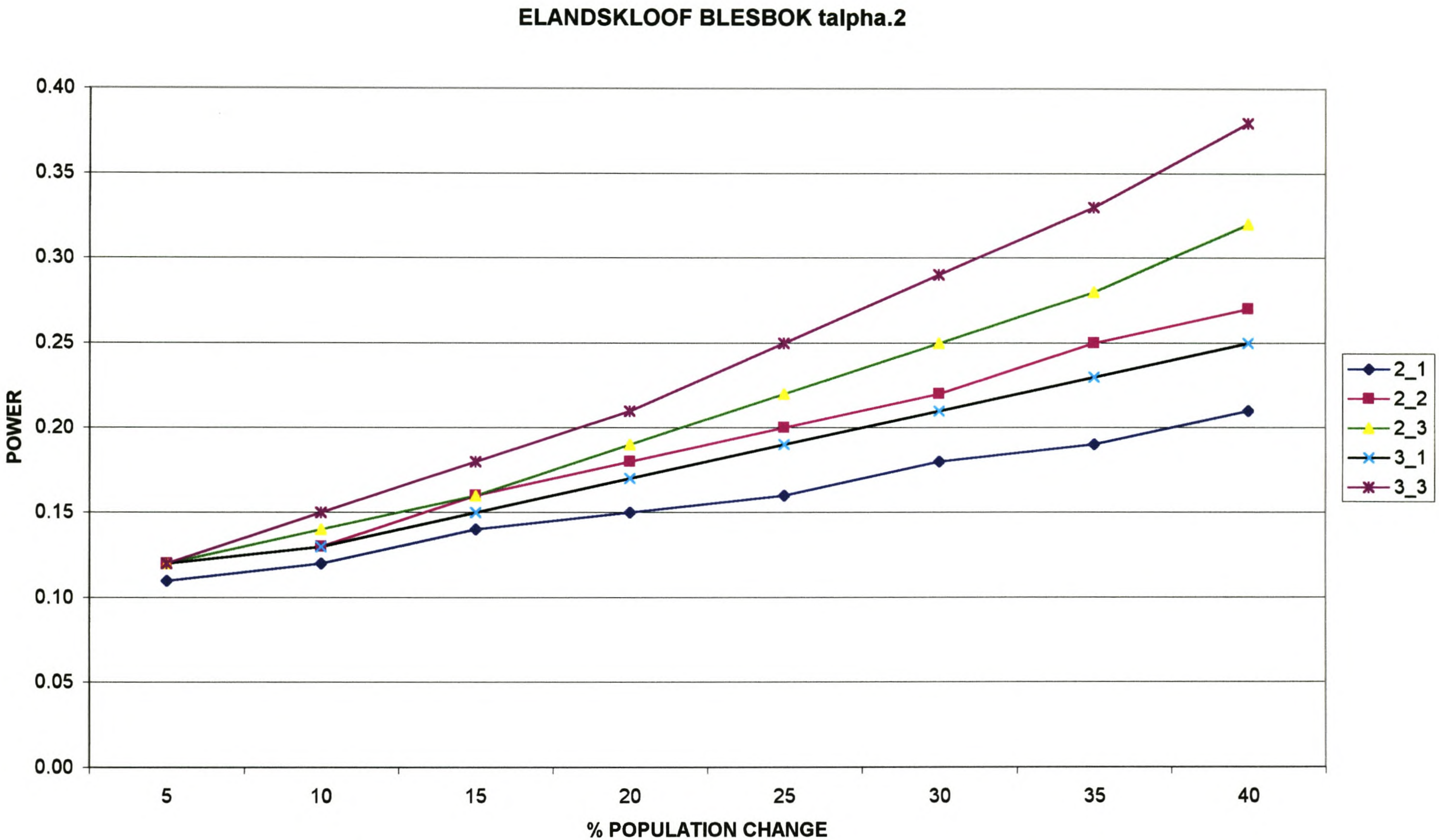


Figure 72: Power curves for various count replicate options at 20% significance for blesbok on the farm Elandskloof, northwest arid bushveld.

Table 73: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for waterbuck on the farm Elandskloof, northwest arid bushveld.

| WATERBUCK | | | MEAN | 77 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 3.85 | 7.70 | 11.55 | 15.40 | 19.25 | 23.10 | 26.95 | 30.80 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.69 | 1.39 | 2.08 | 2.78 | 3.47 | 4.16 | 4.86 | 5.55 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.85 | 1.70 | 2.55 | 3.40 | 4.25 | 5.10 | 5.95 | 6.80 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.93 | 1.86 | 2.79 | 3.72 | 4.66 | 5.59 | 6.52 | 7.45 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.74 | 1.47 | 2.21 | 2.94 | 3.68 | 4.42 | 5.15 | 5.89 |
| 3 | 3 | 4 | 2.13 | 1.53 | 1.04 | 2.08 | 3.12 | 4.16 | 5.20 | 6.25 | 7.29 | 8.33 |

Table 74: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for waterbuck at 10% and 20% significance on the farm Ealndskloof, northwest arid bushveld.

talpha.1 WATERBUCK

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.10 | 0.18 | 0.26 | 0.34 | 0.41 | 0.49 | 0.55 | 0.61 |
| **2_2** | 0.15 | 0.31 | 0.51 | 0.70 | 0.84 | 0.92 | 0.97 | 0.99 |
| **2_3** | 0.18 | 0.42 | 0.68 | 0.87 | 0.96 | 0.99 | 1.00 | 1.00 |
| **3_1** | 0.13 | 0.26 | 0.43 | 0.60 | 0.75 | 0.86 | 0.93 | 0.97 |
| **3_3** | 0.22 | 0.53 | 0.82 | 0.96 | 0.99 | 1.00 | 1.00 | 1.00 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.21 | 0.34 | 0.48 | 0.61 | 0.72 | 0.80 | 0.87 | 0.91 |
| **2_2** | 0.28 | 0.53 | 0.76 | 0.90 | 0.97 | 0.99 | 1.00 | 1.00 |
| **2_3** | 0.32 | 0.62 | 0.86 | 0.97 | 1.00 | 1.00 | 1.00 | 1.00 |
| **3_1** | 0.25 | 0.46 | 0.67 | 0.83 | 0.93 | 0.98 | 0.99 | 1.00 |
| **3_3** | 0.36 | 0.72 | 0.93 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 |

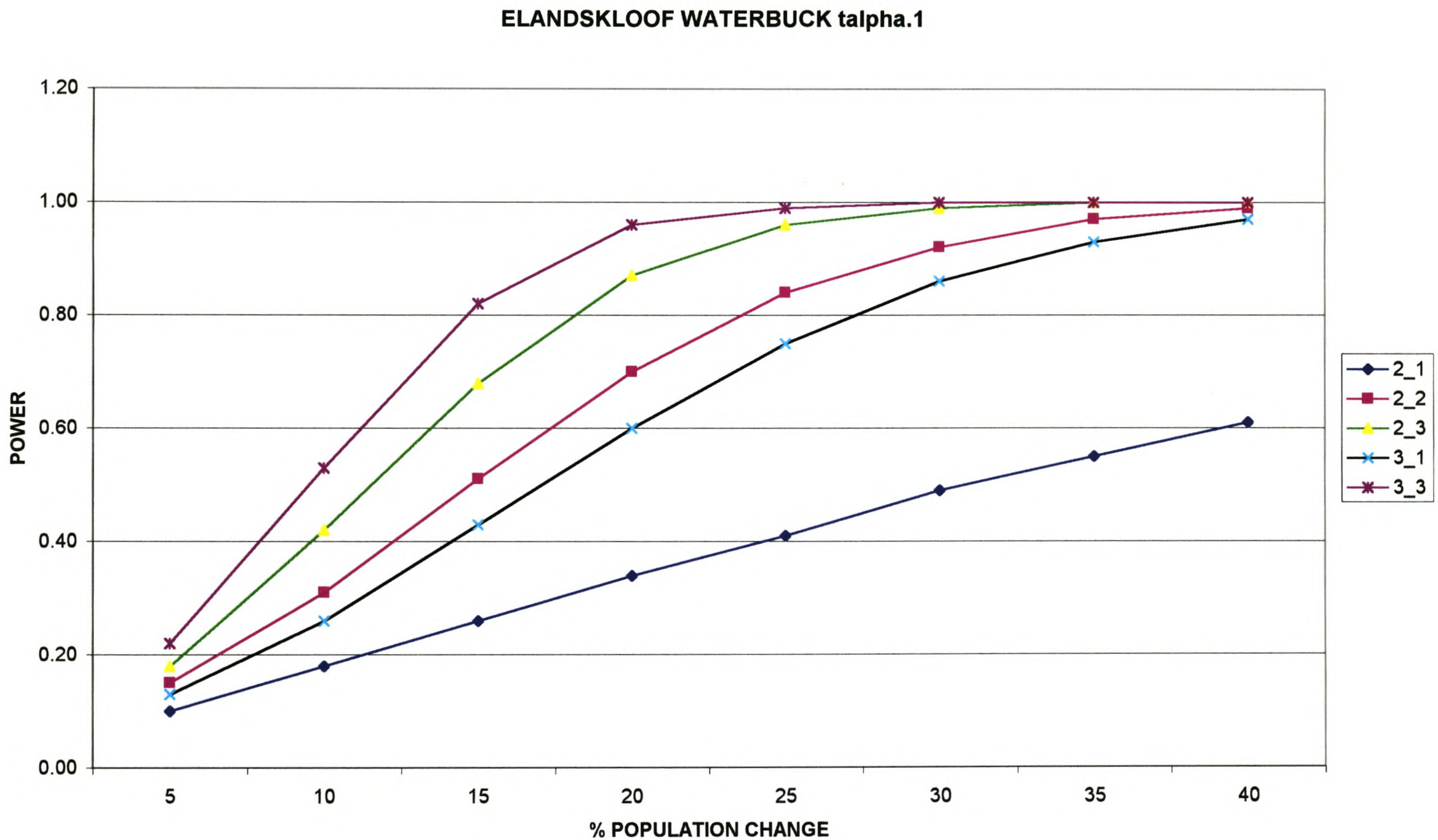


Figure 73: Power curves for various count replicate options at 10% significance for waterbuck on the farm Elandskloof, northwest arid bushveld.

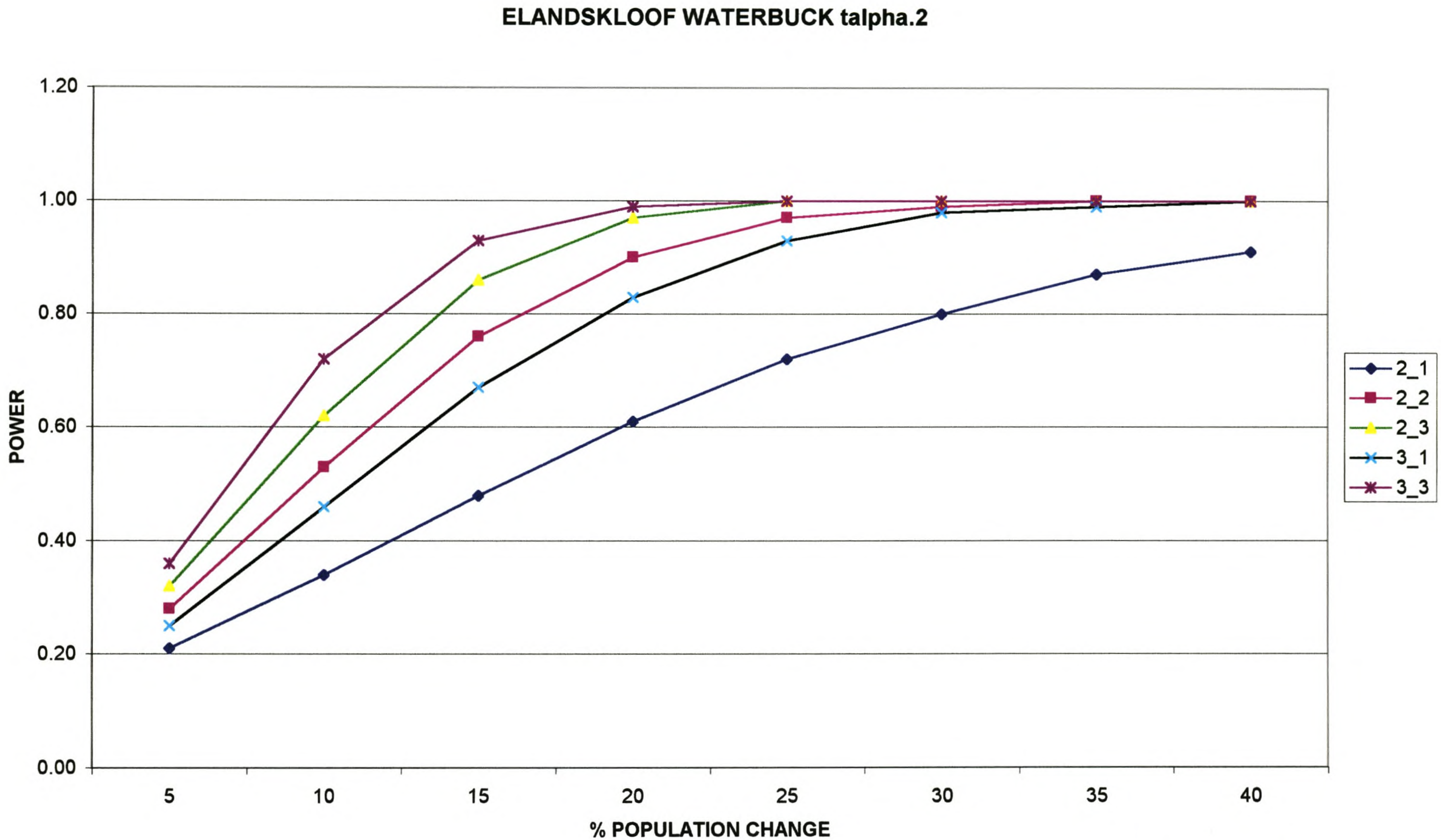


Figure 74: Power curves for various count replicate options at 20% significance for waterbuck on the farm Elandskloof, northwest arid bushveld.

Table 75: Summary statistics of three replicate helicopter counts of the farm Groengoud, northwest arid bushveld.

| SPECIES | COUNT REPLICATES | | | MEAN | STANDARD DEVIATION(n2) | STANDARD DEVIATION(n3) |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | | | |
| *KUDU* | **22** | **26** | **33** | 27.0 | 3.18 | 2.60 |
| *IMPALA* | **117** | **78** | **123** | 106.0 | 14.22 | 11.60 |
| *WARTHOG* | **71** | **81** | **49** | 67.0 | 9.53 | 7.81 |

| SPECIES | SEdiff21 | SEdiff22 | SEdiff23 | SEdiff31 | SEdiff33 |
|---|---|---|---|---|---|
| *KUDU* | 3.89 | 3.18 | 2.90 | 3.00 | 2.12 |
| *IMPALA* | 17.42 | 14.22 | 12.98 | 13.39 | 9.47 |
| *WARTHOG* | 11.67 | 9.53 | 8.70 | 9.02 | 6.38 |

Table 76: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for kudu on the farm Groengoud, northwest arid bushveld.

| KUDU | | MEAN | 27.0 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | 1.35 | 2.70 | 4.05 | 5.40 | 6.75 | 8.10 | 9.45 | 10.80 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.35 | 0.69 | 1.04 | 1.39 | 1.73 | 2.08 | 2.43 | 2.77 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.42 | 0.85 | 1.27 | 1.70 | 2.12 | 2.55 | 2.97 | 3.40 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.47 | 0.93 | 1.40 | 1.86 | 2.33 | 2.79 | 3.26 | 3.72 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.45 | 0.90 | 1.35 | 1.80 | 2.25 | 2.70 | 3.15 | 3.60 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.64 | 1.27 | 1.91 | 2.54 | 3.18 | 3.82 | 4.45 | 5.09 |

Table 77: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for kudu at 10% and 20% significance on the farm Groengoud, northwest arid bushveld.

talpha.1 KUDU

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.07 | 0.10 | 0.14 | 0.18 | 0.22 | 0.26 | 0.30 | 0.34 |
| **2_2** | 0.09 | 0.15 | 0.22 | 0.31 | 0.41 | 0.51 | 0.61 | 0.70 |
| **2_3** | 0.10 | 0.18 | 0.29 | 0.42 | 0.56 | 0.68 | 0.79 | 0.87 |
| **3_1** | 0.09 | 0.16 | 0.24 | 0.34 | 0.44 | 0.55 | 0.65 | 0.74 |
| **3_3** | 0.13 | 0.28 | 0.48 | 0.67 | 0.83 | 0.93 | 0.97 | 0.99 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.15 | 0.21 | 0.27 | 0.34 | 0.41 | 0.48 | 0.55 | 0.61 |
| **2_2** | 0.18 | 0.28 | 0.40 | 0.53 | 0.65 | 0.76 | 0.84 | 0.90 |
| **2_3** | 0.19 | 0.32 | 0.47 | 0.62 | 0.76 | 0.86 | 0.93 | 0.97 |
| **3_1** | 0.18 | 0.29 | 0.42 | 0.56 | 0.68 | 0.79 | 0.87 | 0.92 |
| **3_3** | 0.24 | 0.44 | 0.66 | 0.84 | 0.94 | 0.98 | 1.00 | 1.00 |

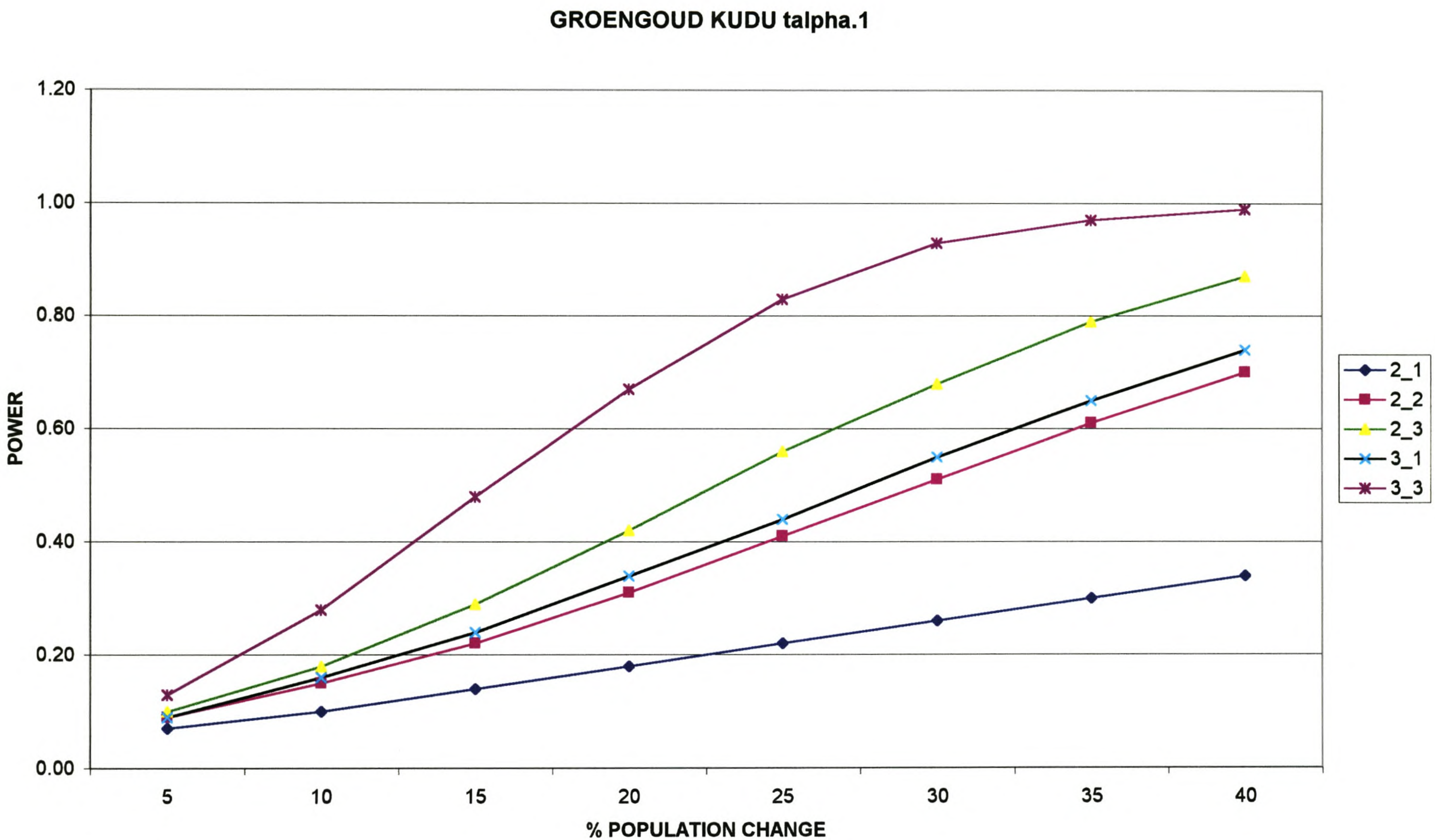


Figure 75: Power curves for various count replicate options at 10% significance for kudu on the farm Groengoud, northwest arid bushveld.

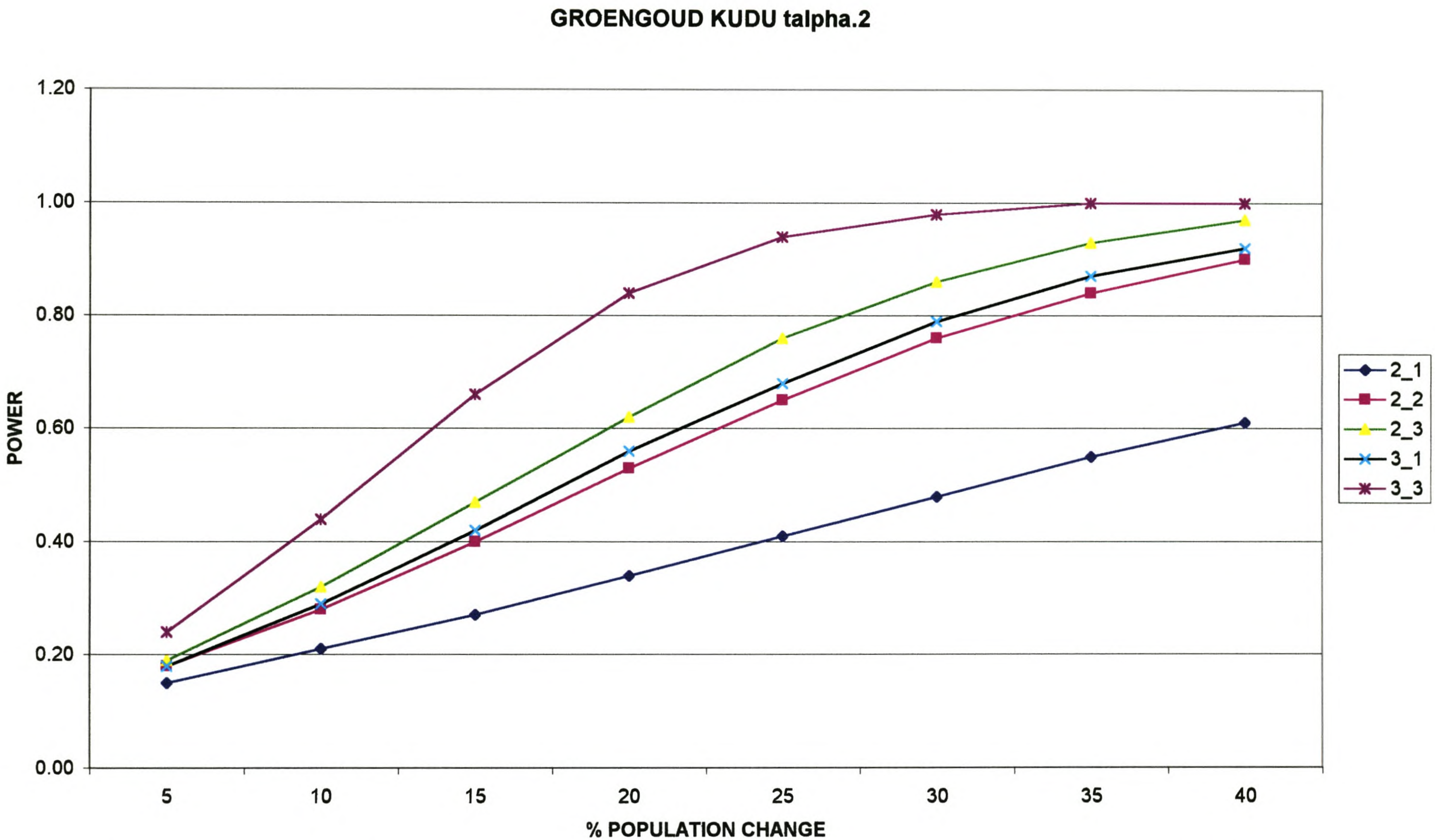


Figure 76: Power curves for various count replicate options at 20% significance for kudu on the farm Groengoud, northwest arid bushveld.

Table 78: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for impala on the farm Groengoud, northwest arid bushveld.

| IMPALA | | MEAN | 106.00 | | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 5.30 | 10.60 | 15.90 | 21.20 | 26.50 | 31.80 | 37.10 | 42.40 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.30 | 0.61 | 0.91 | 1.22 | 1.52 | 1.83 | 2.13 | 2.43 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.37 | 0.75 | 1.12 | 1.49 | 1.86 | 2.24 | 2.61 | 2.98 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.41 | 0.82 | 1.22 | 1.63 | 2.04 | 2.45 | 2.86 | 3.27 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.40 | 0.79 | 1.19 | 1.58 | 1.98 | 2.37 | 2.77 | 3.17 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.56 | 1.12 | 1.68 | 2.24 | 2.80 | 3.36 | 3.92 | 4.48 |

**Table 79: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for impala at 10% and 20% significance on the farm Groengoud, northwest arid bushveld.**

talpha.1 IMPALA

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.07 | 0.10 | 0.13 | 0.16 | 0.19 | 0.23 | 0.26 | 0.30 |
| **2_2** | 0.08 | 0.13 | 0.19 | 0.27 | 0.35 | 0.44 | 0.53 | 0.61 |
| **2_3** | 0.09 | 0.16 | 0.25 | 0.35 | 0.47 | 0.59 | 0.70 | 0.79 |
| **3_1** | 0.09 | 0.14 | 0.21 | 0.29 | 0.38 | 0.47 | 0.57 | 0.65 |
| **3_3** | 0.12 | 0.24 | 0.40 | 0.58 | 0.74 | 0.86 | 0.94 | 0.98 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.14 | 0.19 | 0.25 | 0.31 | 0.37 | 0.43 | 0.49 | 0.55 |
| **2_2** | 0.17 | 0.25 | 0.35 | 0.46 | 0.57 | 0.68 | 0.77 | 0.84 |
| **2_3** | 0.18 | 0.28 | 0.41 | 0.55 | 0.68 | 0.79 | 0.87 | 0.93 |
| **3_1** | 0.17 | 0.26 | 0.37 | 0.49 | 0.61 | 0.71 | 0.80 | 0.87 |
| **3_3** | 0.22 | 0.39 | 0.59 | 0.76 | 0.89 | 0.95 | 0.99 | 1.00 |

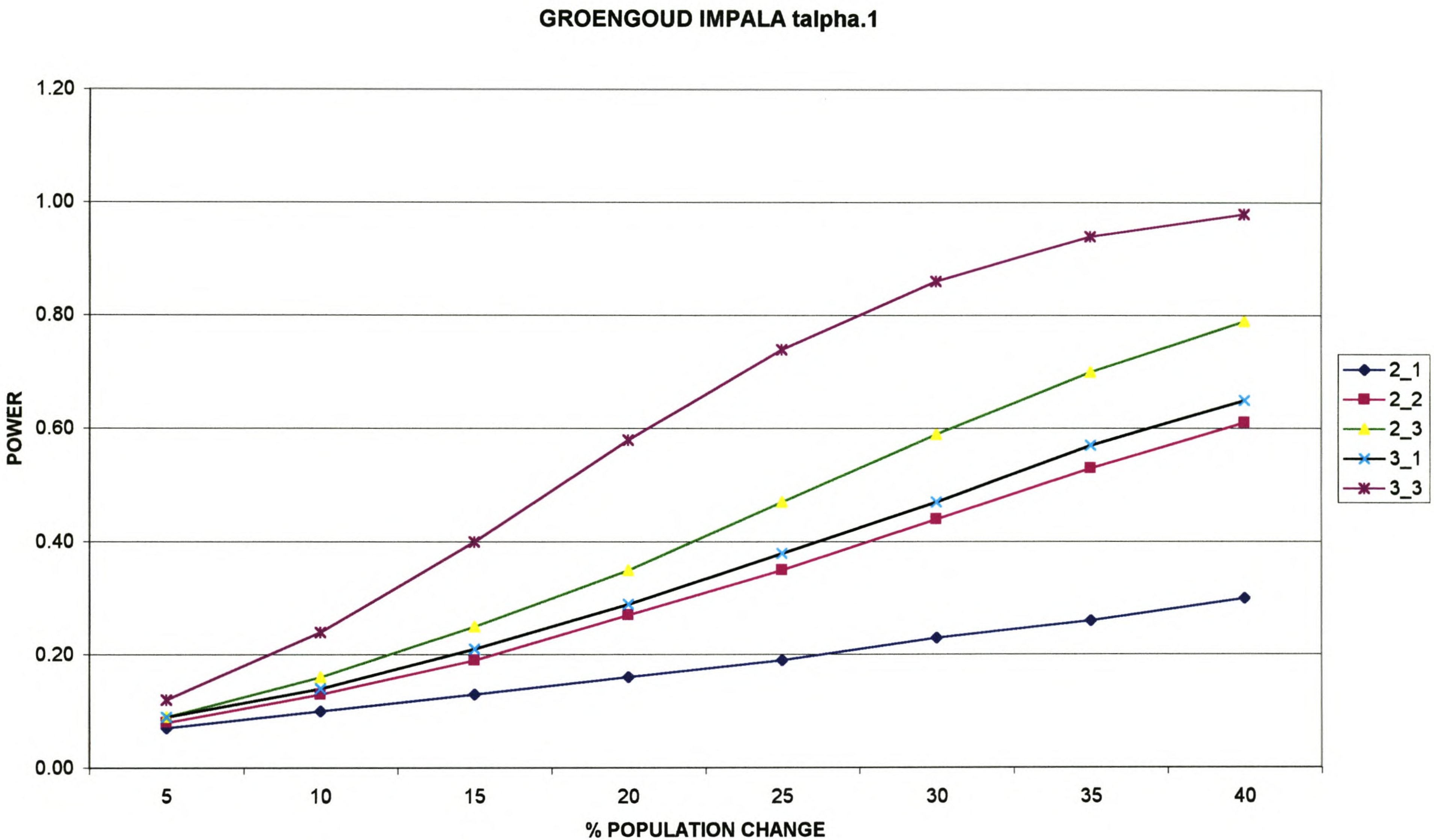


Figure 77: Power curves for various count replicate options at 10% significance for impala on the farm Groengoud, northwest arid bushveld.

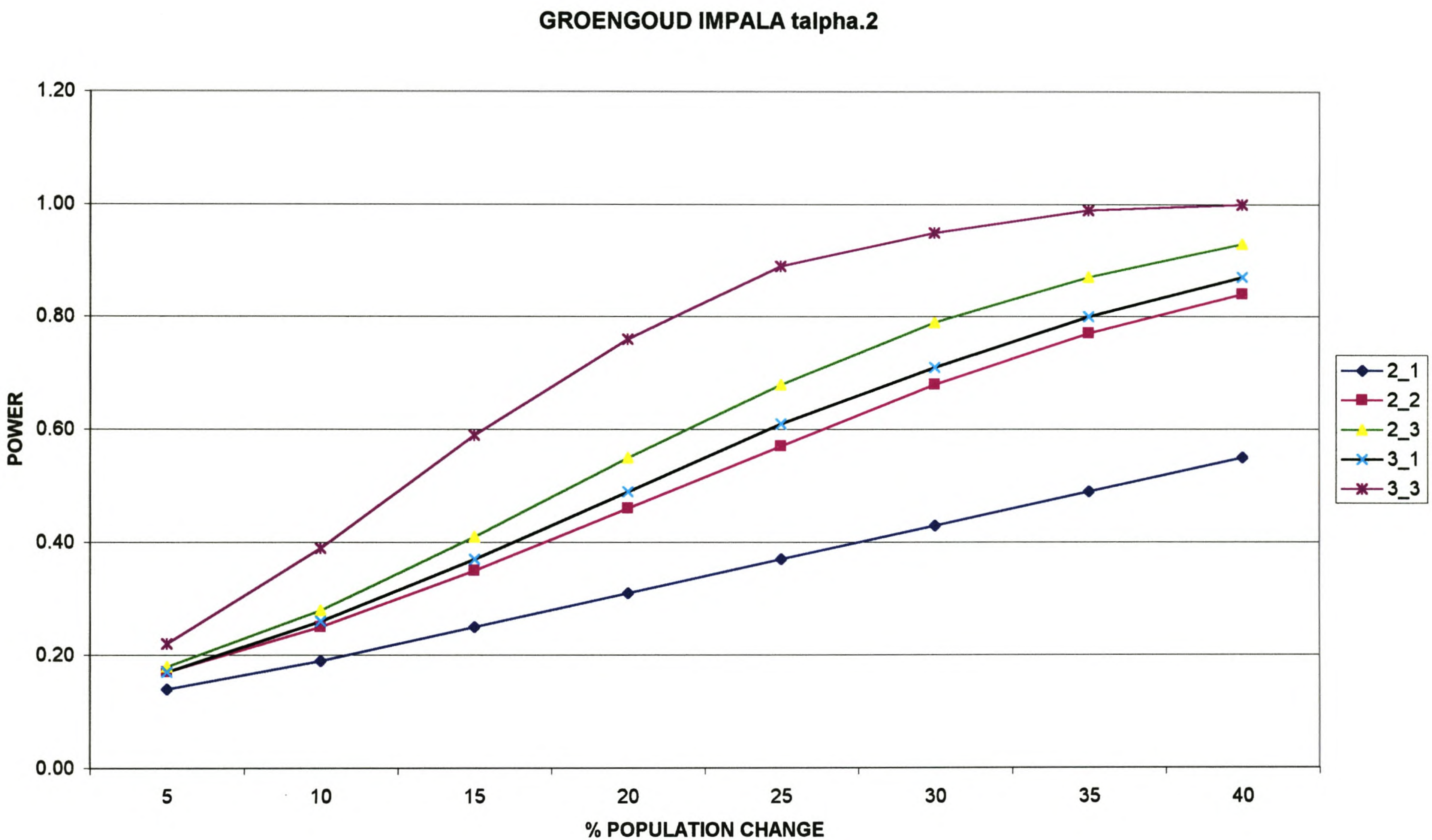


Figure 78: Power curves for various count replicate options at 20% significance for impala on the farm Groengoud, northwest arid bushveld.

Table 80: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for warthog on the farm Groengoud, northwest arid bushveld.

| WARTHOG | | | MEAN | 67.00 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 3.35 | 6.70 | 10.05 | 13.40 | 16.75 | 20.10 | 23.45 | 26.80 |
| **n1** | **n2** | **df** | **talpha.1** | **talpha.2** | **NON CENTRALITY PARAMETERS** | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.29 | 0.57 | 0.86 | 1.15 | 1.44 | 1.72 | 2.01 | 2.30 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.35 | 0.70 | 1.05 | 1.41 | 1.76 | 2.11 | 2.46 | 2.81 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.39 | 0.77 | 1.16 | 1.54 | 1.93 | 2.31 | 2.70 | 3.08 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.37 | 0.74 | 1.11 | 1.49 | 1.86 | 2.23 | 2.60 | 2.97 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.53 | 1.05 | 1.58 | 2.10 | 2.63 | 3.15 | 3.68 | 4.20 |

Table 81: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for warthog at 10% and 20% significance on the farm Groengoud, northwest arid bushveld.

talpha.1 WARTHOG

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.07 | 0.09 | 0.12 | 0.15 | 0.18 | 0.21 | 0.25 | 0.28 |
| **2_2** | 0.08 | 0.13 | 0.18 | 0.25 | 0.33 | 0.41 | 0.49 | 0.57 |
| **2_3** | 0.09 | 0.15 | 0.23 | 0.33 | 0.44 | 0.55 | 0.66 | 0.75 |
| **3_1** | 0.08 | 0.13 | 0.19 | 0.27 | 0.35 | 0.44 | 0.53 | 0.61 |
| **3_3** | 0.12 | 0.22 | 0.37 | 0.54 | 0.70 | 0.82 | 0.91 | 0.96 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.14 | 0.18 | 0.24 | 0.29 | 0.35 | 0.41 | 0.47 | 0.52 |
| **2_2** | 0.16 | 0.24 | 0.33 | 0.44 | 0.54 | 0.64 | 0.73 | 0.81 |
| **2_3** | 0.17 | 0.27 | 0.39 | 0.51 | 0.64 | 0.75 | 0.84 | 0.91 |
| **3_1** | 0.17 | 0.25 | 0.35 | 0.46 | 0.57 | 0.68 | 0.77 | 0.84 |
| **3_3** | 0.21 | 0.37 | 0.55 | 0.72 | 0.85 | 0.93 | 0.98 | 0.99 |

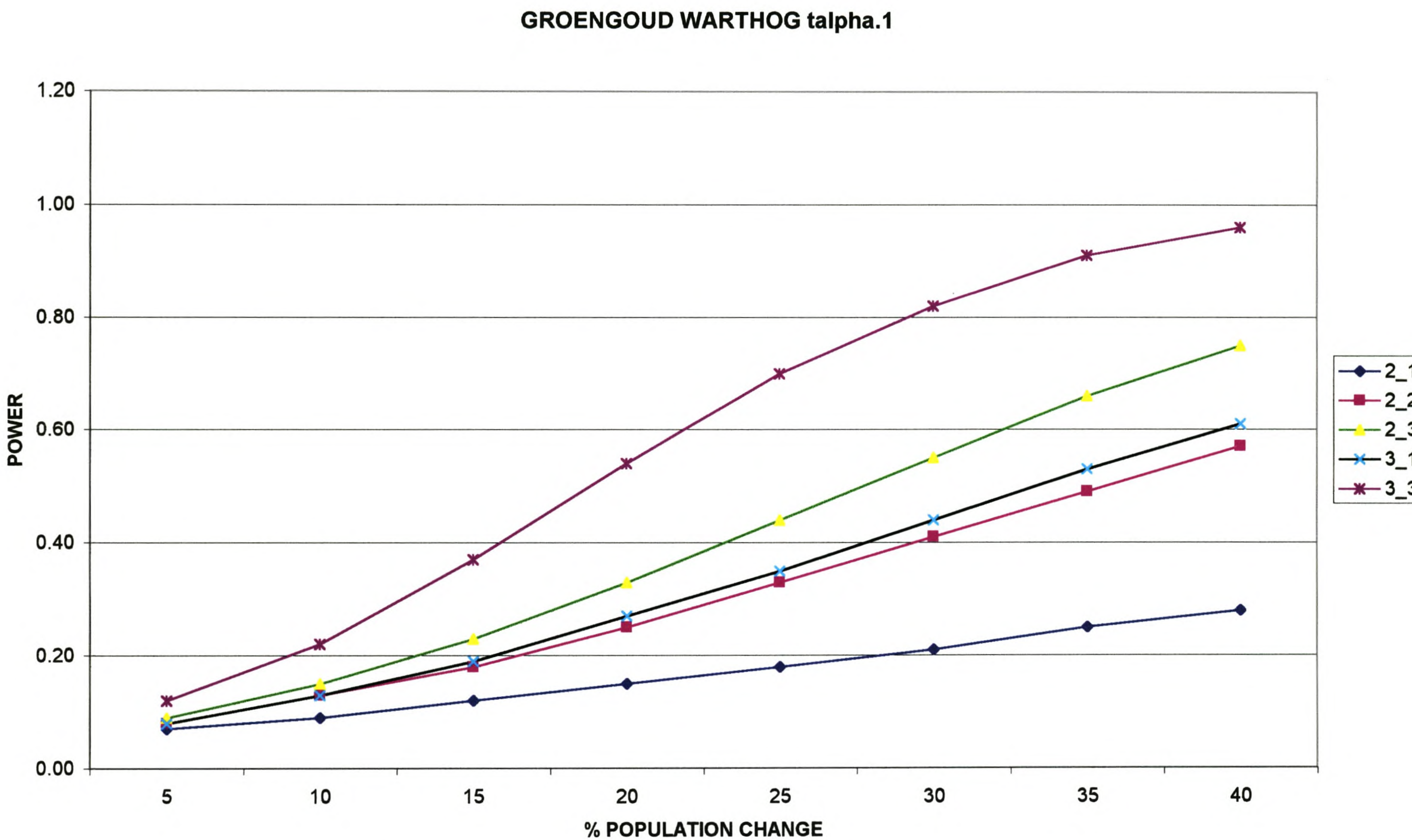


Figure 79: Power curves for various count replicate options at 10% significance for warthog on the farm Groengoud, northwest arid bushveld.

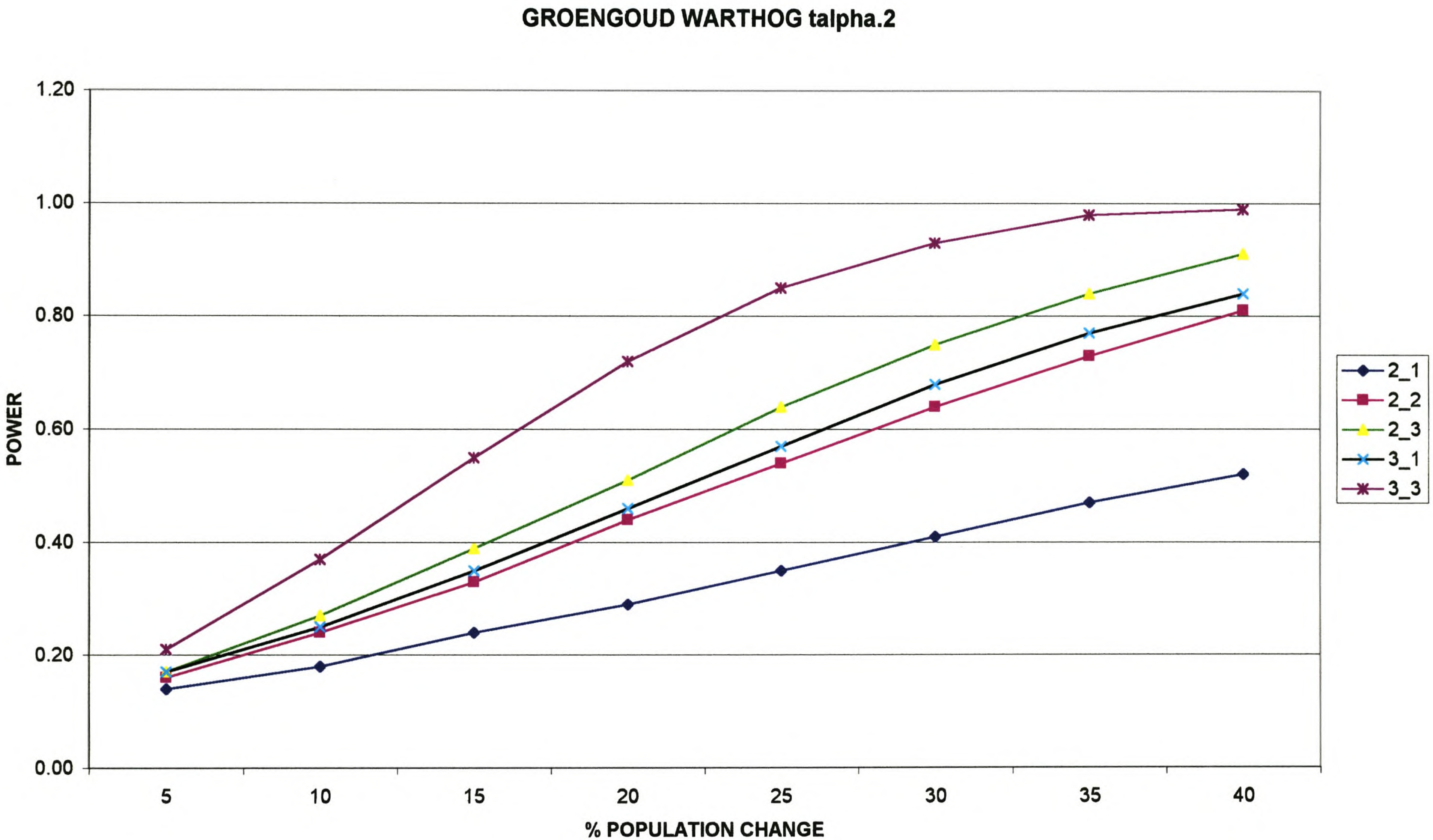


Figure 80: Power curves for various count replicate options at 20% significance for warthog on the farm Groengoud, northwest arid bushveld.

Table 82: Summary statistics of three replicate helicopter counts of the farm Grootvlei, northwest arid bushveld.

| SPECIES | COUNT REPLICATES | | | MEAN | STANDARD | STANDARD |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | | DEVIATION(n2) | DEVIATION(n3) |
| *KUDU* | **19** | **33** | **24** | 25.3 | 5.76 | 5.77 |
| *IMPALA* | **17** | **16** | **0** | 11.0 | 7.80 | 7.82 |
| *WARTHOG* | **22** | **31** | **22** | 25.0 | 4.22 | 4.22 |

| SPECIES | SEdiff21 | SEdiff22 | SEdiff23 | SEdiff31 | SEdiff33 |
|---|---|---|---|---|---|
| *KUDU* | 7.05 | 5.76 | 5.26 | 6.66 | 4.71 |
| *IMPALA* | 9.55 | 7.80 | 7.12 | 9.03 | 6.39 |
| *WARTHOG* | 5.17 | 4.22 | 3.85 | 4.87 | 3.45 |

Table 83: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for kudu on the farm Grootvlei, northwest arid bushveld.

| KUDU | | | MEAN | 25.3 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 1.27 | 2.53 | 3.80 | 5.06 | 6.33 | 7.59 | 8.86 | 10.12 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.18 | 0.36 | 0.54 | 0.72 | 0.90 | 1.08 | 1.26 | 1.43 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.22 | 0.44 | 0.66 | 0.88 | 1.10 | 1.32 | 1.54 | 1.76 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.24 | 0.48 | 0.72 | 0.96 | 1.20 | 1.44 | 1.68 | 1.92 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.19 | 0.38 | 0.57 | 0.76 | 0.95 | 1.14 | 1.33 | 1.52 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.27 | 0.54 | 0.81 | 1.07 | 1.34 | 1.61 | 1.88 | 2.15 |

**Table 84**: **Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for kudu at 10% and 20% significance on the farm Grootvlei, northwest arid bushveld.**

talpha.1 KUDU

| | **5** | **10** | **15** | **20** | **25** | **30** | **35** | **40** |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.06 | 0.08 | 0.09 | 0.11 | 0.12 | 0.14 | 0.16 | 0.18 |
| **2_2** | 0.07 | 0.09 | 0.12 | 0.15 | 0.19 | 0.23 | 0.28 | 0.33 |
| **2_3** | 0.07 | 0.10 | 0.14 | 0.19 | 0.24 | 0.30 | 0.37 | 0.44 |
| **3_1** | 0.07 | 0.09 | 0.11 | 0.13 | 0.17 | 0.20 | 0.24 | 0.28 |
| **3_3** | 0.08 | 0.12 | 0.17 | 0.23 | 0.30 | 0.38 | 0.47 | 0.55 |

talpha.2

| | **5** | **10** | **15** | **20** | **25** | **30** | **35** | **40** |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.12 | 0.15 | 0.18 | 0.21 | 0.24 | 0.28 | 0.32 | 0.35 |
| **2_2** | 0.14 | 0.18 | 0.23 | 0.29 | 0.35 | 0.41 | 0.48 | 0.54 |
| **2_3** | 0.14 | 0.19 | 0.25 | 0.32 | 0.40 | 0.48 | 0.56 | 0.64 |
| **3_1** | 0.13 | 0.17 | 0.21 | 0.25 | 0.30 | 0.36 | 0.41 | 0.47 |
| **3_3** | 0.15 | 0.21 | 0.29 | 0.37 | 0.47 | 0.56 | 0.65 | 0.74 |

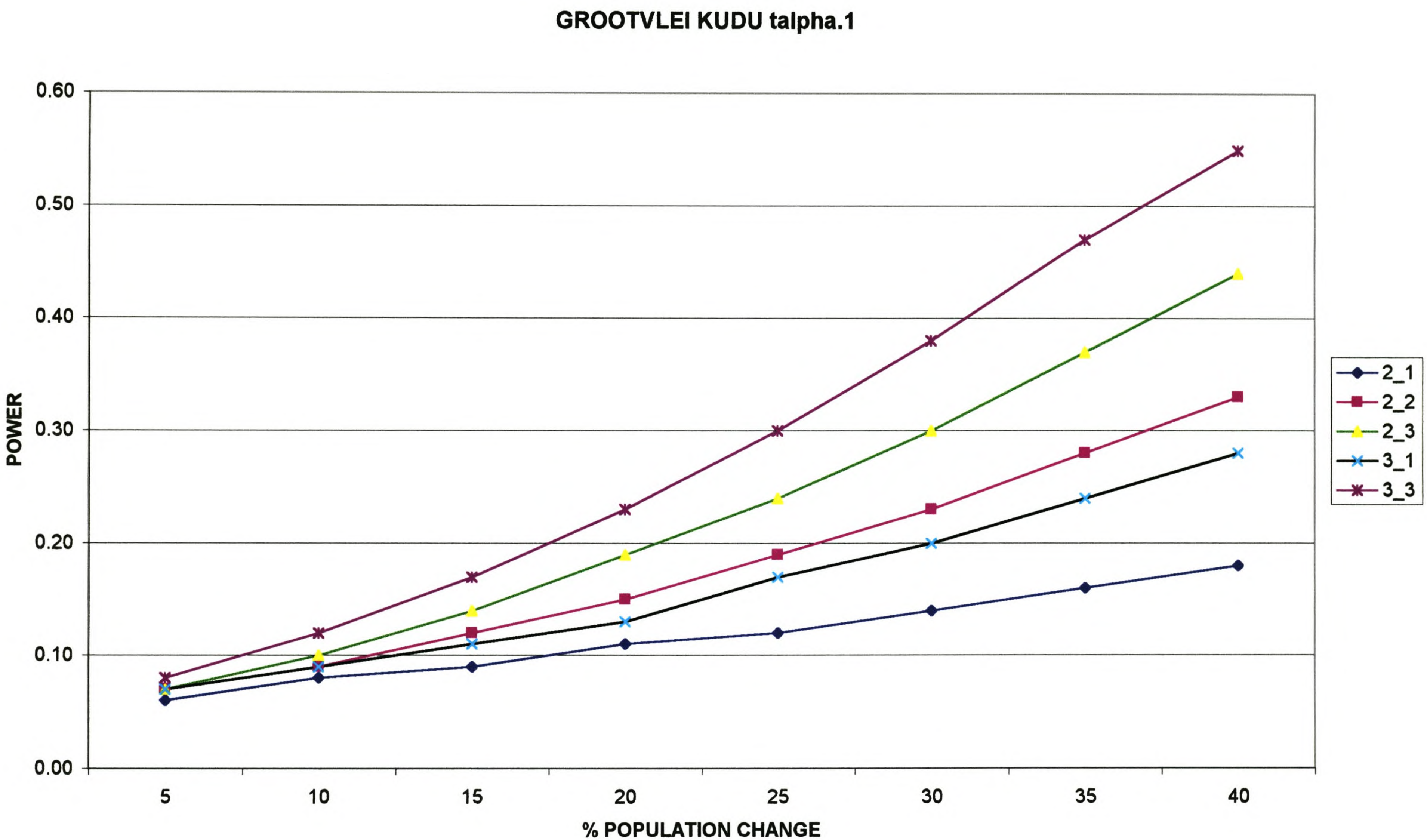


Figure 81: Power curves for various count replicate options at 10% significance for kudu on the farm Grootvlei, northwest arid bushveld.

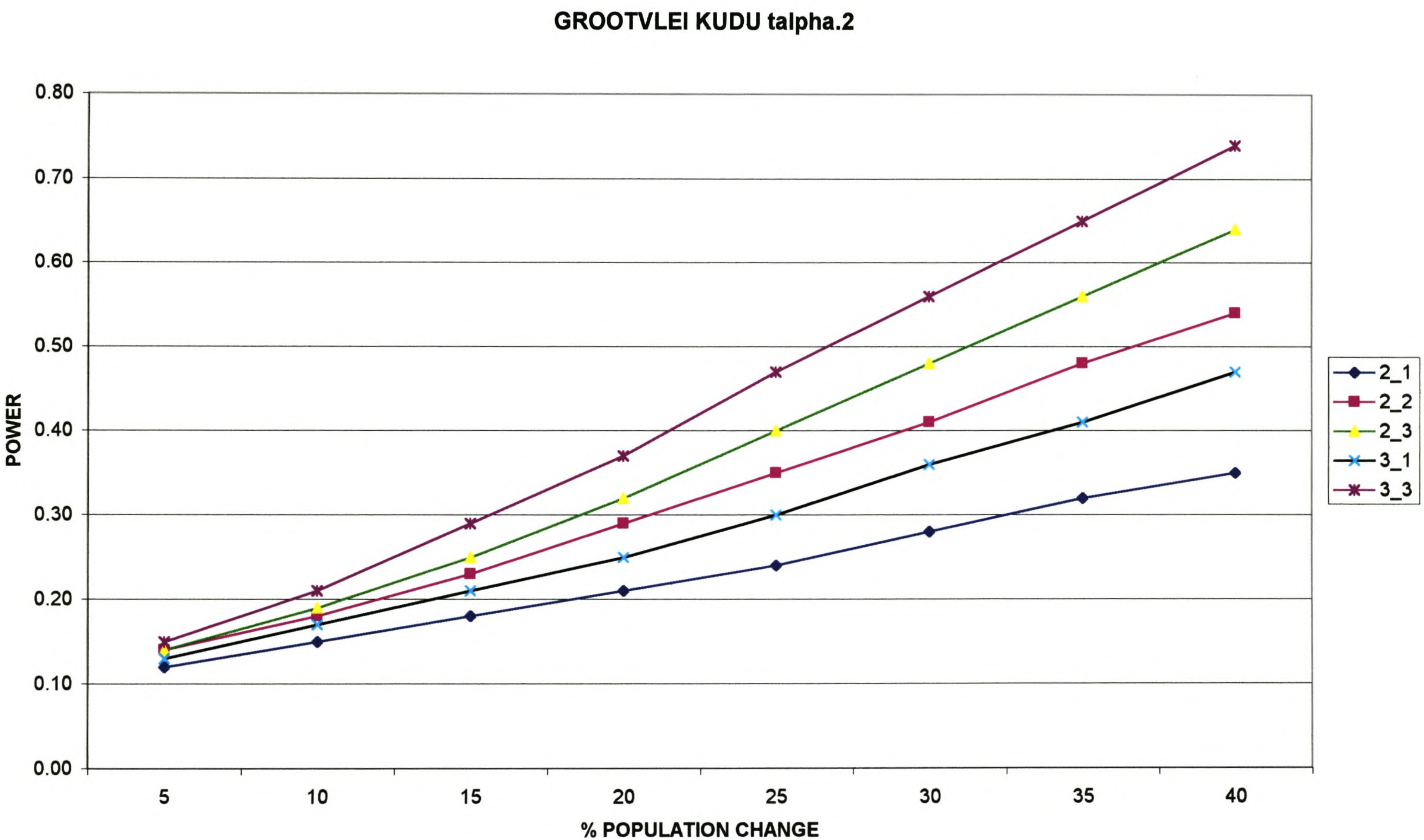


Figure 82: Power curves for various count replicate options at 20% significance for kudu on the farm Grootvlei, northwest arid bushveld.

Table 85: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for impala on the farm Grootvlei, northwest arid bushveld.

| IMPALA | | MEAN | 11.00 | | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 0.55 | 1.10 | 1.65 | 2.20 | 2.75 | 3.30 | 3.85 | 4.40 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.06 | 0.12 | 0.17 | 0.23 | 0.29 | 0.35 | 0.40 | 0.46 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.07 | 0.14 | 0.21 | 0.28 | 0.35 | 0.42 | 0.49 | 0.56 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.08 | 0.15 | 0.23 | 0.31 | 0.39 | 0.46 | 0.54 | 0.62 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.06 | 0.12 | 0.18 | 0.24 | 0.30 | 0.37 | 0.43 | 0.49 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.09 | 0.17 | 0.26 | 0.34 | 0.43 | 0.52 | 0.60 | 0.69 |

Table 86: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for impala at 10% and 20% significance on the farm Grootvlei, northwest arid bushveld.

talpha.1 IMPALA

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| 2_1 | 0.05 | 0.06 | 0.06 | 0.07 | 0.07 | 0.07 | 0.08 | 0.08 |
| 2_2 | 0.06 | 0.06 | 0.07 | 0.07 | 0.08 | 0.09 | 0.10 | 0.11 |
| 2_3 | 0.06 | 0.06 | 0.07 | 0.08 | 0.09 | 0.10 | 0.11 | 0.13 |
| 3_1 | 0.05 | 0.06 | 0.07 | 0.07 | 0.08 | 0.08 | 0.09 | 0.10 |
| 3_3 | 0.06 | 0.07 | 0.08 | 0.09 | 0.10 | 0.11 | 0.13 | 0.14 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| 2_1 | 0.11 | 0.12 | 0.12 | 0.13 | 0.14 | 0.15 | 0.16 | 0.17 |
| 2_2 | 0.11 | 0.12 | 0.13 | 0.15 | 0.16 | 0.18 | 0.19 | 0.21 |
| 2_3 | 0.11 | 0.12 | 0.14 | 0.16 | 0.17 | 0.19 | 0.21 | 0.23 |
| 3_1 | 0.11 | 0.12 | 0.13 | 0.14 | 0.15 | 0.17 | 0.18 | 0.19 |
| 3_3 | 0.12 | 0.13 | 0.15 | 0.17 | 0.19 | 0.21 | 0.23 | 0.25 |

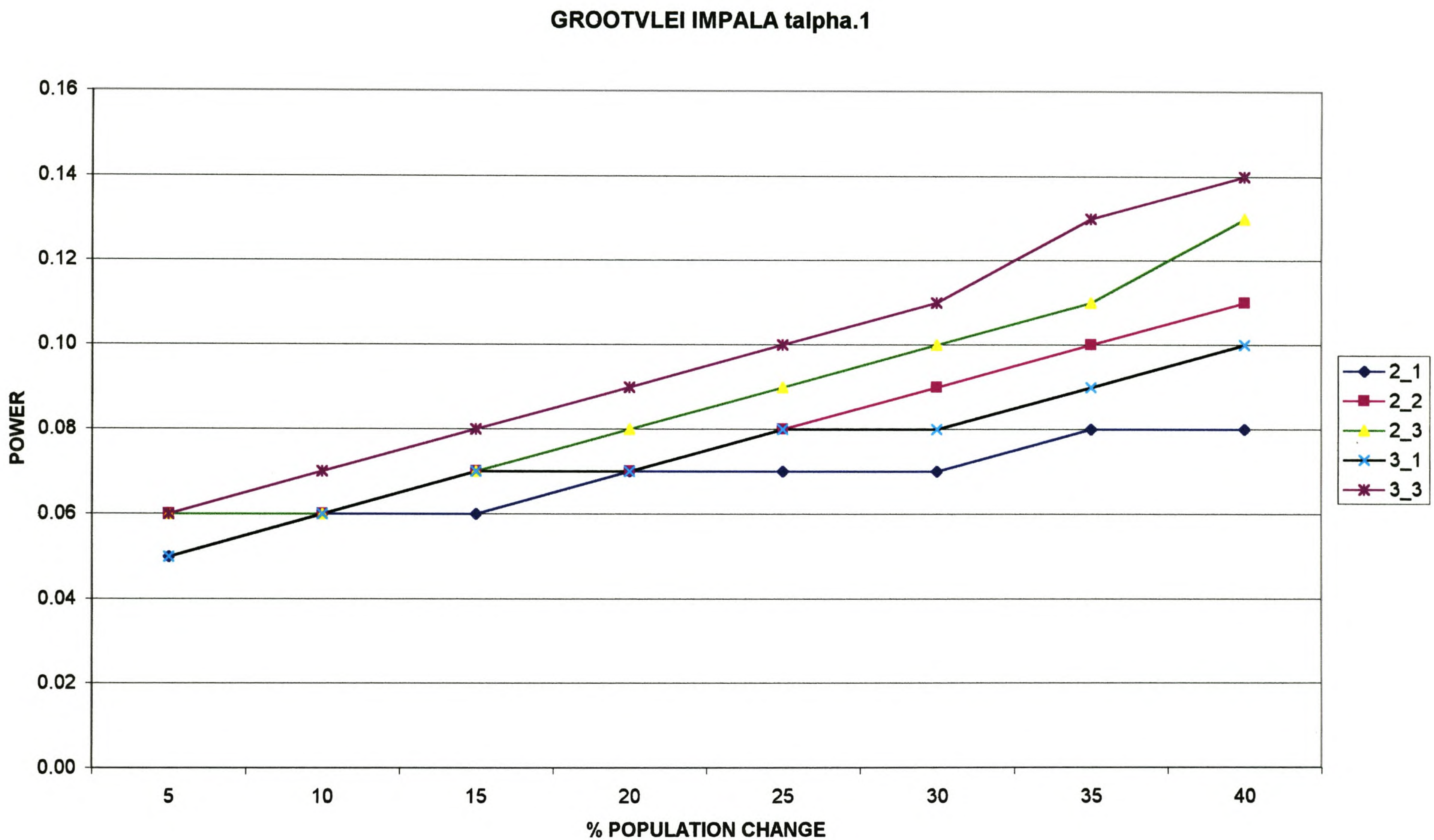


Figure 83: Power curves for various count replicate options at 10% significance for impala on the farm Grootvlei, northwest arid bushveld.

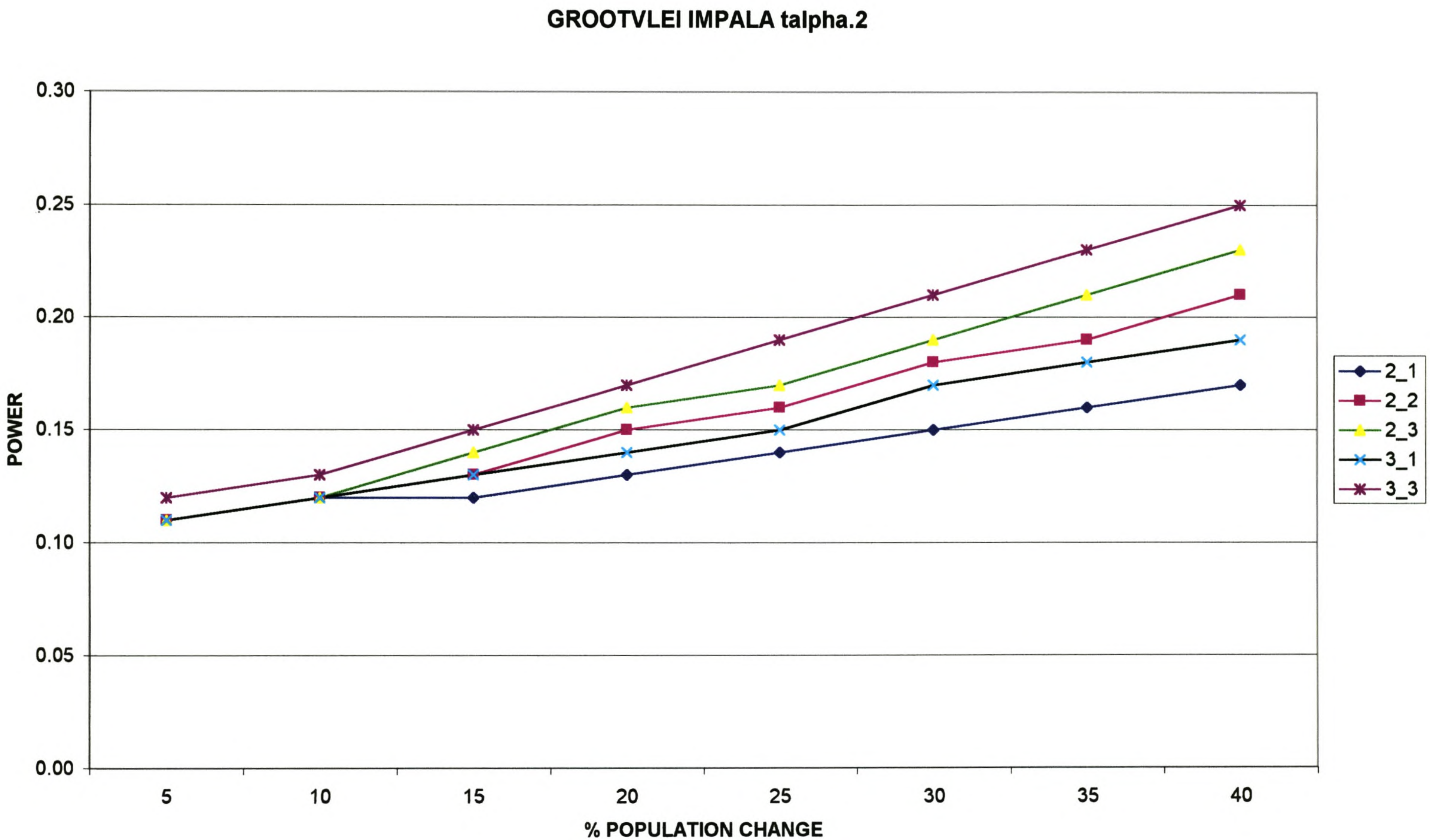


Figure 84: Power curves for various count replicate options at 20% significance for impala on the farm Grootvlei, northwest arid bushveld.

Table 87: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for warthog on the farm Grootvlei, northwest arid bushveld.

| WARTHOG | | MEAN | | 25.00 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 1.25 | 2.50 | 3.75 | 5.00 | 6.25 | 7.50 | 8.75 | 10.00 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.24 | 0.48 | 0.73 | 0.97 | 1.21 | 1.45 | 1.69 | 1.93 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.30 | 0.59 | 0.89 | 1.18 | 1.48 | 1.78 | 2.07 | 2.37 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.32 | 0.65 | 0.97 | 1.30 | 1.62 | 1.95 | 2.27 | 2.60 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.26 | 0.51 | 0.77 | 1.03 | 1.28 | 1.54 | 1.80 | 2.05 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.36 | 0.73 | 1.09 | 1.45 | 1.81 | 2.18 | 2.54 | 2.90 |

Table 88: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for warthog at 10% and 20% significance on the farm Grootvlei, northwest arid bushveld.

talpha.1 WARTHOG

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.07 | 0.09 | 0.11 | 0.13 | 0.16 | 0.18 | 0.21 | 0.24 |
| **2_2** | 0.08 | 0.11 | 0.16 | 0.21 | 0.27 | 0.33 | 0.40 | 0.47 |
| **2_3** | 0.08 | 0.13 | 0.19 | 0.27 | 0.35 | 0.45 | 0.54 | 0.63 |
| **3_1** | 0.07 | 0.10 | 0.14 | 0.18 | 0.23 | 0.28 | 0.34 | 0.40 |
| **3_3** | 0.09 | 0.15 | 0.23 | 0.33 | 0.44 | 0.56 | 0.67 | 0.77 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.13 | 0.17 | 0.21 | 0.26 | 0.31 | 0.35 | 0.40 | 0.45 |
| **2_2** | 0.15 | 0.21 | 0.29 | 0.37 | 0.46 | 0.55 | 0.63 | 0.71 |
| **2_3** | 0.16 | 0.24 | 0.33 | 0.43 | 0.54 | 0.65 | 0.74 | 0.82 |
| **3_1** | 0.14 | 0.19 | 0.26 | 0.33 | 0.40 | 0.48 | 0.56 | 0.63 |
| **3_3** | 0.17 | 0.27 | 0.38 | 0.51 | 0.63 | 0.75 | 0.84 | 0.90 |

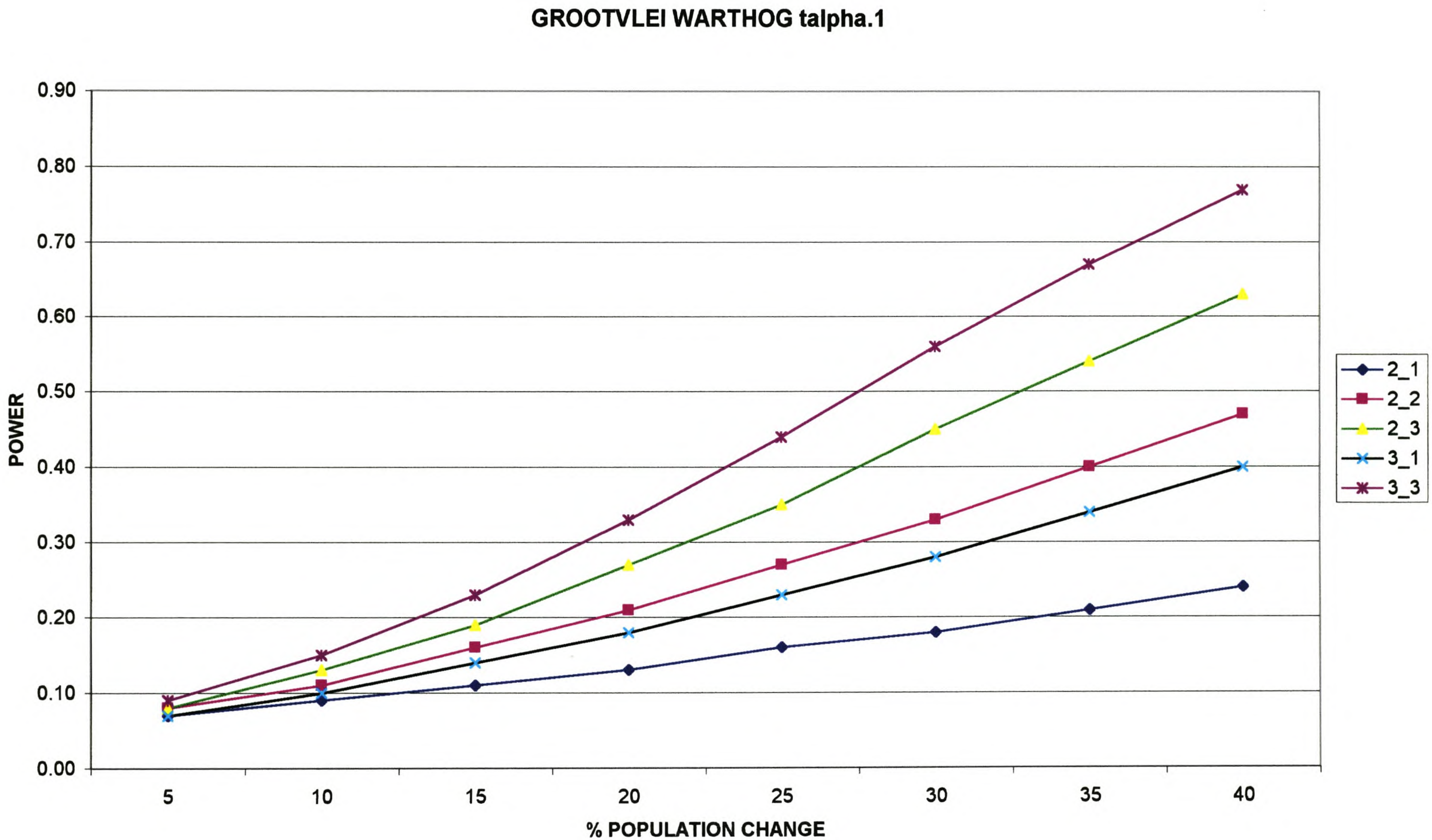


Figure 85: Power curves for various count replicate options at 10% significance for warthog on the farm Grootvlei, northwest arid bushveld.

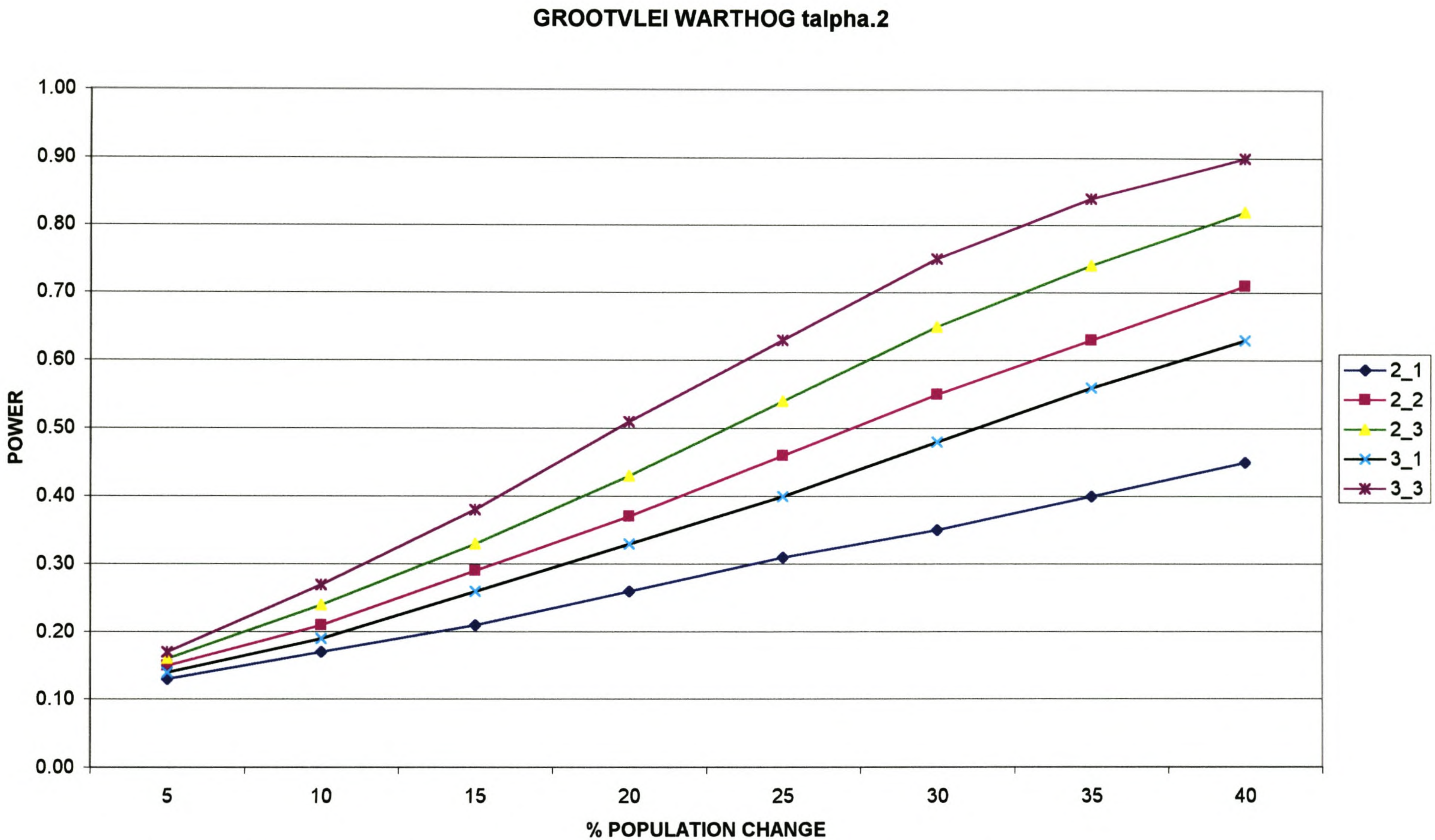


Figure 86: Power curves for various count replicate options at 20% significance for warthog on the farm Grootvlei, northwest arid bushveld.

Table 89: Summary statistics of three replicate helicopter counts of the farm Laagwater, northwest arid bushveld.

| SPECIES | COUNT REPLICATES | | | MEAN | STANDARD | STANDARD |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | | DEVIATION(n2) | DEVIATION(n3) |
| *KUDU* | **34** | **33** | **28** | 31.7 | 2.63 | 2.65 |
| *HARTEBEEST* | **29** | **22** | **30** | 27.0 | 3.54 | 3.56 |
| *OSTRICH* | **21** | **20** | **25** | 22.0 | 2.17 | 2.16 |
| *IMPALA* | **141** | **179** | **167** | 162.3 | 15.81 | 15.92 |
| *WARTHOG* | **54** | **33** | **41** | 42.7 | 8.60 | 8.59 |
| *BLESBOK* | **49** | **44** | **49** | 47.3 | 2.38 | 2.37 |

| SPECIES | SEdiff21 | SEdiff22 | SEdiff23 | SEdiff31 | SEdiff33 |
|---|---|---|---|---|---|
| *KUDU* | 3.22 | 2.63 | 2.40 | 3.06 | 2.16 |
| *HARTEBEEST* | 4.34 | 3.54 | 3.23 | 4.11 | 2.91 |
| *OSTRICH* | 2.66 | 2.17 | 1.98 | 2.49 | 1.76 |
| *IMPALA* | 19.36 | 15.81 | 14.43 | 18.38 | 13.00 |
| *WARTHOG* | 10.53 | 8.60 | 7.85 | 9.92 | 7.01 |
| *BLESBOK* | 2.91 | 2.38 | 2.17 | 2.74 | 1.94 |

Table 90: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for kudu on the farm Laagwater, northwest arid bushveld.

| KUDU | | MEAN | 31.7 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | 1.59 | 3.17 | 4.76 | 6.34 | 7.93 | 9.51 | 11.10 | 12.68 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.49 | 0.98 | 1.48 | 1.97 | 2.46 | 2.95 | 3.44 | 3.94 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.60 | 1.21 | 1.81 | 2.41 | 3.01 | 3.62 | 4.22 | 4.82 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.66 | 1.32 | 1.98 | 2.64 | 3.30 | 3.96 | 4.62 | 5.28 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.52 | 1.04 | 1.55 | 2.07 | 2.59 | 3.11 | 3.63 | 4.14 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.73 | 1.47 | 2.20 | 2.93 | 3.66 | 4.40 | 5.13 | 5.86 |

Table 91: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for kudu at 10% and 20% significance on the farm Laagwater, northwest arid bushveld.

talpha.1 KUDU

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.09 | 0.13 | 0.19 | 0.24 | 0.30 | 0.36 | 0.41 | 0.46 |
| **2_2** | 0.11 | 0.21 | 0.34 | 0.48 | 0.62 | 0.74 | 0.83 | 0.90 |
| **2_3** | 0.13 | 0.27 | 0.46 | 0.65 | 0.80 | 0.90 | 0.96 | 0.99 |
| **3_1** | 0.10 | 0.18 | 0.28 | 0.40 | 0.52 | 0.64 | 0.74 | 0.82 |
| **3_3** | 0.15 | 0.34 | 0.57 | 0.78 | 0.91 | 0.97 | 0.99 | 1.00 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.17 | 0.26 | 0.36 | 0.46 | 0.55 | 0.64 | 0.71 | 0.78 |
| **2_2** | 0.21 | 0.38 | 0.56 | 0.72 | 0.85 | 0.93 | 0.97 | 0.99 |
| **2_3** | 0.24 | 0.44 | 0.66 | 0.83 | 0.93 | 0.98 | 0.99 | 1.00 |
| **3_1** | 0.20 | 0.33 | 0.48 | 0.63 | 0.76 | 0.86 | 0.93 | 0.96 |
| **3_3** | 0.27 | 0.51 | 0.75 | 0.91 | 0.97 | 1.00 | 1.00 | 1.00 |

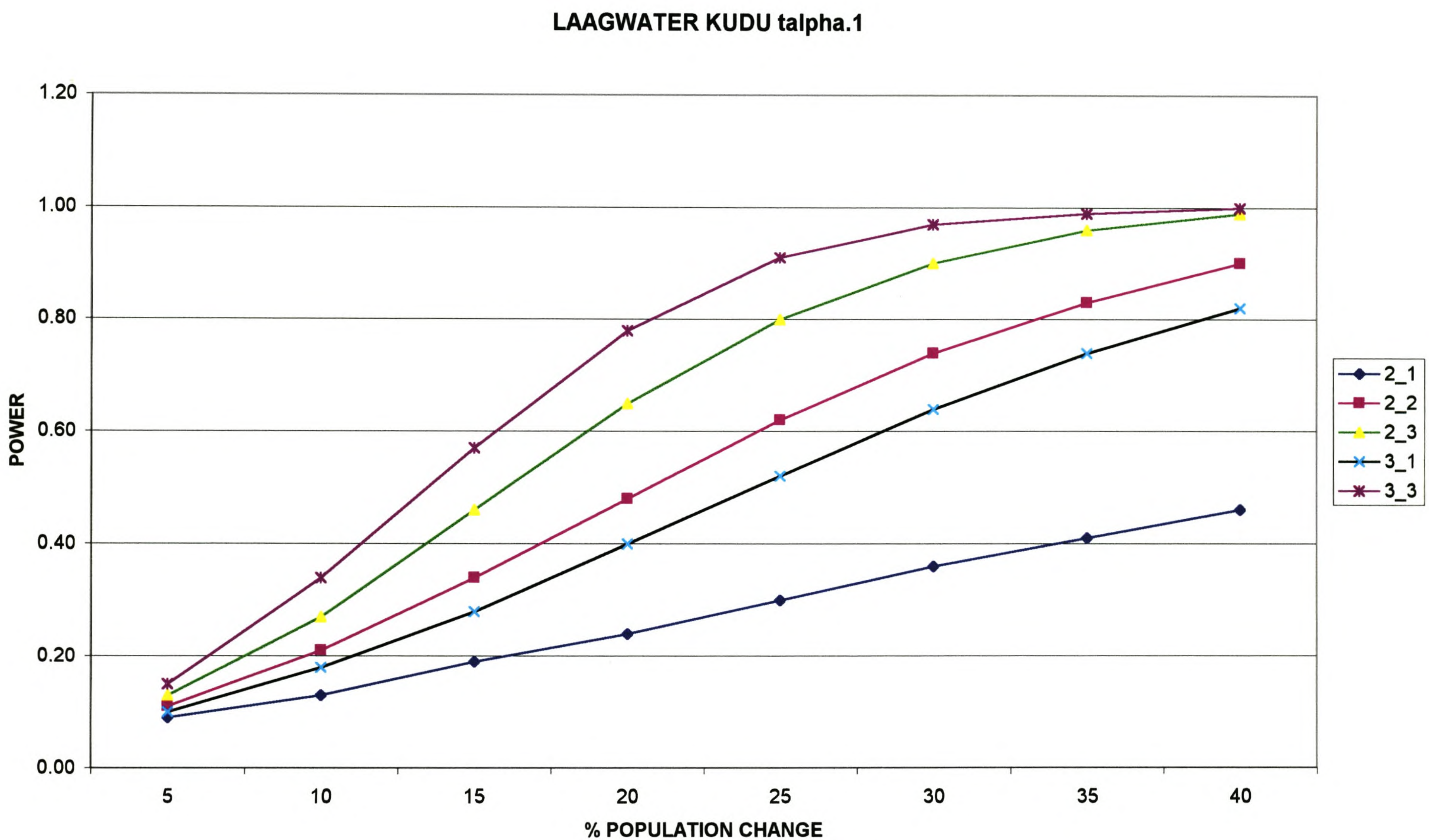


Figure 87: Power curves for various count replicate options at 10% significance on the farm Laagwater, northwest arid bushveld.

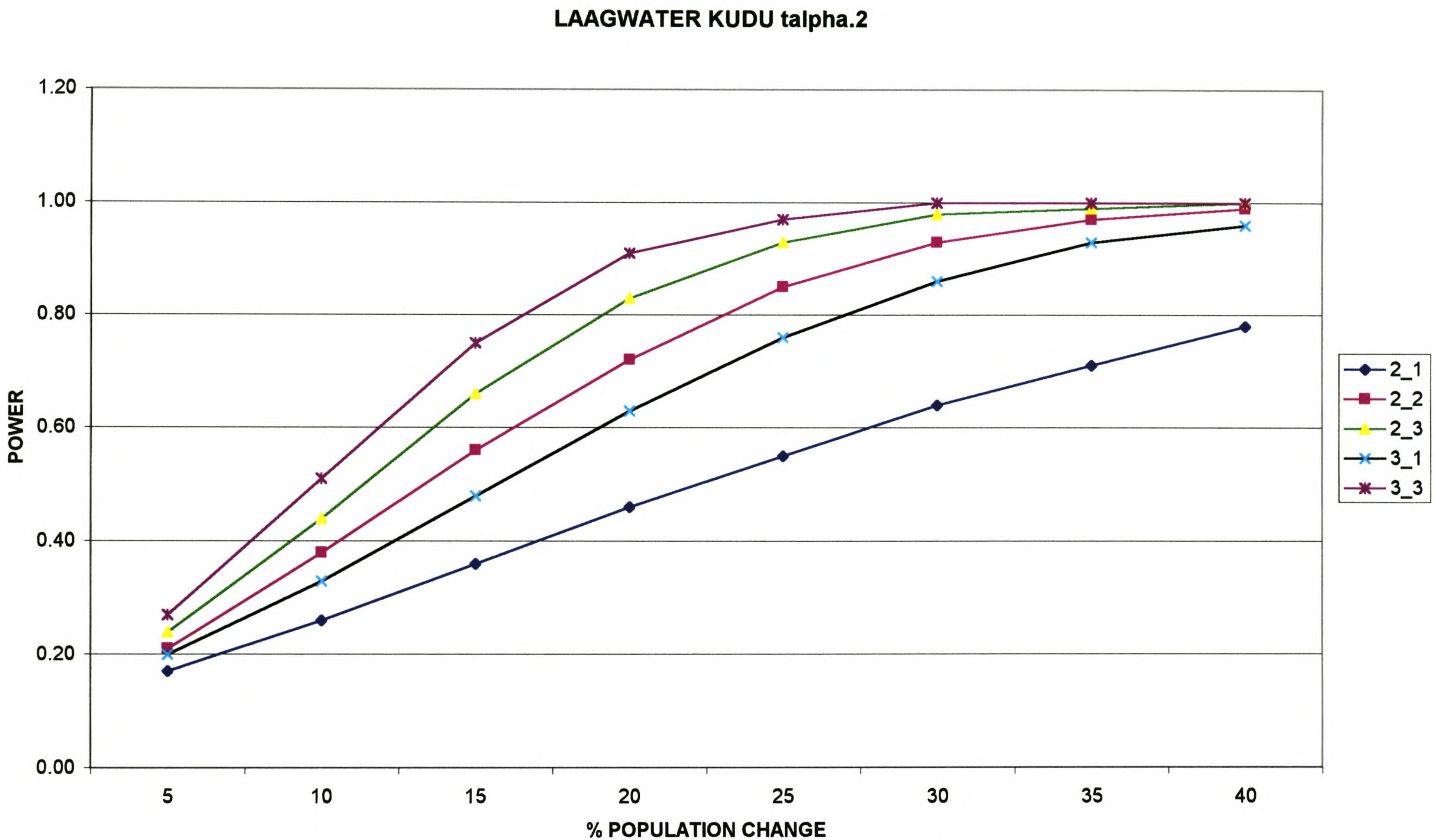


Figure 88: Power curves for various count replicate options at 20% significance for kudu on the farm Laagwater, northwest arid bushveld.

Table 92: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for hartebeest on the farm Laagwater, northwest arid bushveld.

| HARTEBEEST | | MEAN | 27.00 | | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 1.35 | 2.70 | 4.05 | 5.40 | 6.75 | 8.10 | 9.45 | 10.80 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.31 | 0.62 | 0.93 | 1.25 | 1.56 | 1.87 | 2.18 | 2.49 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.38 | 0.76 | 1.14 | 1.53 | 1.91 | 2.29 | 2.67 | 3.05 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.42 | 0.84 | 1.25 | 1.67 | 2.09 | 2.51 | 2.92 | 3.34 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.33 | 0.66 | 0.99 | 1.31 | 1.64 | 1.97 | 2.30 | 2.63 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.46 | 0.93 | 1.39 | 1.86 | 2.32 | 2.79 | 3.25 | 3.72 |

Table 93: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for hartebeest at 10% and 20% significance on the farm Laagwater, northwest arid bushveld.

talpha.1 HARTEBEEST

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.07 | 0.10 | 0.13 | 0.16 | 0.20 | 0.23 | 0.27 | 0.30 |
| **2_2** | 0.09 | 0.13 | 0.20 | 0.28 | 0.36 | 0.45 | 0.54 | 0.63 |
| **2_3** | 0.10 | 0.16 | 0.25 | 0.37 | 0.49 | 0.61 | 0.72 | 0.81 |
| **3_1** | 0.08 | 0.12 | 0.17 | 0.23 | 0.30 | 0.38 | 0.46 | 0.53 |
| **3_3** | 0.10 | 0.19 | 0.31 | 0.46 | 0.61 | 0.74 | 0.84 | 0.92 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.14 | 0.19 | 0.25 | 0.31 | 0.38 | 0.44 | 0.50 | 0.56 |
| **2_2** | 0.17 | 0.25 | 0.36 | 0.47 | 0.59 | 0.69 | 0.78 | 0.85 |
| **2_3** | 0.18 | 0.29 | 0.42 | 0.56 | 0.69 | 0.80 | 0.88 | 0.94 |
| **3_1** | 0.16 | 0.23 | 0.31 | 0.41 | 0.51 | 0.60 | 0.69 | 0.77 |
| **3_3** | 0.19 | 0.33 | 0.49 | 0.65 | 0.78 | 0.88 | 0.94 | 0.98 |

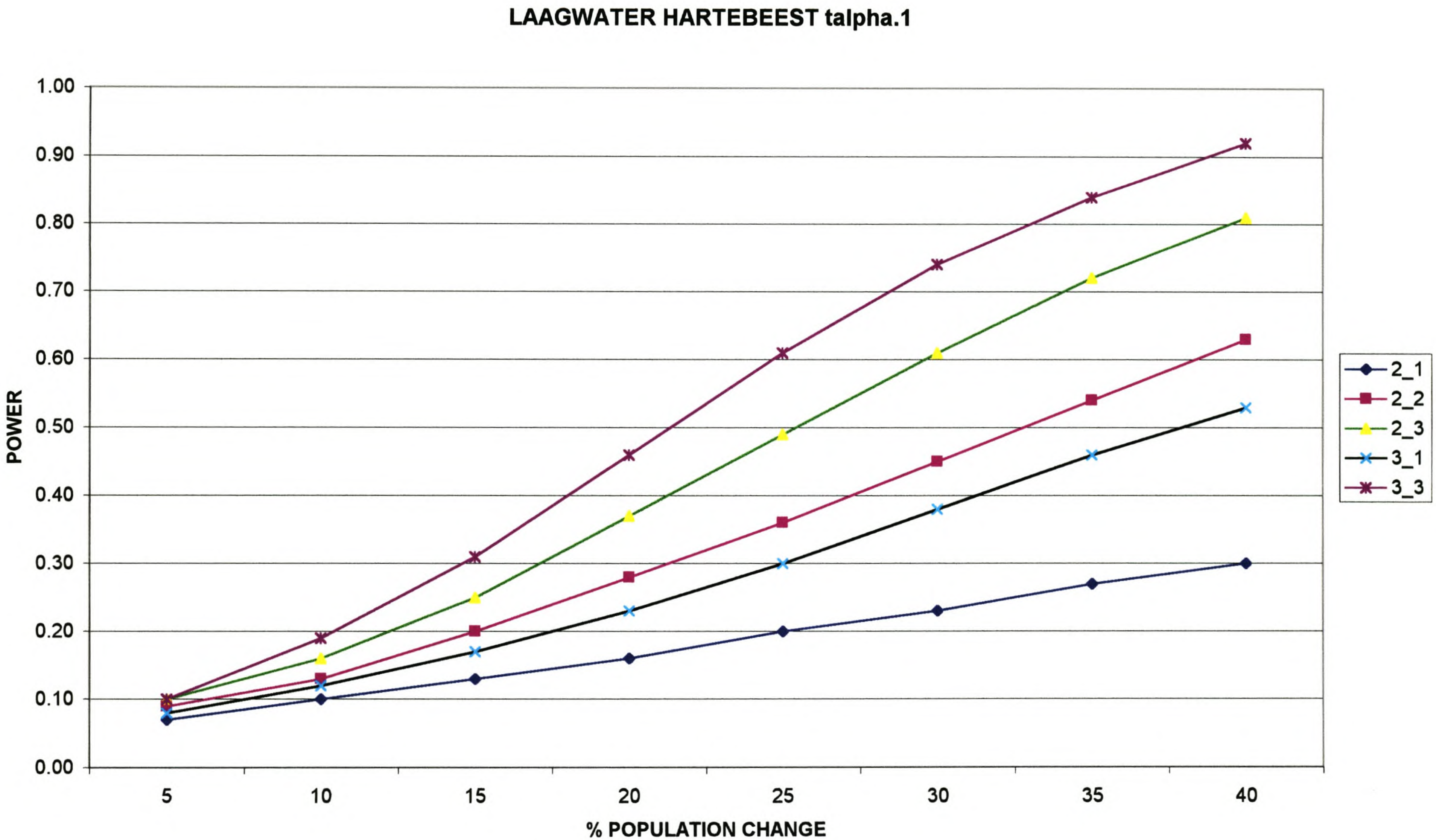


Figure 89: Power curves for various count replicate options at 10% significance for hartebeest on the farm Laagwater, northwest arid bushveld.

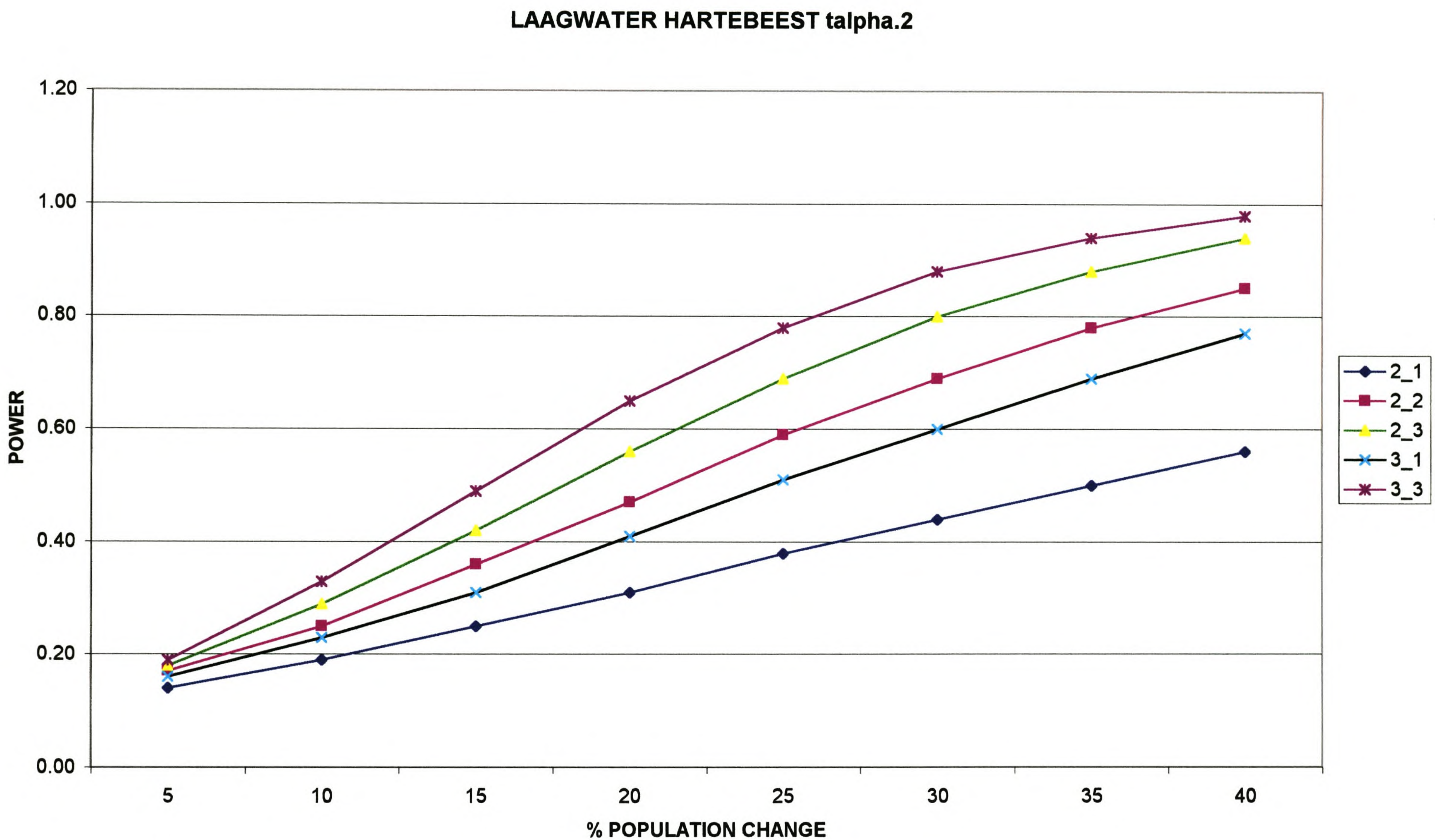


Figure 90: Power curves for various count replicate options at 20% significance for hartebeest on the farm Laagwater, northwest arid bushveld.

Table 94: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for ostrich on the farm Laagwater, northwest arid bushveld.

| OSTRICH | | | MEAN | 22.00 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 1.10 | 2.20 | 3.30 | 4.40 | 5.50 | 6.60 | 7.70 | 8.80 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.41 | 0.83 | 1.24 | 1.66 | 2.07 | 2.48 | 2.90 | 3.31 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.51 | 1.01 | 1.52 | 2.03 | 2.53 | 3.04 | 3.55 | 4.06 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.56 | 1.11 | 1.67 | 2.22 | 2.78 | 3.33 | 3.89 | 4.44 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.44 | 0.88 | 1.32 | 1.76 | 2.21 | 2.65 | 3.09 | 3.53 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.62 | 1.25 | 1.87 | 2.49 | 3.12 | 3.74 | 4.37 | 4.99 |

Table 95: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for ostrich at 10% and 20% significance on the farm Laagwater, northwest arid bushveld.

talpha.1 OSTRICH

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.08 | 0.12 | 0.16 | 0.21 | 0.25 | 0.30 | 0.35 | 0.40 |
| **2_2** | 0.10 | 0.18 | 0.28 | 0.39 | 0.51 | 0.63 | 0.73 | 0.81 |
| **2_3** | 0.12 | 0.22 | 0.37 | 0.53 | 0.68 | 0.81 | 0.90 | 0.95 |
| **3_1** | 0.09 | 0.15 | 0.23 | 0.33 | 0.43 | 0.54 | 0.64 | 0.72 |
| **3_3** | 0.13 | 0.27 | 0.46 | 0.66 | 0.82 | 0.92 | 0.97 | 0.99 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.16 | 0.23 | 0.31 | 0.40 | 0.48 | 0.56 | 0.63 | 0.69 |
| **2_2** | 0.19 | 0.32 | 0.47 | 0.62 | 0.75 | 0.85 | 0.92 | 0.96 |
| **2_3** | 0.21 | 0.37 | 0.56 | 0.73 | 0.86 | 0.94 | 0.98 | 0.99 |
| **3_1** | 0.18 | 0.29 | 0.41 | 0.54 | 0.67 | 0.78 | 0.86 | 0.92 |
| **3_3** | 0.24 | 0.44 | 0.65 | 0.82 | 0.93 | 0.98 | 0.99 | 1.00 |

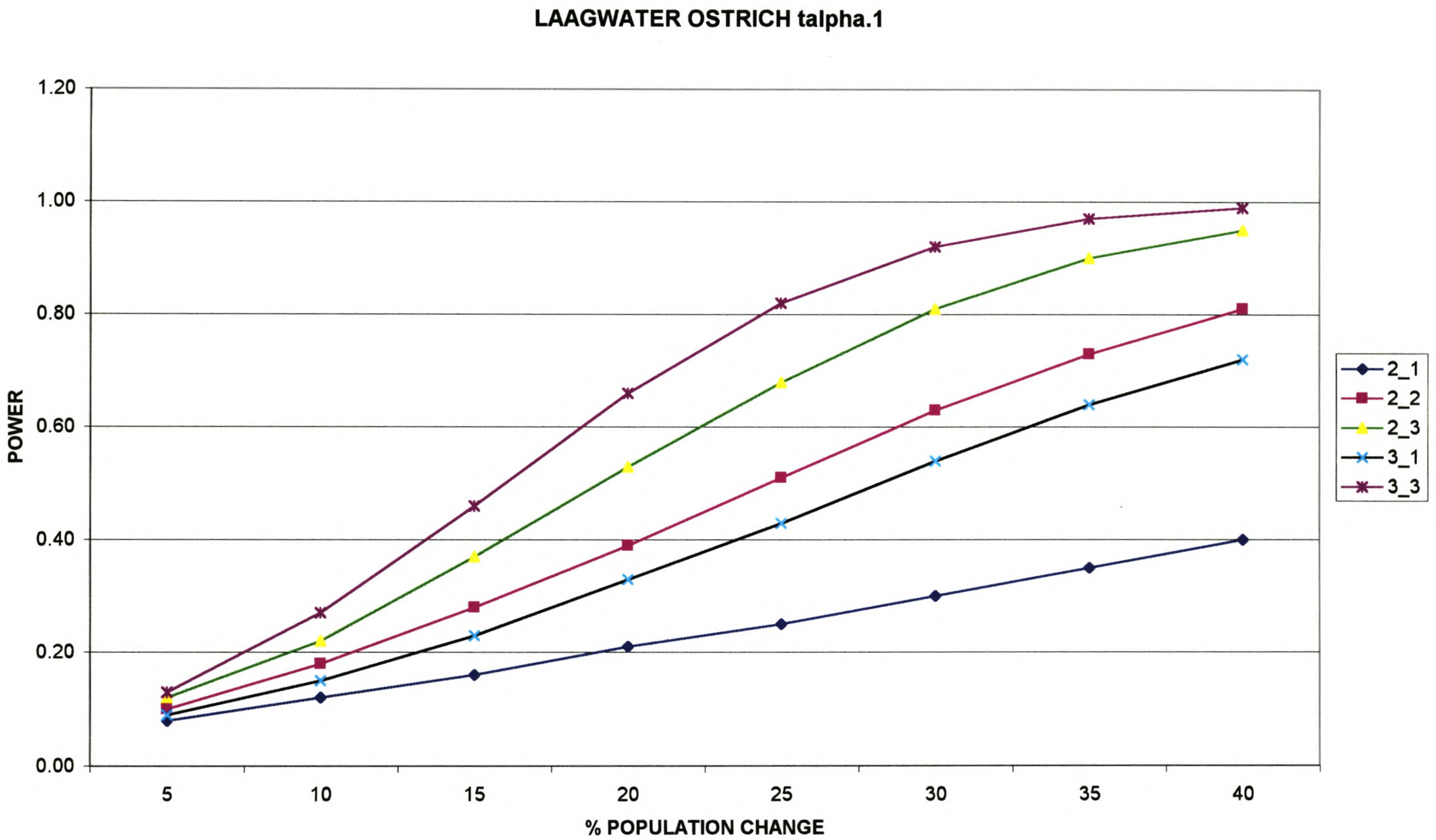


Figure 91: Power curves for various count replicate options at 10% significance for ostrich on the farm Laagwater, northwest arid bushveld.

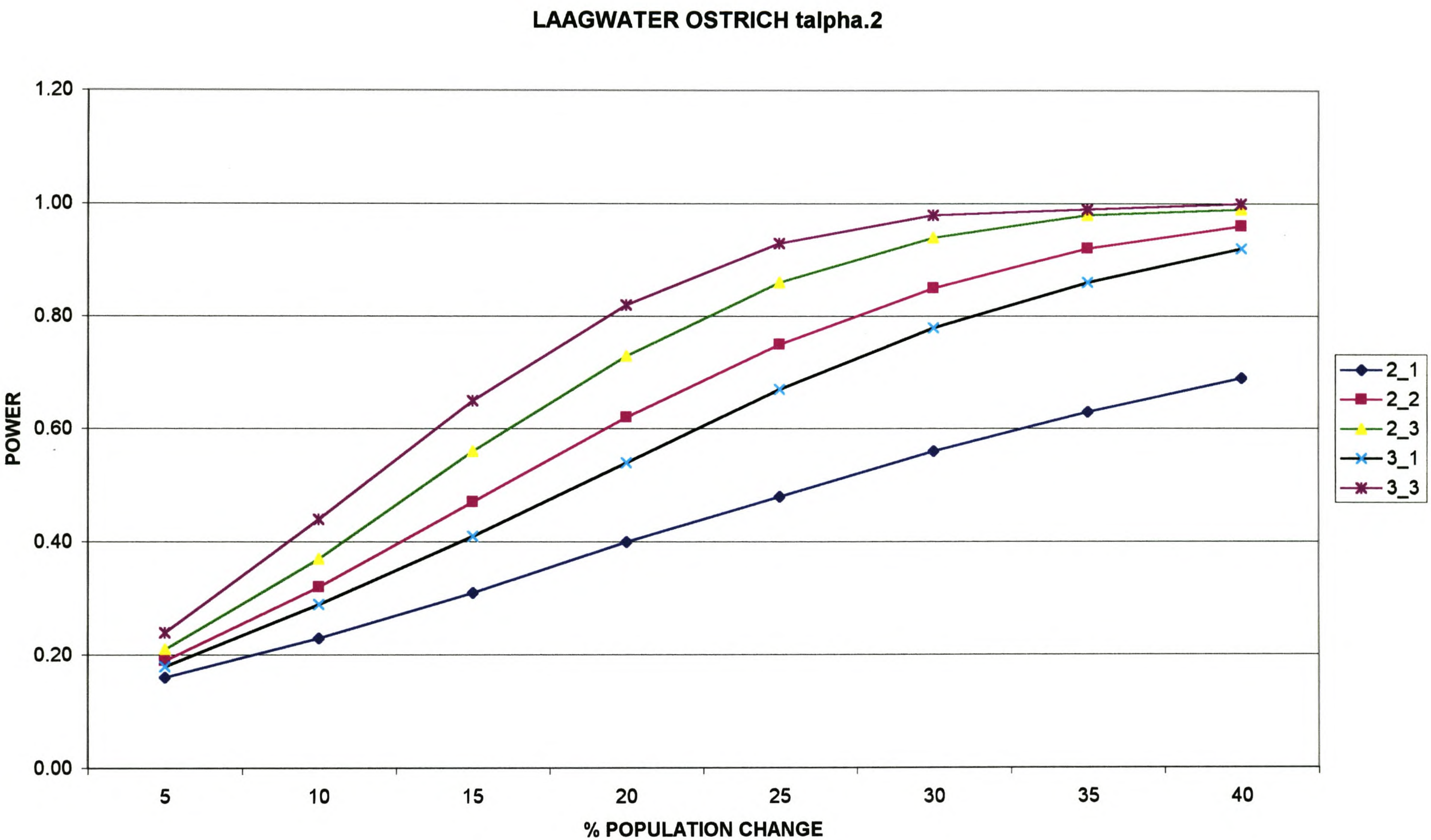


Figure 92: Power curves for various count replicate options at 20% significance for ostrich on the farm Laagwater, northwest arid bushveld.

Table 96: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for impala on the farm Laagwater, northwest arid bushveld.

| IMPALA | | MEAN | 162.30 | | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 8.12 | 16.23 | 24.35 | 32.46 | 40.58 | 48.69 | 56.81 | 64.92 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.42 | 0.84 | 1.26 | 1.68 | 2.10 | 2.51 | 2.93 | 3.35 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.51 | 1.03 | 1.54 | 2.05 | 2.57 | 3.08 | 3.59 | 4.11 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.56 | 1.12 | 1.69 | 2.25 | 2.81 | 3.37 | 3.94 | 4.50 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.44 | 0.88 | 1.32 | 1.77 | 2.21 | 2.65 | 3.09 | 3.53 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.62 | 1.25 | 1.87 | 2.50 | 3.12 | 3.75 | 4.37 | 4.99 |

Table 97: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for impala at 10% and 20% significance on the farm Laagwater, northwest arid bushveld.

talpha.1 IMPALA

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.08 | 0.12 | 0.16 | 0.21 | 0.26 | 0.31 | 0.35 | 0.40 |
| **2_2** | 0.10 | 0.18 | 0.28 | 0.40 | 0.52 | 0.63 | 0.74 | 0.82 |
| **2_3** | 0.12 | 0.22 | 0.37 | 0.54 | 0.69 | 0.81 | 0.90 | 0.95 |
| **3_1** | 0.09 | 0.15 | 0.23 | 0.33 | 0.43 | 0.54 | 0.64 | 0.72 |
| **3_3** | 0.13 | 0.27 | 0.46 | 0.66 | 0.82 | 0.92 | 0.97 | 0.99 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.16 | 0.23 | 0.32 | 0.40 | 0.48 | 0.56 | 0.63 | 0.70 |
| **2_2** | 0.19 | 0.33 | 0.48 | 0.63 | 0.76 | 0.86 | 0.92 | 0.96 |
| **2_3** | 0.21 | 0.38 | 0.56 | 0.74 | 0.86 | 0.94 | 0.98 | 0.99 |
| **3_1** | 0.18 | 0.29 | 0.41 | 0.55 | 0.67 | 0.78 | 0.86 | 0.92 |
| **3_3** | 0.24 | 0.44 | 0.65 | 0.83 | 0.93 | 0.98 | 0.99 | 1.00 |

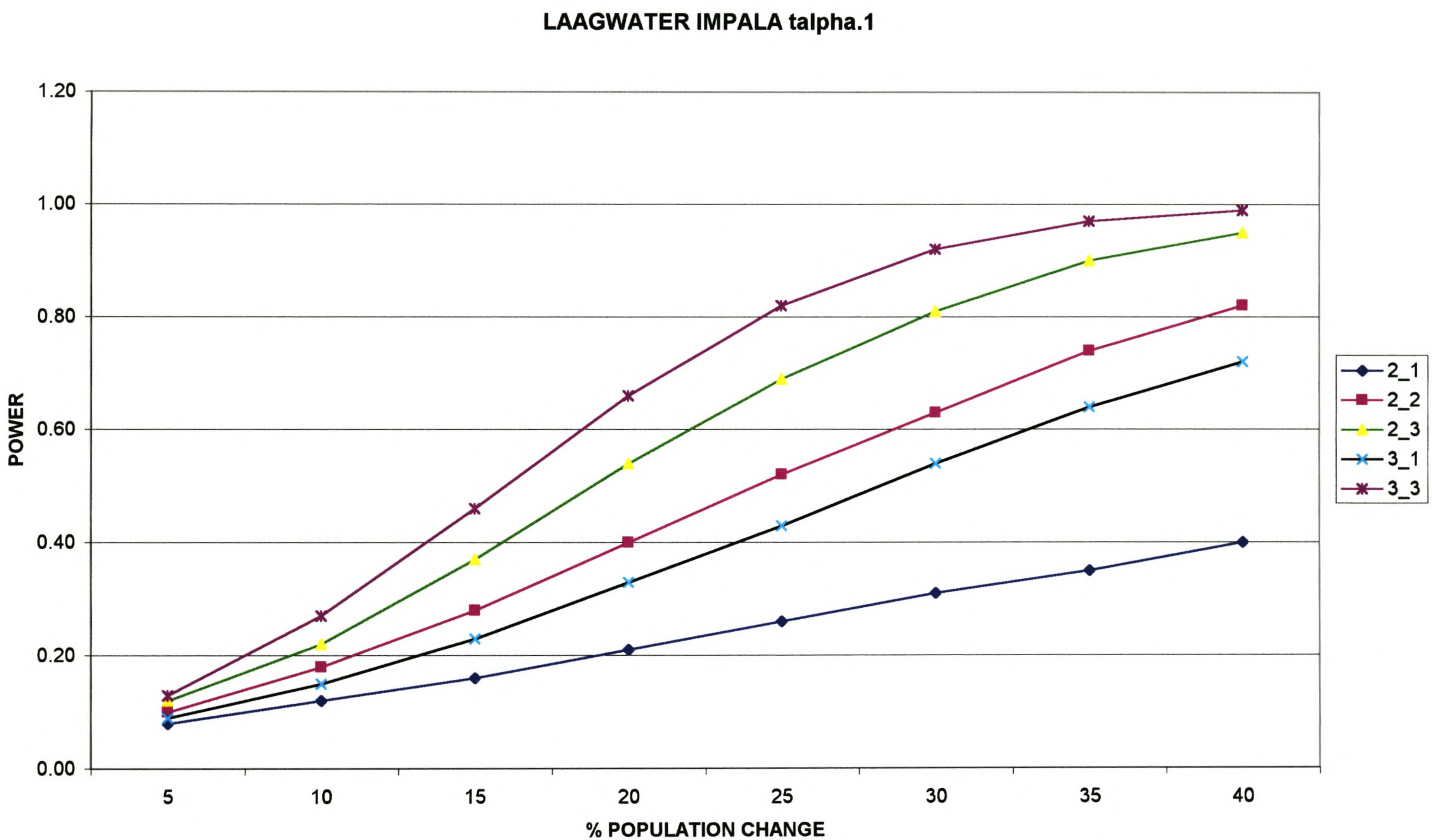


Figure 93: Power curves for various count replicate options at 10% significance for impala on the farm Laagwater, northwest arid bushveld.

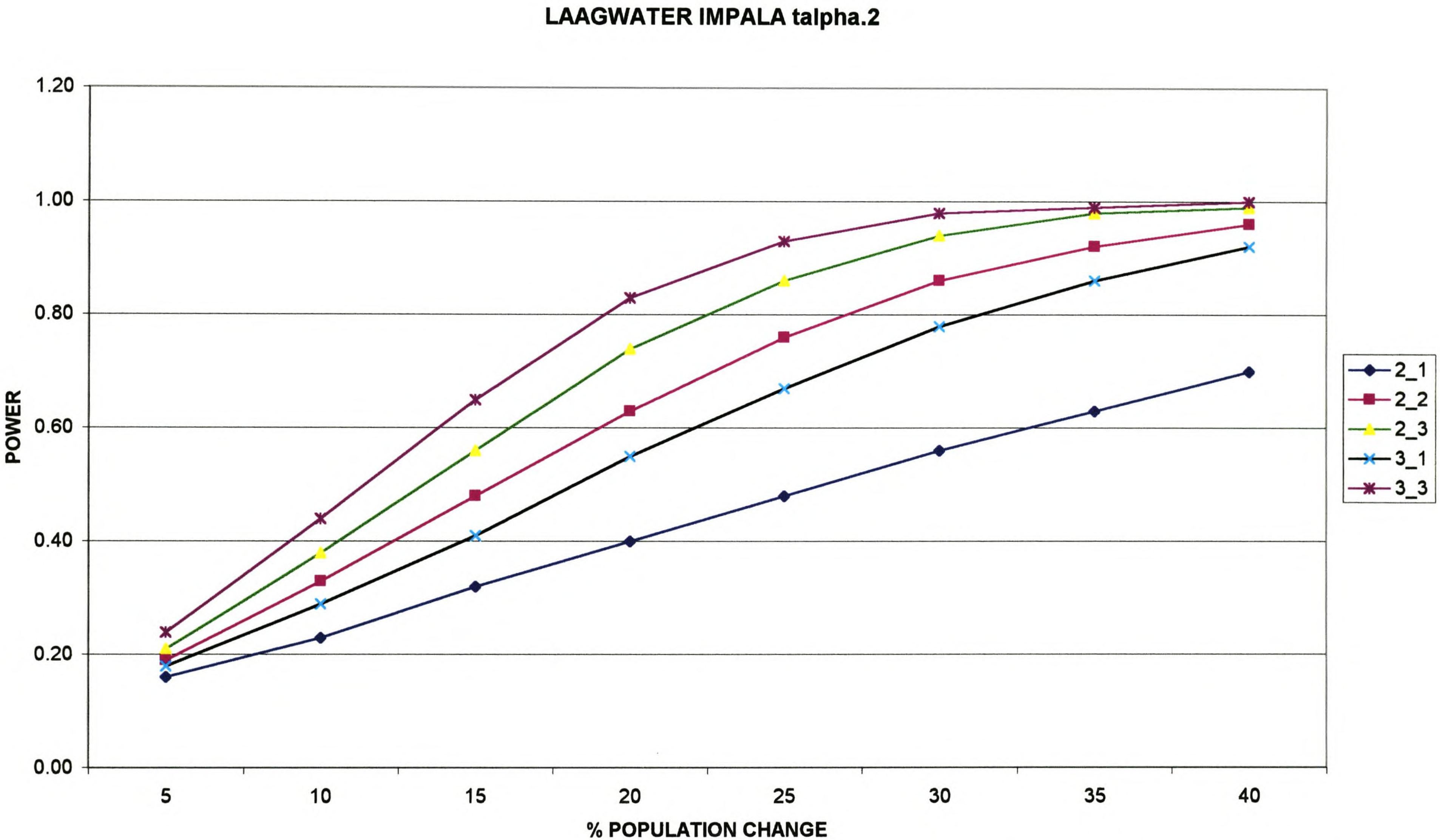


Figure 94: Power curves for various count replicate options at 20% significance for impala on the farm Laagwater, northwest arid bushveld.

Table 98: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for warthog on the farm Laagwater, northwest arid bushveld.

| WARTHOG | | | MEAN | 42.7 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 2.14 | 4.27 | 6.41 | 8.54 | 10.68 | 12.81 | 14.95 | 17.08 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.20 | 0.41 | 0.61 | 0.81 | 1.01 | 1.22 | 1.42 | 1.62 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.25 | 0.50 | 0.74 | 0.99 | 1.24 | 1.49 | 1.74 | 1.99 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.27 | 0.54 | 0.82 | 1.09 | 1.36 | 1.63 | 1.90 | 2.18 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.22 | 0.43 | 0.65 | 0.86 | 1.08 | 1.29 | 1.51 | 1.72 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.30 | 0.61 | 0.91 | 1.22 | 1.52 | 1.83 | 2.13 | 2.44 |

Table 99: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for warthog at 10% and 20% significance on the farm Laagwater, northwest arid bushveld.

talpha.1 WARTHOG

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.06 | 0.08 | 0.10 | 0.12 | 0.14 | 0.16 | 0.18 | 0.20 |
| **2_2** | 0.07 | 0.10 | 0.13 | 0.17 | 0.22 | 0.27 | 0.32 | 0.38 |
| **2_3** | 0.08 | 0.11 | 0.16 | 0.22 | 0.28 | 0.35 | 0.43 | 0.51 |
| **3_1** | 0.07 | 0.09 | 0.12 | 0.15 | 0.19 | 0.23 | 0.27 | 0.32 |
| **3_3** | 0.08 | 0.13 | 0.19 | 0.27 | 0.35 | 0.45 | 0.55 | 0.64 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.13 | 0.16 | 0.19 | 0.23 | 0.27 | 0.31 | 0.35 | 0.39 |
| **2_2** | 0.14 | 0.19 | 0.25 | 0.31 | 0.39 | 0.46 | 0.54 | 0.61 |
| **2_3** | 0.15 | 0.21 | 0.28 | 0.37 | 0.45 | 0.55 | 0.63 | 0.72 |
| **3_1** | 0.14 | 0.18 | 0.23 | 0.28 | 0.34 | 0.40 | 0.47 | 0.53 |
| **3_3** | 0.16 | 0.23 | 0.32 | 0.43 | 0.53 | 0.64 | 0.73 | 0.81 |

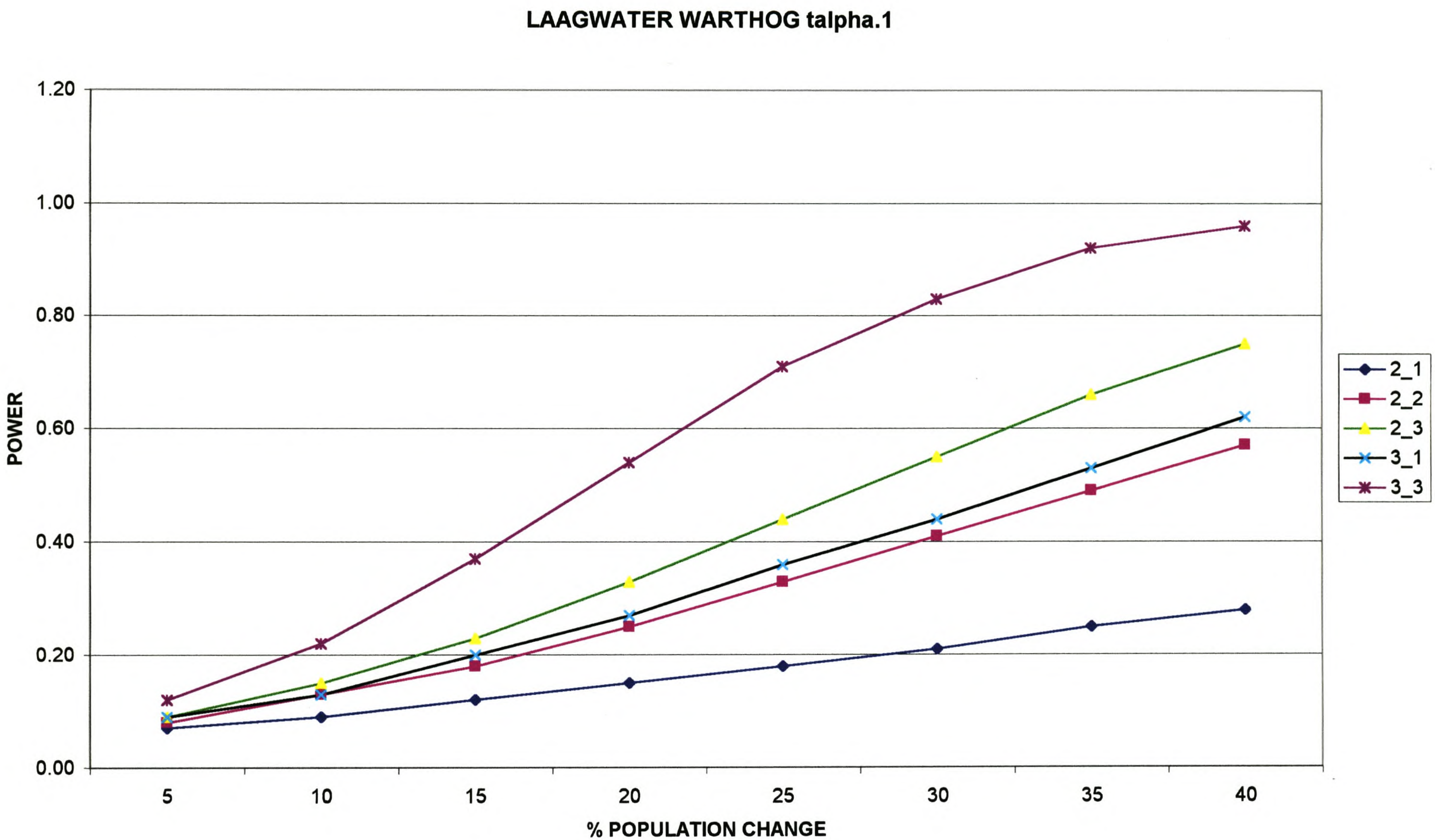


Figure 95: Power curves for various count replicate options at 10% significance for warthog on the farm Laagwater, northwest arid bushveld.

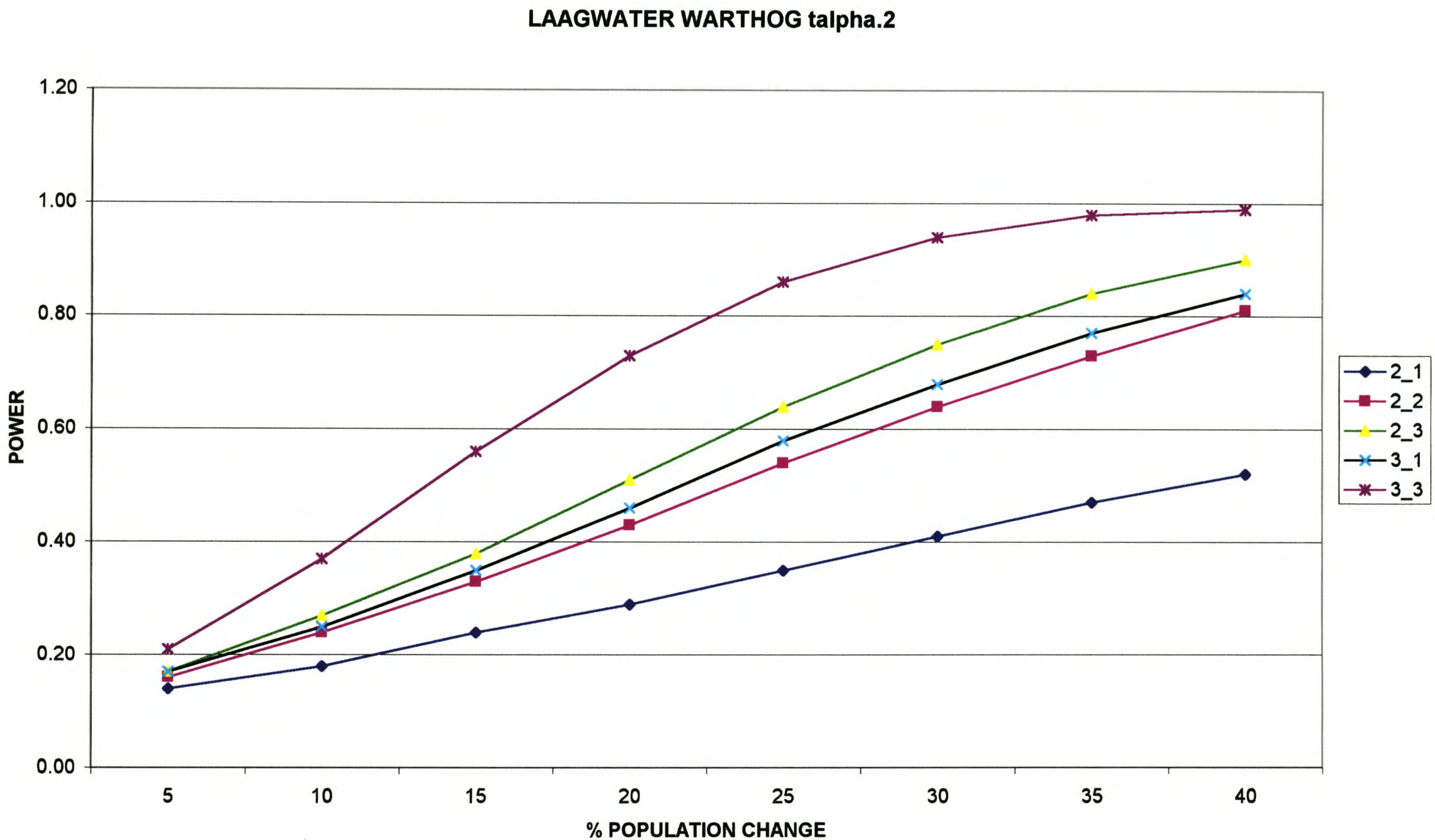


Figure 96: Power curves for various count replicate options at 20% significance for warthog on the farm Laagwater, northwest arid bushveld.

Table 100: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for blesbok on the farm Laagwater, northwest arid bushveld.

| BLESBOK | | MEAN | 47.30 | | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 2.37 | 4.73 | 7.10 | 9.46 | 11.83 | 14.19 | 16.56 | 18.92 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.81 | 1.62 | 2.43 | 3.25 | 4.06 | 4.87 | 5.68 | 6.49 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.99 | 1.99 | 2.98 | 3.97 | 4.97 | 5.96 | 6.96 | 7.95 |
| 2 | 3 | 3 | 2.35 | 1.64 | 1.09 | 2.18 | 3.27 | 4.35 | 5.44 | 6.53 | 7.62 | 8.71 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.86 | 1.73 | 2.59 | 3.46 | 4.32 | 5.19 | 6.05 | 6.91 |
| 3 | 3 | 4 | 2.13 | 1.53 | 1.22 | 2.44 | 3.67 | 4.89 | 6.11 | 7.33 | 8.56 | 9.78 |

Table 101: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for blesbok at 10% and 20% significance on the farm Laagwater, northwest arid bushveld.

talpha.1 BLESBOK

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| 2_1 | 0.12 | 0.20 | 0.30 | 0.39 | 0.47 | 0.55 | 0.63 | 0.69 |
| 2_2 | 0.17 | 0.38 | 0.61 | 0.80 | 0.91 | 0.97 | 0.99 | 1.00 |
| 2_3 | 0.22 | 0.51 | 0.79 | 0.94 | 0.99 | 1.00 | 1.00 | 1.00 |
| 3_1 | 0.15 | 0.32 | 0.52 | 0.71 | 0.85 | 0.93 | 0.97 | 0.99 |
| 3_3 | 0.27 | 0.64 | 0.91 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| 2_1 | 0.23 | 0.39 | 0.55 | 0.68 | 0.79 | 0.87 | 0.92 | 0.95 |
| 2_2 | 0.31 | 0.61 | 0.84 | 0.95 | 0.99 | 1.00 | 1.00 | 1.00 |
| 2_3 | 0.37 | 0.72 | 0.93 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 |
| 3_1 | 0.28 | 0.53 | 0.76 | 0.91 | 0.97 | 0.99 | 1.00 | 1.00 |
| 3_3 | 0.43 | 0.81 | 0.97 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

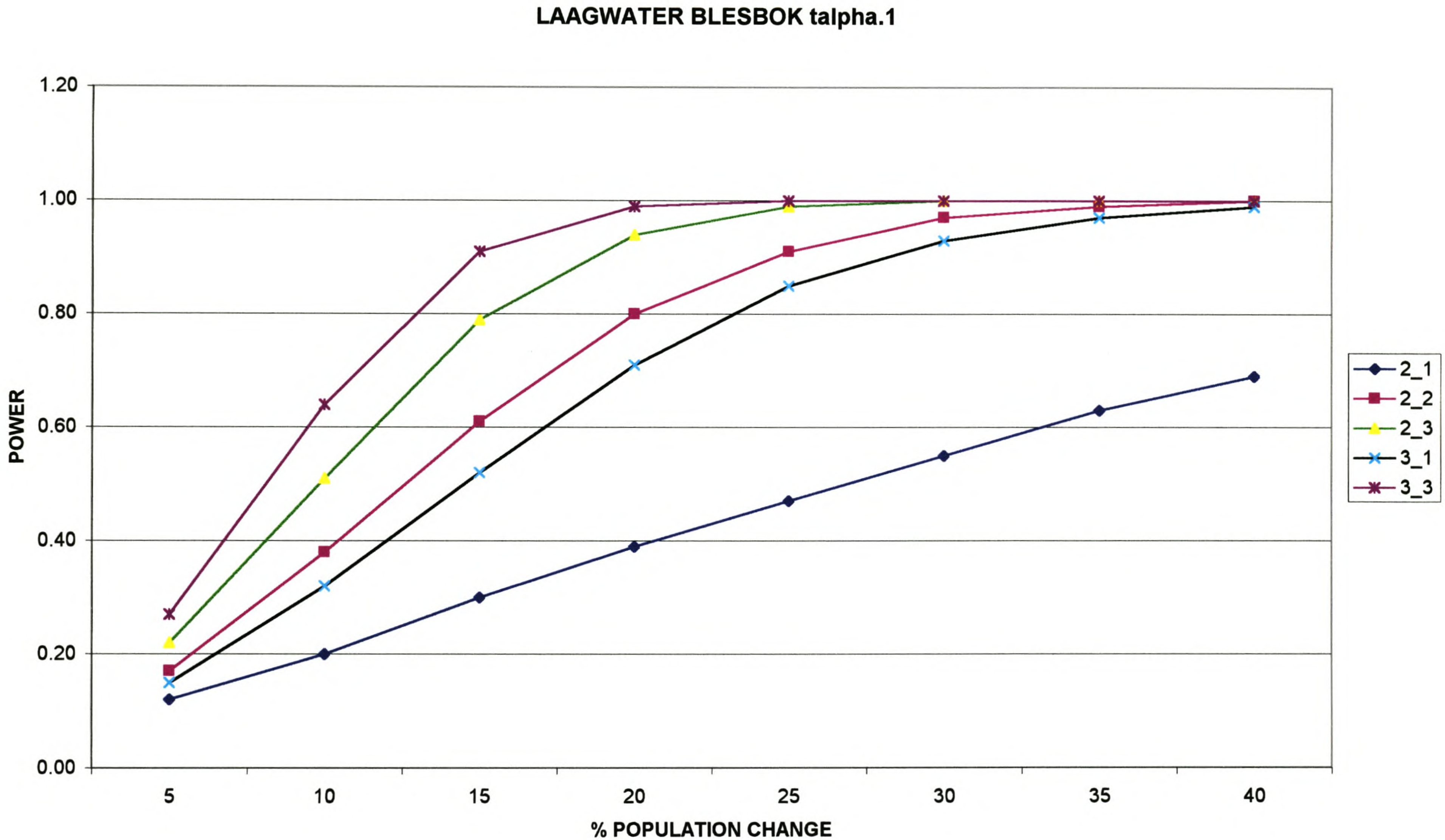


Figure 97: Power curves for various count replicate options at 10% significance for blesbok on the farm Laagwater, northwest arid bushveld.

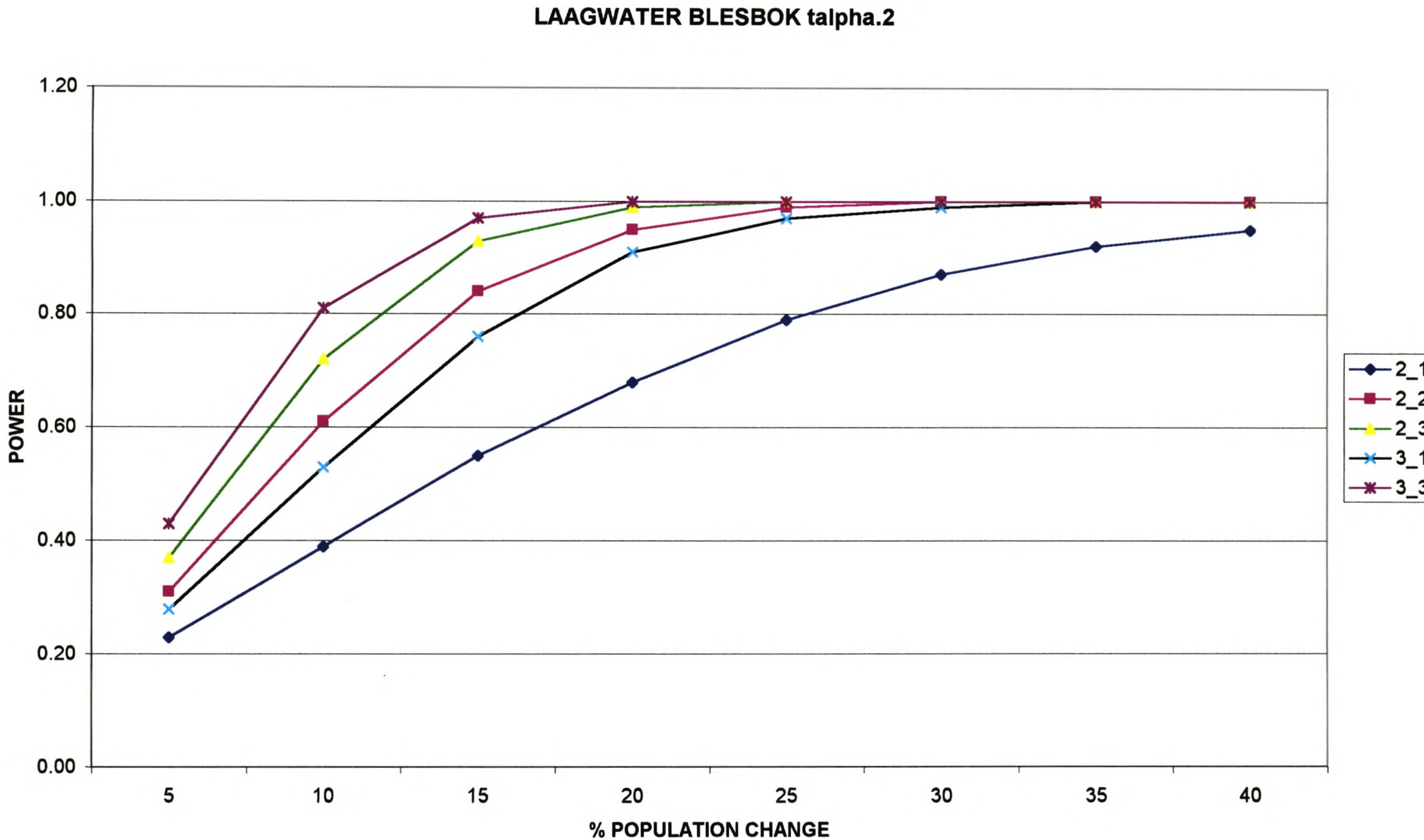


Figure 98: Power curves for various count replicate options at 20% significance for blesbok on the farm Laagwater, northwest arid bushveld.

Table 102: Summary statistics of three replicate helicopter counts of the farm Onrus, northwest arid bushveld.

| SPECIES | COUNT REPLICATES | | | MEAN | STANDARD | STANDARD |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | | DEVIATION(n2) | DEVIATION(n3) |
| *KUDU* | **26** | **30** | **50** | 35.3 | 10.56 | 10.52 |
| *ZEBRA* | **55** | **55** | **61** | 57.0 | 2.87 | 2.84 |
| *WILDEBEEST* | **94** | **106** | **100** | 100.0 | 4.96 | 4.90 |
| *IMPALA* | **210** | **160** | **178** | 182.7 | 20.51 | 20.42 |
| *WARTHOG* | **21** | **26** | **11** | 19.3 | 6.33 | 6.27 |
| *GEMSBOK* | **26** | **27** | **28** | 27.0 | 0.82 | 0.82 |
| *OSTRICH* | **17** | **20** | **18** | 18.3 | 1.25 | 1.25 |
| *HARTEBEEST* | **22** | **15** | **26** | 21.0 | 4.58 | 4.54 |
| *WATERBUCK* | **27** | **15** | **15** | 19.0 | 5.66 | 5.68 |

| SPECIES | SEdiff21 | SEdiff22 | SEdiff23 | SEdiff31 | SEdiff33 |
|---|---|---|---|---|---|
| *KUDU* | 12.93 | 10.56 | 9.64 | 12.15 | 8.59 |
| *ZEBRA* | 3.52 | 2.87 | 2.62 | 3.28 | 2.32 |
| *WILDEBEEST* | 6.07 | 4.96 | 4.53 | 5.66 | 4.00 |
| *IMPALA* | 25.12 | 20.51 | 18.72 | 23.58 | 16.67 |
| *WARTHOG* | 7.75 | 6.33 | 5.78 | 7.24 | 5.12 |
| *SABLE* | 1.00 | 0.82 | 0.75 | 0.95 | 0.67 |
| *WHITE RHINO* | 1.53 | 1.25 | 1.14 | 1.44 | 1.02 |
| *MT.REEDBUCK* | 5.61 | 4.58 | 4.18 | 5.24 | 3.71 |
| *GIRAFFE* | 6.93 | 5.66 | 5.17 | 6.56 | 4.64 |

Table 103: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for kudu on the farm Onrus, northwest arid bushveld.

| KUDU | | MEAN | 35.3 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | 1.77 | 3.53 | 5.30 | 7.06 | 8.83 | 10.59 | 12.36 | 14.12 |
| **n1** | **n2** | **df** | **talpha.1** | **talpha.2** | **NON CENTRALITY PARAMETERS** | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.14 | 0.27 | 0.41 | 0.55 | 0.68 | 0.82 | 0.96 | 1.09 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.17 | 0.33 | 0.50 | 0.67 | 0.84 | 1.00 | 1.17 | 1.34 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.18 | 0.37 | 0.55 | 0.73 | 0.92 | 1.10 | 1.28 | 1.46 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.15 | 0.29 | 0.44 | 0.58 | 0.73 | 0.87 | 1.02 | 1.16 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.21 | 0.41 | 0.62 | 0.82 | 1.03 | 1.23 | 1.44 | 1.64 |

Table 104: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for kudu at 10% and 20% significance on the farm Onrus, northwest arid bushveld.

talpha.1 KUDU

| | **5** | **10** | **15** | **20** | **25** | **30** | **35** | **40** |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.06 | 0.07 | 0.08 | 0.09 | 0.10 | 0.12 | 0.13 | 0.14 |
| **2_2** | 0.06 | 0.08 | 0.10 | 0.12 | 0.15 | 0.17 | 0.20 | 0.24 |
| **2_3** | 0.07 | 0.09 | 0.11 | 0.14 | 0.18 | 0.22 | 0.26 | 0.31 |
| **3_1** | 0.06 | 0.08 | 0.09 | 0.11 | 0.13 | 0.15 | 0.18 | 0.20 |
| **3_3** | 0.07 | 0.10 | 0.13 | 0.17 | 0.22 | 0.27 | 0.33 | 0.39 |

talpha.2

| | **5** | **10** | **15** | **20** | **25** | **30** | **35** | **40** |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.12 | 0.14 | 0.16 | 0.18 | 0.20 | 0.23 | 0.26 | 0.28 |
| **2_2** | 0.13 | 0.16 | 0.19 | 0.23 | 0.27 | 0.32 | 0.37 | 0.42 |
| **2_3** | 0.13 | 0.17 | 0.21 | 0.26 | 0.31 | 0.37 | 0.43 | 0.49 |
| **3_1** | 0.12 | 0.15 | 0.18 | 0.21 | 0.25 | 0.28 | 0.32 | 0.36 |
| **3_3** | 0.14 | 0.18 | 0.24 | 0.29 | 0.36 | 0.43 | 0.50 | 0.57 |

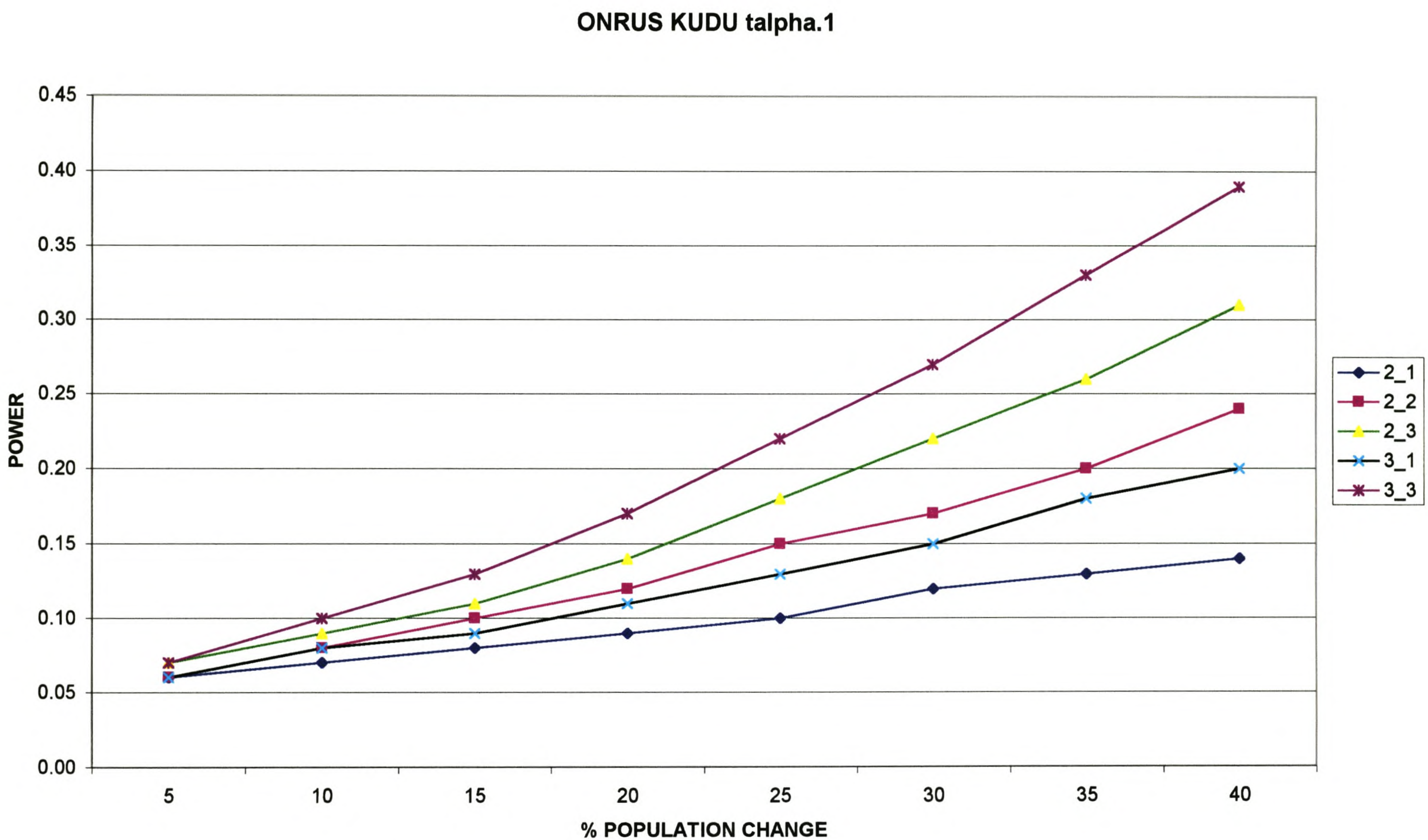


Figure 99: Power curves for various count replicate options at 10% significance for kudu on the farm Onrus, northwest arid bushveld.

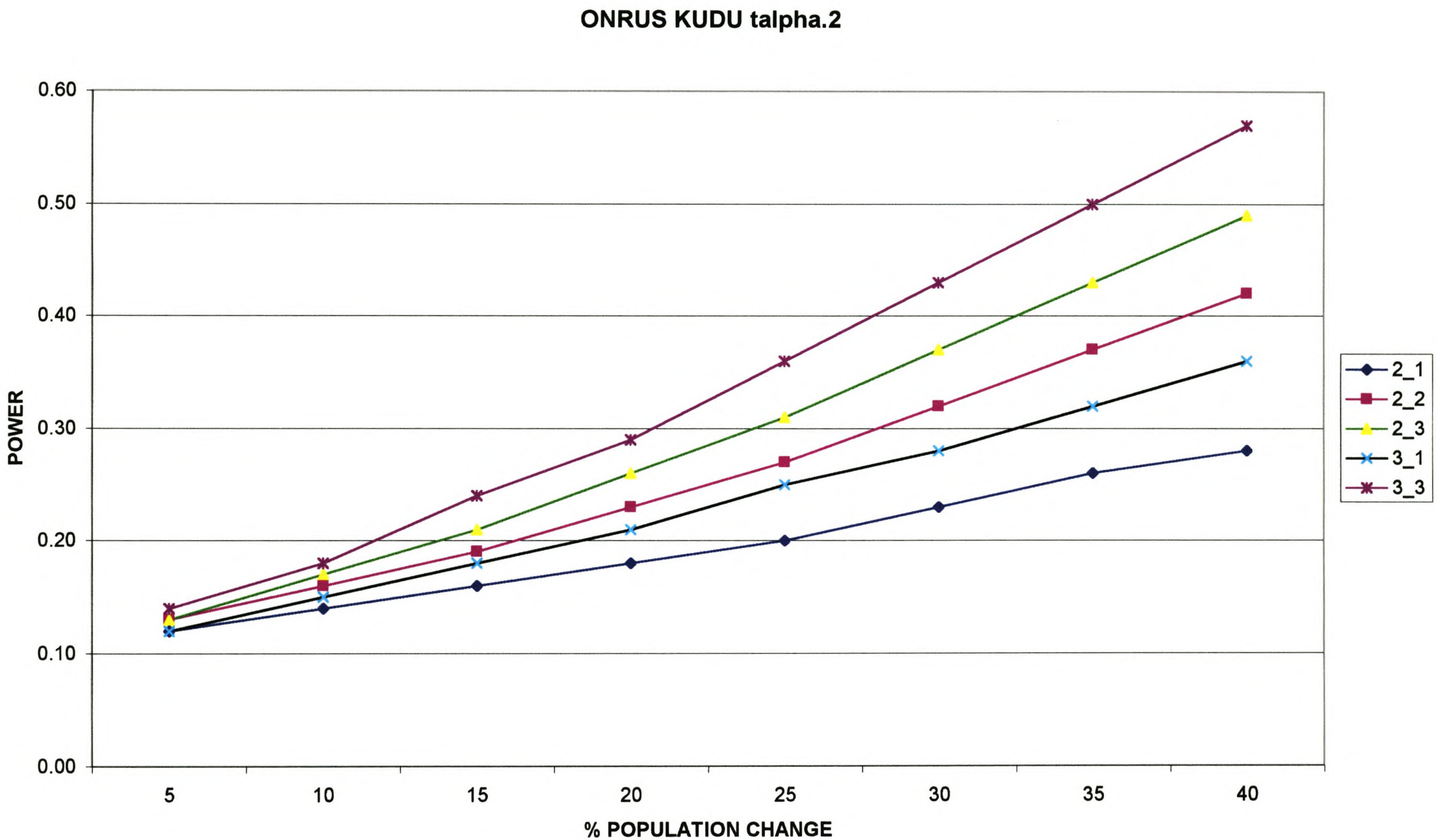


Figure 100: Power curves for various count replicate options at 20% significance for kudu on the farm Onrus, northwest arid bushveld.

Table 105: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for zebra on the farm Onrus, northwest arid bushveld.

| ZEBRA | | MEAN | | 57.00 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 2.85 | 5.70 | 8.55 | 11.40 | 14.25 | 17.10 | 19.95 | 22.80 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.81 | 1.62 | 2.43 | 3.24 | 4.05 | 4.86 | 5.68 | 6.49 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.99 | 1.99 | 2.98 | 3.97 | 4.97 | 5.96 | 6.95 | 7.94 |
| 2 | 3 | 3 | 2.35 | 1.64 | 1.09 | 2.18 | 3.26 | 4.35 | 5.44 | 6.53 | 7.61 | 8.70 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.87 | 1.74 | 2.61 | 3.48 | 4.35 | 5.21 | 6.08 | 6.95 |
| 3 | 3 | 4 | 2.13 | 1.53 | 1.23 | 2.46 | 3.69 | 4.92 | 6.15 | 7.37 | 8.60 | 9.83 |

**Table 106: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for zebra at 10% and 20% significance on the farm Onrus, northwest arid bushveld.**

talpha.1 ZEBRA

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.12 | 0.20 | 0.30 | 0.39 | 0.47 | 0.55 | 0.63 | 0.69 |
| **2_2** | 0.17 | 0.38 | 0.61 | 0.80 | 0.91 | 0.97 | 0.99 | 1.00 |
| **2_3** | 0.22 | 0.51 | 0.79 | 0.94 | 0.99 | 1.00 | 1.00 | 1.00 |
| **3_1** | 0.15 | 0.32 | 0.53 | 0.72 | 0.85 | 0.93 | 0.97 | 0.99 |
| **3_3** | 0.27 | 0.65 | 0.91 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.23 | 0.39 | 0.55 | 0.68 | 0.79 | 0.87 | 0.92 | 0.95 |
| **2_2** | 0.31 | 0.61 | 0.84 | 0.95 | 0.99 | 1.00 | 1.00 | 1.00 |
| **2_3** | 0.37 | 0.72 | 0.93 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 |
| **3_1** | 0.28 | 0.54 | 0.77 | 0.91 | 0.97 | 0.99 | 1.00 | 1.00 |
| **3_3** | 0.43 | 0.82 | 0.98 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

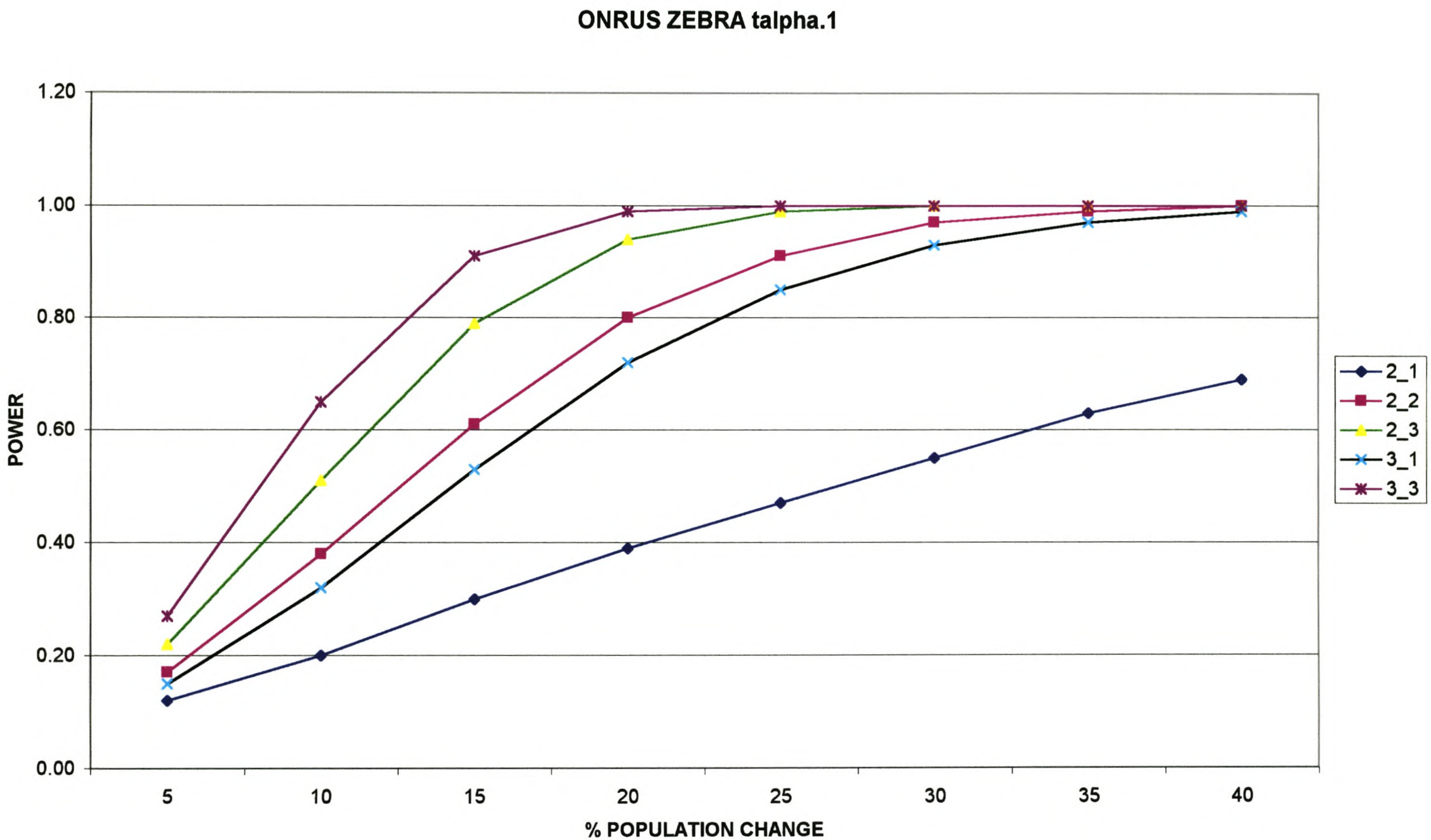


Figure 101: Power curves for various count replicate options at 10% significance for zebra on the farm Onrus, northwest arid bushveld.

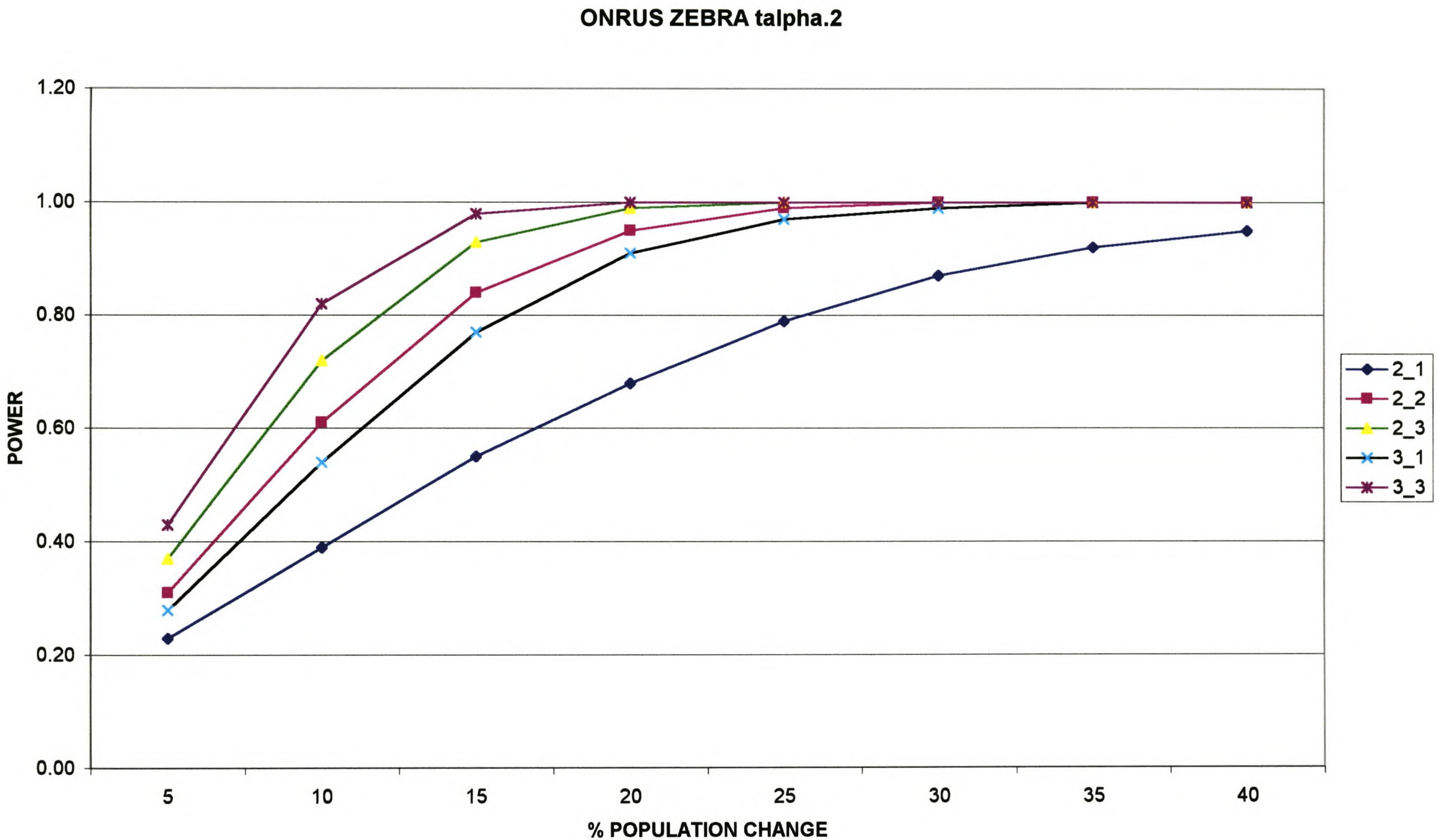


Figure 102: Power curves for various count replicate options at 20% significance for zebra on the farm Onrus, northwest arid bushveld.

Table 107: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for wildebeest on the farm Elandskloof, northwest arid bushveld.

| WILDEBEEST | | | MEAN | 100.00 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 5.00 | 10.00 | 15.00 | 20.00 | 25.00 | 30.00 | 35.00 | 40.00 |
| **n1** | **n2** | **df** | **talpha.1** | **talpha.2** | **NON CENTRALITY PARAMETERS** | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.82 | 1.65 | 2.47 | 3.29 | 4.12 | 4.94 | 5.76 | 6.58 |
| 2 | 2 | 2 | 2.92 | 1.87 | 1.01 | 2.02 | 3.02 | 4.03 | 5.04 | 6.05 | 7.06 | 8.06 |
| 2 | 3 | 3 | 2.35 | 1.64 | 1.10 | 2.21 | 3.31 | 4.42 | 5.52 | 6.63 | 7.73 | 8.83 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.88 | 1.77 | 2.65 | 3.53 | 4.42 | 5.30 | 6.19 | 7.07 |
| 3 | 3 | 4 | 2.13 | 1.53 | 1.25 | 2.50 | 3.75 | 5.00 | 6.25 | 7.50 | 8.75 | 10.00 |

Table 108: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for wildebeest at 10% and 20% significance on the farm Onrus, northwest arid bushveld.

talpha.1 WILDEBEEST

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.12 | 0.21 | 0.30 | 0.39 | 0.48 | 0.56 | 0.63 | 0.70 |
| **2_2** | 0.18 | 0.39 | 0.62 | 0.81 | 0.92 | 0.97 | 0.99 | 1.00 |
| **2_3** | 0.22 | 0.52 | 0.80 | 0.95 | 0.99 | 1.00 | 1.00 | 1.00 |
| **3_1** | 0.15 | 0.33 | 0.54 | 0.72 | 0.86 | 0.94 | 0.98 | 0.99 |
| **3_3** | 0.27 | 0.66 | 0.92 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.23 | 0.39 | 0.55 | 0.69 | 0.80 | 0.87 | 0.92 | 0.96 |
| **2_2** | 0.32 | 0.62 | 0.85 | 0.96 | 0.99 | 1.00 | 1.00 | 1.00 |
| **2_3** | 0.37 | 0.73 | 0.93 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 |
| **3_1** | 0.29 | 0.55 | 0.78 | 0.92 | 0.98 | 1.00 | 1.00 | 1.00 |
| **3_3** | 0.44 | 0.83 | 0.98 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

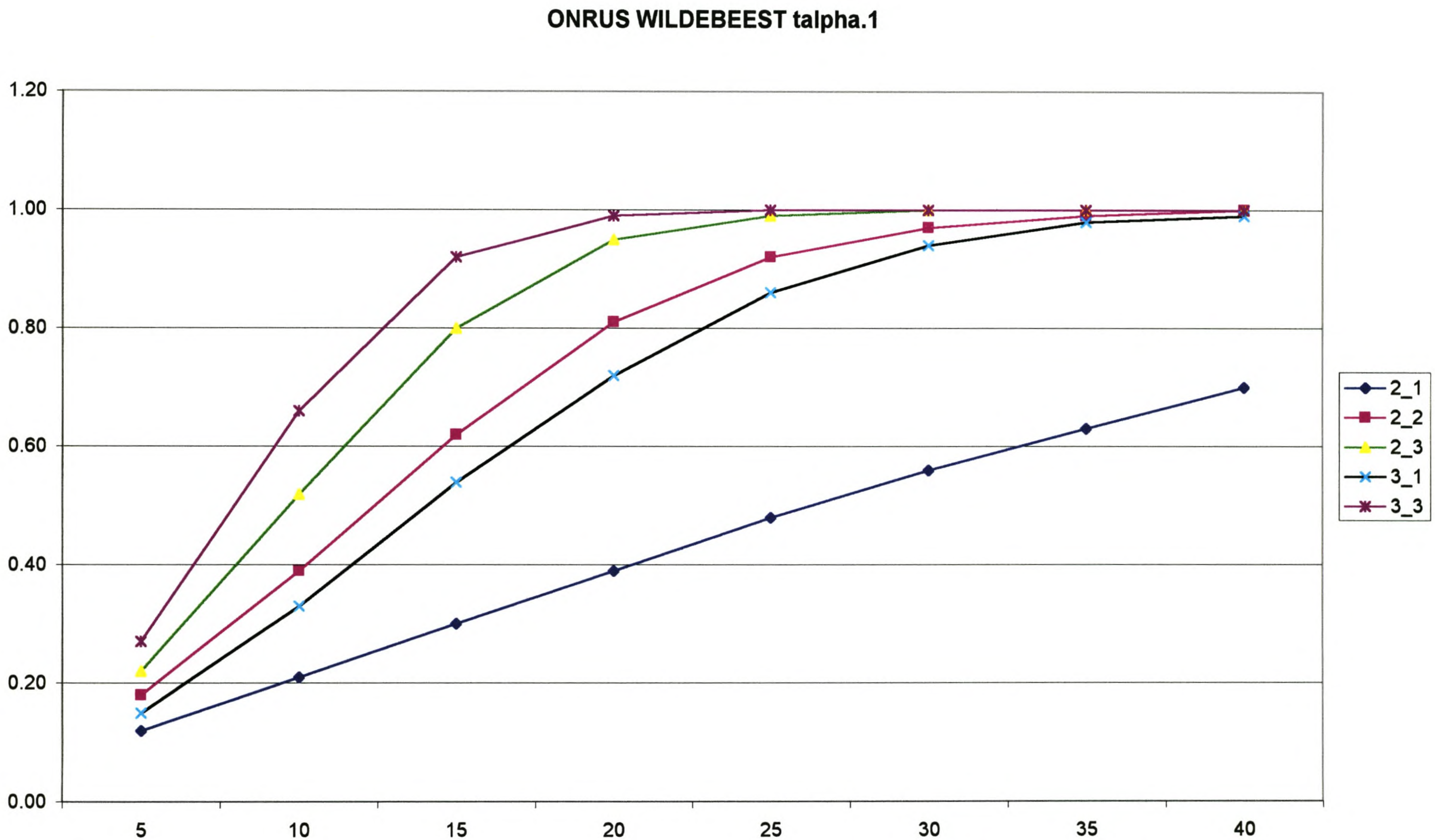


Figure 103: Power curves for various count replicate options at 10% significance for wildebeest on the farm Onrus, northwest arid bushveld.

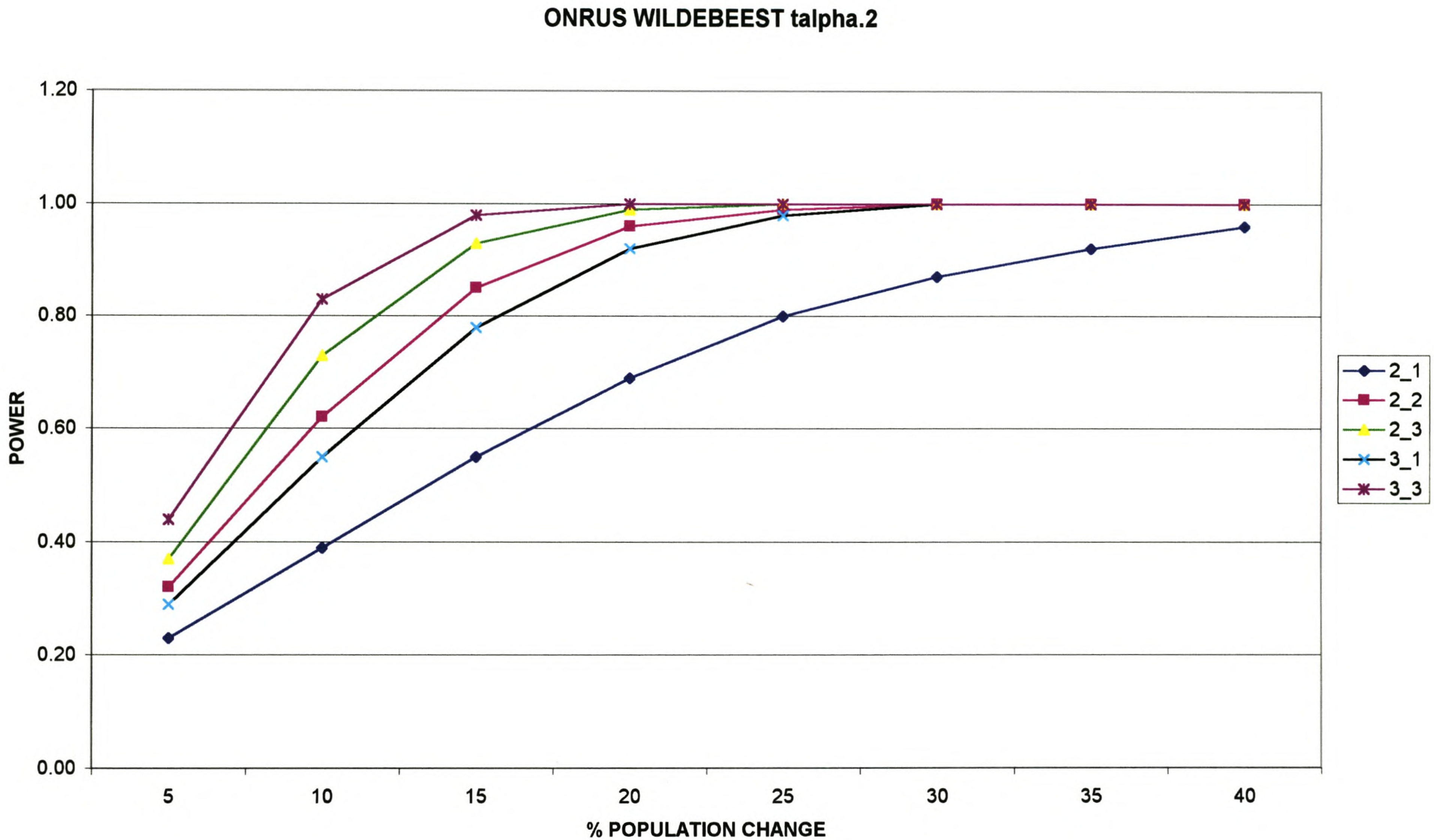


Figure 104: Power curves for various count replicate options at 20% significance for wildebeest on the farm Onrus, northwest arid bushveld.

Table 109: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for impala on the farm Onrus, northwest arid bushveld.

| IMPALA | | MEAN | 182.70 | | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 9.14 | 18.27 | 27.41 | 36.54 | 45.68 | 54.81 | 63.95 | 73.08 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.36 | 0.73 | 1.09 | 1.45 | 1.82 | 2.18 | 2.55 | 2.91 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.45 | 0.89 | 1.34 | 1.78 | 2.23 | 2.67 | 3.12 | 3.56 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.49 | 0.98 | 1.46 | 1.95 | 2.44 | 2.93 | 3.42 | 3.90 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.39 | 0.77 | 1.16 | 1.55 | 1.94 | 2.32 | 2.71 | 3.10 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.55 | 1.10 | 1.64 | 2.19 | 2.74 | 3.29 | 3.84 | 4.38 |

Table 110: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for impala at 10% and 20% significance on the farm Onrus, northwest arid bushveld.

talpha.1 IMPALA

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| 2_1 | 0.08 | 0.11 | 0.14 | 0.18 | 0.23 | 0.27 | 0.31 | 0.35 |
| 2_2 | 0.09 | 0.16 | 0.24 | 0.33 | 0.44 | 0.54 | 0.64 | 0.73 |
| 2_3 | 0.11 | 0.19 | 0.31 | 0.45 | 0.59 | 0.72 | 0.82 | 0.90 |
| 3_1 | 0.09 | 0.14 | 0.20 | 0.28 | 0.37 | 0.46 | 0.55 | 0.64 |
| 3_3 | 0.12 | 0.23 | 0.39 | 0.57 | 0.73 | 0.85 | 0.93 | 0.97 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| 2_1 | 0.15 | 0.21 | 0.28 | 0.35 | 0.43 | 0.50 | 0.57 | 0.63 |
| 2_2 | 0.18 | 0.29 | 0.42 | 0.55 | 0.68 | 0.78 | 0.86 | 0.92 |
| 2_3 | 0.20 | 0.33 | 0.49 | 0.65 | 0.78 | 0.88 | 0.94 | 0.98 |
| 3_1 | 0.17 | 0.26 | 0.36 | 0.48 | 0.60 | 0.70 | 0.79 | 0.86 |
| 3_3 | 0.22 | 0.38 | 0.57 | 0.75 | 0.88 | 0.95 | 0.98 | 0.99 |

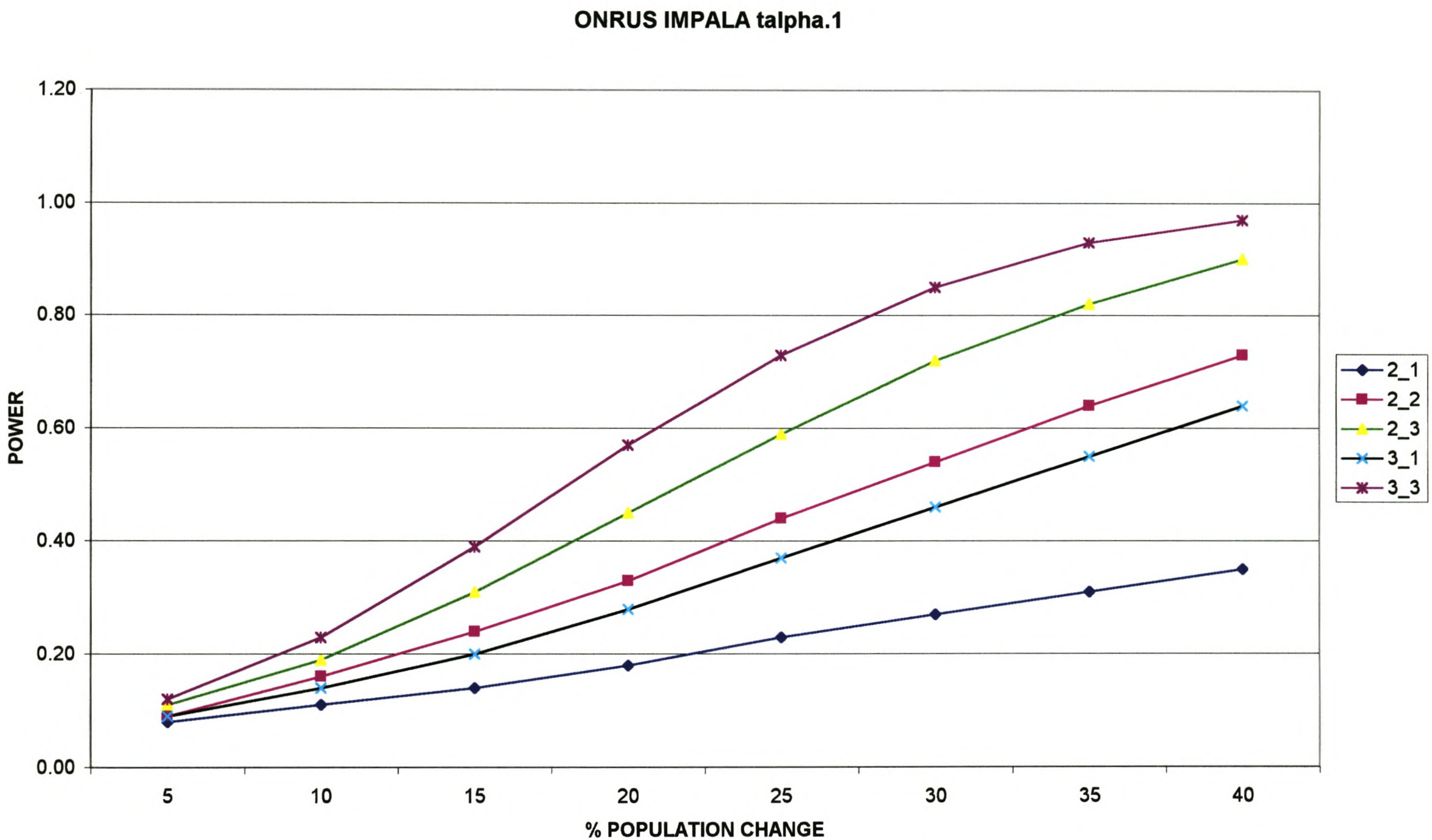


Figure 105: Power curves for various count replicate options at 10% significance for impala on the farm Onrus, northwest arid bushveld.

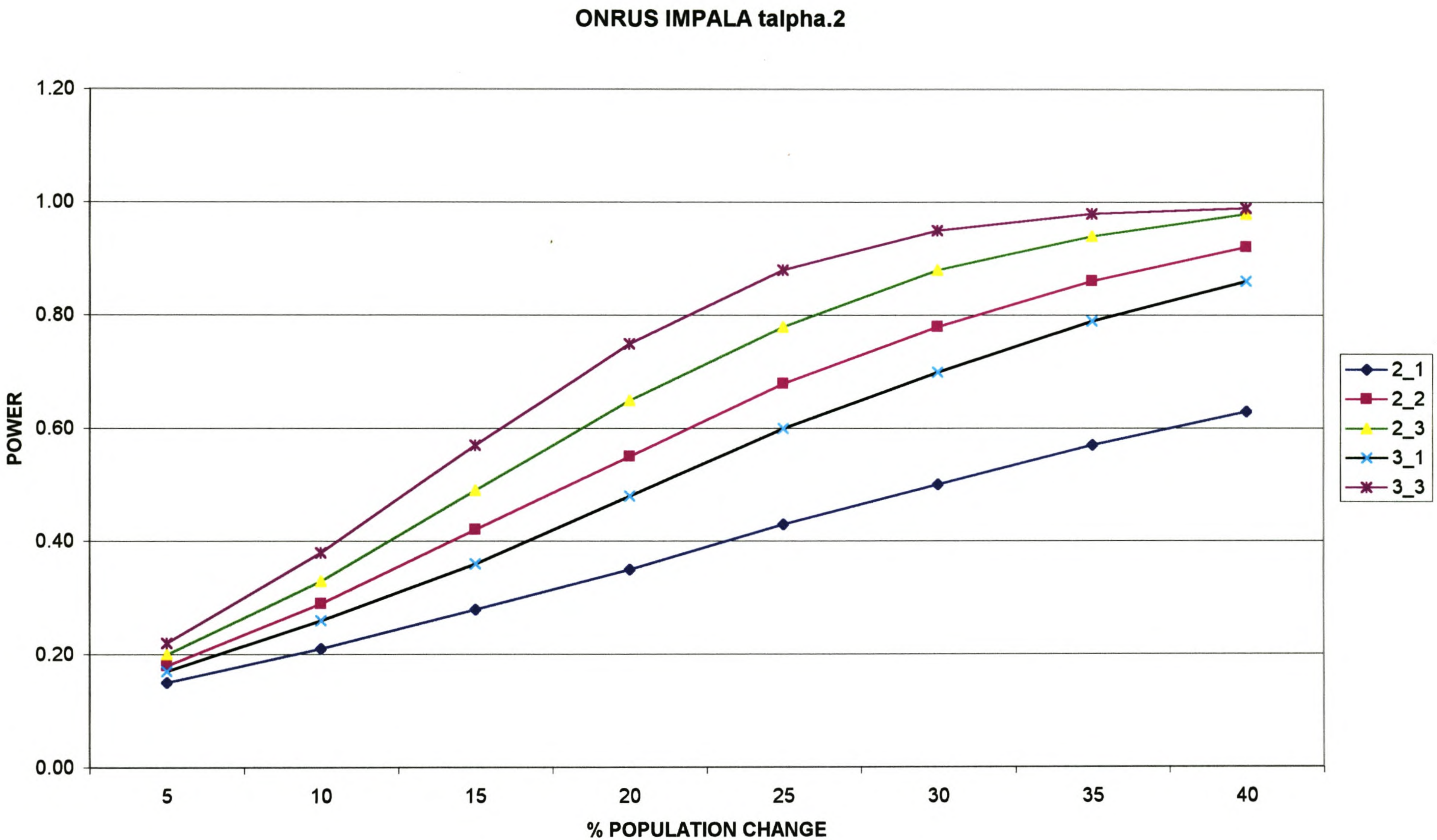


Figure 106: Power curves for various count replicate options at 20% significance for impala on the farm Onrus, northwest arid bushveld.

Table 111: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for warthog on the farm Onrus, northwest arid bushveld.

| WARTHOG | | MEAN | 19.3 | | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 0.97 | 1.93 | 2.90 | 3.86 | 4.83 | 5.79 | 6.76 | 7.72 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.12 | 0.25 | 0.37 | 0.50 | 0.62 | 0.75 | 0.87 | 1.00 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.15 | 0.30 | 0.46 | 0.61 | 0.76 | 0.91 | 1.07 | 1.22 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.17 | 0.33 | 0.50 | 0.67 | 0.83 | 1.00 | 1.17 | 1.34 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.13 | 0.27 | 0.40 | 0.53 | 0.67 | 0.80 | 0.93 | 1.07 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.19 | 0.38 | 0.57 | 0.75 | 0.94 | 1.13 | 1.32 | 1.51 |

Table 112: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for warthog at 10% and 20% significance on the farm Onrus, northwest arid bushveld.

talpha.1 WARTHOG

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.06 | 0.07 | 0.08 | 0.09 | 0.10 | 0.11 | 0.12 | 0.13 |
| **2_2** | 0.06 | 0.08 | 0.09 | 0.11 | 0.13 | 0.16 | 0.19 | 0.21 |
| **2_3** | 0.07 | 0.08 | 0.11 | 0.13 | 0.16 | 0.20 | 0.23 | 0.28 |
| **3_1** | 0.06 | 0.07 | 0.09 | 0.10 | 0.12 | 0.14 | 0.16 | 0.19 |
| **3_3** | 0.07 | 0.09 | 0.12 | 0.16 | 0.20 | 0.24 | 0.29 | 0.35 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.12 | 0.13 | 0.15 | 0.17 | 0.19 | 0.22 | 0.24 | 0.26 |
| **2_2** | 0.12 | 0.15 | 0.18 | 0.22 | 0.25 | 0.29 | 0.34 | 0.38 |
| **2_3** | 0.13 | 0.16 | 0.20 | 0.24 | 0.29 | 0.34 | 0.39 | 0.45 |
| **3_1** | 0.12 | 0.15 | 0.17 | 0.20 | 0.23 | 0.26 | 0.30 | 0.34 |
| **3_3** | 0.13 | 0.17 | 0.22 | 0.27 | 0.33 | 0.39 | 0.46 | 0.53 |

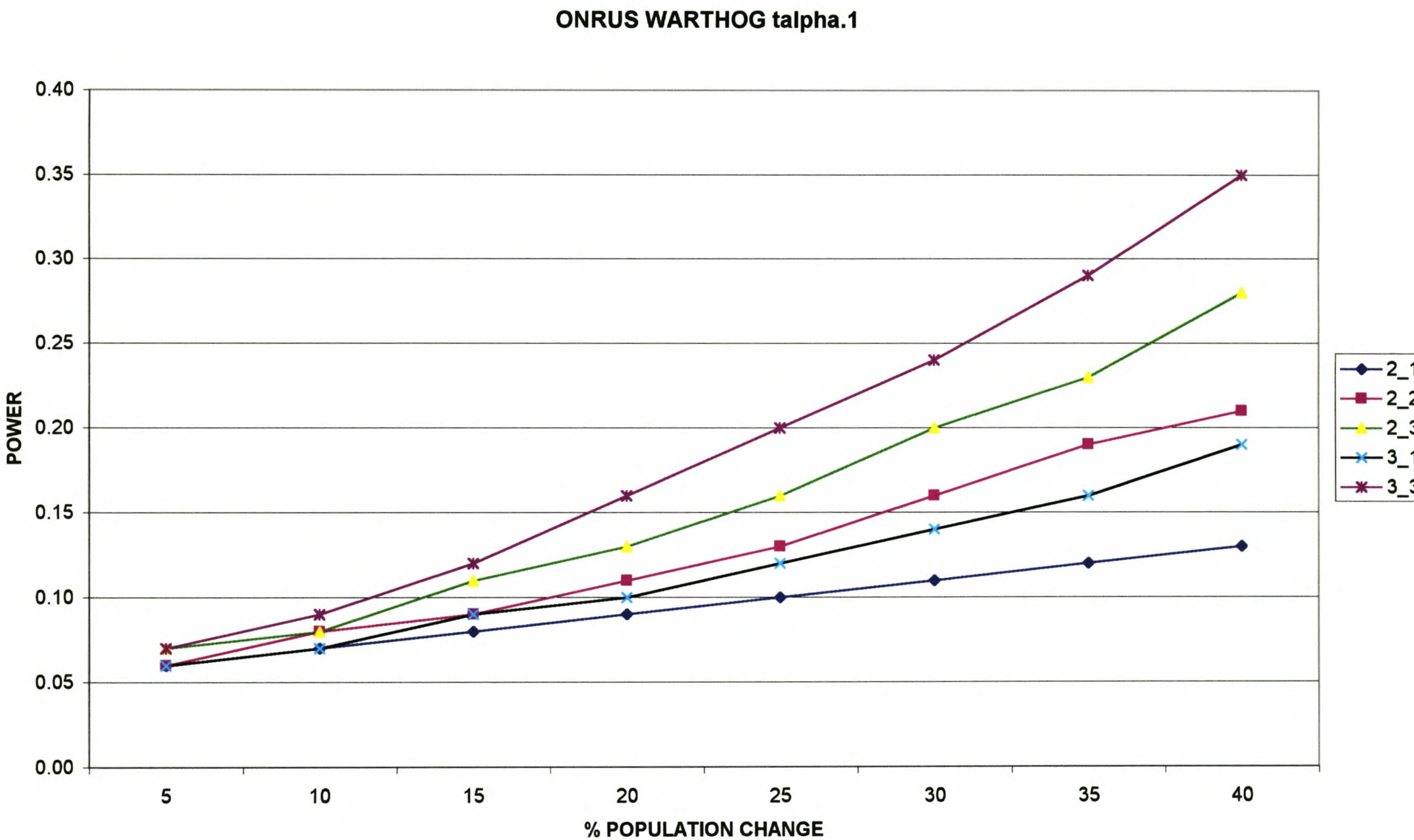


Figure 107: Power curves for various count replicate options at 10% significance for warthog on the farm Onrus, northwest arid bushveld.

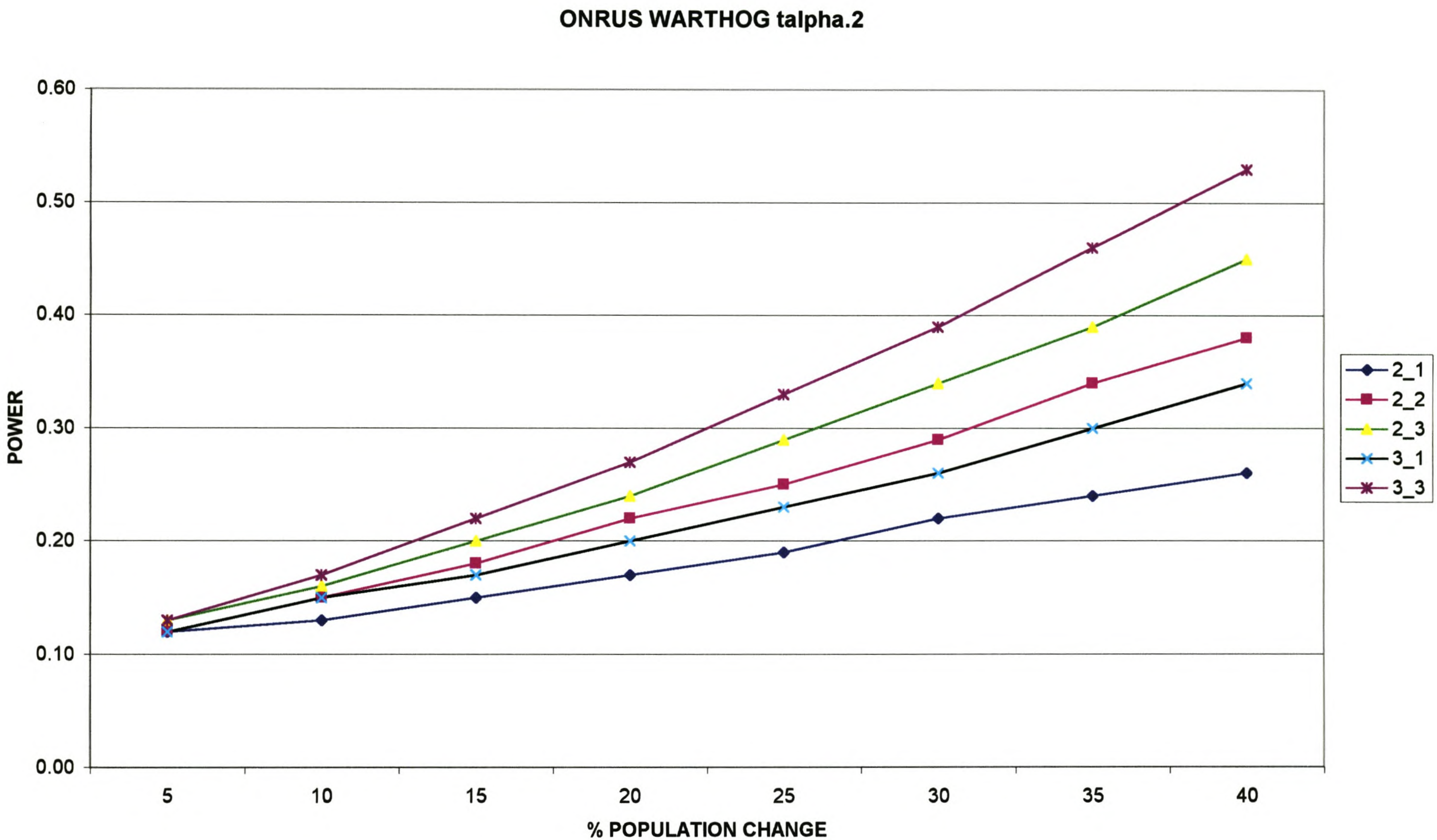


Figure 108: Power curves for various count replicate options at 20% significance for warthog on the farm Onrus, northwest arid bushveld.

Table 113: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for gemsbok on the farm Onrus, northwest arid bushveld.

| GEMSBOK | | | MEAN | 27.00 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 1.35 | 2.70 | 4.05 | 5.40 | 6.75 | 8.10 | 9.45 | 10.80 |
| **n1** | **n2** | **df** | **talpha.1** | **talpha.2** | **NON CENTRALITY PARAMETERS** | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 1.34 | 2.69 | 4.03 | 5.38 | 6.72 | 8.07 | 9.41 | 10.75 |
| 2 | 2 | 2 | 2.92 | 1.87 | 1.65 | 3.29 | 4.94 | 6.59 | 8.23 | 9.88 | 11.52 | 13.17 |
| 2 | 3 | 3 | 2.35 | 1.64 | 1.80 | 3.61 | 5.41 | 7.21 | 9.02 | 10.82 | 12.62 | 14.43 |
| 3 | 1 | 2 | 2.92 | 1.87 | 1.43 | 2.85 | 4.28 | 5.70 | 7.13 | 8.55 | 9.98 | 11.41 |
| 3 | 3 | 4 | 2.13 | 1.53 | 2.02 | 4.03 | 6.05 | 8.07 | 10.08 | 12.10 | 14.11 | 16.13 |

Table 114: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for gemsbok at 10% and 20% significance on the farm Onrus, northwest arid bushveld.

talpha.1 GEMSBOK

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.17 | 0.33 | 0.47 | 0.60 | 0.71 | 0.79 | 0.86 | 0.91 |
| **2_2** | 0.30 | 0.68 | 0.91 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 |
| **2_3** | 0.40 | 0.86 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| **3_1** | 0.26 | 0.58 | 0.84 | 0.96 | 0.99 | 1.00 | 1.00 | 1.00 |
| **3_3** | 0.51 | 0.95 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.33 | 0.59 | 0.79 | 0.90 | 0.96 | 0.99 | 1.00 | 1.00 |
| **2_2** | 0.51 | 0.89 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| **2_3** | 0.60 | 0.96 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| **3_1** | 0.44 | 0.82 | 0.97 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| **3_3** | 0.70 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

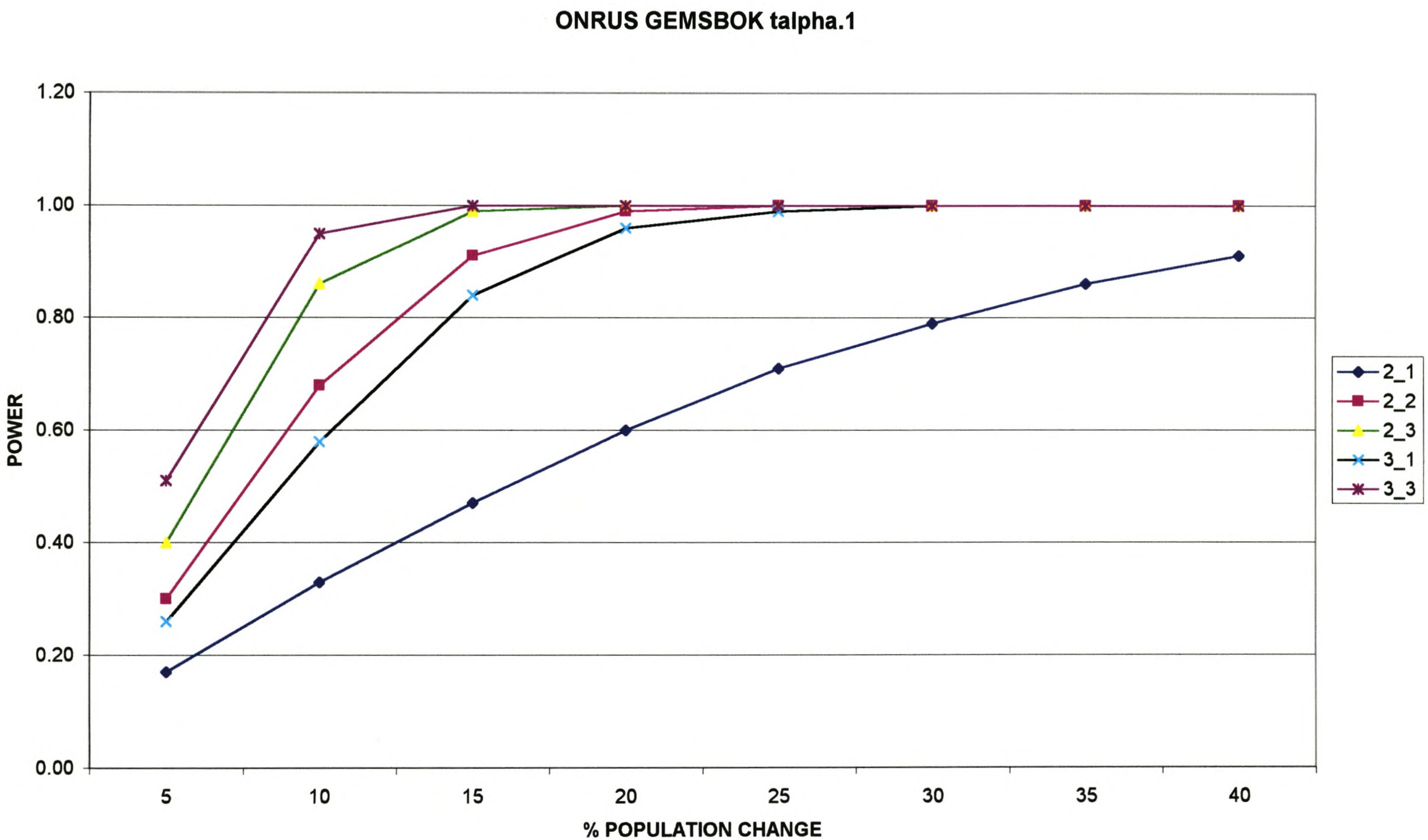


Figure 109: Power curves for various count replicate options at 10% significance for gemsbok on the farm Onrus, northwest arid bushveld.

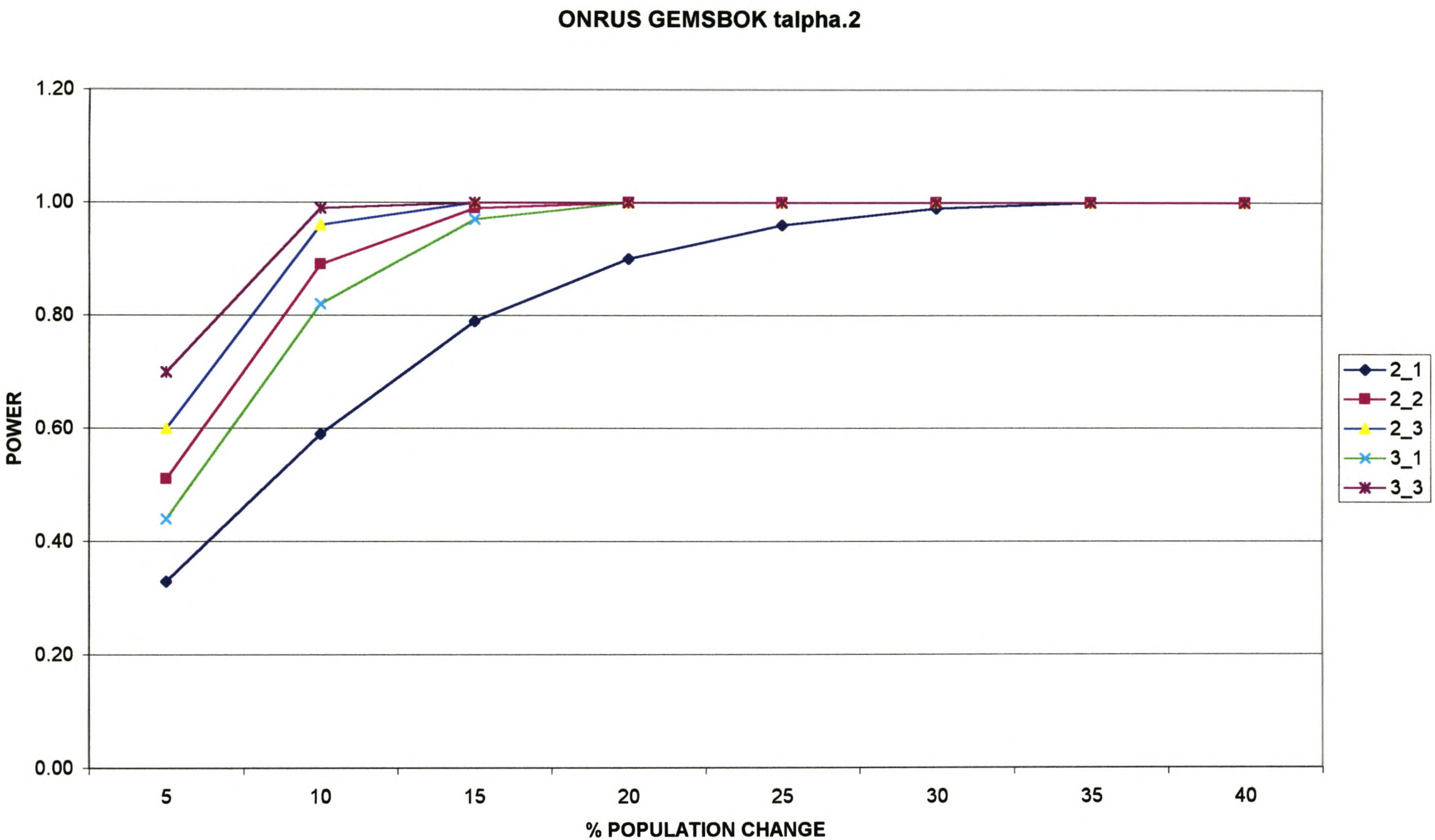


Figure 110: Power curves for various count replicate options at 10% significance for gemsbok on the farm Onrus, northwest arid bushveld.

Table 115: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for ostrich on the farm Onrus, northwest arid bushveld.

| OSTRICH | | MEAN | | 18.30 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 0.92 | 1.83 | 2.75 | 3.66 | 4.58 | 5.49 | 6.41 | 7.32 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.60 | 1.20 | 1.79 | 2.39 | 2.99 | 3.59 | 4.18 | 4.78 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.73 | 1.46 | 2.20 | 2.93 | 3.66 | 4.39 | 5.12 | 5.86 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.80 | 1.60 | 2.41 | 3.21 | 4.01 | 4.81 | 5.61 | 6.41 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.63 | 1.27 | 1.90 | 2.54 | 3.17 | 3.80 | 4.44 | 5.07 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.90 | 1.79 | 2.69 | 3.59 | 4.48 | 5.38 | 6.28 | 7.17 |

Table 116: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for ostrich at 10% and 20% significance on the farm Onrus, northwest arid bushveld.

talpha.1 OSTRICH

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.10 | 0.16 | 0.22 | 0.29 | 0.36 | 0.43 | 0.49 | 0.55 |
| **2_2** | 0.13 | 0.26 | 0.43 | 0.60 | 0.75 | 0.86 | 0.93 | 0.97 |
| **2_3** | 0.16 | 0.35 | 0.58 | 0.78 | 0.91 | 0.97 | 0.99 | 1.00 |
| **3_1** | 0.12 | 0.22 | 0.36 | 0.51 | 0.65 | 0.77 | 0.86 | 0.92 |
| **3_3** | 0.19 | 0.44 | 0.71 | 0.90 | 0.98 | 1.00 | 1.00 | 1.00 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.19 | 0.30 | 0.42 | 0.54 | 0.64 | 0.73 | 0.80 | 0.86 |
| **2_2** | 0.25 | 0.45 | 0.67 | 0.83 | 0.93 | 0.98 | 0.99 | 1.00 |
| **2_3** | 0.28 | 0.54 | 0.78 | 0.92 | 0.98 | 1.00 | 1.00 | 1.00 |
| **3_1** | 0.22 | 0.40 | 0.58 | 0.75 | 0.87 | 0.94 | 0.98 | 0.99 |
| **3_3** | 0.32 | 0.62 | 0.87 | 0.97 | 1.00 | 1.00 | 1.00 | 1.00 |

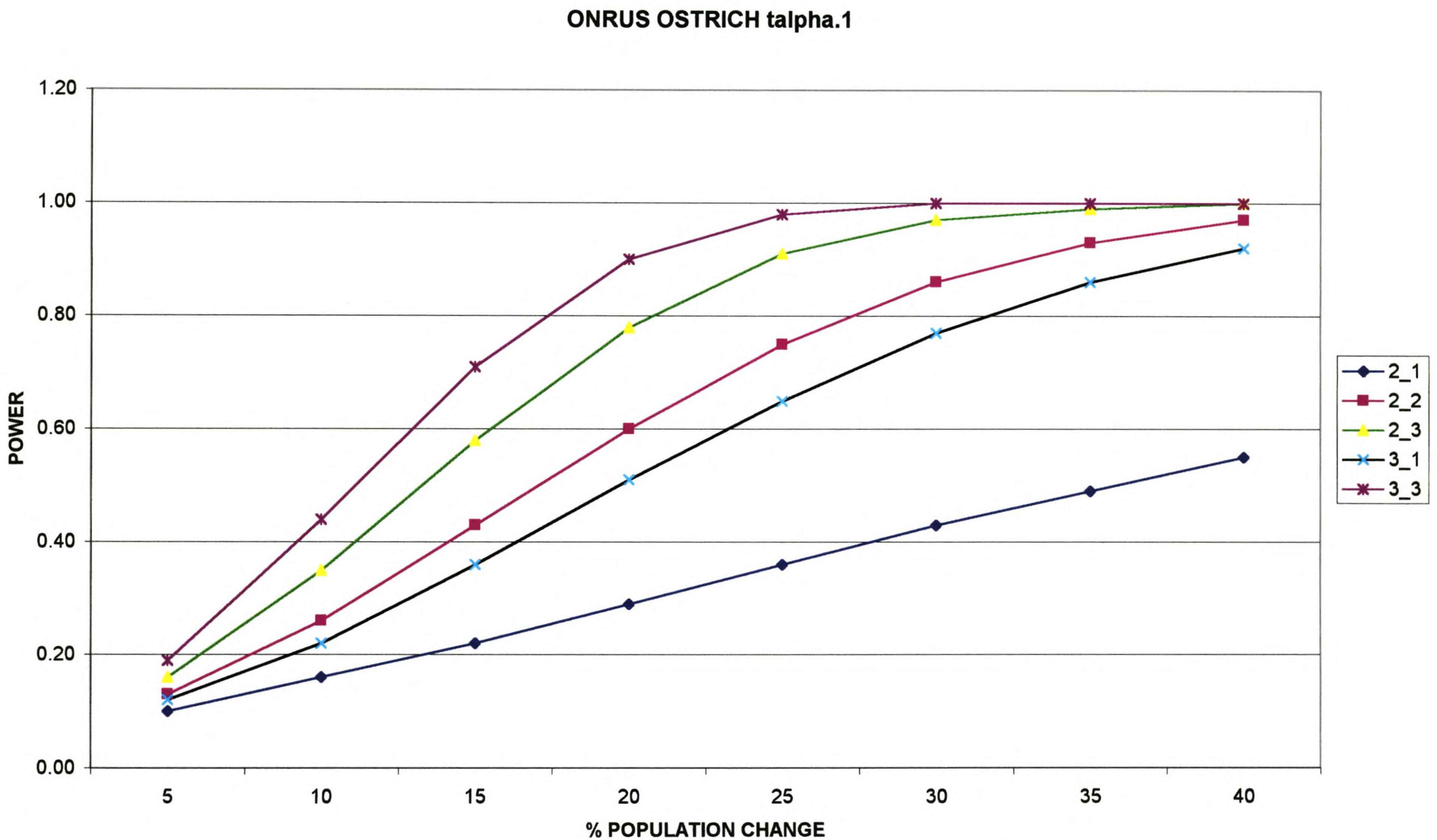


Figure 111: Power curves for various count replicate options at 10% significance for ostrich on the farm Onrus, northwest arid bushveld.

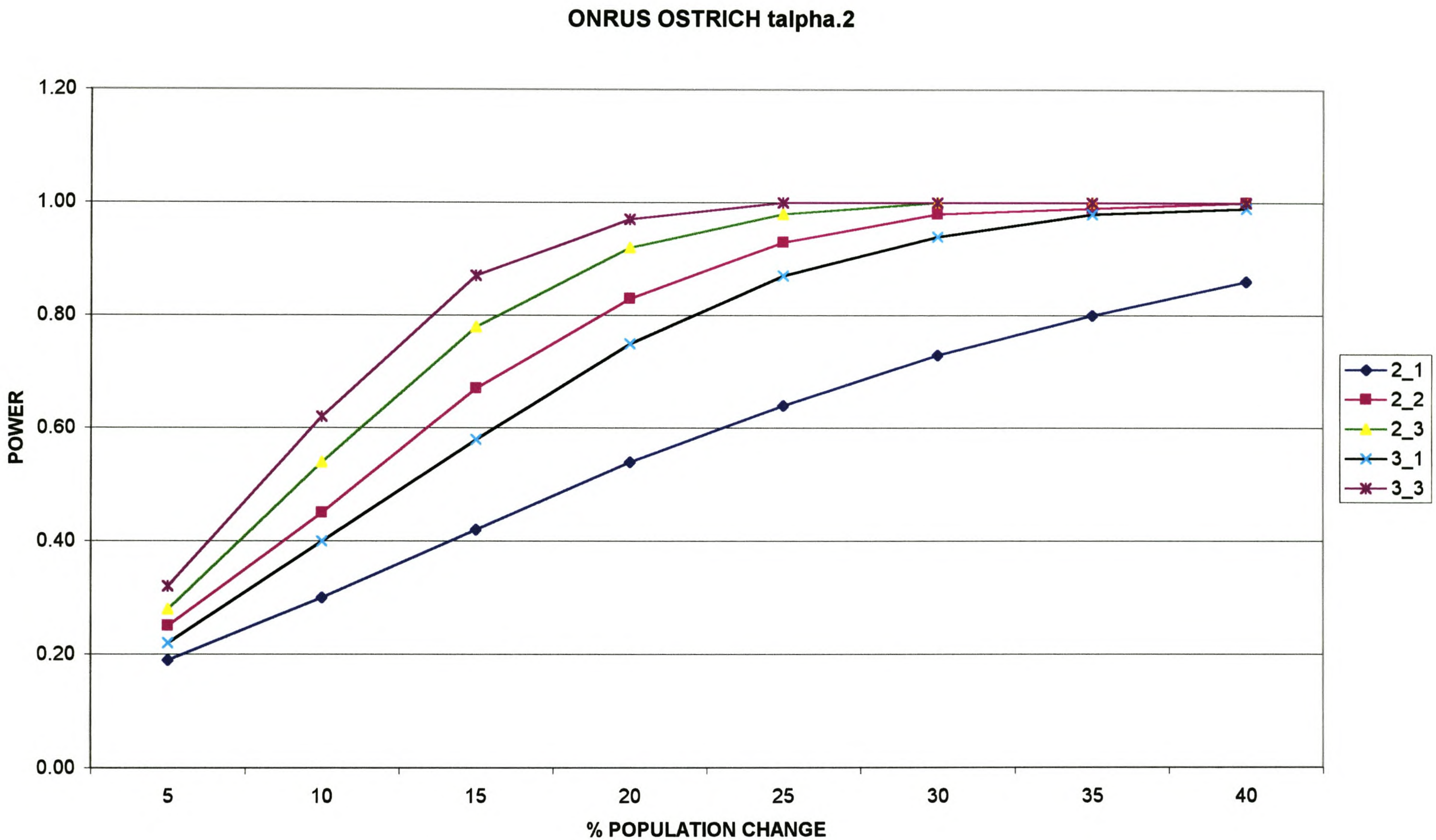


Figure 112: Power curves for various count replicate options at 20% significance for ostrich on the farm Onrus, northwest arid bushveld.

Table 117: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for hartebeest on the farm Onrus, northwest arid bushveld.

| HARTEBEEST | | MEAN | 18.3 | | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 0.92 | 1.83 | 2.75 | 3.66 | 4.58 | 5.49 | 6.41 | 7.32 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.16 | 0.33 | 0.49 | 0.65 | 0.82 | 0.98 | 1.14 | 1.30 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.20 | 0.40 | 0.60 | 0.80 | 1.00 | 1.20 | 1.40 | 1.60 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.22 | 0.44 | 0.66 | 0.88 | 1.09 | 1.31 | 1.53 | 1.75 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.17 | 0.35 | 0.52 | 0.70 | 0.87 | 1.05 | 1.22 | 1.40 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.25 | 0.49 | 0.74 | 0.99 | 1.23 | 1.48 | 1.73 | 1.97 |

**Table 118: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for hartebeest at 10% and 20% significance on the farm Onrus, northwest arid bushveld.**

talpha.1 HARTEBEEST

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.06 | 0.07 | 0.09 | 0.10 | 0.12 | 0.13 | 0.15 | 0.17 |
| **2_2** | 0.07 | 0.09 | 0.11 | 0.14 | 0.17 | 0.21 | 0.25 | 0.29 |
| **2_3** | 0.07 | 0.10 | 0.13 | 0.17 | 0.22 | 0.27 | 0.33 | 0.39 |
| **3_1** | 0.06 | 0.08 | 0.10 | 0.13 | 0.15 | 0.18 | 0.21 | 0.25 |
| **3_3** | 0.08 | 0.11 | 0.15 | 0.21 | 0.27 | 0.34 | 0.42 | 0.50 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.12 | 0.15 | 0.17 | 0.20 | 0.23 | 0.26 | 0.29 | 0.32 |
| **2_2** | 0.13 | 0.17 | 0.21 | 0.26 | 0.32 | 0.38 | 0.43 | 0.50 |
| **2_3** | 0.14 | 0.18 | 0.24 | 0.30 | 0.37 | 0.44 | 0.51 | 0.58 |
| **3_1** | 0.13 | 0.16 | 0.20 | 0.24 | 0.28 | 0.33 | 0.38 | 0.43 |
| **3_3** | 0.15 | 0.20 | 0.27 | 0.35 | 0.43 | 0.52 | 0.60 | 0.68 |

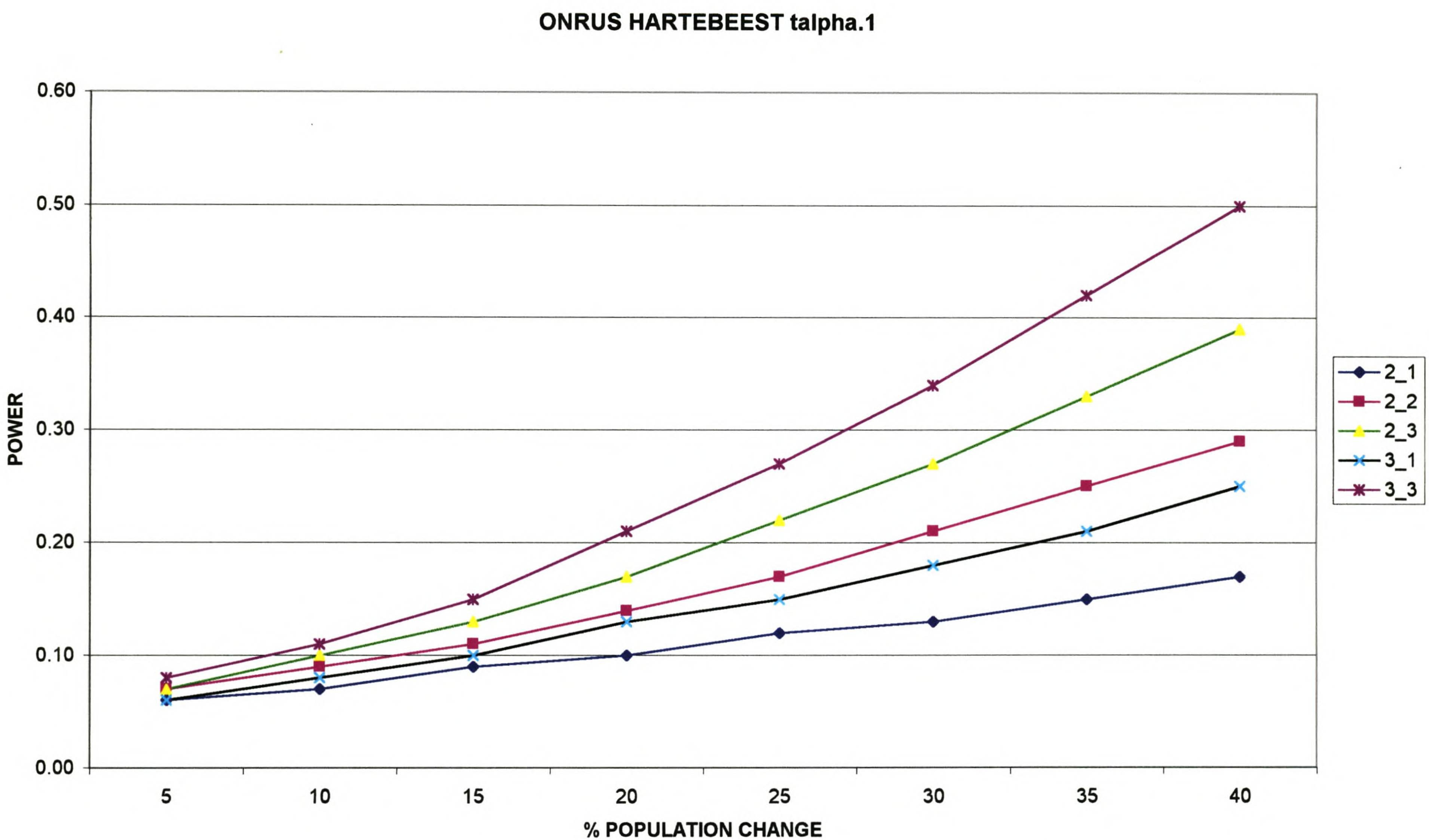


Figure 113: Power curves for various count replicate options at 10% significance for hartebeest on the farm Onrus, northwest arid bushveld.

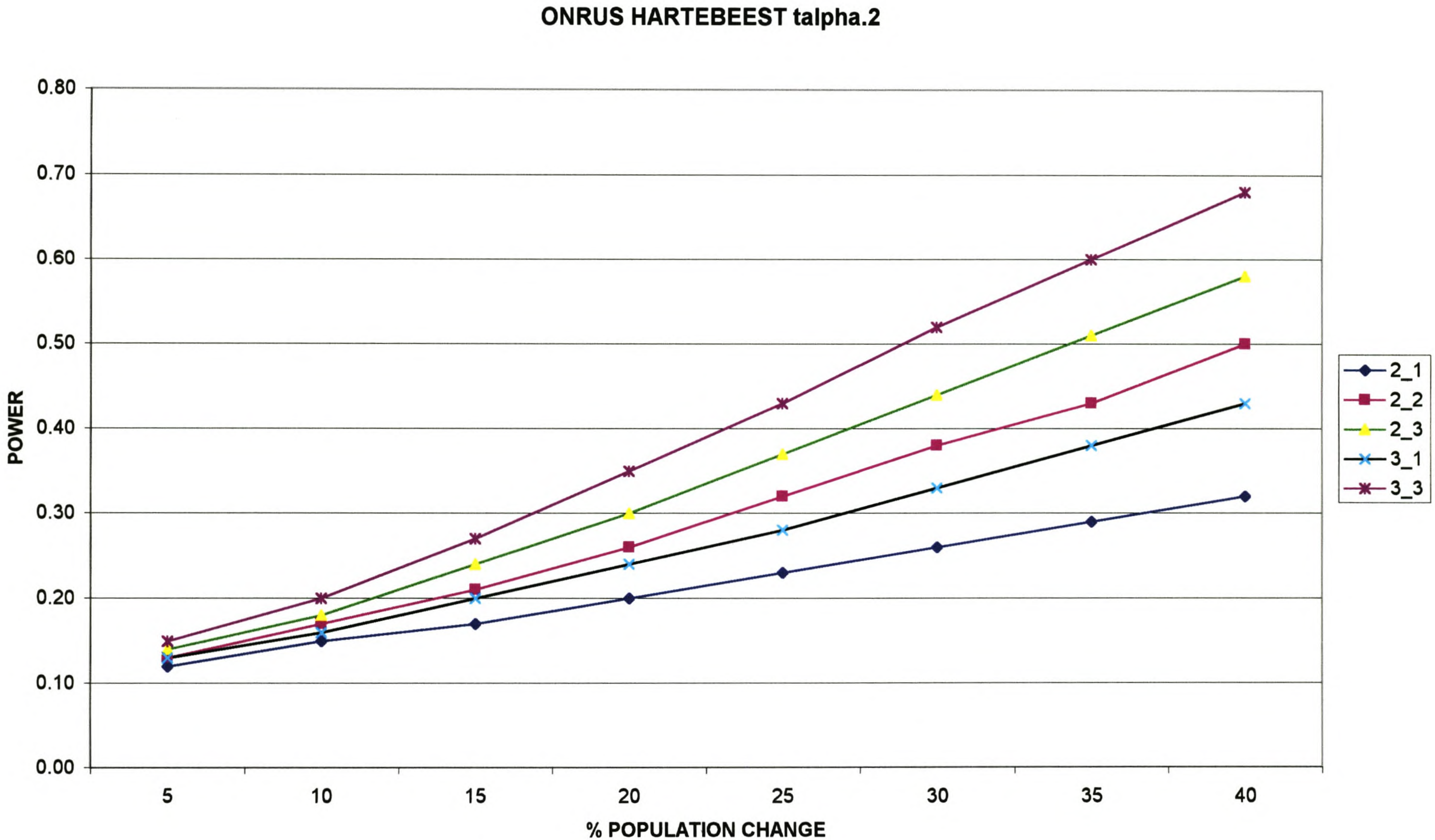


Figure 114: Power curves for various count replicate options at 20% significance for hartebeest on the farm Onrus, northwest arid bushveld.

Table 119: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for waterbuck on the farm Onrus, northwest arid bushveld.

| WATERBUCK | | MEAN | 21 | | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 1.05 | 2.10 | 3.15 | 4.20 | 5.25 | 6.30 | 7.35 | 8.40 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.15 | 0.30 | 0.45 | 0.61 | 0.76 | 0.91 | 1.06 | 1.21 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.19 | 0.37 | 0.56 | 0.74 | 0.93 | 1.11 | 1.30 | 1.48 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.20 | 0.41 | 0.61 | 0.81 | 1.02 | 1.22 | 1.42 | 1.63 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.16 | 0.32 | 0.48 | 0.64 | 0.80 | 0.96 | 1.12 | 1.28 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.23 | 0.45 | 0.68 | 0.91 | 1.13 | 1.36 | 1.58 | 1.81 |

Table 120: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for waterbuck at 10% and 20% significance on the farm Onrus, northwest arid bushveld.

talpha.1 WATERBUCK

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.06 | 0.07 | 0.08 | 0.10 | 0.11 | 0.13 | 0.14 | 0.16 |
| **2_2** | 0.07 | 0.08 | 0.11 | 0.13 | 0.16 | 0.19 | 0.23 | 0.27 |
| **2_3** | 0.07 | 0.09 | 0.12 | 0.16 | 0.20 | 0.25 | 0.30 | 0.35 |
| **3_1** | 0.06 | 0.08 | 0.10 | 0.12 | 0.14 | 0.17 | 0.19 | 0.23 |
| **3_3** | 0.07 | 0.10 | 0.14 | 0.19 | 0.24 | 0.31 | 0.37 | 0.44 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.12 | 0.14 | 0.16 | 0.19 | 0.22 | 0.25 | 0.28 | 0.31 |
| **2_2** | 0.13 | 0.17 | 0.21 | 0.25 | 0.30 | 0.35 | 0.40 | 0.46 |
| **2_3** | 0.13 | 0.18 | 0.23 | 0.28 | 0.34 | 0.41 | 0.47 | 0.55 |
| **3_1** | 0.13 | 0.16 | 0.19 | 0.22 | 0.26 | 0.31 | 0.35 | 0.40 |
| **3_3** | 0.14 | 0.19 | 0.25 | 0.32 | 0.39 | 0.48 | 0.55 | 0.63 |

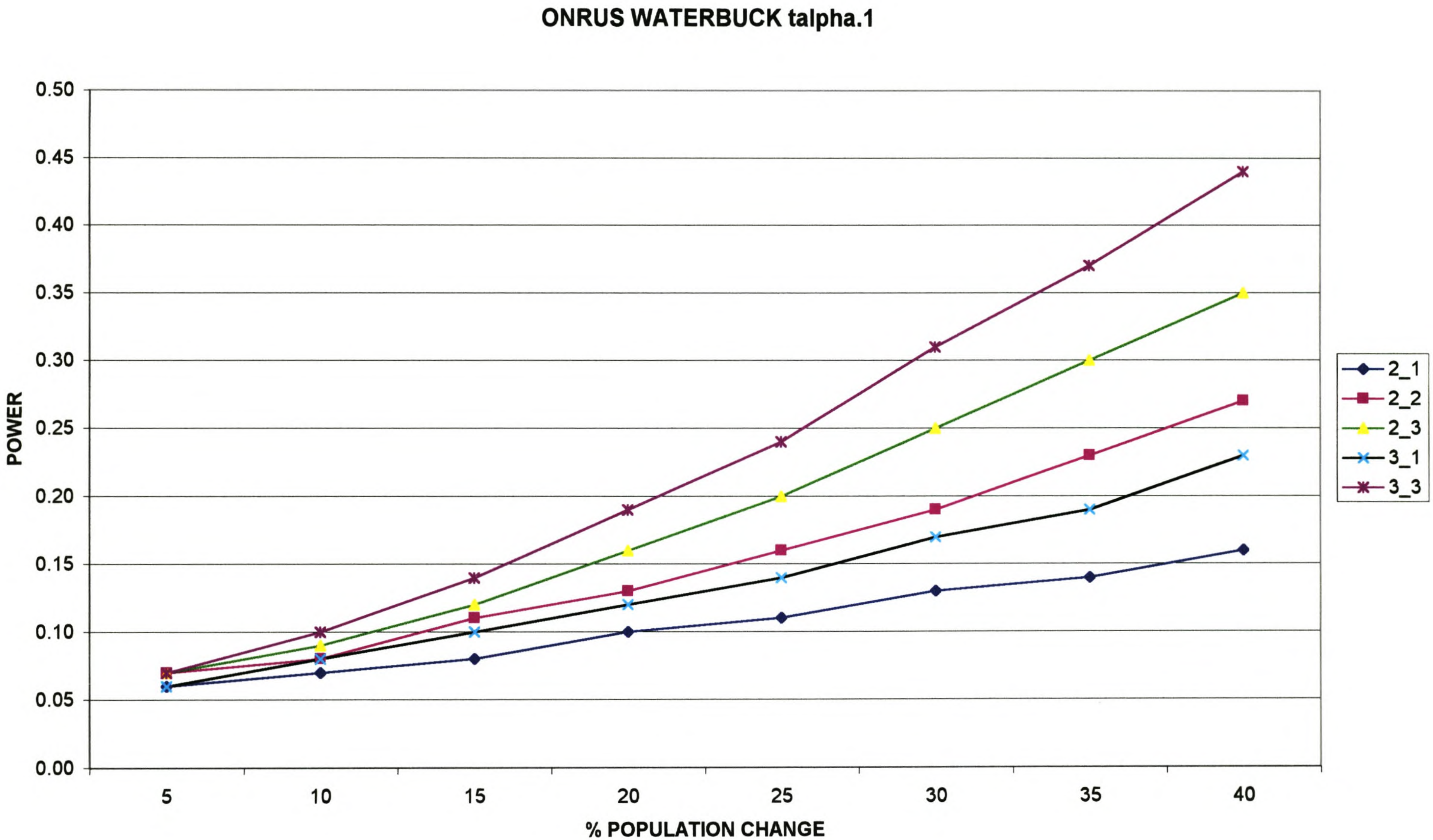


Figure 115: Power curves for various count replicate options at 10% significance for waterbuck on the farm Onrus, northwest arid bushveld.

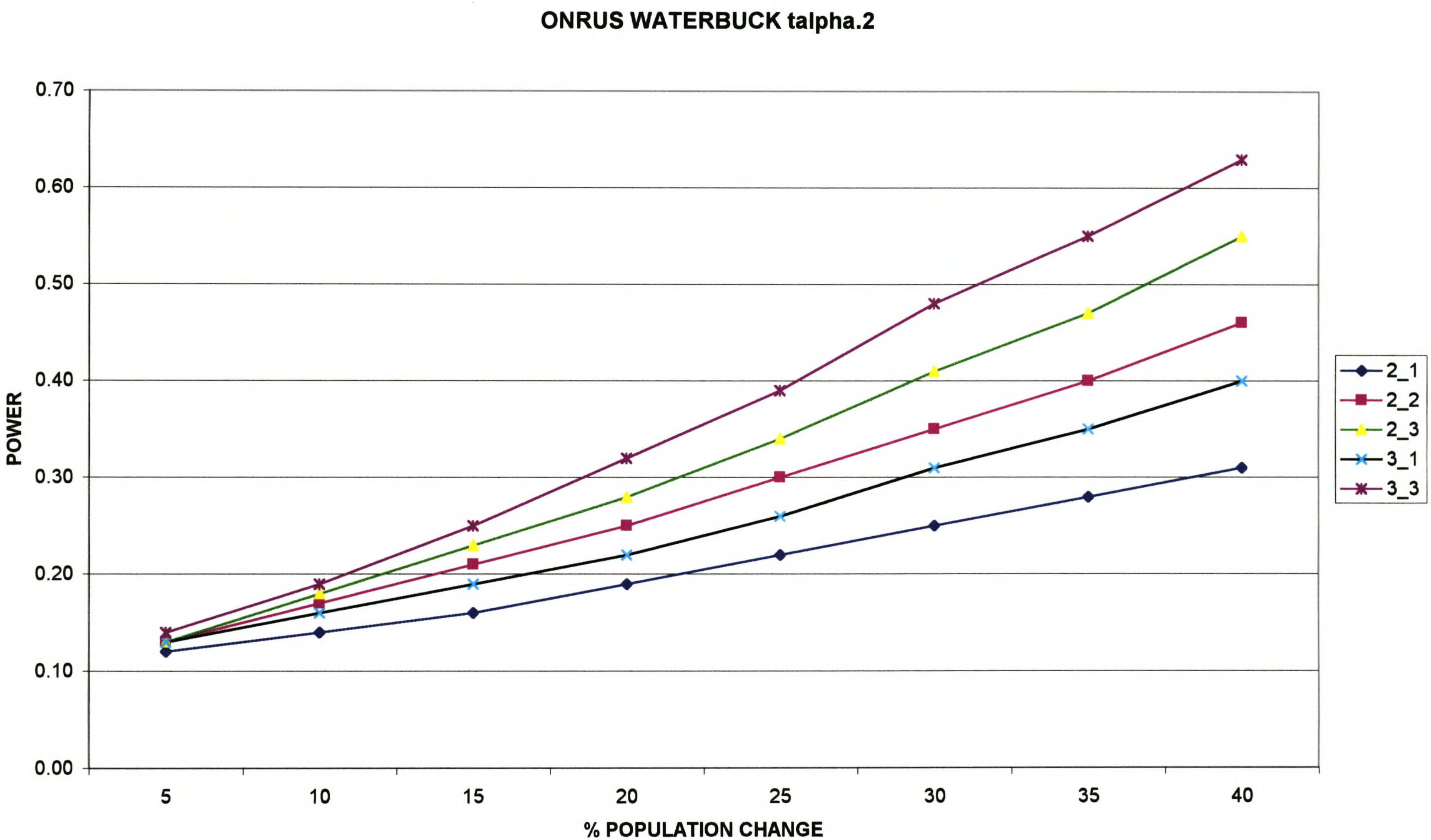


Figure 116: Power curves for various count replicate options at 20% significance for waterbuck on the farm Onrus, northwest arid bushveld.

Table 121: Summary statistics of three replicate helicopter counts of the farm Greefswald, northern mopane veld.

| SPECIES | COUNT REPLICATES | | | MEAN | STANDARD | STANDARD |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | | DEVIATION(n2) | DEVIATION(n3) |
| *KUDU* | **3** | **13** | **7** | 7.7 | 4.14 | 4.14 |
| *ZEBRA* | **13** | **3** | **5** | 7.0 | 4.29 | 4.32 |
| *WILDEBEEST* | **23** | **0** | **21** | 14.7 | 10.47 | 10.40 |
| *IMPALA* | **120** | **85** | **122** | 109.0 | 16.76 | 16.77 |
| *WARTHOG* | **5** | **3** | **2** | 3.3 | 1.26 | 1.25 |
| *ELAND* | **3** | **7** | **3** | 4.3 | 1.89 | 1.88 |
| *WATERBUCK* | **5** | **14** | **16** | 11.7 | 4.77 | 4.77 |

| SPECIES | SEdiff21 | SEdiff22 | SEdiff23 | SEdiff31 | SEdiff33 |
|---|---|---|---|---|---|
| *KUDU* | 5.07 | 4.14 | 3.78 | 4.78 | 3.38 |
| *ZEBRA* | 5.25 | 4.29 | 3.92 | 4.99 | 3.53 |
| *WILDEBEEST* | 12.82 | 10.47 | 9.56 | 12.01 | 8.49 |
| *IMPALA* | 20.53 | 16.76 | 15.30 | 19.36 | 13.69 |
| *WARTHOG* | 1.54 | 1.26 | 1.15 | 1.44 | 1.02 |
| *ELAND* | 2.31 | 1.89 | 1.73 | 2.17 | 1.54 |
| *WATERBUCK* | 5.84 | 4.77 | 4.35 | 5.51 | 3.89 |

Table 122: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for kudu on the farm Greefswald, northern mopane veld.

| KUDU | | MEAN | 7.7 | | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 0.39 | 0.77 | 1.16 | 1.54 | 1.93 | 2.31 | 2.70 | 3.08 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.08 | 0.15 | 0.23 | 0.30 | 0.38 | 0.46 | 0.53 | 0.61 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.09 | 0.19 | 0.28 | 0.37 | 0.46 | 0.56 | 0.65 | 0.74 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.10 | 0.20 | 0.31 | 0.41 | 0.51 | 0.61 | 0.71 | 0.81 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.08 | 0.16 | 0.24 | 0.32 | 0.40 | 0.48 | 0.56 | 0.64 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.11 | 0.23 | 0.34 | 0.46 | 0.57 | 0.68 | 0.80 | 0.91 |

**Table 123: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for kudu at 10% and 20% significance on the farm Greefswald, northern mopane veld.**

talpha.1 KUDU

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.06 | 0.06 | 0.07 | 0.07 | 0.08 | 0.08 | 0.09 | 0.10 |
| **2_2** | 0.06 | 0.07 | 0.07 | 0.08 | 0.09 | 0.11 | 0.12 | 0.13 |
| **2_3** | 0.06 | 0.07 | 0.08 | 0.09 | 0.11 | 0.12 | 0.14 | 0.16 |
| **3_1** | 0.06 | 0.06 | 0.07 | 0.08 | 0.09 | 0.10 | 0.11 | 0.12 |
| **3_3** | 0.06 | 0.07 | 0.09 | 0.10 | 0.12 | 0.14 | 0.17 | 0.19 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.11 | 0.12 | 0.13 | 0.14 | 0.15 | 0.17 | 0.18 | 0.19 |
| **2_2** | 0.11 | 0.13 | 0.15 | 0.17 | 0.18 | 0.21 | 0.23 | 0.25 |
| **2_3** | 0.12 | 0.13 | 0.16 | 0.18 | 0.20 | 0.23 | 0.25 | 0.28 |
| **3_1** | 0.11 | 0.13 | 0.14 | 0.16 | 0.17 | 0.19 | 0.21 | 0.22 |
| **3_3** | 0.12 | 0.14 | 0.17 | 0.19 | 0.22 | 0.25 | 0.29 | 0.32 |

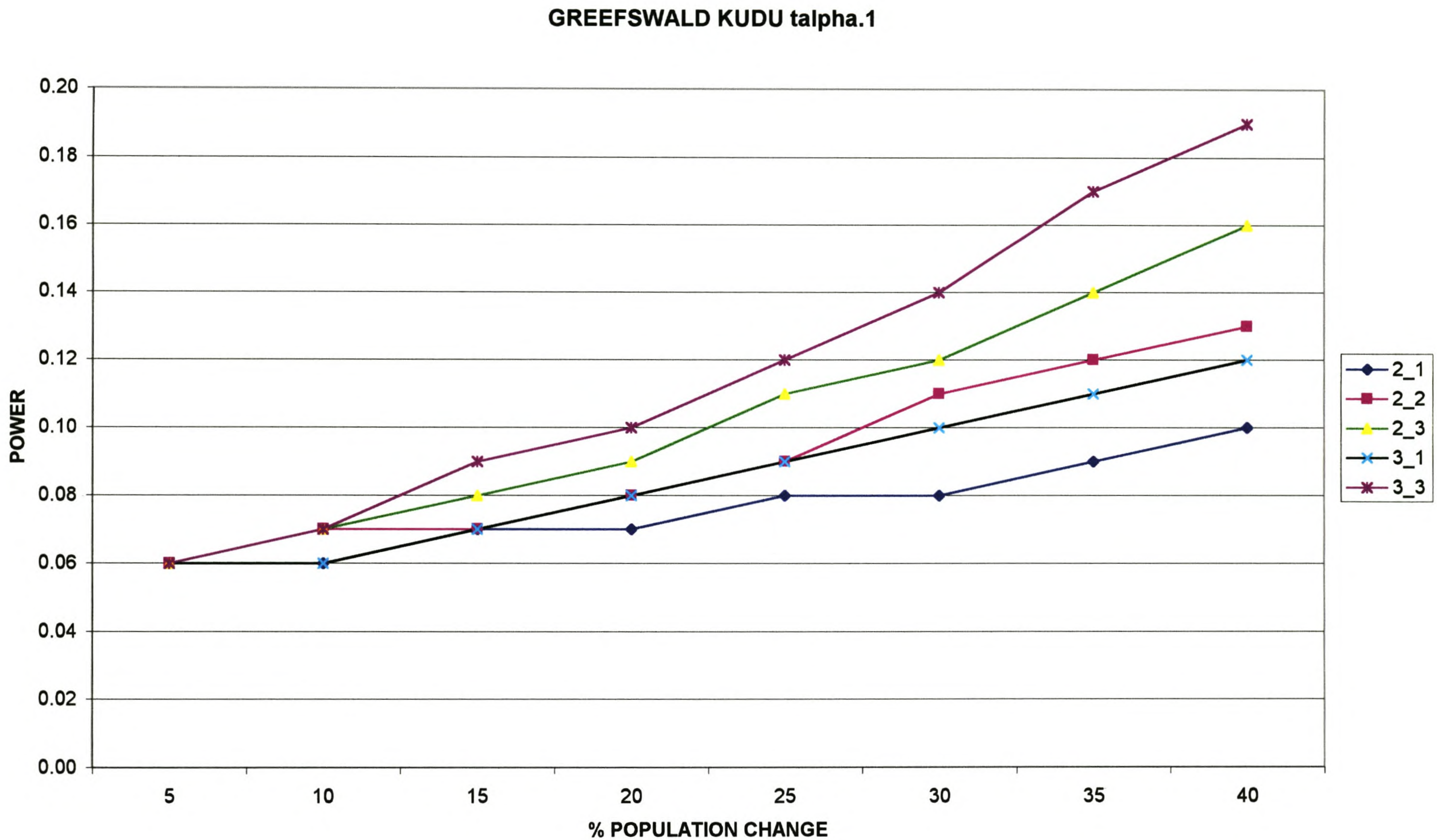


Figure 117: Power curves for various count replicate options at 10% significance for kudu on the farm Greefswald, northern mopane veld.

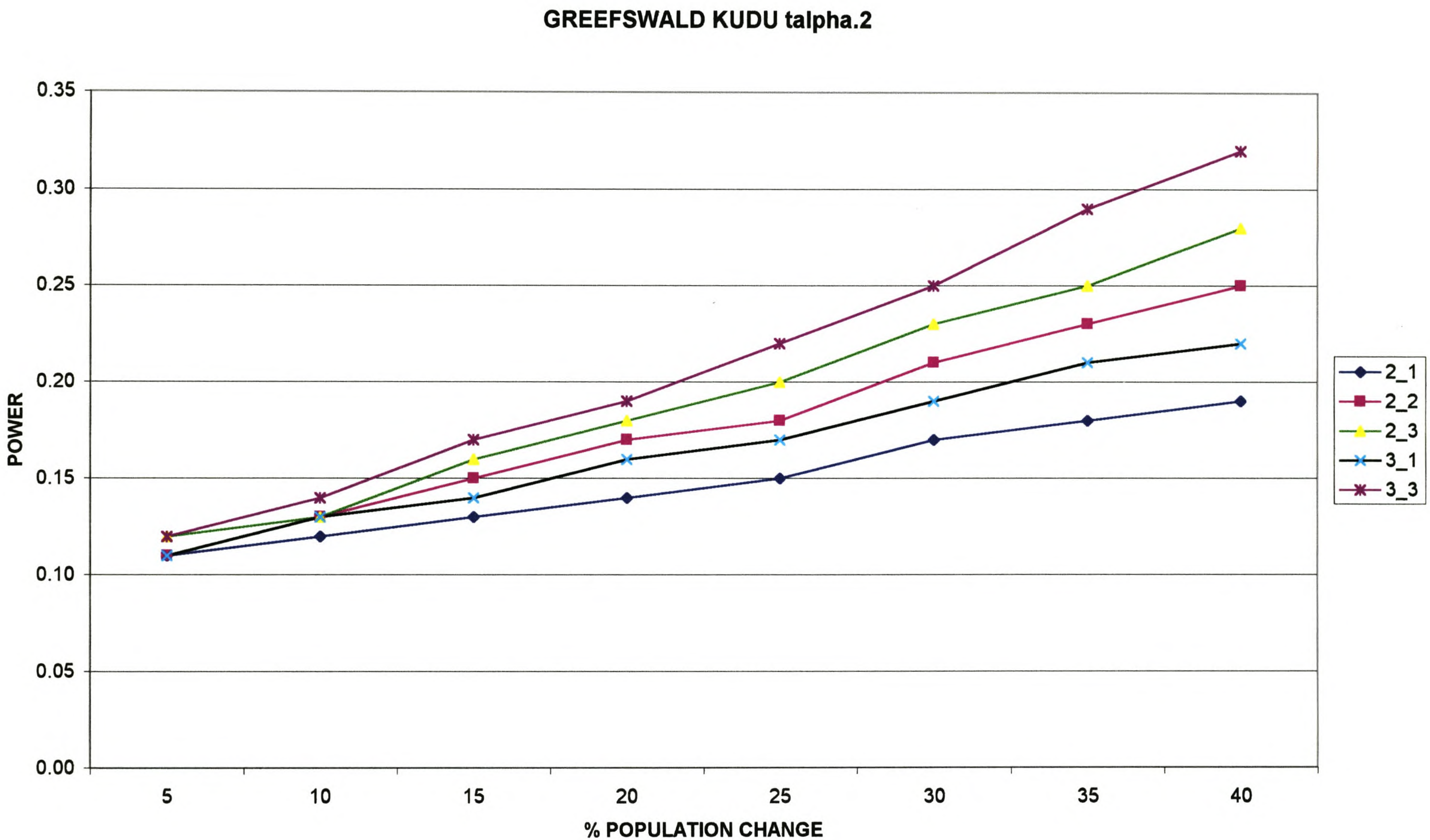


Figure 118: Power curves for various count replicate options at 20% significance for kudu on the farm Greefswald, northern mopane veld.

Table 124: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for zebra on the farm Greefswald, northern mopane veld.

| ZEBRA | | MEAN | | 7.00 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 0.35 | 0.70 | 1.05 | 1.40 | 1.75 | 2.10 | 2.45 | 2.80 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.07 | 0.13 | 0.20 | 0.27 | 0.33 | 0.40 | 0.47 | 0.53 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.08 | 0.16 | 0.24 | 0.33 | 0.41 | 0.49 | 0.57 | 0.65 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.09 | 0.18 | 0.27 | 0.36 | 0.45 | 0.54 | 0.63 | 0.71 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.07 | 0.14 | 0.21 | 0.28 | 0.35 | 0.42 | 0.49 | 0.56 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.10 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.69 | 0.79 |

**Table 125**: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for zebra at 10% and 20% significance on the farm Greefswald, northern mopane veld.

talpha.1 ZEBRA

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| 2_1 | 0.05 | 0.06 | 0.06 | 0.07 | 0.07 | 0.08 | 0.08 | 0.09 |
| 2_2 | 0.06 | 0.06 | 0.07 | 0.08 | 0.09 | 0.10 | 0.11 | 0.12 |
| 2_3 | 0.06 | 0.07 | 0.08 | 0.09 | 0.10 | 0.11 | 0.13 | 0.14 |
| 3_1 | 0.06 | 0.06 | 0.07 | 0.07 | 0.08 | 0.09 | 0.10 | 0.11 |
| 3_3 | 0.06 | 0.07 | 0.08 | 0.10 | 0.11 | 0.13 | 0.14 | 0.16 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| 2_1 | 0.11 | 0.12 | 0.13 | 0.14 | 0.15 | 0.16 | 0.17 | 0.18 |
| 2_2 | 0.11 | 0.13 | 0.14 | 0.16 | 0.17 | 0.19 | 0.21 | 0.23 |
| 2_3 | 0.11 | 0.13 | 0.15 | 0.17 | 0.19 | 0.21 | 0.23 | 0.25 |
| 3_1 | 0.11 | 0.12 | 0.13 | 0.15 | 0.16 | 0.18 | 0.19 | 0.21 |
| 3_3 | 0.12 | 0.14 | 0.16 | 0.18 | 0.20 | 0.23 | 0.25 | 0.28 |

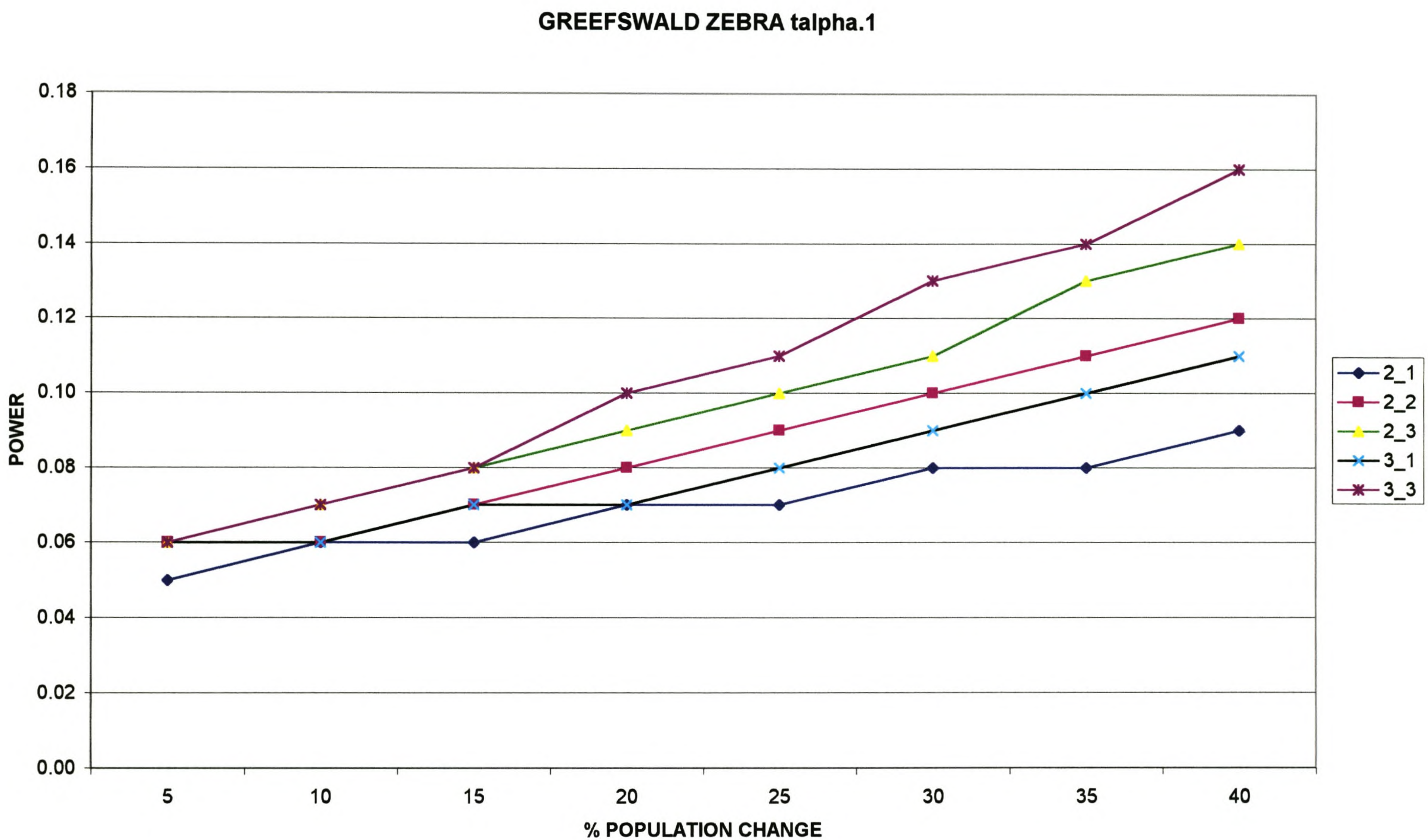


Figure 119: Power curves for various count replicate options at 10% significance for zebra on the farm Greefswald, northern mopane veld.

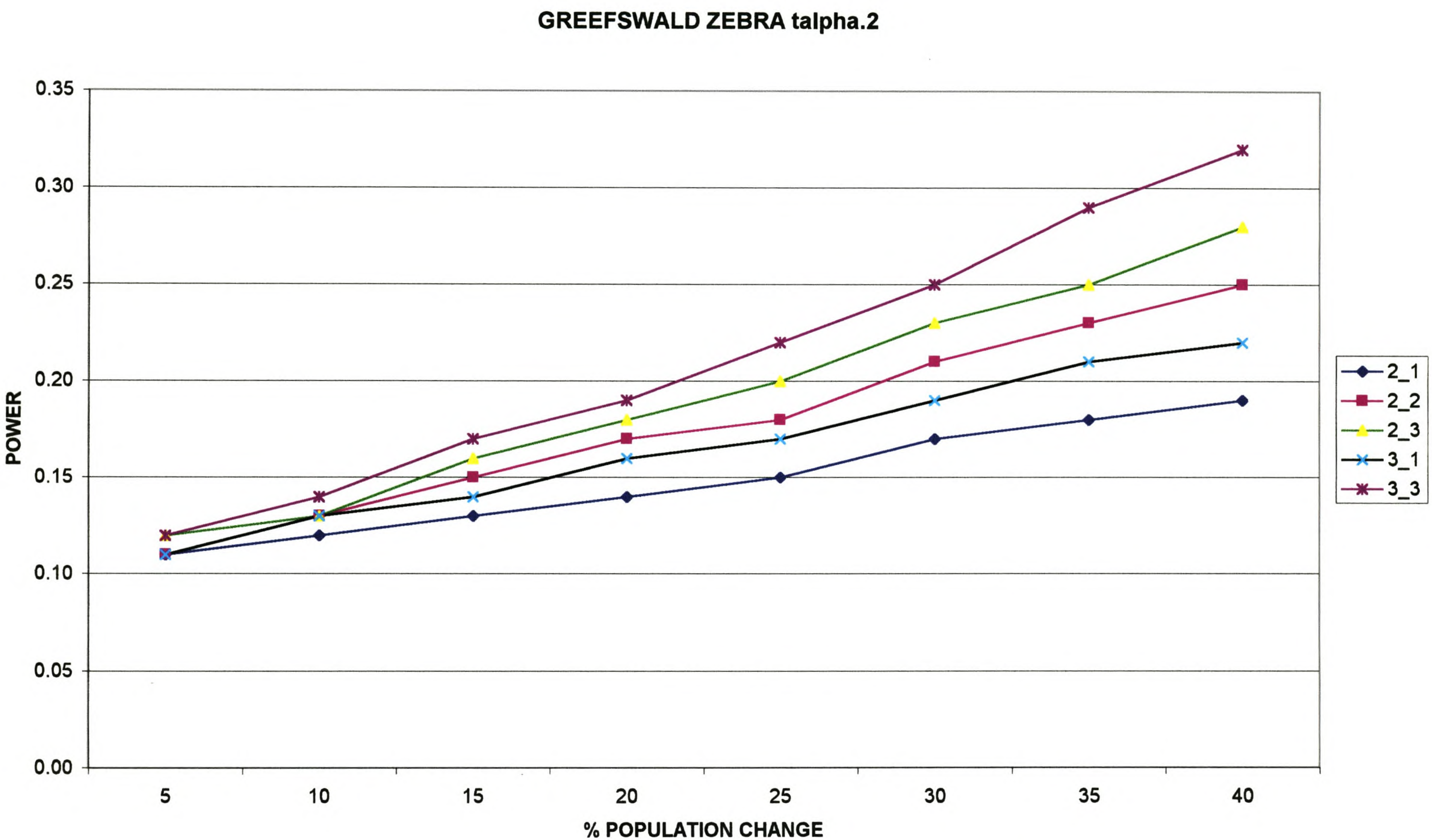


Figure 120: Power curves for various count replicate options at 20% significance for zebra on the farm Greefswald, northern mopane veld.

Table 126: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for wildebeest on the farm Greefswald, northern mopane veld.

| WILDEBEEST | | MEAN | | 14.70 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 0.74 | 1.47 | 2.21 | 2.94 | 3.68 | 4.41 | 5.15 | 5.88 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.06 | 0.11 | 0.17 | 0.23 | 0.29 | 0.34 | 0.40 | 0.46 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.07 | 0.14 | 0.21 | 0.28 | 0.35 | 0.42 | 0.49 | 0.56 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.08 | 0.15 | 0.23 | 0.31 | 0.38 | 0.46 | 0.54 | 0.62 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.06 | 0.12 | 0.18 | 0.24 | 0.31 | 0.37 | 0.43 | 0.49 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.09 | 0.17 | 0.26 | 0.35 | 0.43 | 0.52 | 0.61 | 0.69 |

Table 127: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for wildebeest at 10% and 20% significance on the farm Greefswald, northern mopane veld.

talpha.1 WILDEBEEST

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| 2_1 | 0.05 | 0.06 | 0.06 | 0.07 | 0.07 | 0.07 | 0.08 | 0.08 |
| 2_2 | 0.06 | 0.06 | 0.07 | 0.07 | 0.08 | 0.09 | 0.10 | 0.11 |
| 2_3 | 0.06 | 0.06 | 0.07 | 0.08 | 0.09 | 0.10 | 0.11 | 0.13 |
| 3_1 | 0.05 | 0.06 | 0.07 | 0.07 | 0.08 | 0.08 | 0.09 | 0.10 |
| 3_3 | 0.06 | 0.07 | 0.08 | 0.09 | 0.10 | 0.11 | 0.13 | 0.14 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| 2_1 | 0.11 | 0.11 | 0.12 | 0.13 | 0.14 | 0.15 | 0.16 | 0.17 |
| 2_2 | 0.11 | 0.12 | 0.13 | 0.15 | 0.16 | 0.18 | 0.19 | 0.21 |
| 2_3 | 0.11 | 0.12 | 0.14 | 0.16 | 0.17 | 0.19 | 0.21 | 0.23 |
| 3_1 | 0.11 | 0.12 | 0.13 | 0.14 | 0.15 | 0.17 | 0.18 | 0.19 |
| 3_3 | 0.12 | 0.13 | 0.15 | 0.17 | 0.19 | 0.21 | 0.23 | 0.25 |

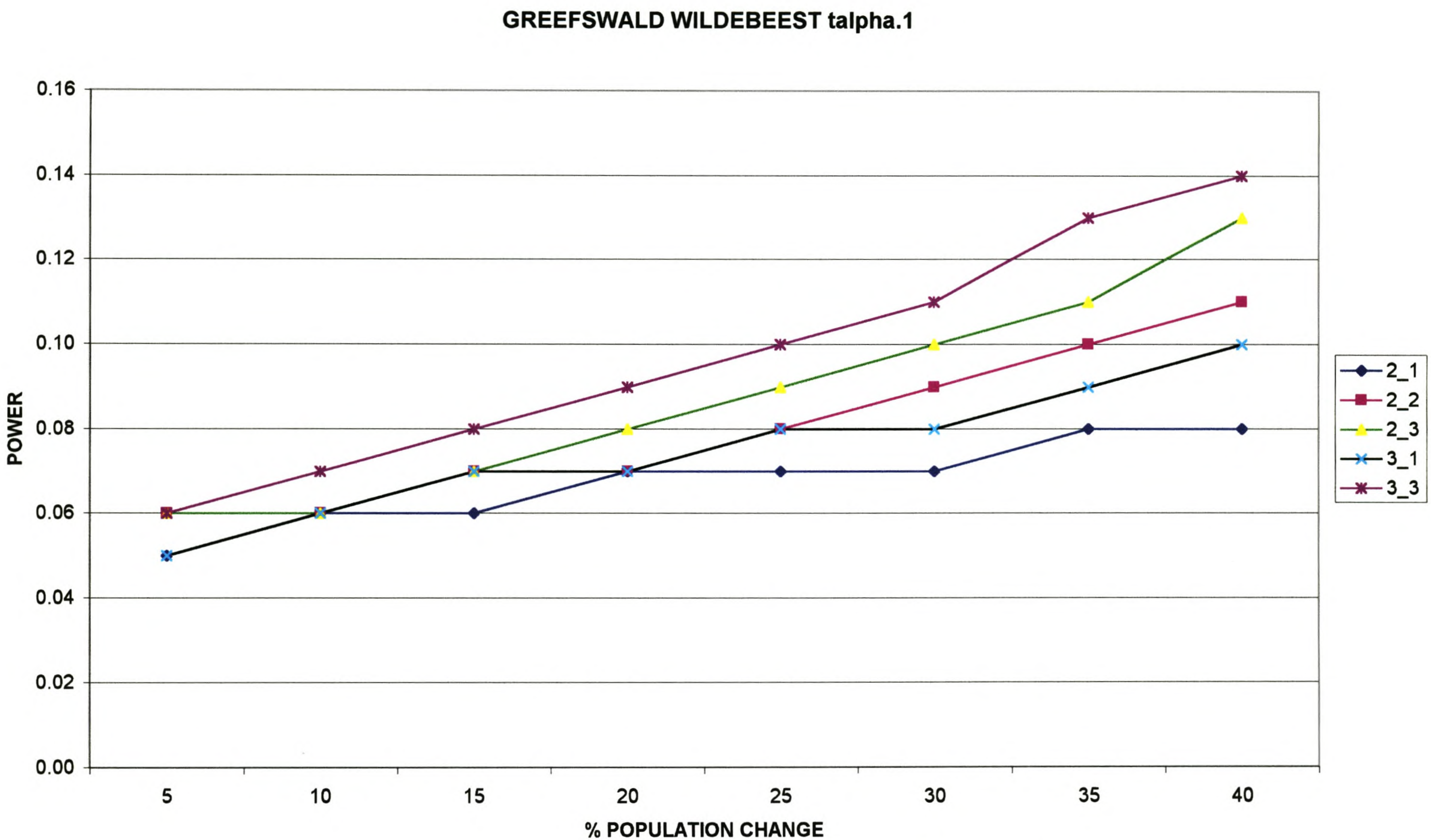


Figure 121: Power curves for various count replicate options at 10% significance for wildebeest on the farm Greefswald, northern mopane veld.

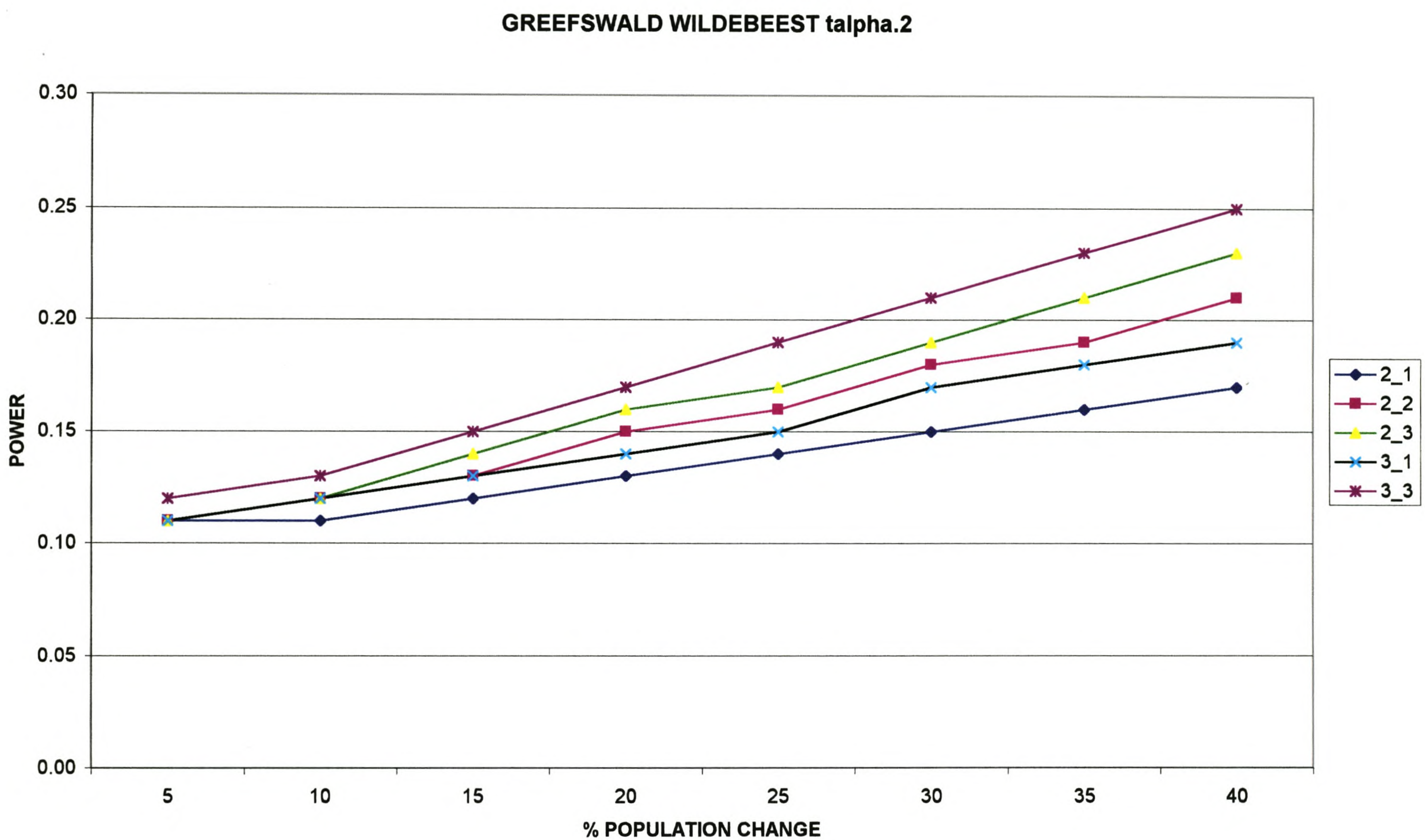


Figure 122: Power curves for various count replicate options at 20% significance for wildebeest on the farm Greefswald, northern mopane veld.

Table 128: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for impala on the farm Greefswald, northern mopane veld.

| IMPALA | | MEAN | 109.00 | | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 5.45 | 10.90 | 16.35 | 21.80 | 27.25 | 32.70 | 38.15 | 43.60 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.27 | 0.53 | 0.80 | 1.06 | 1.33 | 1.59 | 1.86 | 2.12 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.33 | 0.65 | 0.98 | 1.30 | 1.63 | 1.95 | 2.28 | 2.60 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.36 | 0.71 | 1.07 | 1.42 | 1.78 | 2.14 | 2.49 | 2.85 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.28 | 0.56 | 0.84 | 1.13 | 1.41 | 1.69 | 1.97 | 2.25 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.40 | 0.80 | 1.19 | 1.59 | 1.99 | 2.39 | 2.79 | 3.18 |

**Table 129: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for impala at 10% and 20% significance on the farm Greefswald, northern mopane veld.**

talpha.1 IMPALA

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| 2_1 | 0.07 | 0.09 | 0.11 | 0.14 | 0.17 | 0.20 | 0.23 | 0.26 |
| 2_2 | 0.08 | 0.12 | 0.17 | 0.23 | 0.30 | 0.37 | 0.45 | 0.53 |
| 2_3 | 0.09 | 0.14 | 0.21 | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 |
| 3_1 | 0.07 | 0.11 | 0.15 | 0.20 | 0.25 | 0.31 | 0.38 | 0.44 |
| 3_3 | 0.10 | 0.17 | 0.26 | 0.37 | 0.50 | 0.63 | 0.74 | 0.83 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| 2_1 | 0.14 | 0.18 | 0.23 | 0.28 | 0.33 | 0.38 | 0.44 | 0.49 |
| 2_2 | 0.16 | 0.23 | 0.31 | 0.40 | 0.50 | 0.60 | 0.69 | 0.77 |
| 2_3 | 0.17 | 0.25 | 0.36 | 0.47 | 0.59 | 0.71 | 0.80 | 0.87 |
| 3_1 | 0.15 | 0.21 | 0.27 | 0.35 | 0.44 | 0.52 | 0.60 | 0.68 |
| 3_3 | 0.18 | 0.29 | 0.42 | 0.56 | 0.69 | 0.80 | 0.88 | 0.94 |

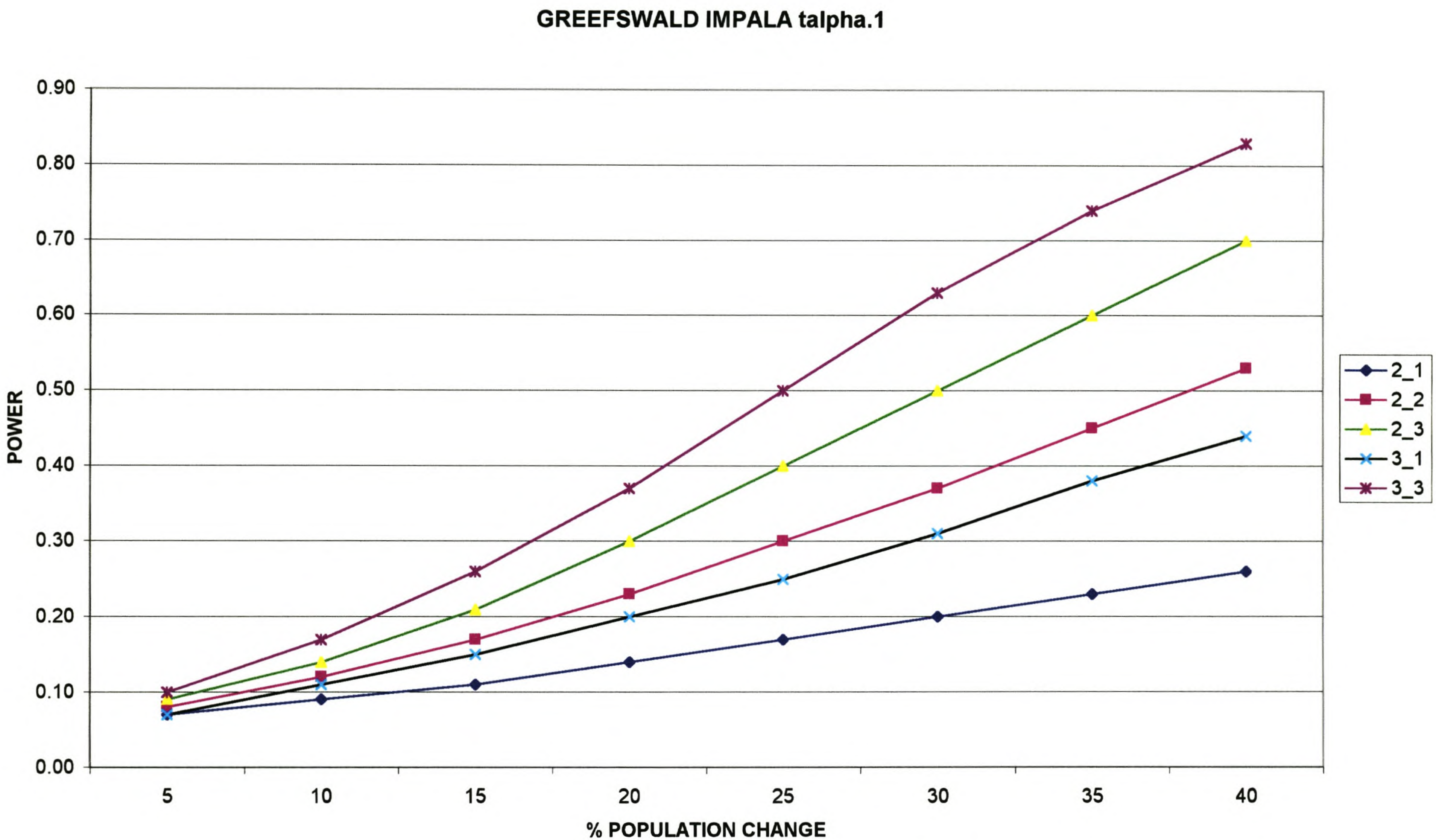


Figure 123: Power curves for various count replicate options at 10% significance for impala on the farm Greefswald, northern mopane veld.

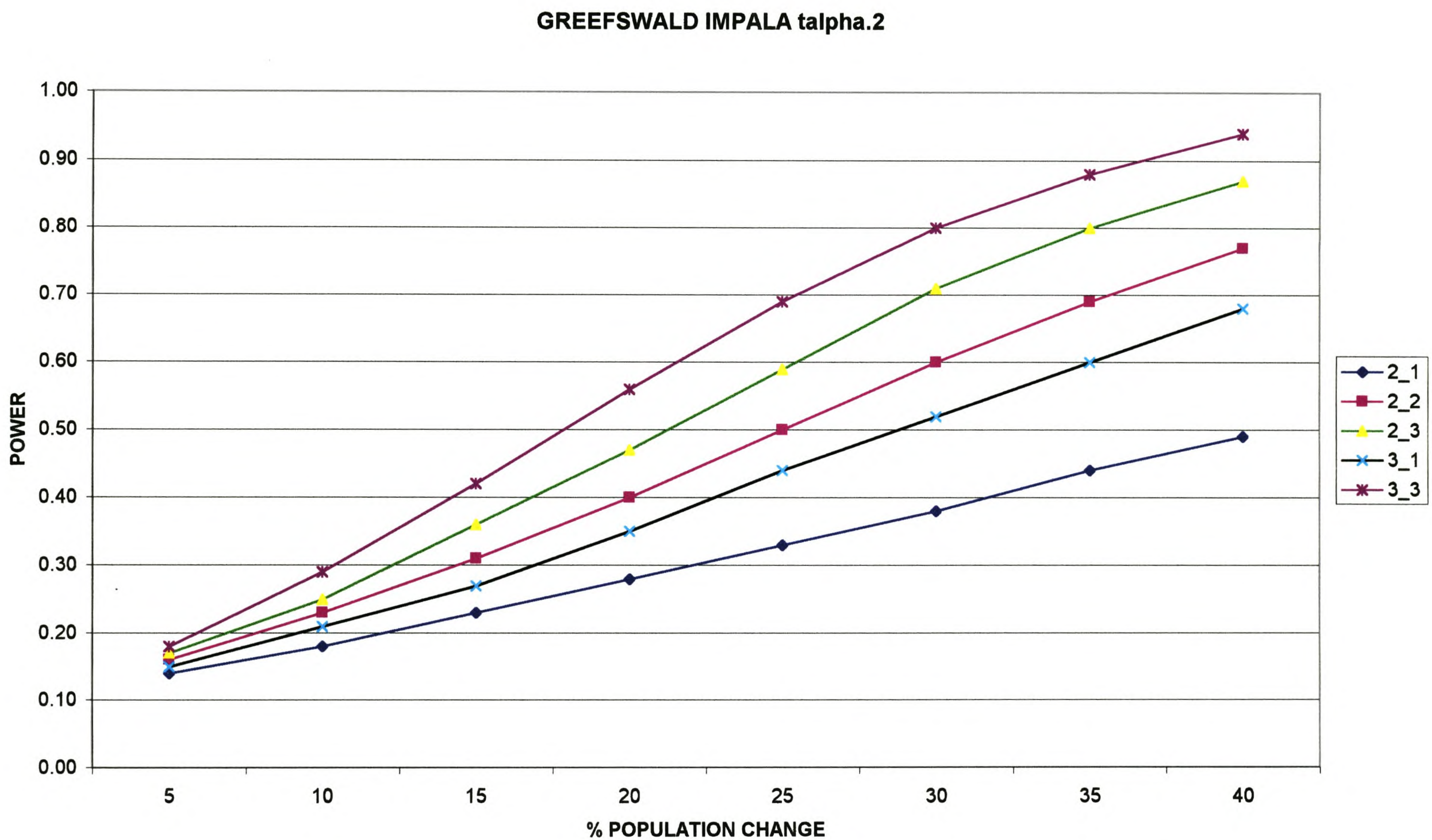


Figure 124: Power curves for various count replicate options at 20% significance for impala on the farm Greefswald, northern mopane veld.

Table 130: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for warthog on the farm Greefswald, northern mopane veld.

| WARTHOG | | | MEAN | 3.3 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 0.17 | 0.33 | 0.50 | 0.66 | 0.83 | 0.99 | 1.16 | 1.32 |
| **n1** | **n2** | **df** | **talpha.1** | **talpha.2** | **NON CENTRALITY PARAMETERS** | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.11 | 0.21 | 0.32 | 0.43 | 0.53 | 0.64 | 0.75 | 0.86 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.13 | 0.26 | 0.39 | 0.52 | 0.65 | 0.79 | 0.92 | 1.05 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.14 | 0.29 | 0.43 | 0.57 | 0.72 | 0.86 | 1.00 | 1.15 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.11 | 0.23 | 0.34 | 0.46 | 0.57 | 0.69 | 0.80 | 0.91 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.16 | 0.32 | 0.48 | 0.65 | 0.81 | 0.97 | 1.13 | 1.29 |

Table 131: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for warthog at 10% and 20% significance on the farm Greefswald, northern mopane veld.

talpha.1 WARTHOG

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| 2_1 | 0.06 | 0.06 | 0.07 | 0.08 | 0.09 | 0.10 | 0.11 | 0.12 |
| 2_2 | 0.06 | 0.07 | 0.09 | 0.10 | 0.12 | 0.14 | 0.16 | 0.18 |
| 2_3 | 0.06 | 0.08 | 0.10 | 0.12 | 0.14 | 0.17 | 0.20 | 0.23 |
| 3_1 | 0.06 | 0.07 | 0.08 | 0.09 | 0.11 | 0.12 | 0.14 | 0.16 |
| 3_3 | 0.07 | 0.08 | 0.11 | 0.14 | 0.17 | 0.20 | 0.24 | 0.29 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| 2_1 | 0.11 | 0.13 | 0.14 | 0.16 | 0.18 | 0.20 | 0.22 | 0.24 |
| 2_2 | 0.12 | 0.14 | 0.17 | 0.20 | 0.23 | 0.26 | 0.30 | 0.33 |
| 2_3 | 0.12 | 0.15 | 0.18 | 0.22 | 0.25 | 0.29 | 0.34 | 0.38 |
| 3_1 | 0.12 | 0.14 | 0.16 | 0.18 | 0.21 | 0.24 | 0.26 | 0.29 |
| 3_3 | 0.13 | 0.16 | 0.20 | 0.24 | 0.29 | 0.34 | 0.39 | 0.45 |

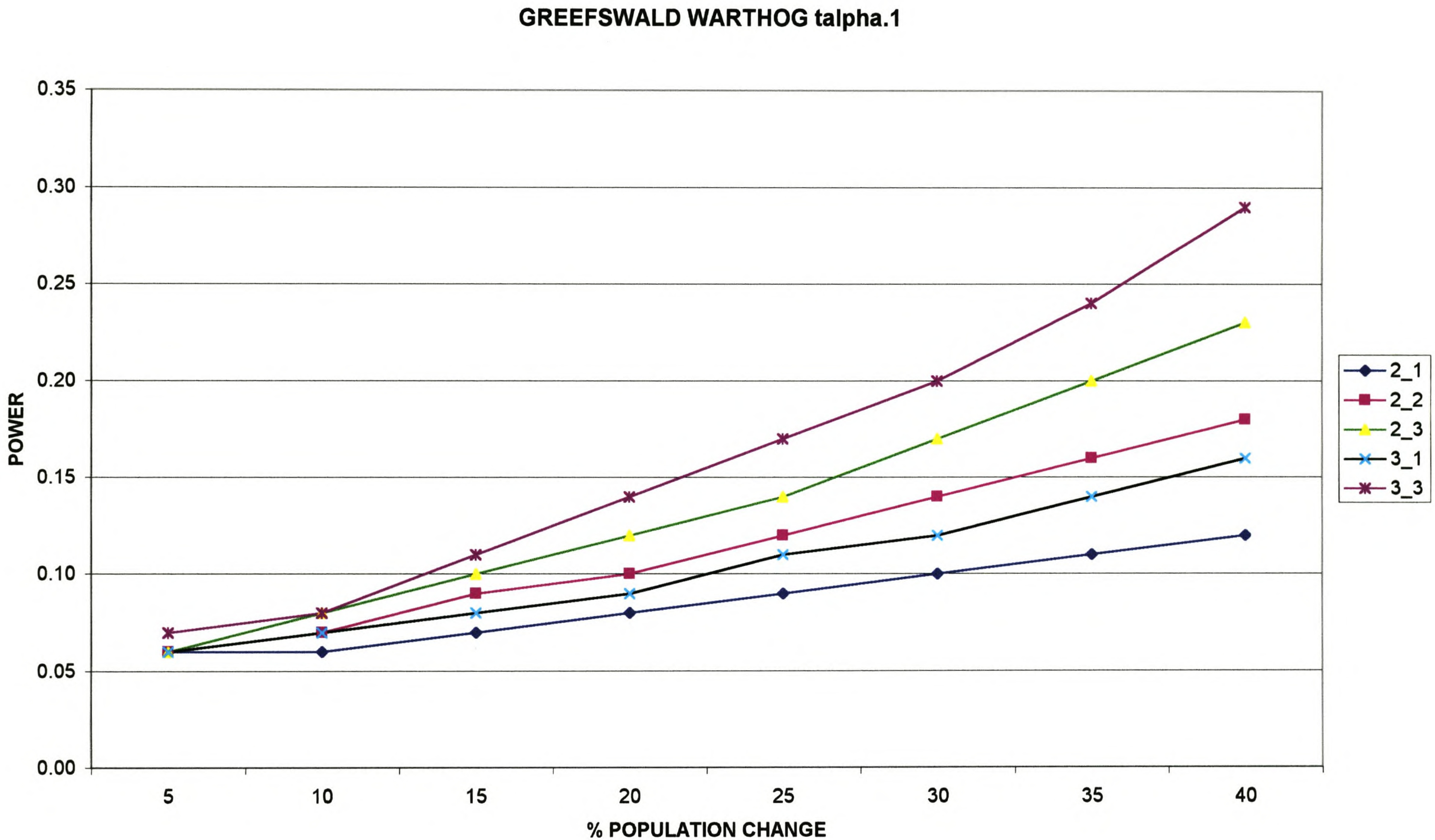


Figure 125: Power curves for various count replicate options at 10% significance for warthog on the farm Greefswald, northern mopane veld.

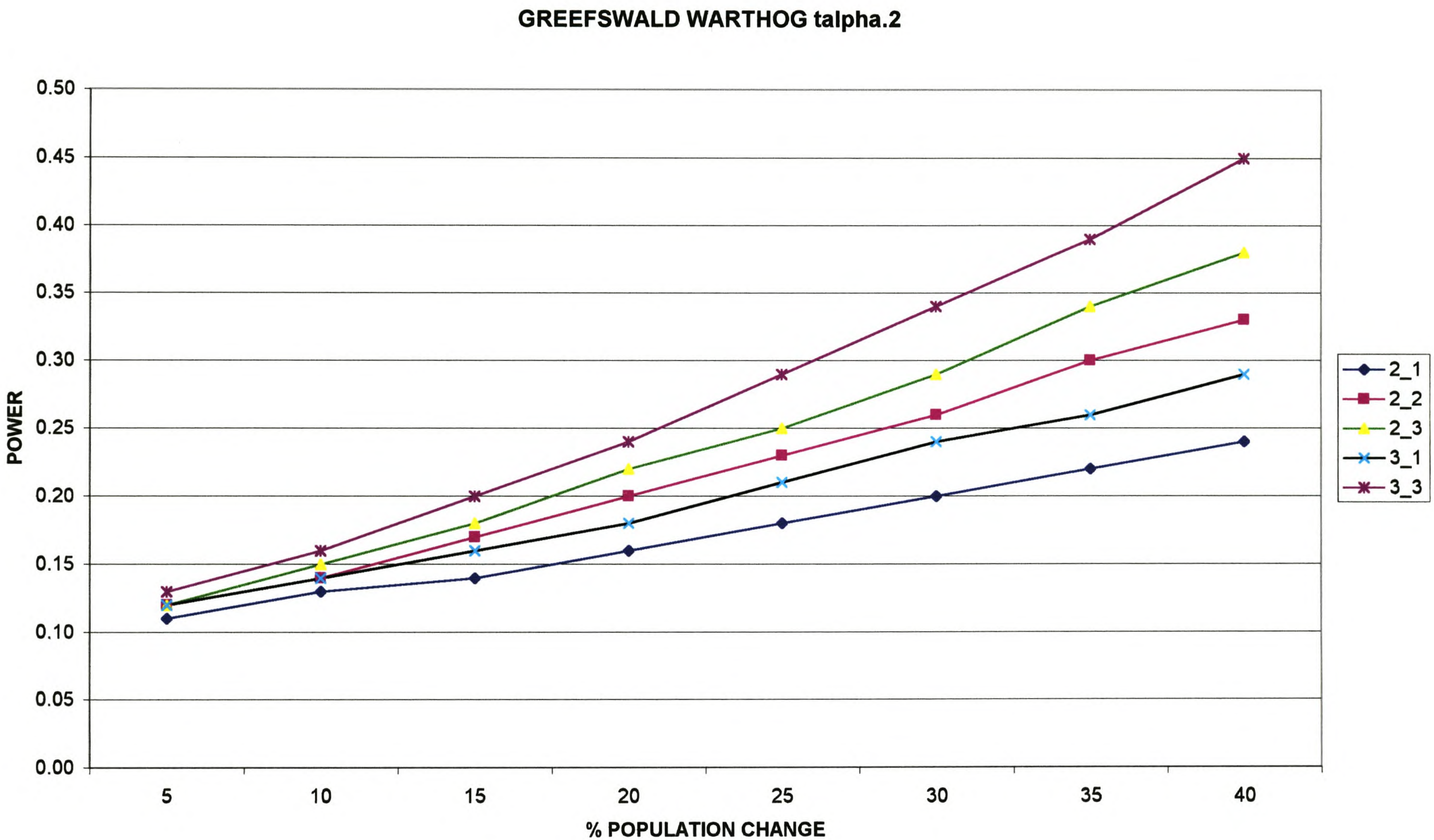


Figure 126: Power curves for various count replicate options at 20% significance for warthog on the farm Greefswald, northern mopane veld.

Table 132: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for eland on the farm Greefswald, northern mopane veld.

| ELAND | | MEAN | | 4.30 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 0.22 | 0.43 | 0.65 | 0.86 | 1.08 | 1.29 | 1.51 | 1.72 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.09 | 0.19 | 0.28 | 0.37 | 0.46 | 0.56 | 0.65 | 0.74 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.11 | 0.23 | 0.34 | 0.46 | 0.57 | 0.68 | 0.80 | 0.91 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.12 | 0.25 | 0.37 | 0.50 | 0.62 | 0.75 | 0.87 | 1.00 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.10 | 0.20 | 0.30 | 0.40 | 0.50 | 0.59 | 0.69 | 0.79 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.14 | 0.28 | 0.42 | 0.56 | 0.70 | 0.84 | 0.98 | 1.12 |

Table 133: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for eland at 10% and 20% significance on the farm Greefswald, northern mopane veld.

talpha.1 ELAND

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.06 | 0.06 | 0.07 | 0.08 | 0.08 | 0.09 | 0.10 | 0.11 |
| **2_2** | 0.06 | 0.07 | 0.08 | 0.09 | 0.11 | 0.12 | 0.14 | 0.16 |
| **2_3** | 0.06 | 0.07 | 0.09 | 0.11 | 0.13 | 0.15 | 0.17 | 0.20 |
| **3_1** | 0.06 | 0.07 | 0.08 | 0.09 | 0.10 | 0.11 | 0.12 | 0.14 |
| **3_3** | 0.06 | 0.08 | 0.10 | 0.12 | 0.15 | 0.17 | 0.21 | 0.24 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.11 | 0.13 | 0.14 | 0.15 | 0.17 | 0.18 | 0.20 | 0.21 |
| **2_2** | 0.12 | 0.14 | 0.16 | 0.18 | 0.21 | 0.23 | 0.26 | 0.29 |
| **2_3** | 0.12 | 0.14 | 0.17 | 0.20 | 0.23 | 0.26 | 0.30 | 0.34 |
| **3_1** | 0.12 | 0.13 | 0.15 | 0.17 | 0.19 | 0.21 | 0.24 | 0.26 |
| **3_3** | 0.12 | 0.15 | 0.18 | 0.22 | 0.26 | 0.30 | 0.34 | 0.39 |

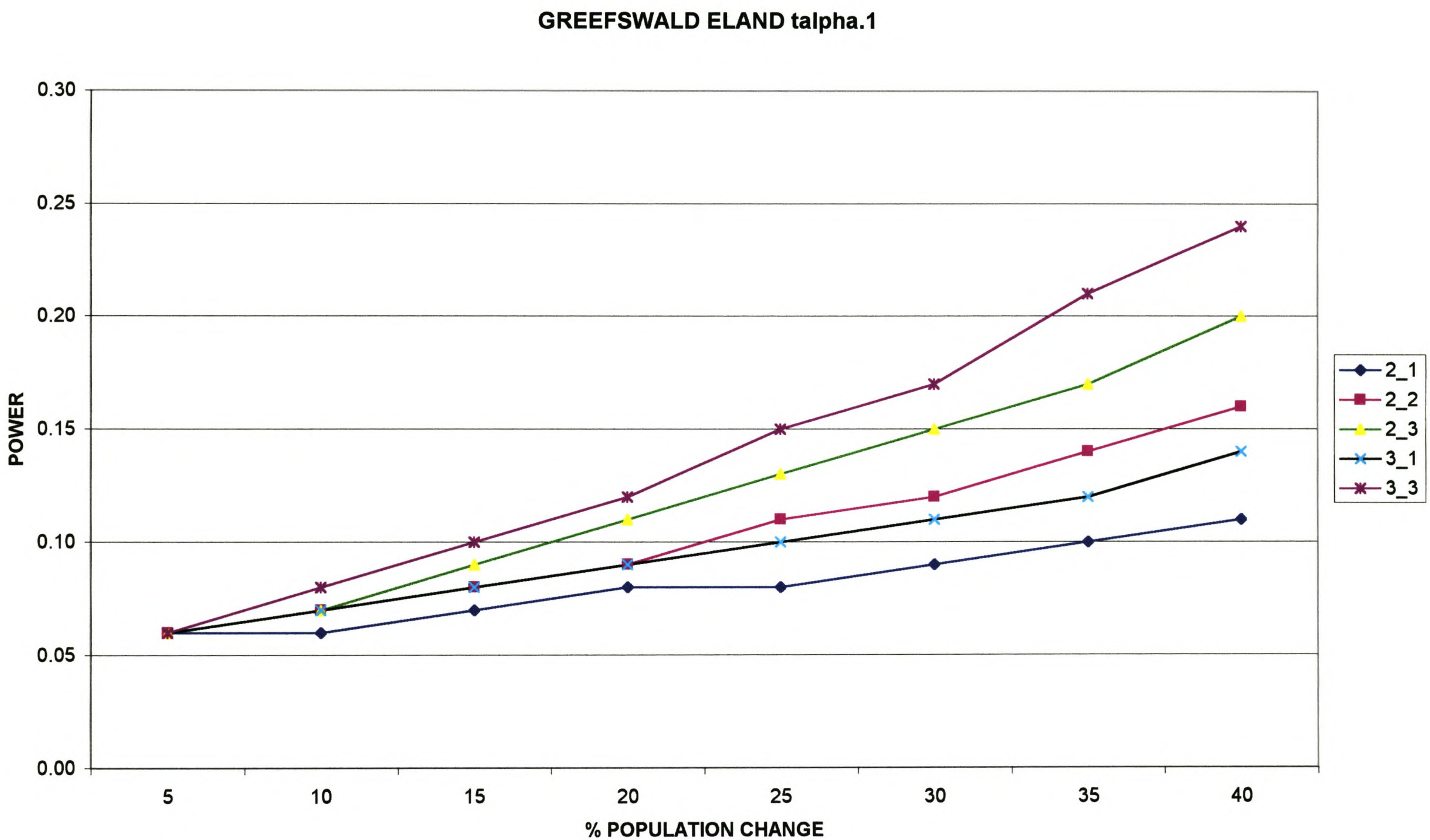


Figure 127: Power curves for various count replicate options at 10% significance for eland on the farm Greefswald, northern mopane veld.

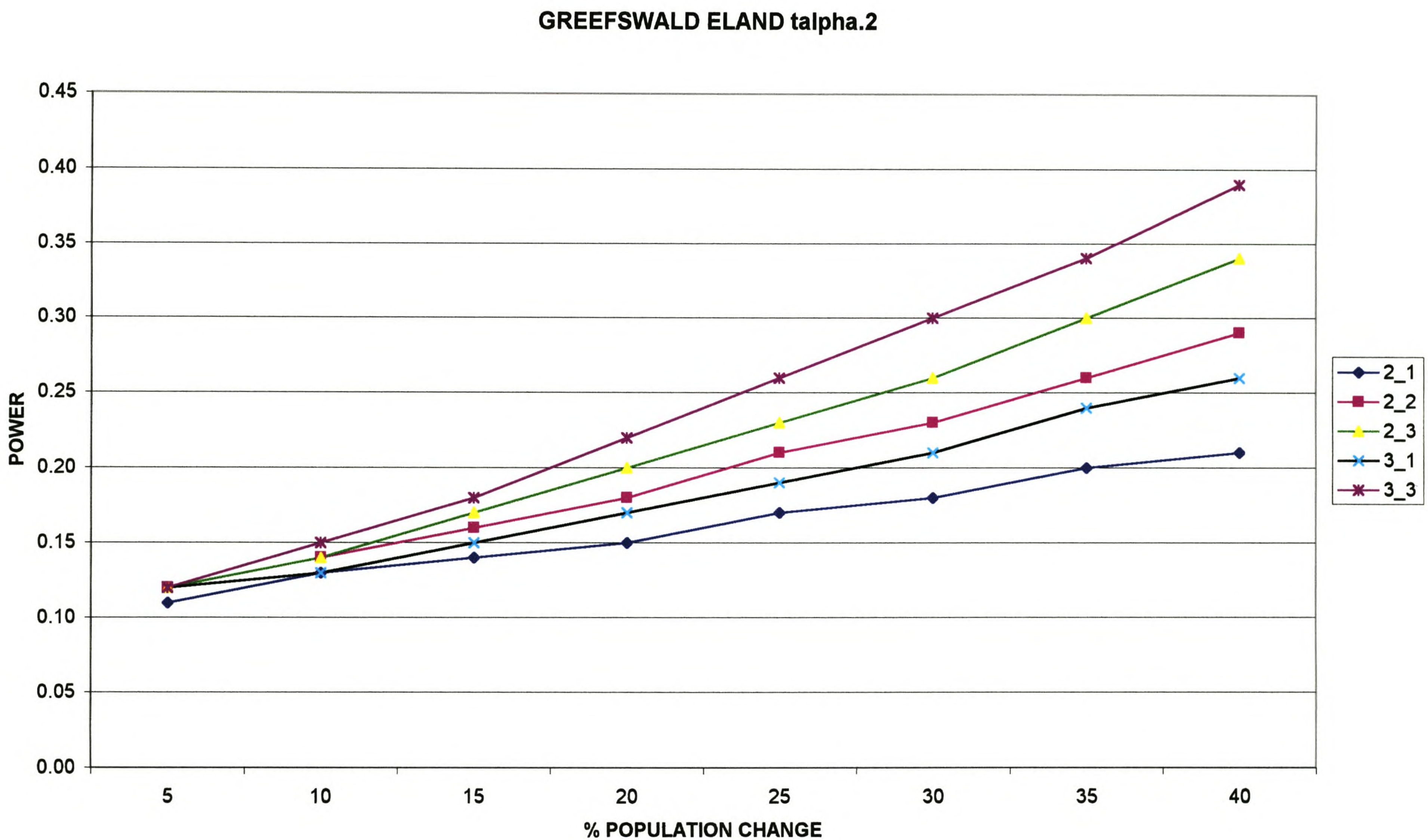


Figure 128: Power curves for various count replicate options at 20% significance for eland on the farm Greefswald, northern mopane veld.

Table 134: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for waterbuck on the farm Greefswald, northern mopane veld.

| WATERBUCK | | MEAN | 11.70 | | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 0.59 | 1.17 | 1.76 | 2.34 | 2.93 | 3.51 | 4.10 | 4.68 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.10 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 | 0.80 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.12 | 0.25 | 0.37 | 0.49 | 0.61 | 0.74 | 0.86 | 0.98 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.13 | 0.27 | 0.40 | 0.54 | 0.67 | 0.81 | 0.94 | 1.07 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.11 | 0.21 | 0.32 | 0.42 | 0.53 | 0.64 | 0.74 | 0.85 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.15 | 0.30 | 0.45 | 0.60 | 0.75 | 0.90 | 1.05 | 1.20 |

Table 135: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for waterbuck at 10% and 20% significance on the farm Greefswald, northern mopane veld.

talpha.1 WATERBUCK

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| 2_1 | 0.06 | 0.06 | 0.07 | 0.08 | 0.09 | 0.10 | 0.11 | 0.11 |
| 2_2 | 0.06 | 0.07 | 0.08 | 0.10 | 0.11 | 0.13 | 0.15 | 0.17 |
| 2_3 | 0.06 | 0.08 | 0.09 | 0.11 | 0.13 | 0.16 | 0.18 | 0.21 |
| 3_1 | 0.06 | 0.07 | 0.08 | 0.09 | 0.10 | 0.12 | 0.13 | 0.15 |
| 3_3 | 0.06 | 0.08 | 0.10 | 0.13 | 0.16 | 0.19 | 0.22 | 0.26 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| 2_1 | 0.11 | 0.13 | 0.14 | 0.16 | 0.17 | 0.19 | 0.21 | 0.23 |
| 2_2 | 0.12 | 0.14 | 0.17 | 0.19 | 0.22 | 0.25 | 0.28 | 0.31 |
| 2_3 | 0.12 | 0.15 | 0.17 | 0.21 | 0.24 | 0.28 | 0.32 | 0.36 |
| 3_1 | 0.12 | 0.13 | 0.16 | 0.18 | 0.20 | 0.22 | 0.25 | 0.28 |
| 3_3 | 0.13 | 0.16 | 0.19 | 0.23 | 0.27 | 0.32 | 0.37 | 0.42 |

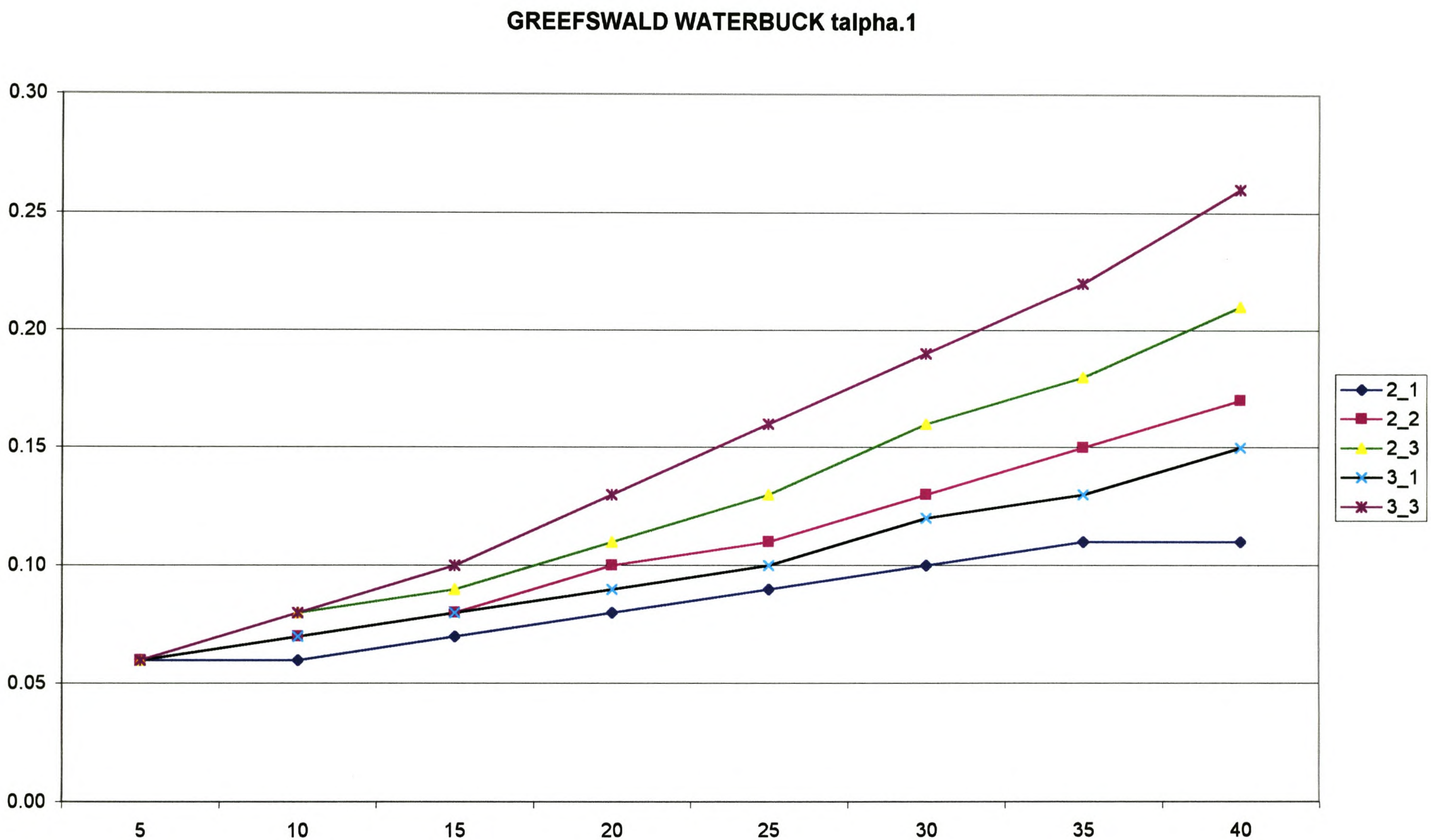


Figure 129: Power curves for various count replicate options at 10% significance for waterbuck on the farm Greefswald, northern mopane veld.

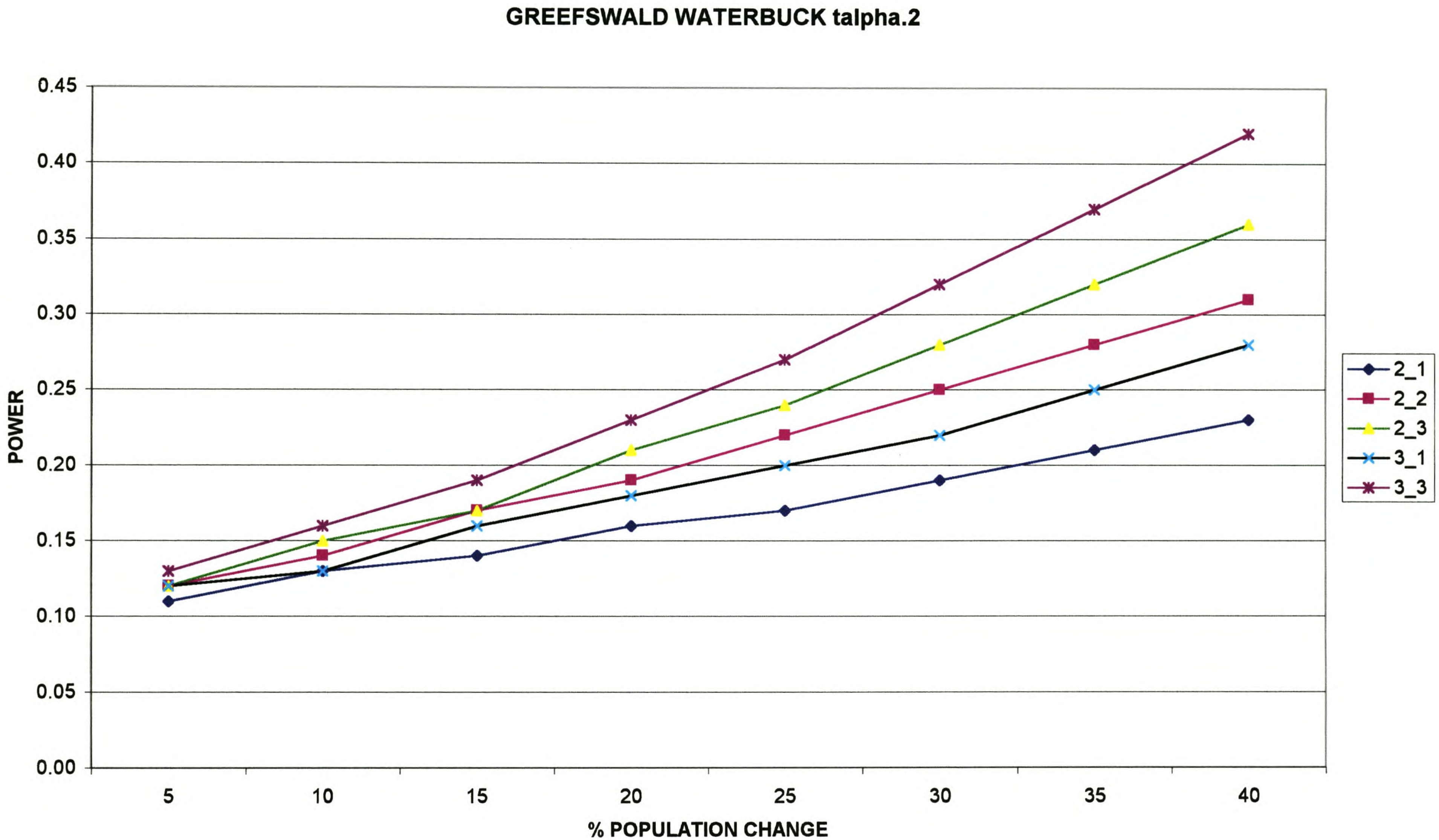


Figure 130: Power curves for various count replicate options at 20% significance for waterbuck on the farm Greefswald, northern mopane veld.

Table 136: Summary statistics of three replicate helicopter counts of the farm Shroda, northern mopane veld.

| SPECIES | COUNT REPLICATES | | | MEAN | STANDARD DEVIATION(n2) | STANDARD DEVIATION(n3) |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | | | |
| *KUDU* | **28** | **26** | **21** | 25.0 | 2.96 | 2.97 |
| *ZEBRA* | **24** | **25** | **20** | 23.0 | 2.15 | 2.16 |
| *WILDEBEEST* | **70** | **64** | **69** | 67.7 | 2.62 | 2.61 |
| *IMPALA* | **175** | **288** | **372** | 278.3 | 80.90 | 80.23 |
| *GEMSBOK* | **75** | **68** | **42** | 61.7 | 14.27 | 14.24 |
| *ELAND* | **39** | **32** | **48** | 39.7 | 6.52 | 6.58 |
| *WATERBUCK* | **12** | **10** | **12** | 11.3 | 0.95 | 0.94 |

| SPECIES | SEdiff21 | SEdiff22 | SEdiff23 | SEdiff31 | SEdiff33 |
|---|---|---|---|---|---|
| *KUDU* | 3.63 | 2.96 | 2.70 | 3.43 | 2.42 |
| *ZEBRA* | 2.63 | 2.15 | 1.96 | 2.49 | 1.76 |
| *WILDEBEEST* | 3.21 | 2.62 | 2.39 | 3.01 | 2.13 |
| *IMPALA* | 99.08 | 80.90 | 73.85 | 92.64 | 65.51 |
| *WARTHOG* | 17.48 | 14.27 | 13.03 | 16.44 | 11.63 |
| *ELAND* | 7.99 | 6.52 | 5.95 | 7.60 | 5.37 |
| *WATERBUCK* | 1.16 | 0.95 | 0.87 | 1.09 | 0.77 |

Table 137: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for kudu on the farm Shroda, northern mopane veld.

| KUDU | | MEAN | 25.0 | | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 1.25 | 2.50 | 3.75 | 5.00 | 6.25 | 7.50 | 8.75 | 10.00 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.34 | 0.69 | 1.03 | 1.38 | 1.72 | 2.07 | 2.41 | 2.76 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.42 | 0.84 | 1.27 | 1.69 | 2.11 | 2.53 | 2.96 | 3.38 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.46 | 0.93 | 1.39 | 1.85 | 2.31 | 2.78 | 3.24 | 3.70 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.36 | 0.73 | 1.09 | 1.46 | 1.82 | 2.19 | 2.55 | 2.92 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.52 | 1.03 | 1.55 | 2.06 | 2.58 | 3.09 | 3.61 | 4.12 |

**Table 138**: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for kudu at 10% and 20% significance on the farm Shroda, northern mopane veld.

talpha.1 KUDU

| | **5** | **10** | **15** | **20** | **25** | **30** | **35** | **40** |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.07 | 0.10 | 0.14 | 0.18 | 0.21 | 0.25 | 0.29 | 0.33 |
| **2_2** | 0.09 | 0.15 | 0.22 | 0.31 | 0.41 | 0.51 | 0.61 | 0.70 |
| **2_3** | 0.10 | 0.18 | 0.29 | 0.42 | 0.55 | 0.68 | 0.79 | 0.87 |
| **3_1** | 0.08 | 0.13 | 0.19 | 0.26 | 0.34 | 0.43 | 0.51 | 0.60 |
| **3_3** | 0.11 | 0.22 | 0.36 | 0.52 | 0.68 | 0.81 | 0.90 | 0.95 |

talpha.2

| | **5** | **10** | **15** | **20** | **25** | **30** | **35** | **40** |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.15 | 0.21 | 0.27 | 0.34 | 0.41 | 0.48 | 0.54 | 0.61 |
| **2_2** | 0.18 | 0.27 | 0.40 | 0.52 | 0.64 | 0.75 | 0.84 | 0.90 |
| **2_3** | 0.19 | 0.32 | 0.46 | 0.62 | 0.75 | 0.86 | 0.93 | 0.97 |
| **3_1** | 0.16 | 0.25 | 0.34 | 0.45 | 0.56 | 0.67 | 0.76 | 0.83 |
| **3_3** | 0.21 | 0.36 | 0.54 | 0.71 | 0.84 | 0.93 | 0.97 | 0.99 |

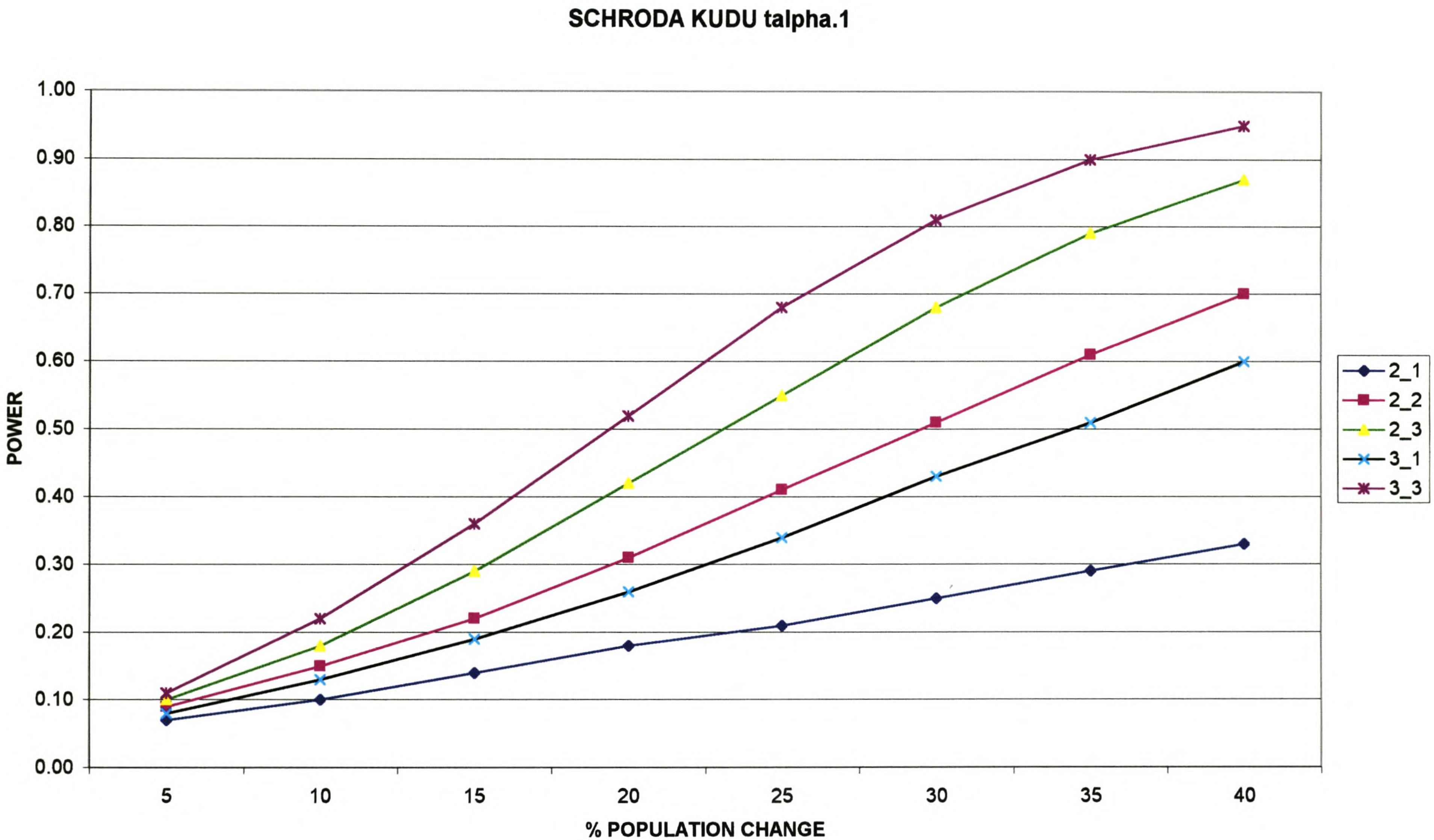


Figure 131: Power curves for various count replicate options at 10% significance for kudu on the farm Shroda, northern mopane veld.

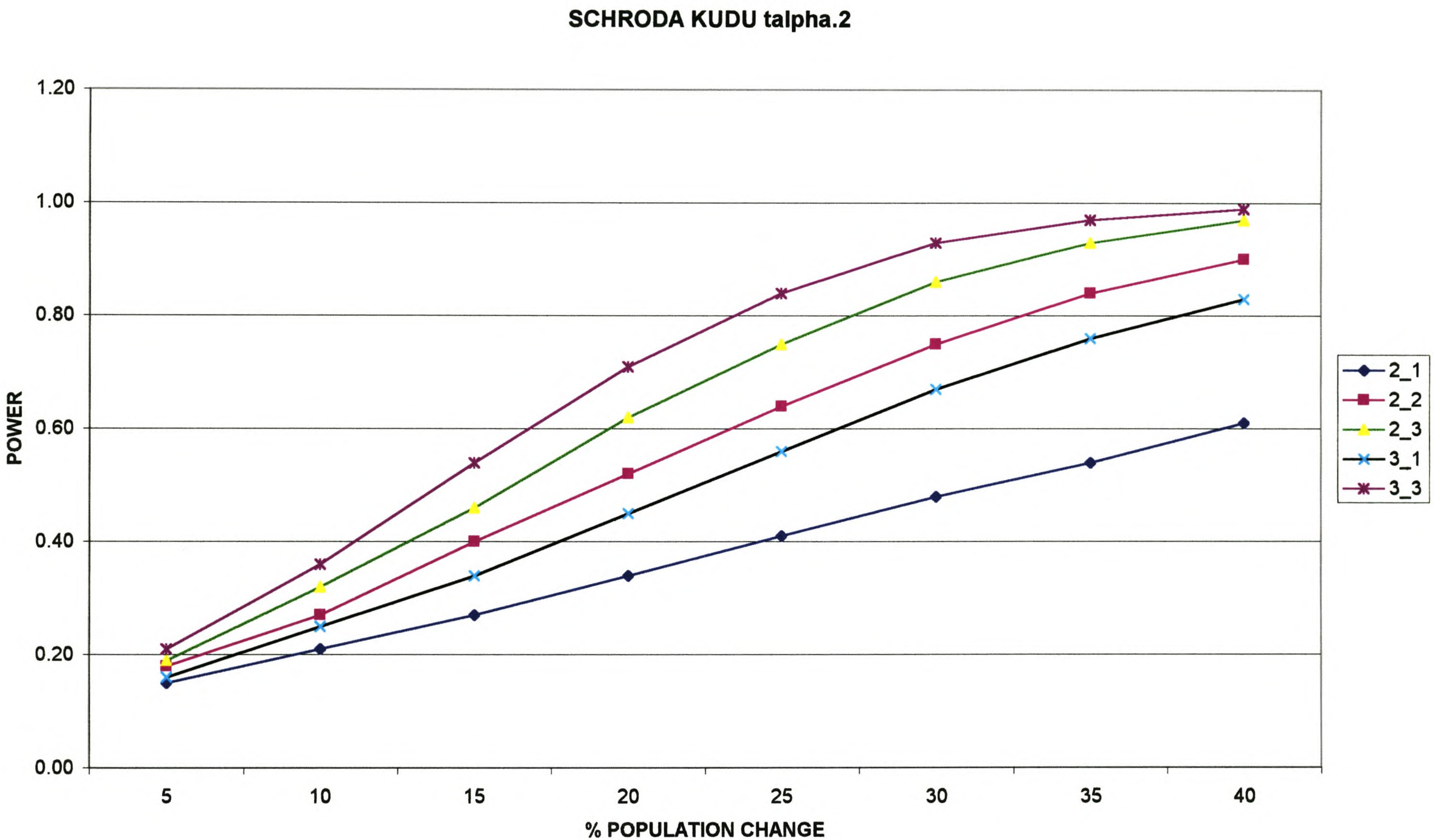


Figure 132: Power curves for various count replicate options at 20% significance for kudu on the farm Shroda, northern mopane veld.

Table 139: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for zebra on the farm Shroda, northern mopane veld.

| ZEBRA | | MEAN | | 23.00 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 1.15 | 2.30 | 3.45 | 4.60 | 5.75 | 6.90 | 8.05 | 9.20 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.44 | 0.87 | 1.31 | 1.75 | 2.18 | 2.62 | 3.06 | 3.49 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.53 | 1.07 | 1.60 | 2.14 | 2.67 | 3.21 | 3.74 | 4.28 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.59 | 1.17 | 1.76 | 2.34 | 2.93 | 3.52 | 4.10 | 4.69 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.46 | 0.92 | 1.38 | 1.84 | 2.31 | 2.77 | 3.23 | 3.69 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.65 | 1.30 | 1.96 | 2.61 | 3.26 | 3.91 | 4.56 | 5.22 |

Table 140: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for zebra at 10% and 20% significance on the farm Shroda, northern mopane veld.

talpha.1 ZEBRA

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.08 | 0.12 | 0.17 | 0.22 | 0.27 | 0.32 | 0.37 | 0.42 |
| **2_2** | 0.10 | 0.19 | 0.29 | 0.42 | 0.54 | 0.66 | 0.76 | 0.84 |
| **2_3** | 0.12 | 0.23 | 0.39 | 0.56 | 0.72 | 0.84 | 0.92 | 0.96 |
| **3_1** | 0.09 | 0.16 | 0.25 | 0.35 | 0.46 | 0.57 | 0.67 | 0.75 |
| **3_3** | 0.14 | 0.29 | 0.49 | 0.69 | 0.85 | 0.94 | 0.98 | 0.99 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.16 | 0.24 | 0.33 | 0.42 | 0.50 | 0.58 | 0.66 | 0.72 |
| **2_2** | 0.20 | 0.34 | 0.50 | 0.65 | 0.78 | 0.88 | 0.94 | 0.97 |
| **2_3** | 0.22 | 0.39 | 0.59 | 0.76 | 0.88 | 0.95 | 0.98 | 1.00 |
| **3_1** | 0.18 | 0.30 | 0.43 | 0.57 | 0.70 | 0.80 | 0.88 | 0.93 |
| **3_3** | 0.24 | 0.45 | 0.68 | 0.85 | 0.95 | 0.98 | 1.00 | 1.00 |

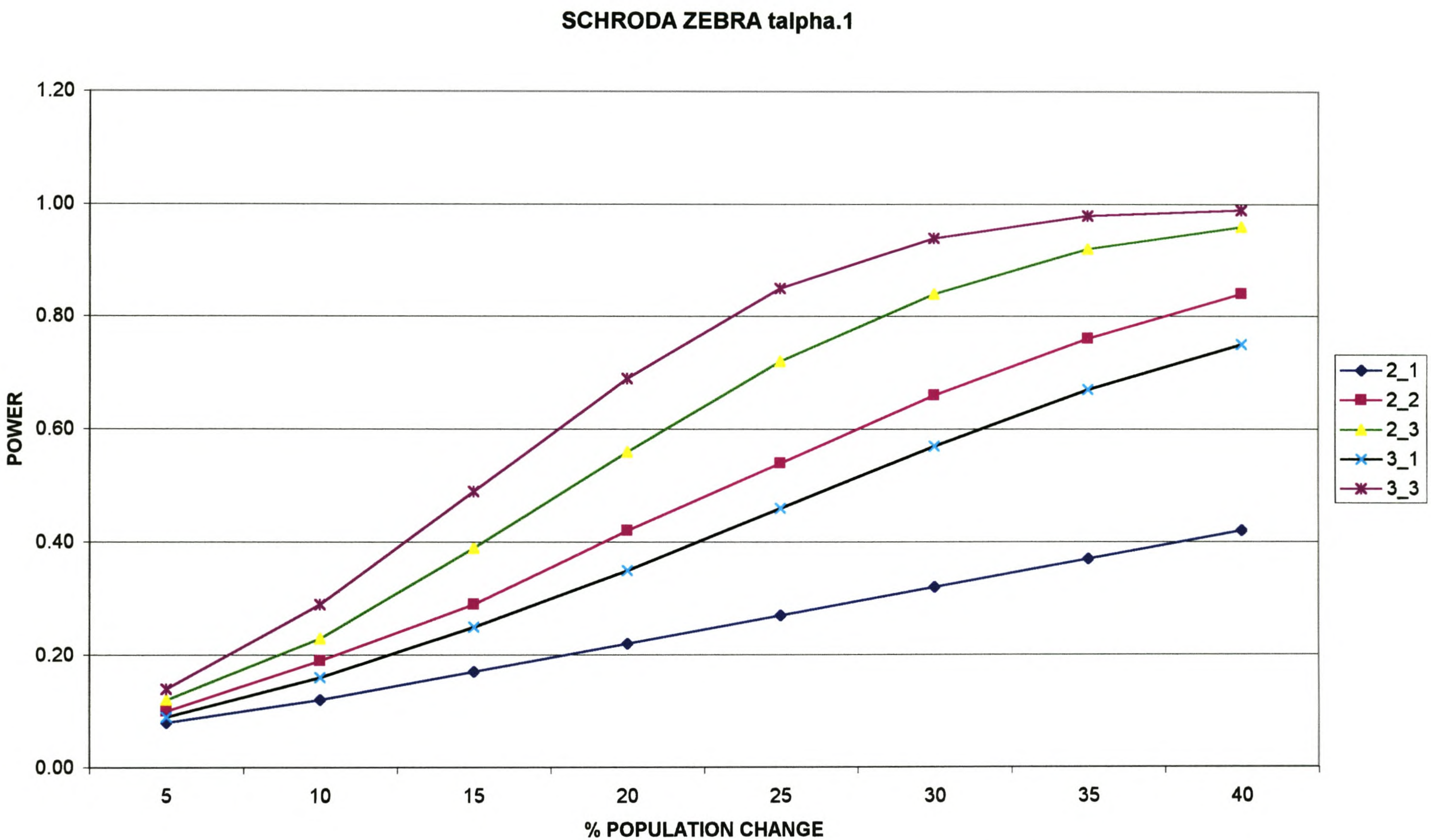


Figure 133: Power curves for various count replicate options at 10% significance for zebra on the farm Shroda, northern mopane veld.

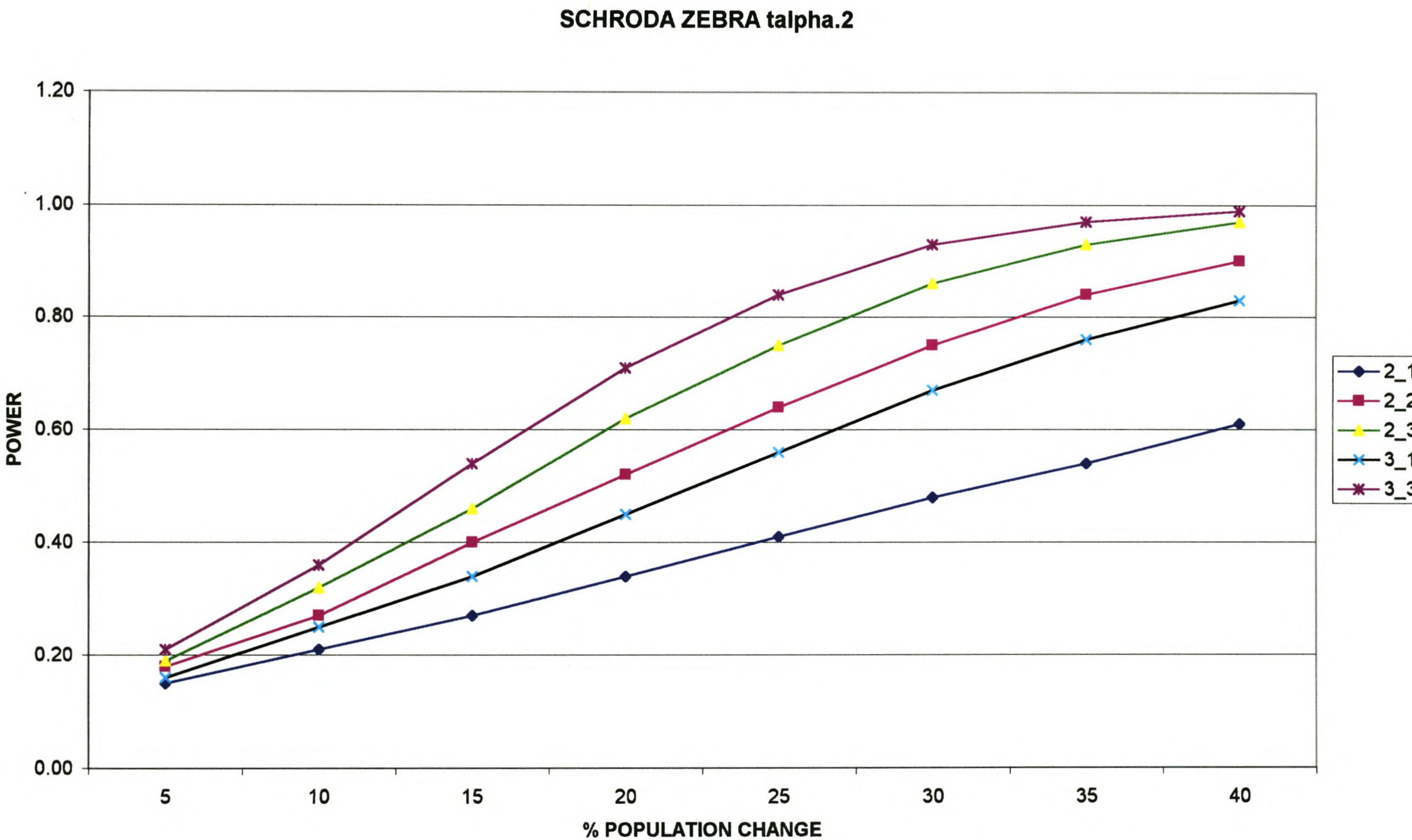


Figure 134: Power curves for various count replicate options at 20% significance for zebra on the farm Shroda, northern mopane veld.

Table 141: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for wildebeest on the farm Shroda, northern mopane veld.

| WILDEBEEST | | MEAN | 67.70 | | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 3.39 | 6.77 | 10.16 | 13.54 | 16.93 | 20.31 | 23.70 | 27.08 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 1.05 | 2.11 | 3.16 | 4.22 | 5.27 | 6.33 | 7.38 | 8.44 |
| 2 | 2 | 2 | 2.92 | 1.87 | 1.29 | 2.58 | 3.88 | 5.17 | 6.46 | 7.75 | 9.04 | 10.34 |
| 2 | 3 | 3 | 2.35 | 1.64 | 1.42 | 2.83 | 4.25 | 5.66 | 7.08 | 8.49 | 9.91 | 11.32 |
| 3 | 1 | 2 | 2.92 | 1.87 | 1.12 | 2.25 | 3.37 | 4.49 | 5.62 | 6.74 | 7.86 | 8.99 |
| 3 | 3 | 4 | 2.13 | 1.53 | 1.59 | 3.18 | 4.77 | 6.35 | 7.94 | 9.53 | 11.12 | 12.71 |

Table 142: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for wildebeest at 10% and 20% significance on the farm Shroda, northern mopane veld.

talpha.1 WILDEBEEST

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| 2_1 | 0.14 | 0.26 | 0.38 | 0.49 | 0.59 | 0.68 | 0.75 | 0.81 |
| 2_2 | 0.23 | 0.52 | 0.78 | 0.93 | 0.98 | 1.00 | 1.00 | 1.00 |
| 2_3 | 0.30 | 0.69 | 0.93 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 |
| 3_1 | 0.19 | 0.44 | 0.69 | 0.87 | 0.96 | 0.99 | 1.00 | 1.00 |
| 3_3 | 0.37 | 0.83 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| 2_1 | 0.27 | 0.49 | 0.67 | 0.81 | 0.90 | 0.95 | 0.98 | 0.99 |
| 2_2 | 0.40 | 0.76 | 0.95 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2_3 | 0.47 | 0.87 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 3_1 | 0.35 | 0.68 | 0.90 | 0.98 | 1.00 | 1.00 | 1.00 | 1.00 |
| 3_3 | 0.56 | 0.94 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |

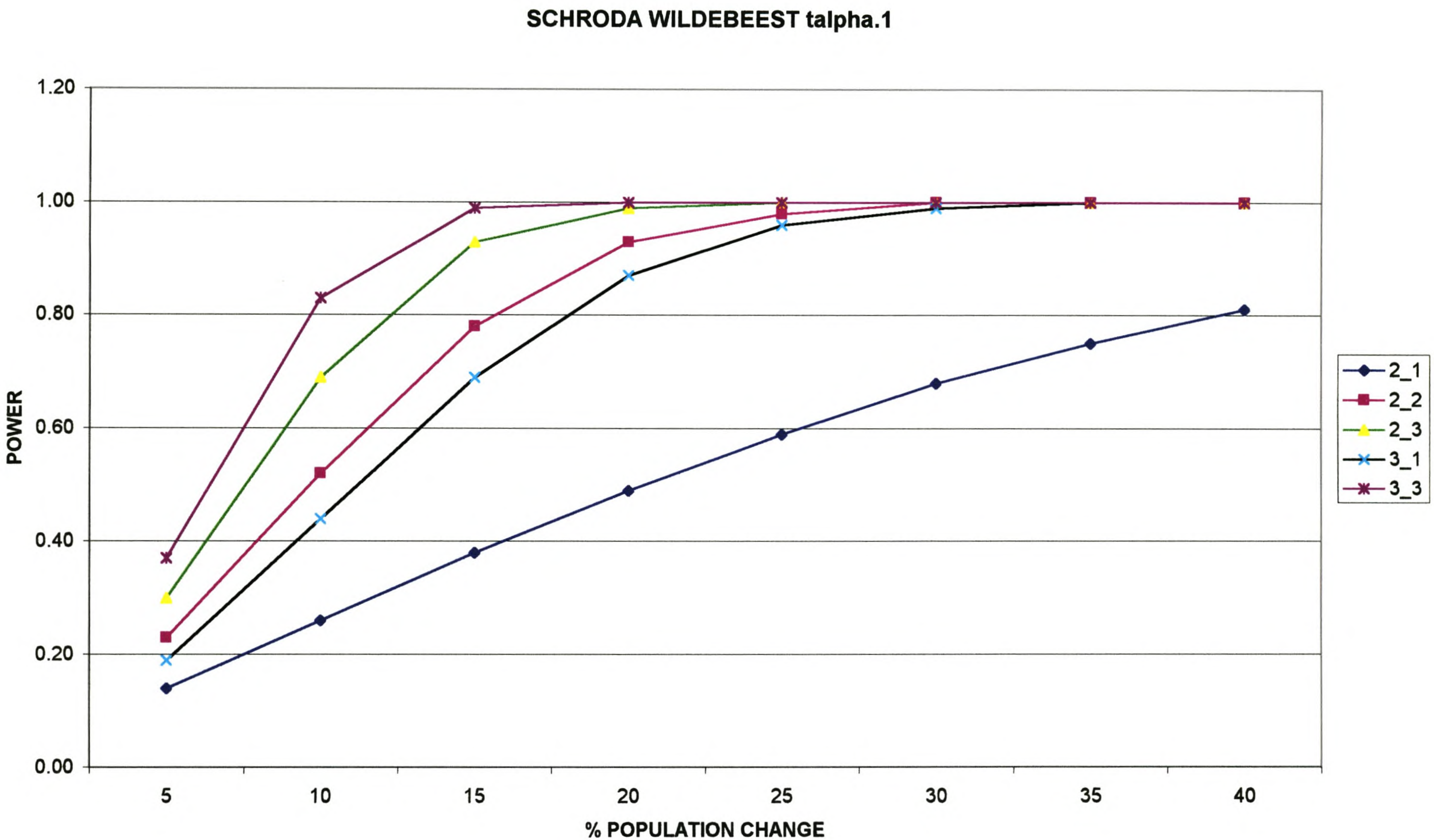


Figure 135: Power curves for various count replicate options at 10% significance for wildebeest on the farm Shroda, northern mopane veld.

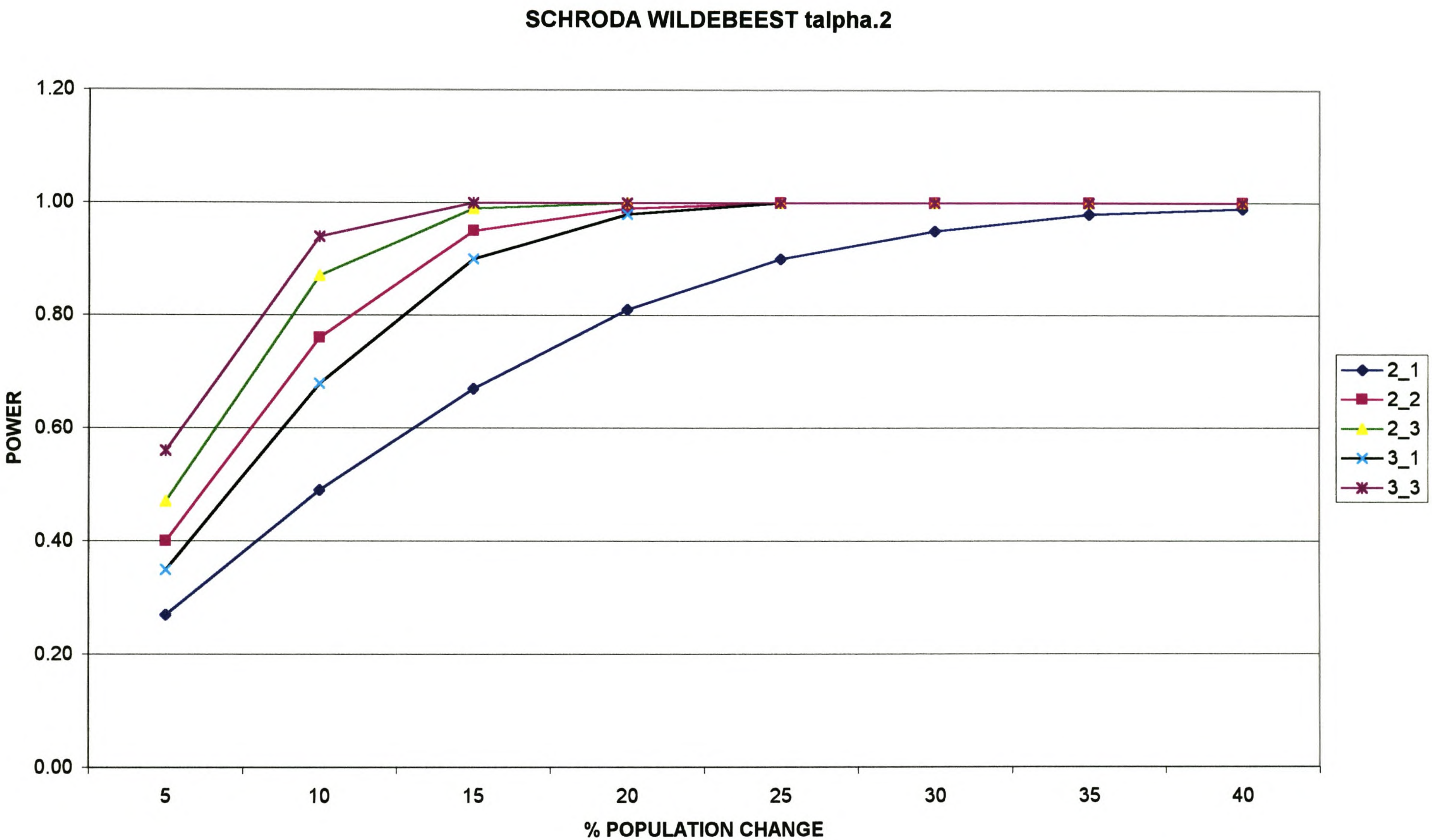


Figure 136: Power curves for various count replicate options at 20% significance for wildebeest on the farm Shroda, northern mopane veld.

Table 143: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for impala on the farm Shroda, northern mopane veld.

| IMPALA | | MEAN | | 278.30 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 13.92 | 27.83 | 41.75 | 55.66 | 69.58 | 83.49 | 97.41 | 111.32 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.14 | 0.28 | 0.42 | 0.56 | 0.70 | 0.84 | 0.98 | 1.12 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.17 | 0.34 | 0.52 | 0.69 | 0.86 | 1.03 | 1.20 | 1.38 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.19 | 0.38 | 0.57 | 0.75 | 0.94 | 1.13 | 1.32 | 1.51 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.15 | 0.30 | 0.45 | 0.60 | 0.75 | 0.90 | 1.05 | 1.20 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.21 | 0.42 | 0.64 | 0.85 | 1.06 | 1.27 | 1.49 | 1.70 |

Table 144: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for impala at 10% and 20% significance on the farm Shroda, northern mopane veld.

talpha.1 IMPALA

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.06 | 0.07 | 0.08 | 0.09 | 0.11 | 0.12 | 0.13 | 0.15 |
| **2_2** | 0.06 | 0.08 | 0.10 | 0.12 | 0.15 | 0.18 | 0.21 | 0.25 |
| **2_3** | 0.07 | 0.09 | 0.12 | 0.15 | 0.18 | 0.23 | 0.27 | 0.32 |
| **3_1** | 0.06 | 0.08 | 0.09 | 0.11 | 0.13 | 0.16 | 0.18 | 0.21 |
| **3_3** | 0.07 | 0.10 | 0.13 | 0.18 | 0.22 | 0.28 | 0.34 | 0.41 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.12 | 0.14 | 0.16 | 0.18 | 0.21 | 0.23 | 0.26 | 0.29 |
| **2_2** | 0.13 | 0.16 | 0.20 | 0.24 | 0.28 | 0.33 | 0.38 | 0.43 |
| **2_3** | 0.13 | 0.17 | 0.22 | 0.26 | 0.32 | 0.38 | 0.44 | 0.50 |
| **3_1** | 0.12 | 0.15 | 0.18 | 0.21 | 0.25 | 0.29 | 0.33 | 0.38 |
| **3_3** | 0.14 | 0.18 | 0.24 | 0.30 | 0.37 | 0.44 | 0.52 | 0.59 |

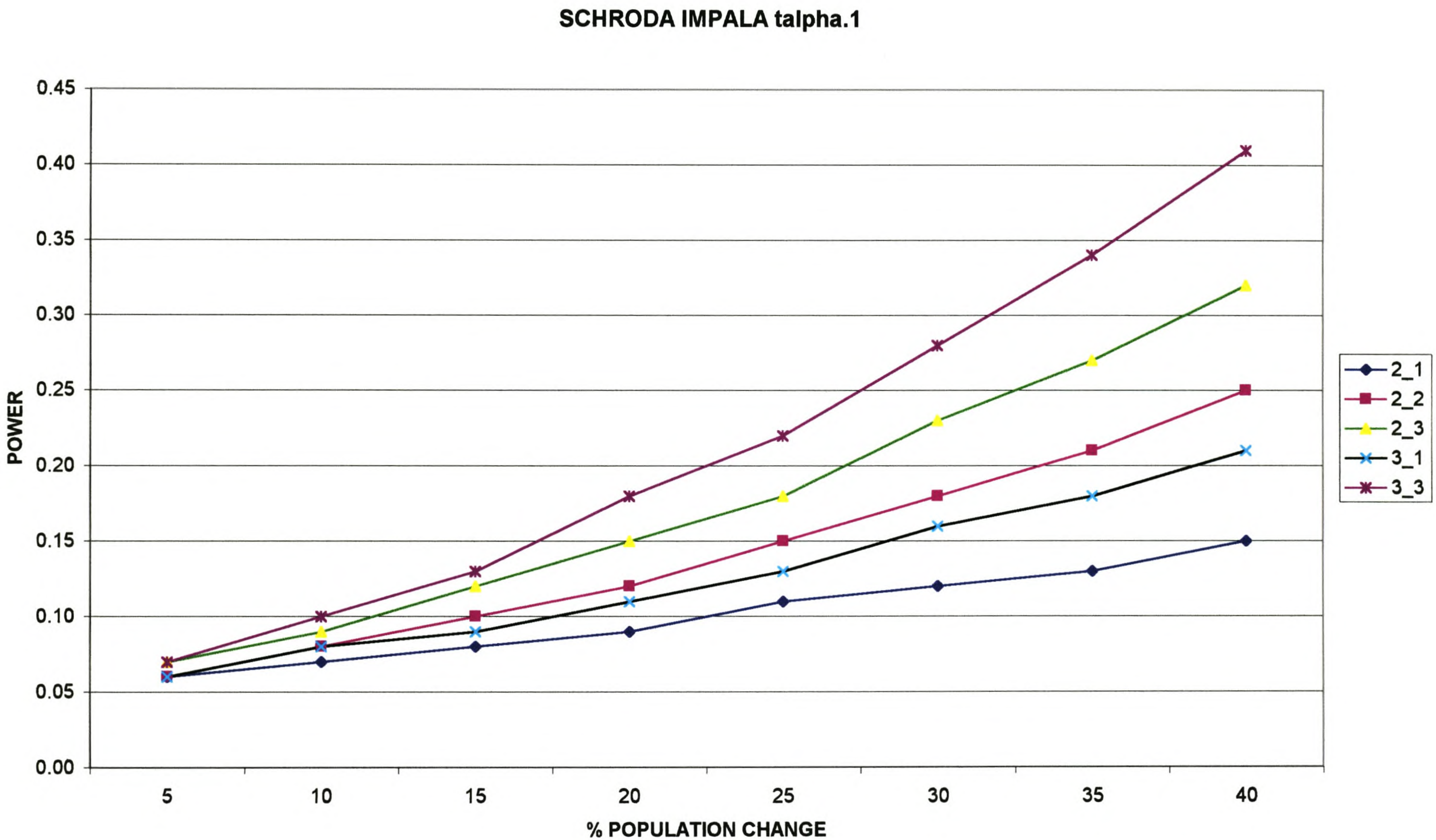


Figure 137: Power curves for various count replicate options at 10% significance for impala on the farm Shroda, northern mopane veld.

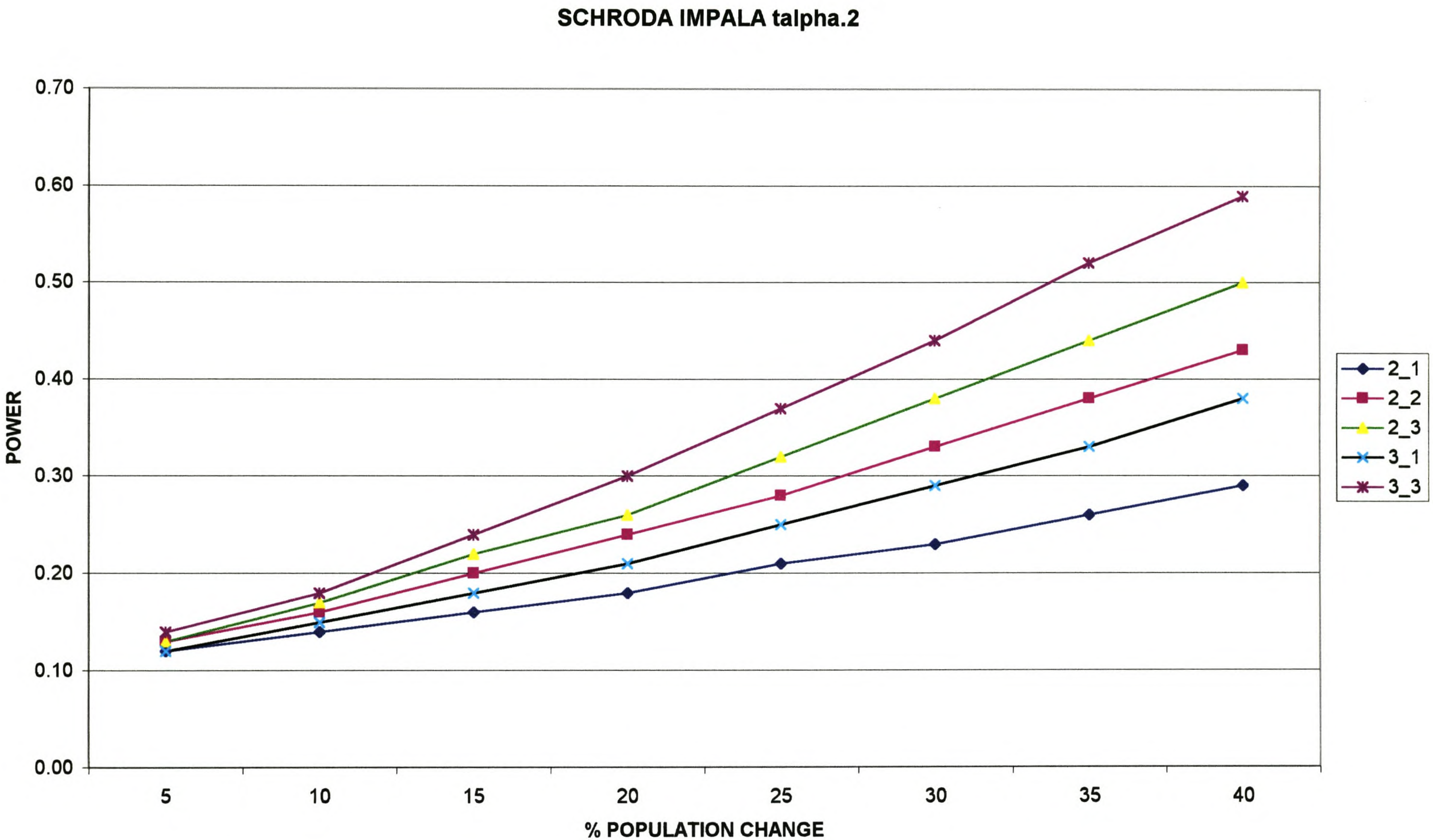


Figure 138: Power curves for various count replicate options at 20% significance for impala on the farm Shroda, northern mopane veld.

Table 145: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for gemsbok on the farm Shroda, northern mopane veld.

| GEMSBOK | | | MEAN | 61.7 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 3.09 | 6.17 | 9.26 | 12.34 | 15.43 | 18.51 | 21.60 | 24.68 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.18 | 0.35 | 0.53 | 0.71 | 0.88 | 1.06 | 1.24 | 1.41 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.22 | 0.43 | 0.65 | 0.86 | 1.08 | 1.30 | 1.51 | 1.73 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.24 | 0.47 | 0.71 | 0.95 | 1.18 | 1.42 | 1.66 | 1.89 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.19 | 0.38 | 0.56 | 0.75 | 0.94 | 1.13 | 1.31 | 1.50 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.27 | 0.53 | 0.80 | 1.06 | 1.33 | 1.59 | 1.86 | 2.12 |

Table 146: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for gemsbok at 10% and 20% significance on the farm Shroda, northern mopane veld.

talpha.1 GEMSBOK

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.06 | 0.07 | 0.09 | 0.11 | 0.12 | 0.14 | 0.16 | 0.18 |
| **2_2** | 0.07 | 0.09 | 0.12 | 0.15 | 0.19 | 0.23 | 0.27 | 0.32 |
| **2_3** | 0.07 | 0.10 | 0.14 | 0.19 | 0.24 | 0.30 | 0.36 | 0.43 |
| **3_1** | 0.07 | 0.09 | 0.11 | 0.13 | 0.16 | 0.20 | 0.23 | 0.27 |
| **3_3** | 0.08 | 0.12 | 0.17 | 0.22 | 0.30 | 0.37 | 0.46 | 0.54 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.12 | 0.15 | 0.18 | 0.21 | 0.24 | 0.28 | 0.31 | 0.35 |
| **2_2** | 0.14 | 0.18 | 0.23 | 0.28 | 0.34 | 0.40 | 0.47 | 0.53 |
| **2_3** | 0.14 | 0.19 | 0.25 | 0.32 | 0.39 | 0.47 | 0.56 | 0.63 |
| **3_1** | 0.13 | 0.17 | 0.21 | 0.25 | 0.30 | 0.35 | 0.41 | 0.46 |
| **3_3** | 0.15 | 0.21 | 0.29 | 0.37 | 0.46 | 0.56 | 0.65 | 0.73 |

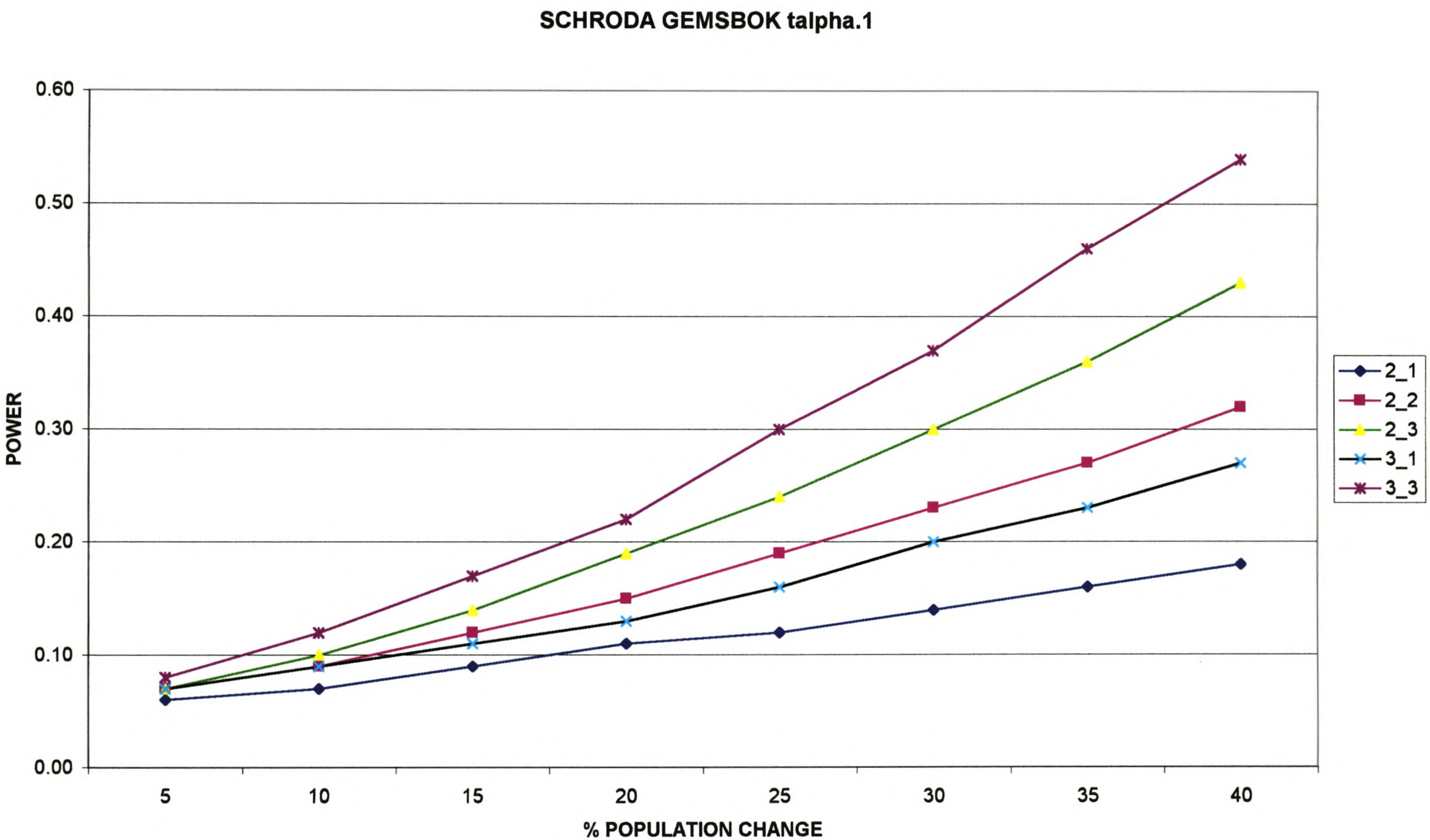


Figure 139: Power curves for various count replicate options at 10% significance for gemsbok on the farm Shroda, northern mopane veld.

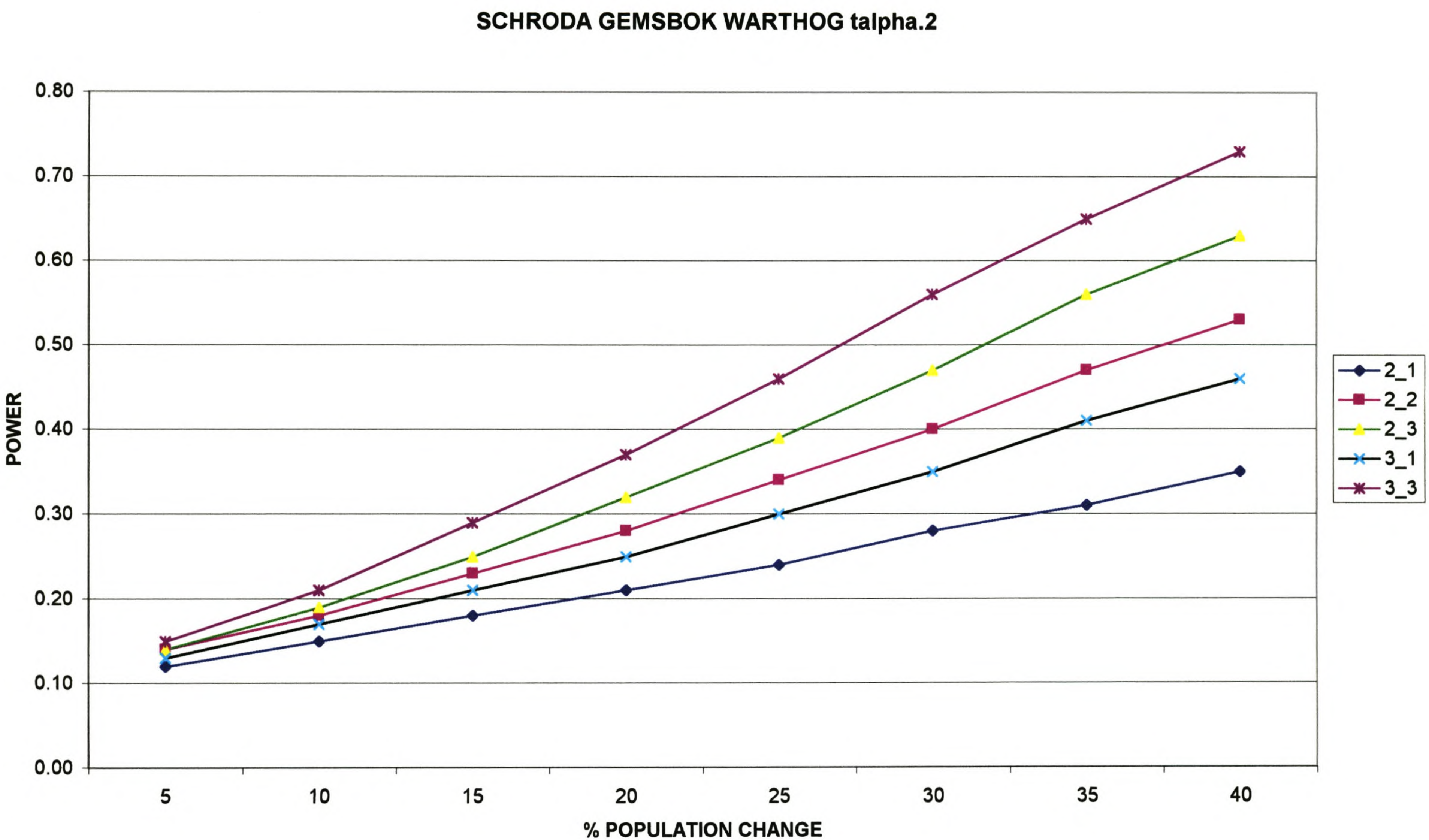


Figure 140: Power curves for various count replicate options at 20% significance for gemsbok on the farm Shroda, northern mopane veld.

Table 147: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for eland on the farm Shroda, northern mopane veld.

| ELAND | | | MEAN | 39.70 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 1.99 | 3.97 | 5.96 | 7.94 | 9.93 | 11.91 | 13.90 | 15.88 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.25 | 0.50 | 0.75 | 0.99 | 1.24 | 1.49 | 1.74 | 1.99 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.30 | 0.61 | 0.91 | 1.22 | 1.52 | 1.83 | 2.13 | 2.44 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.33 | 0.67 | 1.00 | 1.33 | 1.67 | 2.00 | 2.33 | 2.67 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.26 | 0.52 | 0.78 | 1.05 | 1.31 | 1.57 | 1.83 | 2.09 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.37 | 0.74 | 1.11 | 1.48 | 1.85 | 2.22 | 2.59 | 2.96 |

Table 148: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for eland at 10% and 20% significance on the farm Shroda, northern mopane veld.

talpha.1 ELAND

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.07 | 0.09 | 0.11 | 0.13 | 0.16 | 0.19 | 0.22 | 0.25 |
| **2_2** | 0.08 | 0.11 | 0.16 | 0.21 | 0.28 | 0.34 | 0.41 | 0.49 |
| **2_3** | 0.08 | 0.13 | 0.20 | 0.27 | 0.37 | 0.46 | 0.56 | 0.65 |
| **3_1** | 0.07 | 0.10 | 0.14 | 0.18 | 0.23 | 0.29 | 0.34 | 0.41 |
| **3_3** | 0.09 | 0.15 | 0.24 | 0.34 | 0.46 | 0.58 | 0.69 | 0.78 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.13 | 0.17 | 0.22 | 0.26 | 0.31 | 0.36 | 0.41 | 0.46 |
| **2_2** | 0.15 | 0.22 | 0.29 | 0.38 | 0.47 | 0.56 | 0.65 | 0.73 |
| **2_3** | 0.16 | 0.24 | 0.34 | 0.44 | 0.56 | 0.66 | 0.76 | 0.84 |
| **3_1** | 0.14 | 0.20 | 0.26 | 0.33 | 0.41 | 0.49 | 0.56 | 0.64 |
| **3_3** | 0.17 | 0.27 | 0.39 | 0.52 | 0.64 | 0.76 | 0.85 | 0.91 |

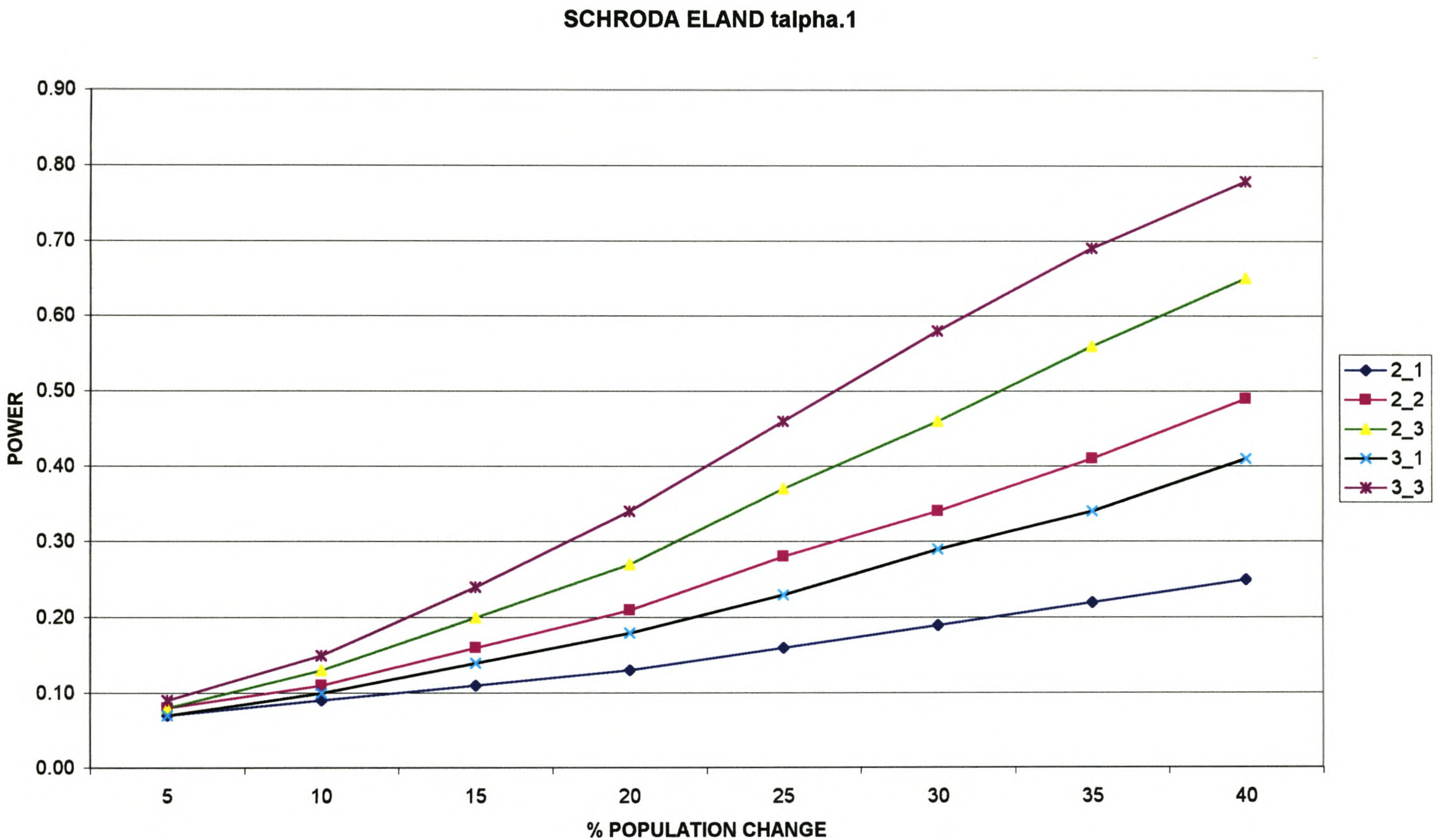


Figure 141: Power curves for various count replicate options at 10% significance for eland on the farm Shroda, northern mopane veld.

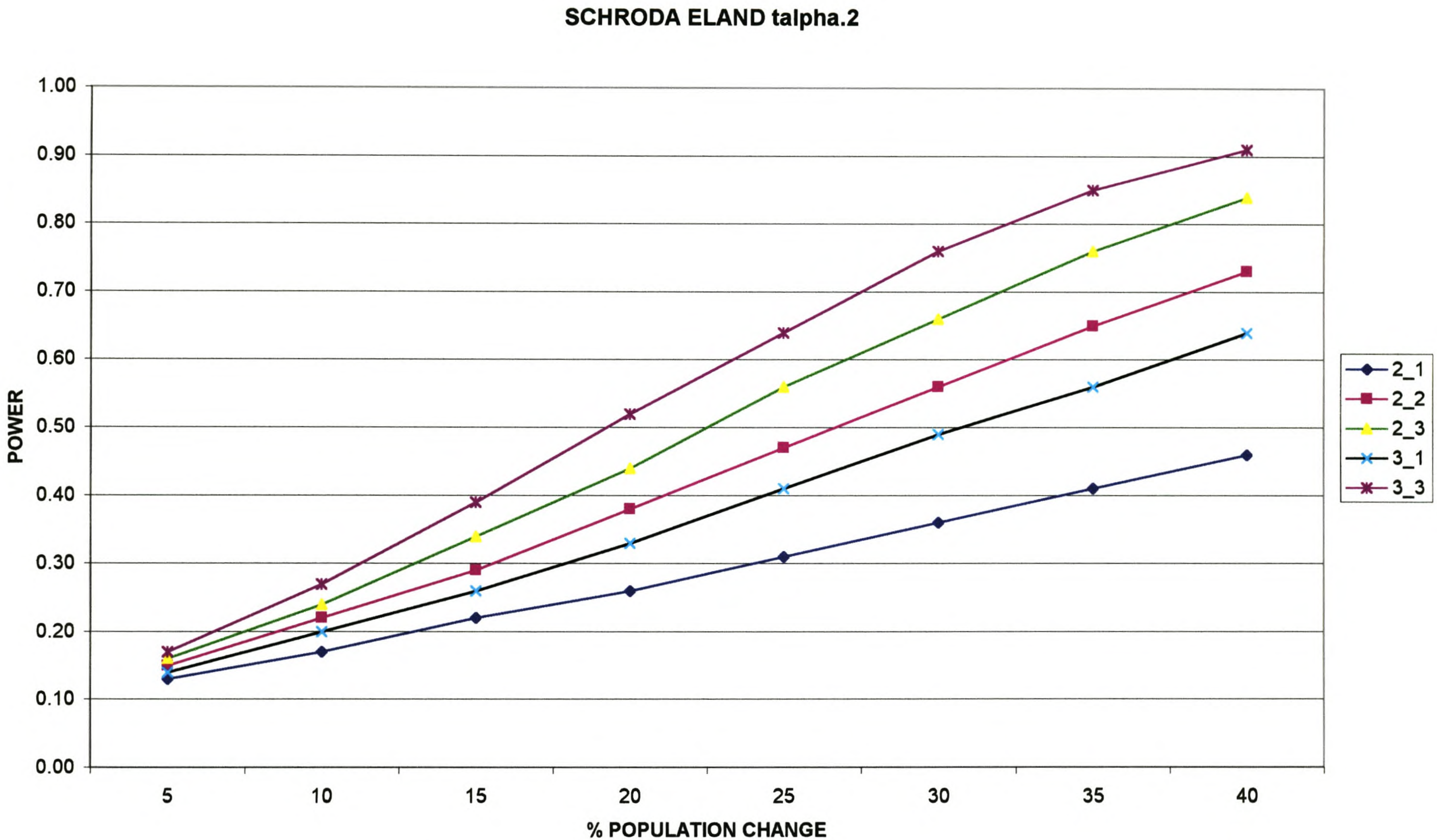


Figure 142: Power curves for various count replicate options at 20% significance for eland on the farm Shroda, northern mopane veld.

Table 149: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for waterbuck on the farm Shroda, northern mopane veld.

| WATERBUCK | | | MEAN | 11.30 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 0.57 | 1.13 | 1.70 | 2.26 | 2.83 | 3.39 | 3.96 | 4.52 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.49 | 0.97 | 1.46 | 1.94 | 2.43 | 2.91 | 3.40 | 3.88 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.59 | 1.19 | 1.78 | 2.38 | 2.97 | 3.57 | 4.16 | 4.76 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.65 | 1.30 | 1.95 | 2.61 | 3.26 | 3.91 | 4.56 | 5.21 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.52 | 1.04 | 1.56 | 2.08 | 2.60 | 3.12 | 3.64 | 4.16 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.74 | 1.47 | 2.21 | 2.94 | 3.68 | 4.42 | 5.15 | 5.89 |

Table 150: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for waterbuck at 10% and 20% significance on the farm Shroda, northern mopane veld.

talpha.1 WATERBUCK

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| 2_1 | 0.09 | 0.13 | 0.18 | 0.24 | 0.30 | 0.35 | 0.41 | 0.46 |
| 2_2 | 0.11 | 0.21 | 0.33 | 0.47 | 0.61 | 0.73 | 0.83 | 0.90 |
| 2_3 | 0.13 | 0.27 | 0.45 | 0.64 | 0.79 | 0.90 | 0.96 | 0.98 |
| 3_1 | 0.10 | 0.18 | 0.28 | 0.40 | 0.53 | 0.64 | 0.74 | 0.83 |
| 3_3 | 0.15 | 0.34 | 0.57 | 0.78 | 0.91 | 0.97 | 0.99 | 1.00 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| 2_1 | 0.17 | 0.26 | 0.36 | 0.45 | 0.55 | 0.63 | 0.71 | 0.77 |
| 2_2 | 0.21 | 0.37 | 0.55 | 0.71 | 0.84 | 0.92 | 0.97 | 0.99 |
| 2_3 | 0.24 | 0.43 | 0.65 | 0.82 | 0.93 | 0.98 | 0.99 | 1.00 |
| 3_1 | 0.20 | 0.33 | 0.48 | 0.64 | 0.77 | 0.86 | 0.93 | 0.97 |
| 3_3 | 0.27 | 0.51 | 0.75 | 0.91 | 0.98 | 1.00 | 1.00 | 1.00 |

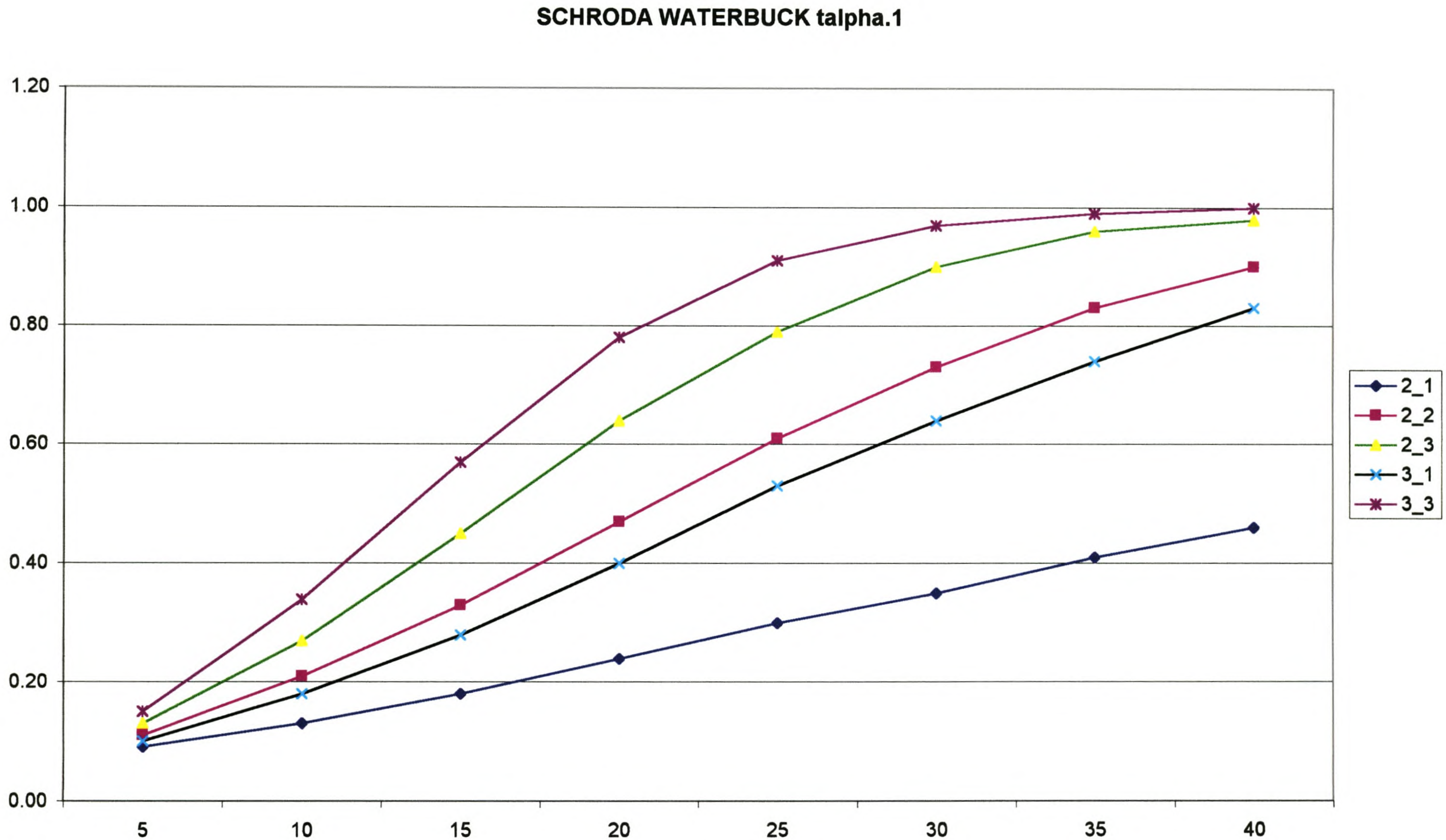


Figure 142: Power curves for various count replicate options at 10% significance for waterbuck on the farm Shroda, northern mopane veld.

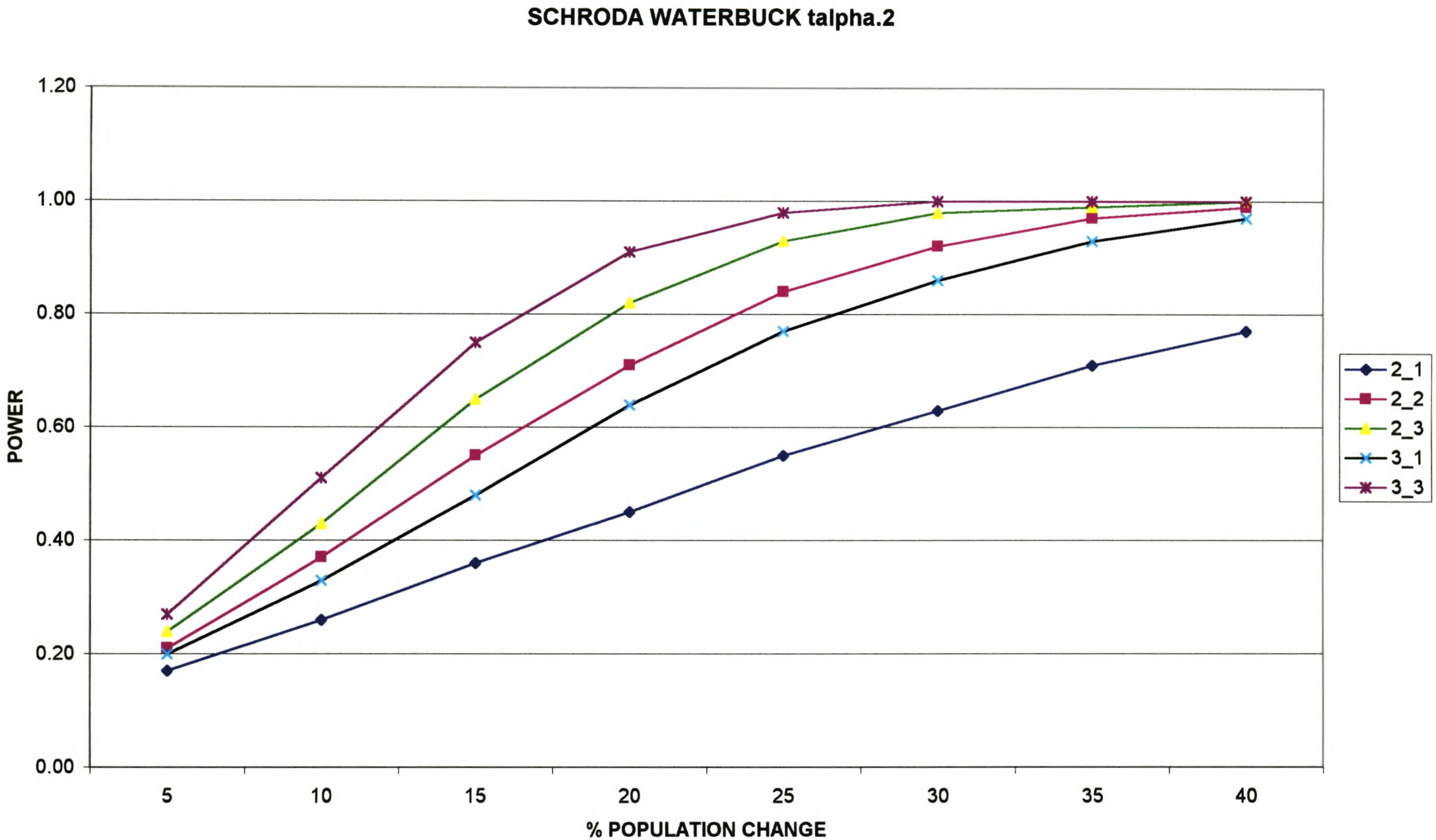


Figure 144: Power curves for various count replicate options at 20% significance for waterbuck on the farm Shroda, northern mopane veld.

Table 151: Summary statistics of three replicate helicopter counts of the farm Samaria 1, northern mopane veld.

| SPECIES | COUNT REPLICATES | | | MEAN | STANDARD | STANDARD |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | | DEVIATION(n2) | DEVIATION(n3) |
| *ELAND* | **5** | **11** | **10** | 8.7 | 2.60 | 2.62 |
| *ZEBRA* | **24** | **25** | **20** | 23.0 | 2.21 | 2.17 |
| *WILDEBEEST* | **32** | **76** | **54** | 54.0 | 17.62 | 17.73 |
| *IMPALA* | **122** | **114** | **137** | 124.3 | 9.38 | 9.49 |

| SPECIES | SEdiff21 | SEdiff22 | SEdiff23 | SEdiff31 | SEdiff33 |
|---|---|---|---|---|---|
| *ELAND* | 3.18 | 2.60 | 2.37 | 3.03 | 2.14 |
| *ZEBRA* | 2.71 | 2.21 | 2.02 | 2.51 | 1.77 |
| *WILDEBEEST* | 21.58 | 17.62 | 16.08 | 20.47 | 14.48 |
| *IMPALA* | 11.49 | 9.38 | 8.56 | 10.96 | 7.75 |

Table 152: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for eland on the farm Samaria 1, northern mopane veld.

| ELAND | | | MEAN | 8.7 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 0.44 | 0.87 | 1.31 | 1.74 | 2.18 | 2.61 | 3.05 | 3.48 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.14 | 0.27 | 0.41 | 0.55 | 0.68 | 0.82 | 0.96 | 1.09 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.17 | 0.33 | 0.50 | 0.67 | 0.84 | 1.00 | 1.17 | 1.34 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.18 | 0.37 | 0.55 | 0.73 | 0.92 | 1.10 | 1.28 | 1.47 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.14 | 0.29 | 0.43 | 0.58 | 0.72 | 0.86 | 1.01 | 1.15 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.20 | 0.41 | 0.61 | 0.81 | 1.02 | 1.22 | 1.42 | 1.63 |

Table 153: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for eland at 10% and 20% significance on the farm Samaria 1, northern mopane veld.

talpha.1 ELAND

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| 2_1 | 0.06 | 0.07 | 0.08 | 0.09 | 0.10 | 0.12 | 0.13 | 0.14 |
| 2_2 | 0.06 | 0.08 | 0.10 | 0.12 | 0.15 | 0.17 | 0.20 | 0.24 |
| 2_3 | 0.07 | 0.09 | 0.11 | 0.14 | 0.18 | 0.22 | 0.26 | 0.31 |
| 3_1 | 0.06 | 0.08 | 0.09 | 0.11 | 0.13 | 0.15 | 0.18 | 0.20 |
| 3_3 | 0.07 | 0.10 | 0.13 | 0.17 | 0.21 | 0.27 | 0.32 | 0.39 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| 2_1 | 0.12 | 0.14 | 0.16 | 0.18 | 0.20 | 0.23 | 0.26 | 0.28 |
| 2_2 | 0.13 | 0.16 | 0.19 | 0.23 | 0.27 | 0.32 | 0.37 | 0.42 |
| 2_3 | 0.13 | 0.17 | 0.21 | 0.26 | 0.31 | 0.37 | 0.43 | 0.49 |
| 3_1 | 0.12 | 0.15 | 0.18 | 0.21 | 0.24 | 0.28 | 0.32 | 0.36 |
| 3_3 | 0.14 | 0.18 | 0.23 | 0.29 | 0.36 | 0.43 | 0.50 | 0.57 |

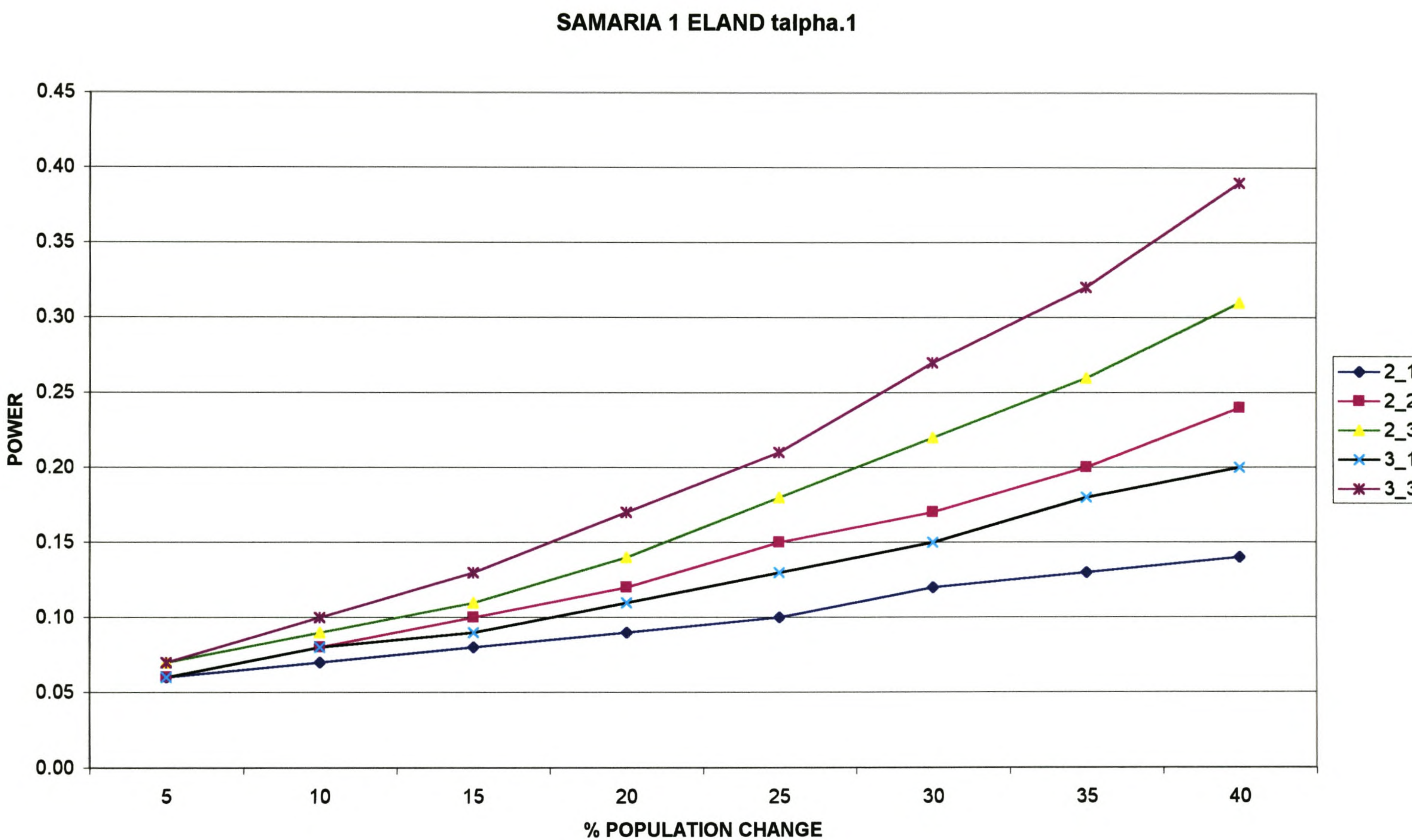


Figure 145: Power curves for various count replicate options at 10% significance for eland on the farm Samaria 1, northern mopane veld.

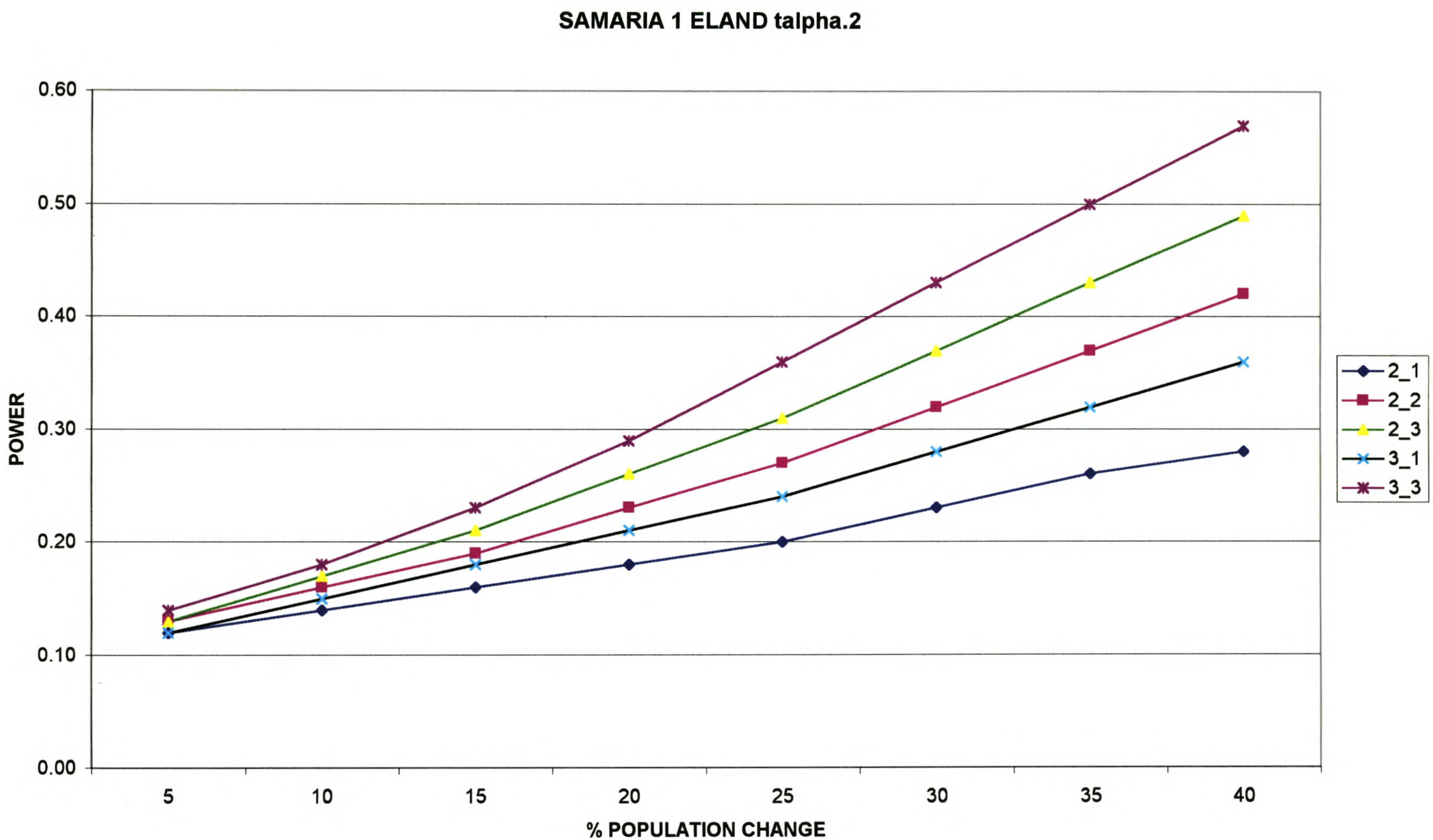


Figure 146: Power curves for various count replicate options at 20% significance for eland on the farm Samaria 1, northern mopane veld.

Table 154: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for zebra on the farm Samaria 1, northern mopane veld.

| ZEBRA | | MEAN | 23.00 | | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 1.15 | 2.30 | 3.45 | 4.60 | 5.75 | 6.90 | 8.05 | 9.20 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.42 | 0.85 | 1.27 | 1.70 | 2.12 | 2.55 | 2.97 | 3.40 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.52 | 1.04 | 1.56 | 2.08 | 2.60 | 3.12 | 3.64 | 4.16 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.57 | 1.14 | 1.71 | 2.28 | 2.85 | 3.42 | 3.99 | 4.56 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.46 | 0.92 | 1.38 | 1.84 | 2.29 | 2.75 | 3.21 | 3.67 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.65 | 1.30 | 1.95 | 2.60 | 3.25 | 3.89 | 4.54 | 5.19 |

**Table 155:** Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for zebra at 10% and 20% significance on the farm Samaria 1, northern mopane veld.

talpha.1 ZEBRA

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.08 | 0.12 | 0.16 | 0.21 | 0.26 | 0.31 | 0.36 | 0.41 |
| **2_2** | 0.10 | 0.18 | 0.28 | 0.40 | 0.53 | 0.64 | 0.74 | 0.83 |
| **2_3** | 0.12 | 0.23 | 0.38 | 0.54 | 0.70 | 0.82 | 0.91 | 0.96 |
| **3_1** | 0.09 | 0.16 | 0.25 | 0.35 | 0.45 | 0.56 | 0.66 | 0.75 |
| **3_3** | 0.14 | 0.29 | 0.49 | 0.69 | 0.84 | 0.93 | 0.98 | 0.99 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.16 | 0.23 | 0.32 | 0.41 | 0.49 | 0.57 | 0.64 | 0.71 |
| **2_2** | 0.20 | 0.33 | 0.48 | 0.64 | 0.77 | 0.86 | 0.93 | 0.97 |
| **2_3** | 0.22 | 0.38 | 0.57 | 0.74 | 0.87 | 0.94 | 0.98 | 0.99 |
| **3_1** | 0.18 | 0.30 | 0.43 | 0.57 | 0.69 | 0.80 | 0.88 | 0.93 |
| **3_3** | 0.24 | 0.45 | 0.68 | 0.85 | 0.94 | 0.98 | 1.00 | 1.00 |

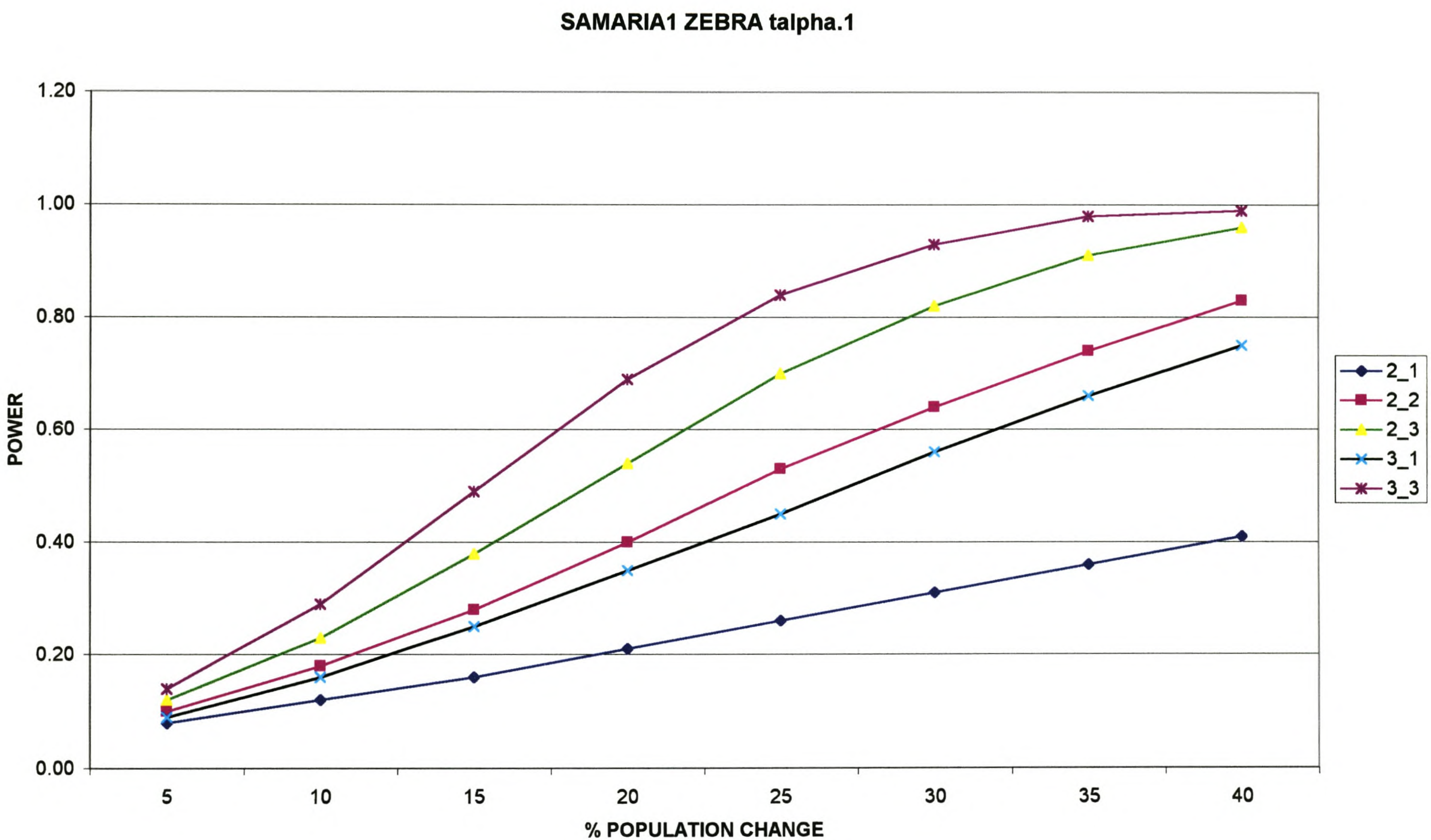


Figure 147: Power curves for various count replicate options at 10% significance for zebra on the farm Samaria 1, northern mopane veld.

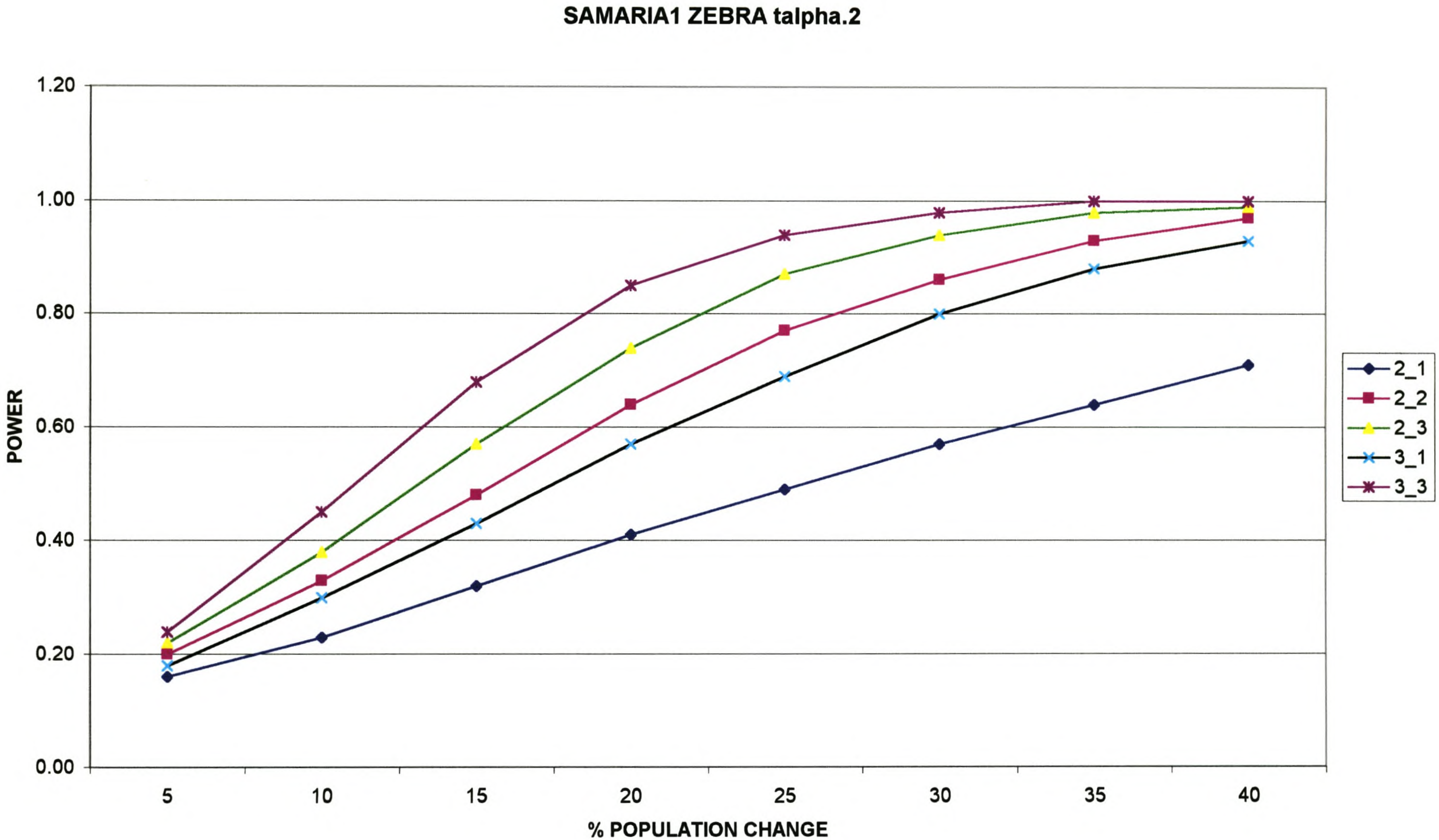


Figure 148: Power curves for various count replicate options at 20% significance for zebra on the farm Samaria 1, northern mopane veld.

Table 156: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for wildebeest on the farm Samaria 1, northern mopane veld.

| WILDEBEEST | | MEAN | | 54.00 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 2.70 | 5.40 | 8.10 | 10.80 | 13.50 | 16.20 | 18.90 | 21.60 |
| **n1** | **n2** | **df** | **talpha.1** | **talpha.2** | **NON CENTRALITY PARAMETERS** | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.13 | 0.25 | 0.38 | 0.50 | 0.63 | 0.75 | 0.88 | 1.00 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.15 | 0.31 | 0.46 | 0.61 | 0.77 | 0.92 | 1.07 | 1.23 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.17 | 0.34 | 0.50 | 0.67 | 0.84 | 1.01 | 1.18 | 1.34 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.13 | 0.26 | 0.40 | 0.53 | 0.66 | 0.79 | 0.92 | 1.06 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.19 | 0.37 | 0.56 | 0.75 | 0.93 | 1.12 | 1.31 | 1.49 |

Table 157: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for wildebeest at 10% and 20% significance on the farm Samaria 1, northern mopane veld.

talpha.1 WILDEBEEST

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.06 | 0.07 | 0.08 | 0.09 | 0.10 | 0.11 | 0.12 | 0.13 |
| **2_2** | 0.06 | 0.08 | 0.09 | 0.11 | 0.14 | 0.16 | 0.19 | 0.22 |
| **2_3** | 0.07 | 0.09 | 0.11 | 0.13 | 0.16 | 0.20 | 0.24 | 0.28 |
| **3_1** | 0.06 | 0.07 | 0.09 | 0.10 | 0.12 | 0.14 | 0.16 | 0.18 |
| **3_3** | 0.07 | 0.09 | 0.12 | 0.16 | 0.19 | 0.24 | 0.29 | 0.34 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.12 | 0.13 | 0.15 | 0.17 | 0.19 | 0.22 | 0.24 | 0.26 |
| **2_2** | 0.12 | 0.15 | 0.18 | 0.22 | 0.26 | 0.30 | 0.34 | 0.38 |
| **2_3** | 0.13 | 0.16 | 0.20 | 0.24 | 0.29 | 0.34 | 0.39 | 0.45 |
| **3_1** | 0.12 | 0.14 | 0.17 | 0.20 | 0.23 | 0.26 | 0.30 | 0.33 |
| **3_3** | 0.13 | 0.17 | 0.22 | 0.27 | 0.33 | 0.39 | 0.46 | 0.52 |

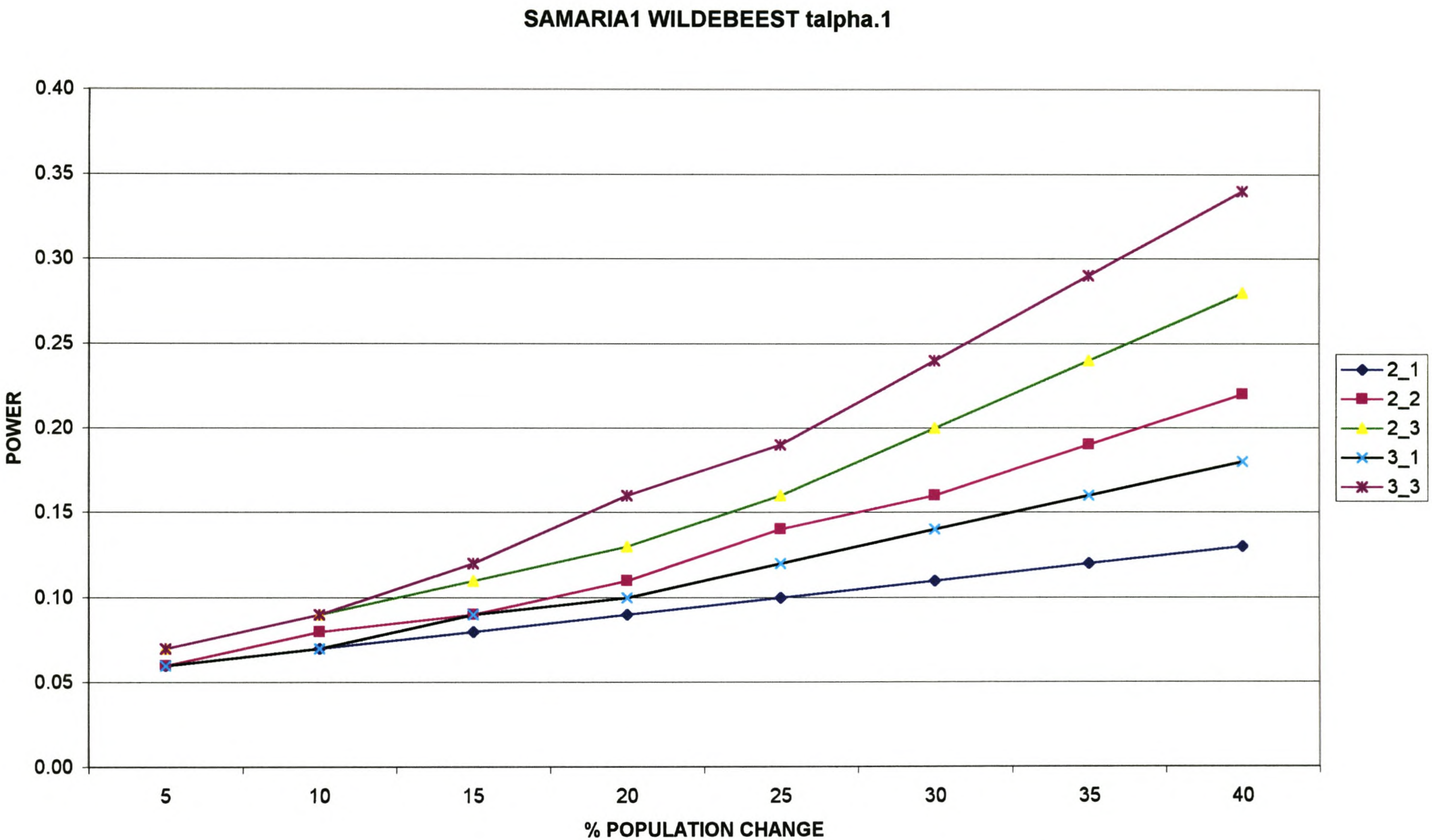


Figure 149: Power curves for various count replicate options at 10% significance for wildebeest on the farm Samaria 1, northern mopane veld.

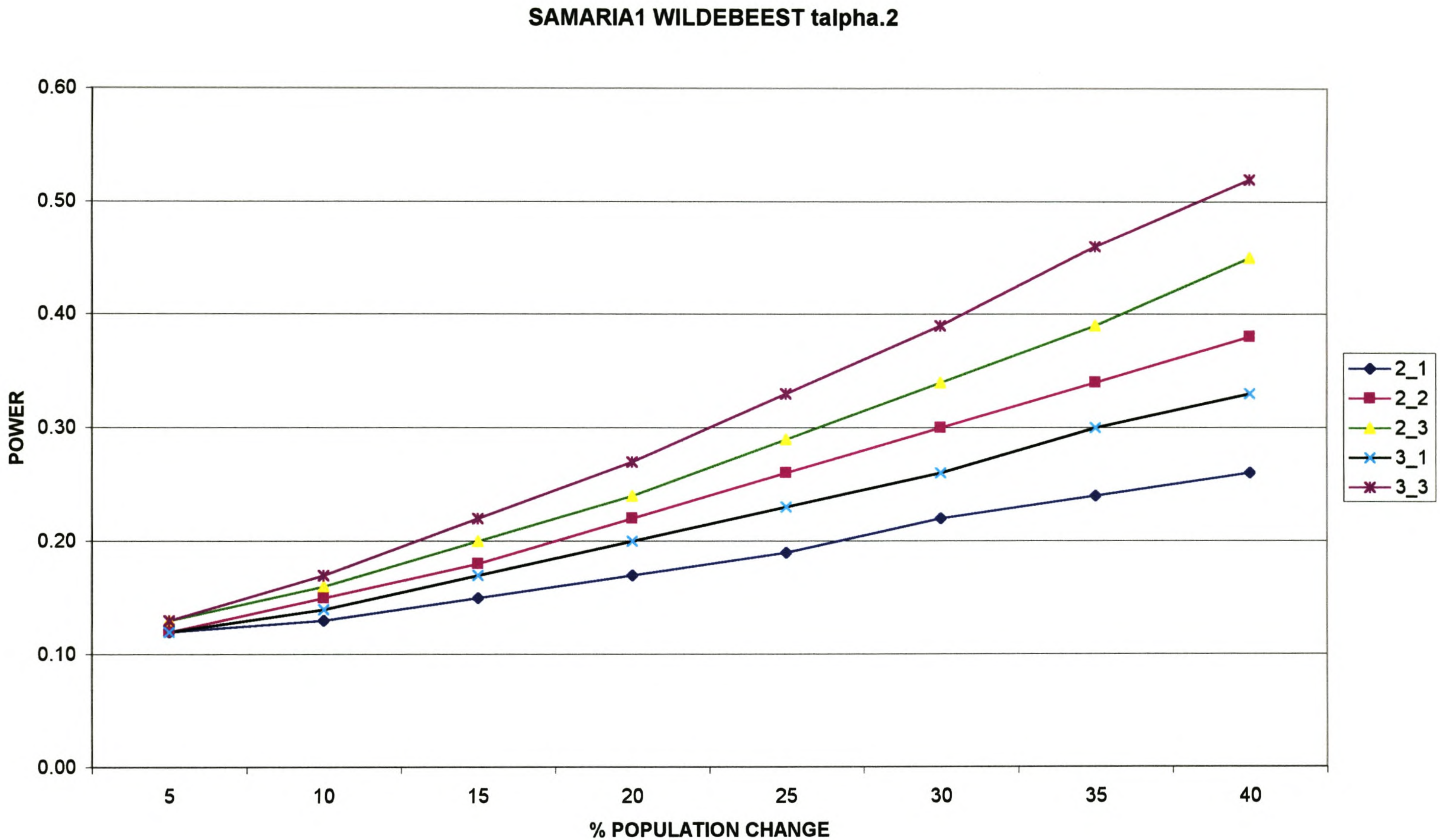


Figure 150: Power curves for various count replicate options at 20% significance for wildebeest on the farm Samaria 1, northern mopane veld.

Table 158: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for impala on the farm Samaria 1, northern mopane veld.

| IMPALA | | MEAN | | 124.30 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 6.22 | 12.43 | 18.65 | 24.86 | 31.08 | 37.29 | 43.51 | 49.72 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.54 | 1.08 | 1.62 | 2.16 | 2.70 | 3.25 | 3.79 | 4.33 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.66 | 1.33 | 1.99 | 2.65 | 3.31 | 3.98 | 4.64 | 5.30 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.73 | 1.45 | 2.18 | 2.90 | 3.63 | 4.35 | 5.08 | 5.81 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.57 | 1.13 | 1.70 | 2.27 | 2.84 | 3.40 | 3.97 | 4.54 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.80 | 1.60 | 2.41 | 3.21 | 4.01 | 4.81 | 5.61 | 6.42 |

**Table 159: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for impala at 10% and 20% significance on the farm Samaria 1, northern mopane veld.**

talpha.1 IMPALA

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.09 | 0.14 | 0.20 | 0.27 | 0.33 | 0.39 | 0.45 | 0.50 |
| **2_2** | 0.12 | 0.24 | 0.38 | 0.54 | 0.68 | 0.80 | 0.88 | 0.94 |
| **2_3** | 0.14 | 0.31 | 0.51 | 0.71 | 0.86 | 0.94 | 0.98 | 0.99 |
| **3_1** | 0.11 | 0.20 | 0.31 | 0.45 | 0.58 | 0.70 | 0.80 | 0.87 |
| **3_3** | 0.17 | 0.38 | 0.63 | 0.84 | 0.95 | 0.99 | 1.00 | 1.00 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.18 | 0.28 | 0.39 | 0.50 | 0.60 | 0.68 | 0.76 | 0.82 |
| **2_2** | 0.23 | 0.41 | 0.61 | 0.78 | 0.89 | 0.96 | 0.98 | 1.00 |
| **2_3** | 0.26 | 0.48 | 0.72 | 0.88 | 0.96 | 0.99 | 1.00 | 1.00 |
| **3_1** | 0.21 | 0.35 | 0.53 | 0.69 | 0.82 | 0.90 | 0.95 | 0.98 |
| **3_3** | 0.29 | 0.56 | 0.81 | 0.94 | 0.99 | 1.00 | 1.00 | 1.00 |

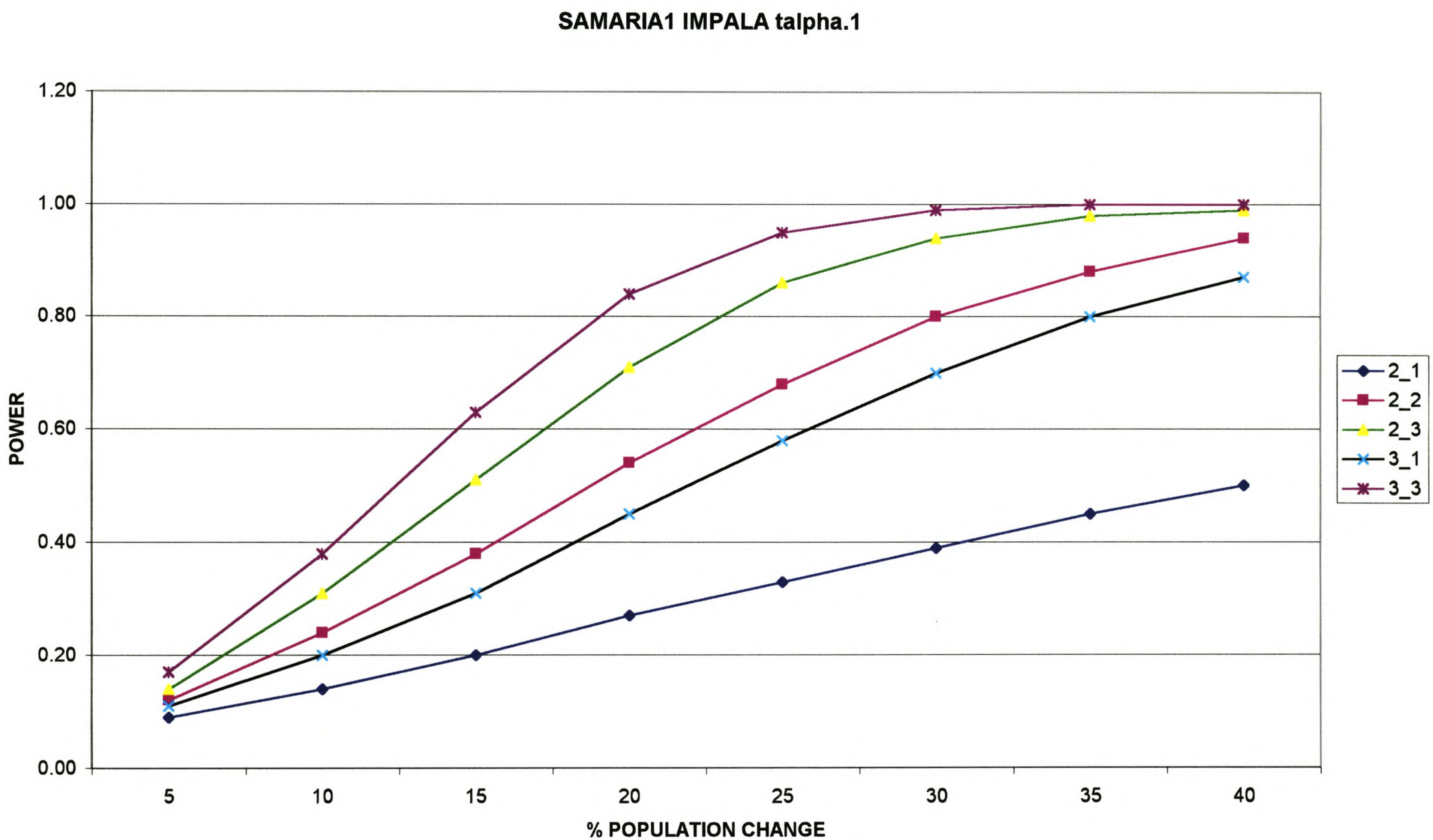


Figure 151: Power curves for various count replicate options at 10% significance for impala on the farm Samaria 1, northern mopane veld.

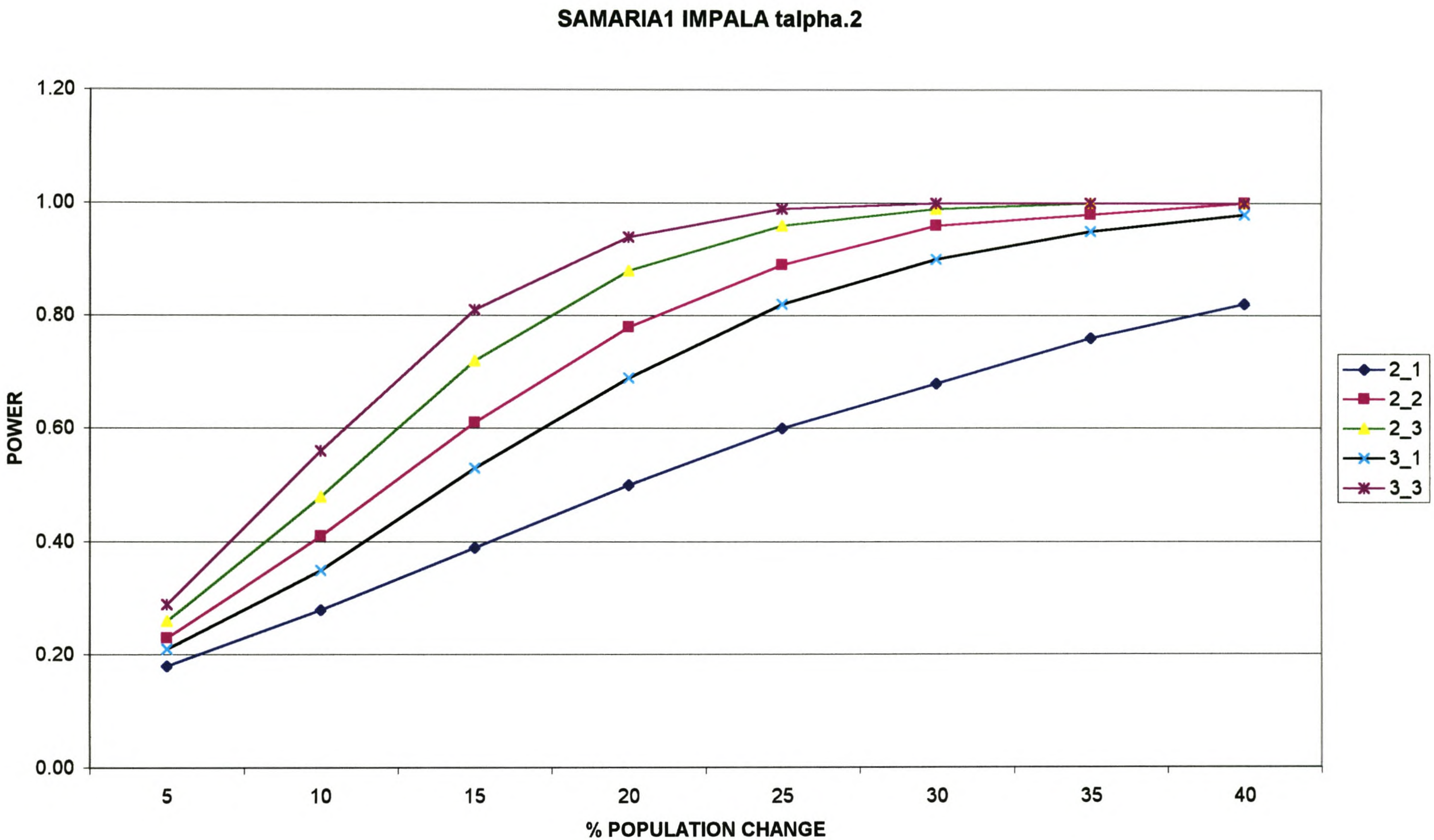


Figure 152: Power curves for various count replicate options at 20% significance for impala on the farm Samaria 1, northern mopane veld.

Table 160: Summary statistics of three replicate helicopter counts of the farm Samaria 3, northern mopane veld.

| SPECIES | COUNT REPLICATES | | | MEAN | STANDARD | STANDARD |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | | DEVIATION(n2) | DEVIATION(n3) |
| *ELAND* | **98** | **86** | **98** | 94.0 | 5.57 | 5.56 |
| *ZEBRA* | **11** | **13** | **11** | 11.7 | 0.92 | 0.94 |
| *WILDEBEEST* | **22** | **31** | **22** | 25.0 | 4.18 | 4.22 |
| *IMPALA* | **70** | **63** | **84** | 72.3 | 8.90 | 8.80 |

| SPECIES | SEdiff21 | SEdiff22 | SEdiff23 | SEdiff31 | SEdiff33 |
|---|---|---|---|---|---|
| *ELAND* | 6.82 | 5.57 | 5.08 | 6.42 | 4.54 |
| *ZEBRA* | 1.13 | 0.92 | 0.84 | 1.09 | 0.77 |
| *WILDEBEEST* | 5.12 | 4.18 | 3.82 | 4.87 | 3.45 |
| *IMPALA* | 10.90 | 8.90 | 8.12 | 10.16 | 7.19 |

Table 161: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for eland on the farm Samaria 3, northern mopane veld.

| ELAND | | MEAN | | 94.0 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 4.70 | 9.40 | 14.10 | 18.80 | 23.50 | 28.20 | 32.90 | 37.60 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.69 | 1.38 | 2.07 | 2.76 | 3.44 | 4.13 | 4.82 | 5.51 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.84 | 1.69 | 2.53 | 3.38 | 4.22 | 5.06 | 5.91 | 6.75 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.92 | 1.85 | 2.77 | 3.70 | 4.62 | 5.55 | 6.47 | 7.39 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.73 | 1.46 | 2.20 | 2.93 | 3.66 | 4.39 | 5.12 | 5.86 |
| 3 | 3 | 4 | 2.13 | 1.53 | 1.04 | 2.07 | 3.11 | 4.14 | 5.18 | 6.21 | 7.25 | 8.28 |

Table 162: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for eland at 10% and 20% significance on the farm Samaria 3, northern mopane veld.

talpha.1 ELAND

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.10 | 0.18 | 0.25 | 0.33 | 0.41 | 0.48 | 0.55 | 0.61 |
| **2_2** | 0.15 | 0.31 | 0.51 | 0.70 | 0.83 | 0.92 | 0.97 | 0.99 |
| **2_3** | 0.18 | 0.42 | 0.68 | 0.87 | 0.96 | 0.99 | 1.00 | 1.00 |
| **3_1** | 0.13 | 0.26 | 0.43 | 0.60 | 0.75 | 0.86 | 0.93 | 0.97 |
| **3_3** | 0.22 | 0.53 | 0.82 | 0.96 | 0.99 | 1.00 | 1.00 | 1.00 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.21 | 0.34 | 0.48 | 0.61 | 0.71 | 0.80 | 0.86 | 0.91 |
| **2_2** | 0.27 | 0.52 | 0.75 | 0.90 | 0.97 | 0.99 | 1.00 | 1.00 |
| **2_3** | 0.31 | 0.62 | 0.86 | 0.97 | 0.99 | 1.00 | 1.00 | 1.00 |
| **3_1** | 0.25 | 0.45 | 0.67 | 0.83 | 0.93 | 0.98 | 0.99 | 1.00 |
| **3_3** | 0.36 | 0.71 | 0.93 | 0.99 | 1.00 | 1.00 | 1.00 | 1.00 |

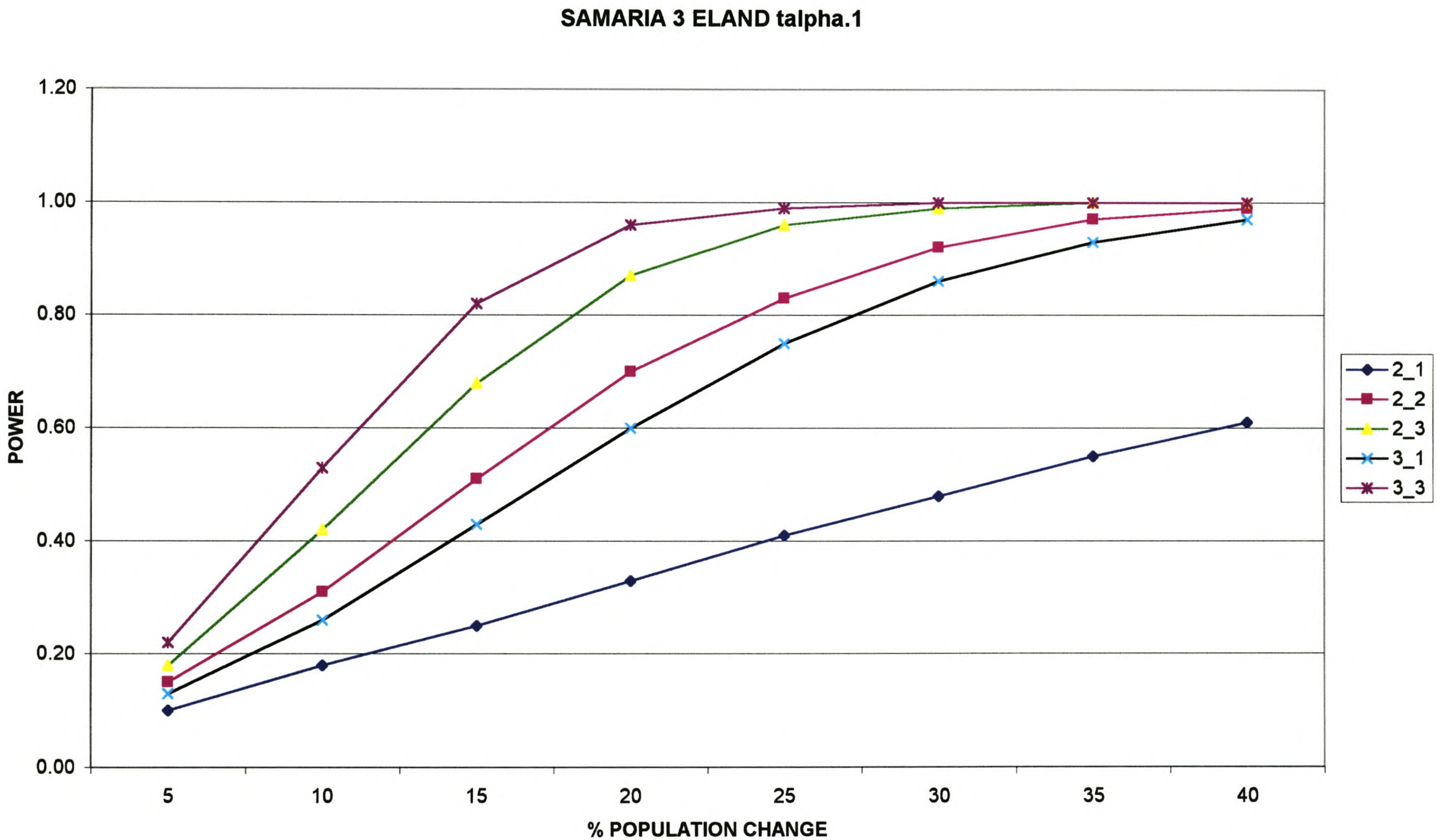


Figure 153: Power curves for various count replicate options at 10% significance for eland on the farm Samaria 3, northern mopane veld.

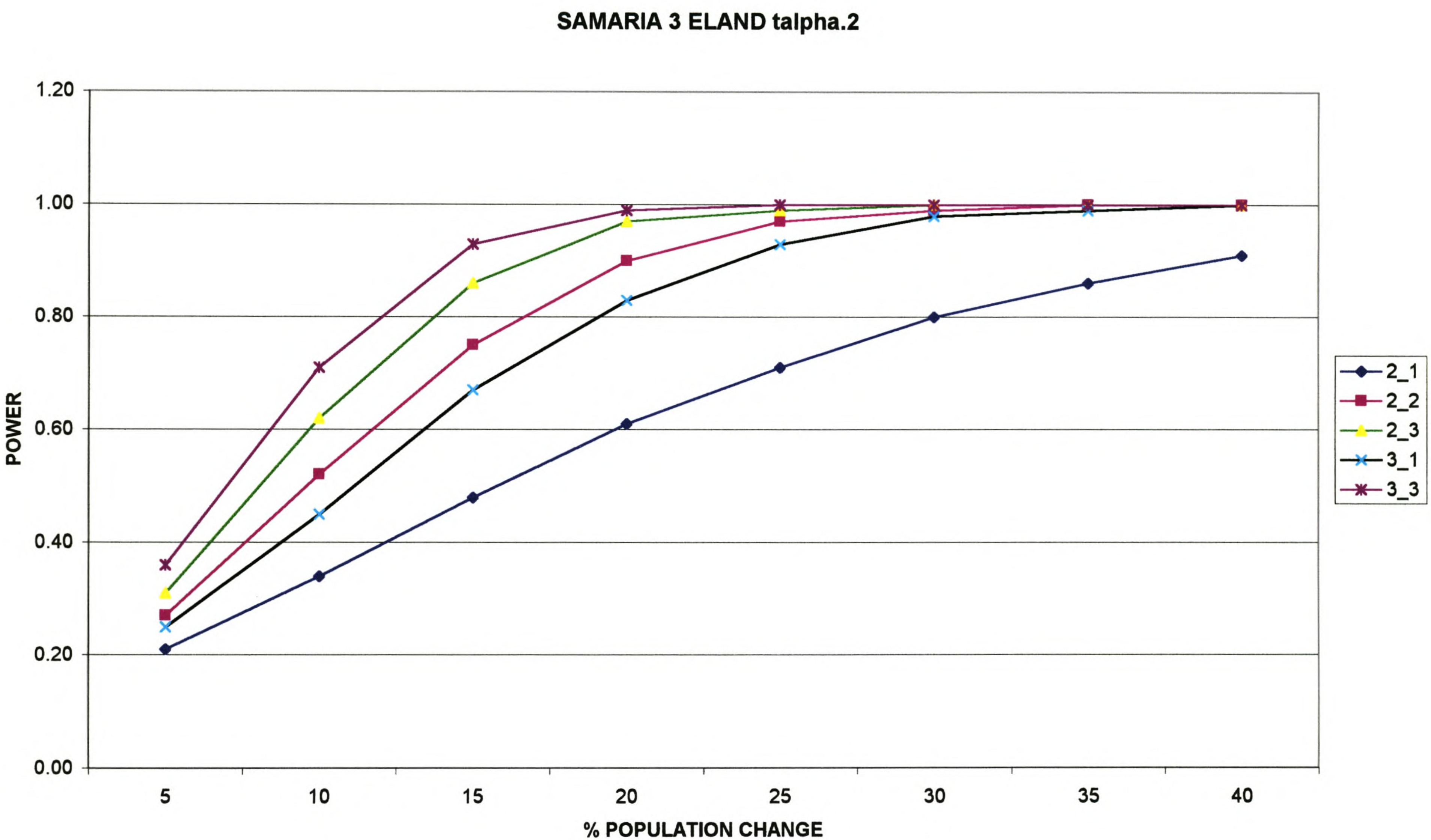


Figure 154: Power curves for various count replicate options at 20% significance for eland on the farm Samaria 3, northern mopane veld.

Table 163: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for zebra on the farm Samaria 3, northern mopane veld.

| ZEBRA | | MEAN | | 11.70 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 0.59 | 1.17 | 1.76 | 2.34 | 2.93 | 3.51 | 4.10 | 4.68 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.52 | 1.04 | 1.56 | 2.08 | 2.60 | 3.12 | 3.63 | 4.15 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.64 | 1.27 | 1.91 | 2.54 | 3.18 | 3.82 | 4.45 | 5.09 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.70 | 1.39 | 2.09 | 2.79 | 3.48 | 4.18 | 4.88 | 5.57 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.54 | 1.08 | 1.62 | 2.16 | 2.69 | 3.23 | 3.77 | 4.31 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.76 | 1.52 | 2.29 | 3.05 | 3.81 | 4.57 | 5.34 | 6.10 |

Table 164: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for zebra at 10% and 20% significance on the farm Samaria 3, northern mopane veld.

talpha.1 ZEBRA

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.09 | 0.14 | 0.20 | 0.26 | 0.32 | 0.37 | 0.43 | 0.48 |
| **2_2** | 0.12 | 0.22 | 0.36 | 0.51 | 0.66 | 0.77 | 0.86 | 0.92 |
| **2_3** | 0.14 | 0.29 | 0.49 | 0.68 | 0.83 | 0.93 | 0.97 | 0.99 |
| **3_1** | 0.10 | 0.19 | 0.30 | 0.42 | 0.55 | 0.67 | 0.77 | 0.85 |
| **3_3** | 0.16 | 0.35 | 0.60 | 0.80 | 0.93 | 0.98 | 1.00 | 1.00 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.18 | 0.27 | 0.38 | 0.48 | 0.58 | 0.66 | 0.74 | 0.80 |
| **2_2** | 0.22 | 0.40 | 0.59 | 0.75 | 0.87 | 0.94 | 0.98 | 0.99 |
| **2_3** | 0.25 | 0.46 | 0.69 | 0.86 | 0.95 | 0.99 | 1.00 | 1.00 |
| **3_1** | 0.20 | 0.34 | 0.50 | 0.66 | 0.79 | 0.88 | 0.94 | 0.97 |
| **3_3** | 0.28 | 0.53 | 0.78 | 0.92 | 0.98 | 1.00 | 1.00 | 1.00 |

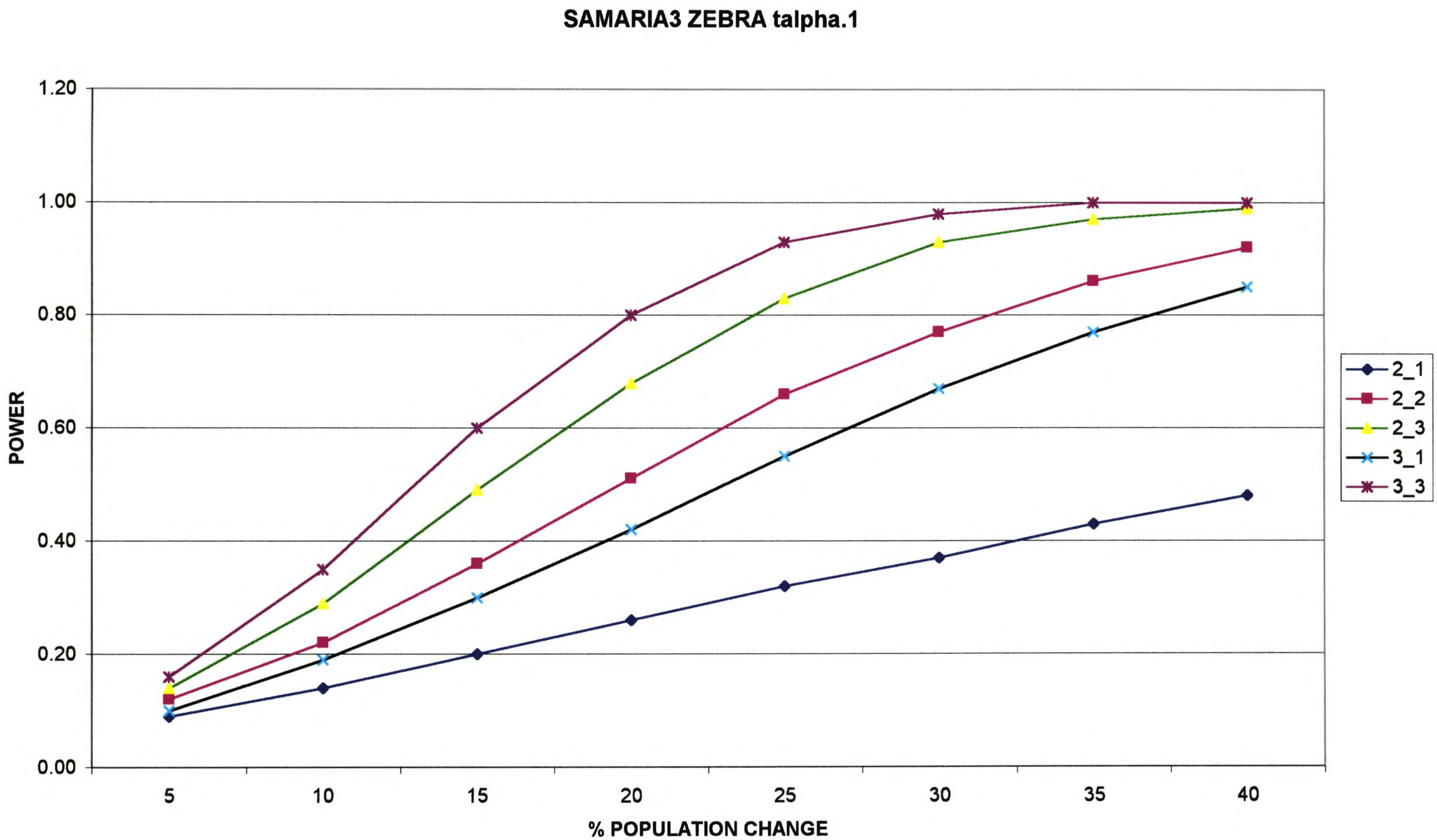


Figure 155: Power curves for various count replicate options at 10% significance for zebra on the farm Samaria 3, northern mopane veld.

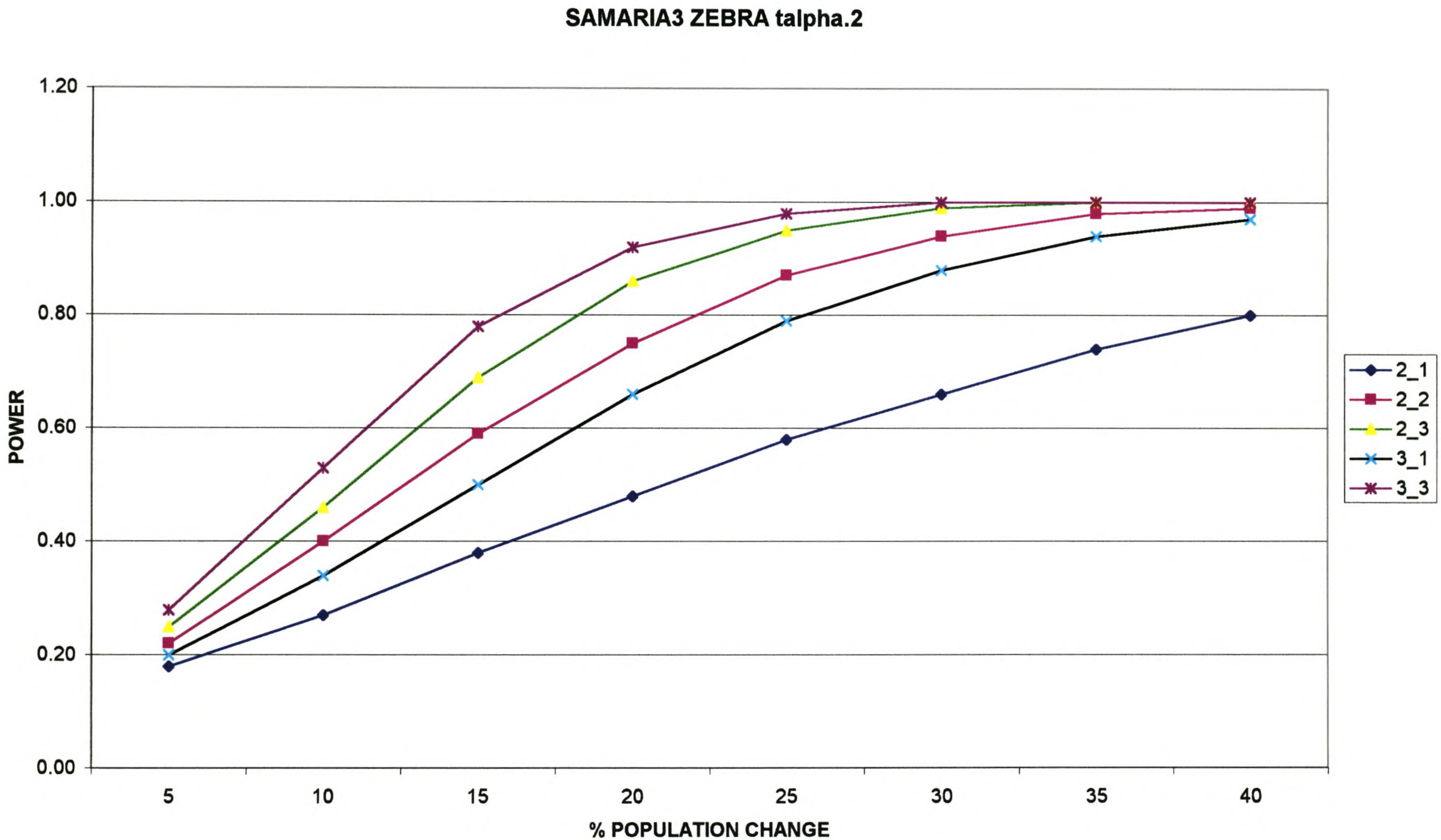


Figure 156: Power curves for various count replicate options at 20% significance for zebra on the farm Samaria 3, northern mopane veld.

Table 165: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for wildebeest on the farm Samaria 3, northern mopane veld.

| WILDEBEEST | | | MEAN | 25.00 | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 1.25 | 2.50 | 3.75 | 5.00 | 6.25 | 7.50 | 8.75 | 10.00 |
| **n1** | **n2** | **df** | **talpha.1** | **talpha.2** | **NON CENTRALITY PARAMETERS** | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.24 | 0.49 | 0.73 | 0.98 | 1.22 | 1.47 | 1.71 | 1.95 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.30 | 0.60 | 0.90 | 1.20 | 1.50 | 1.79 | 2.09 | 2.39 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.33 | 0.66 | 0.98 | 1.31 | 1.64 | 1.97 | 2.29 | 2.62 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.26 | 0.51 | 0.77 | 1.03 | 1.28 | 1.54 | 1.80 | 2.05 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.36 | 0.73 | 1.09 | 1.45 | 1.81 | 2.18 | 2.54 | 2.90 |

Table 166: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for wildebeest at 10% and 20% significance on the farm Samaria 3, northern mopane veld.

talpha.1 WILDEBEEST

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.07 | 0.09 | 0.11 | 0.13 | 0.16 | 0.19 | 0.21 | 0.24 |
| **2_2** | 0.08 | 0.11 | 0.16 | 0.21 | 0.27 | 0.34 | 0.41 | 0.48 |
| **2_3** | 0.08 | 0.13 | 0.19 | 0.27 | 0.36 | 0.45 | 0.55 | 0.64 |
| **3_1** | 0.07 | 0.10 | 0.14 | 0.18 | 0.23 | 0.28 | 0.34 | 0.40 |
| **3_3** | 0.09 | 0.15 | 0.23 | 0.33 | 0.44 | 0.56 | 0.67 | 0.77 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.13 | 0.17 | 0.21 | 0.26 | 0.31 | 0.36 | 0.41 | 0.46 |
| **2_2** | 0.15 | 0.21 | 0.29 | 0.38 | 0.46 | 0.55 | 0.64 | 0.72 |
| **2_3** | 0.16 | 0.24 | 0.33 | 0.44 | 0.55 | 0.65 | 0.75 | 0.83 |
| **3_1** | 0.14 | 0.19 | 0.26 | 0.33 | 0.40 | 0.48 | 0.56 | 0.63 |
| **3_3** | 0.17 | 0.27 | 0.38 | 0.51 | 0.63 | 0.75 | 0.84 | 0.90 |

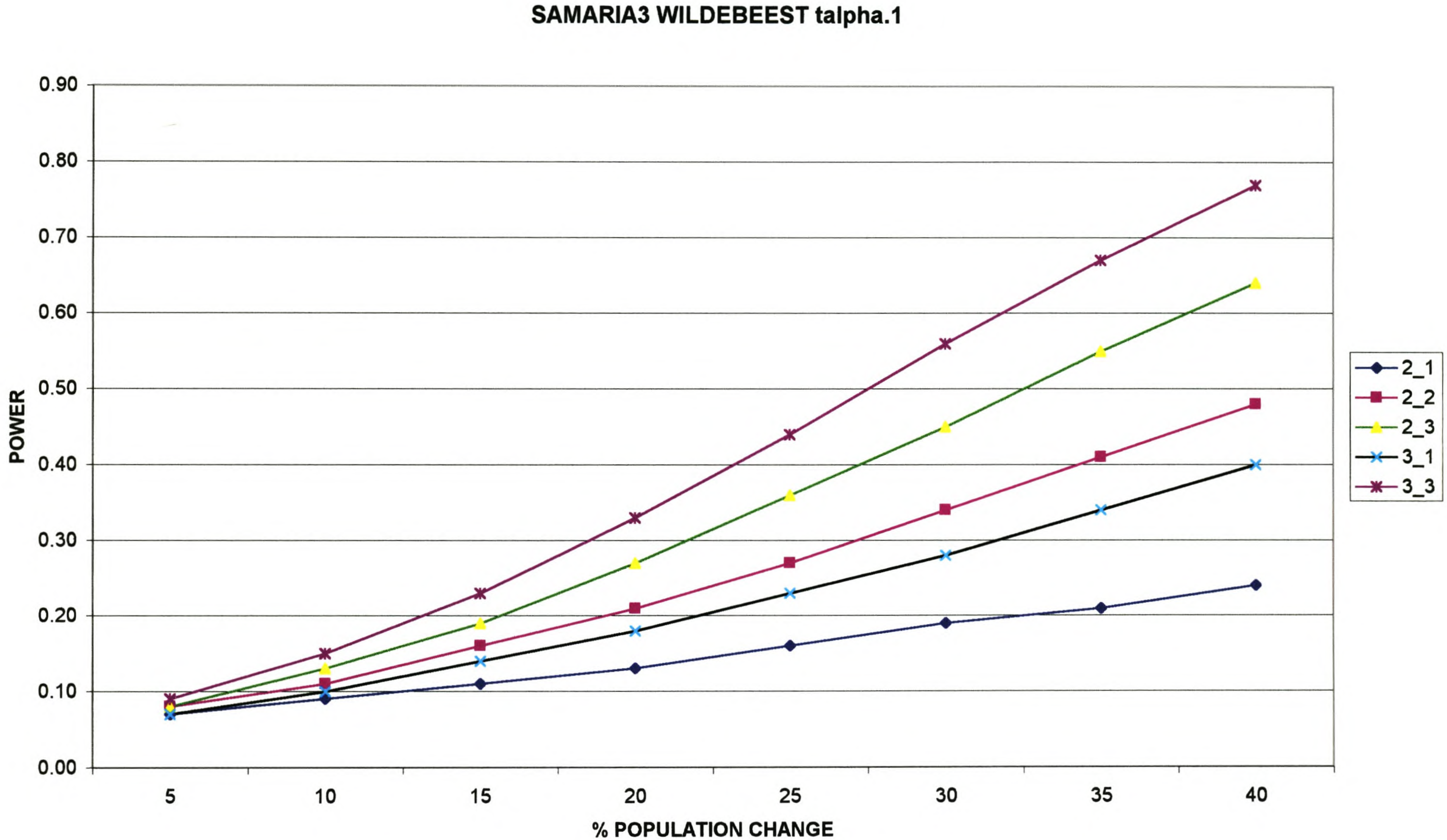


Figure 157: Power curves for various count replicate options at 10% significance for wildebeest on the farm Samaria 3, northern mopane veld.

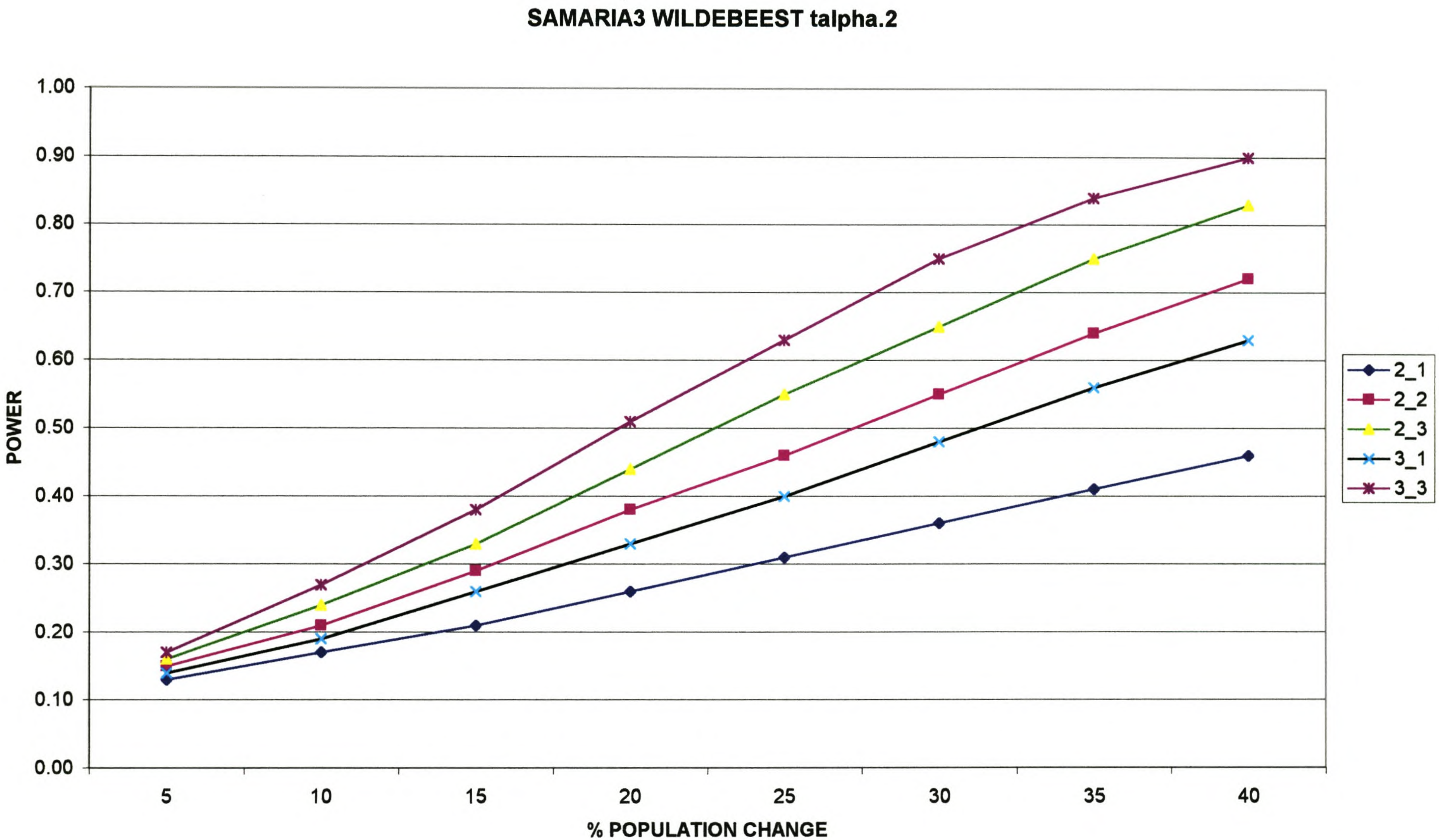


Figure 158: Power curves for various count replicate options at 20% significance for wildebeest on the farm Samaria 3, northern mopane veld.

Table 167: Non-centrality (t) parameters for effect sizes ranging from 5 to 40% of mean for different replicate options from year 1 to year 2 for calculation of power for impala on the farm Samaria 3, northern mopane veld.

| IMPALA | | MEAN | 72.30 | | EFFECT SIZE(%MEAN) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 0.05 | 0.1 | 0.15 | 0.2 | 0.25 | 0.3 | 0.35 | 0.4 |
| | | | | | 3.62 | 7.23 | 10.85 | 14.46 | 18.08 | 21.69 | 25.31 | 28.92 |
| n1 | n2 | df | talpha.1 | talpha.2 | NON CENTRALITY PARAMETERS | | | | | | | |
| 2 | 1 | 1 | 6.31 | 3.08 | 0.33 | 0.66 | 0.99 | 1.33 | 1.66 | 1.99 | 2.32 | 2.65 |
| 2 | 2 | 2 | 2.92 | 1.87 | 0.41 | 0.81 | 1.22 | 1.62 | 2.03 | 2.44 | 2.84 | 3.25 |
| 2 | 3 | 3 | 2.35 | 1.64 | 0.44 | 0.89 | 1.33 | 1.78 | 2.22 | 2.67 | 3.11 | 3.56 |
| 3 | 1 | 2 | 2.92 | 1.87 | 0.36 | 0.71 | 1.07 | 1.42 | 1.78 | 2.13 | 2.49 | 2.85 |
| 3 | 3 | 4 | 2.13 | 1.53 | 0.50 | 1.01 | 1.51 | 2.01 | 2.52 | 3.02 | 3.52 | 4.02 |

Table 168: Power values to detect population change as percentage of mean for various count replicate options in year 1 and year 2 for impala at 10% and 20% significance on the farm Samaria 3, northern mopane veld.

talpha.1 IMPALA

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.07 | 0.10 | 0.13 | 0.17 | 0.21 | 0.25 | 0.28 | 0.32 |
| **2_2** | 0.09 | 0.14 | 0.21 | 0.30 | 0.39 | 0.49 | 0.58 | 0.67 |
| **2_3** | 0.10 | 0.17 | 0.27 | 0.40 | 0.53 | 0.65 | 0.76 | 0.85 |
| **3_1** | 0.08 | 0.13 | 0.19 | 0.25 | 0.33 | 0.41 | 0.50 | 0.58 |
| **3_3** | 0.11 | 0.21 | 0.35 | 0.51 | 0.67 | 0.80 | 0.89 | 0.95 |

talpha.2

| | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 40 |
|---|---|---|---|---|---|---|---|---|
| **2_1** | 0.15 | 0.20 | 0.26 | 0.33 | 0.40 | 0.46 | 0.53 | 0.59 |
| **2_2** | 0.17 | 0.27 | 0.38 | 0.50 | 0.62 | 0.73 | 0.82 | 0.88 |
| **2_3** | 0.18 | 0.30 | 0.44 | 0.59 | 0.73 | 0.84 | 0.91 | 0.96 |
| **3_1** | 0.16 | 0.24 | 0.34 | 0.44 | 0.55 | 0.65 | 0.74 | 0.82 |
| **3_3** | 0.20 | 0.35 | 0.53 | 0.70 | 0.83 | 0.92 | 0.97 | 0.99 |

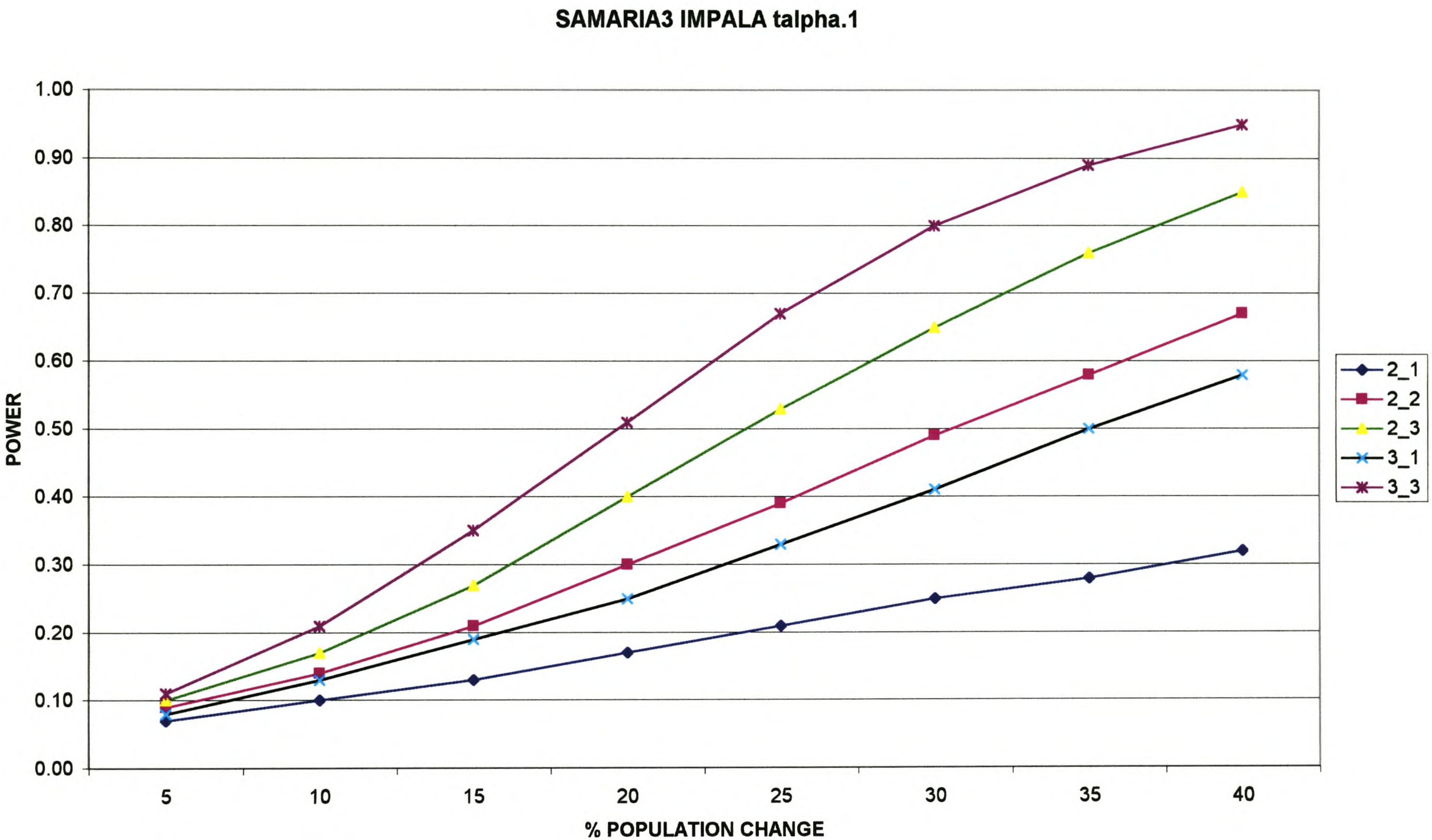


Figure 159: Power curves for various count replicate options at 10% significance for impala on the farm Samaria 3, northern mopane veld.

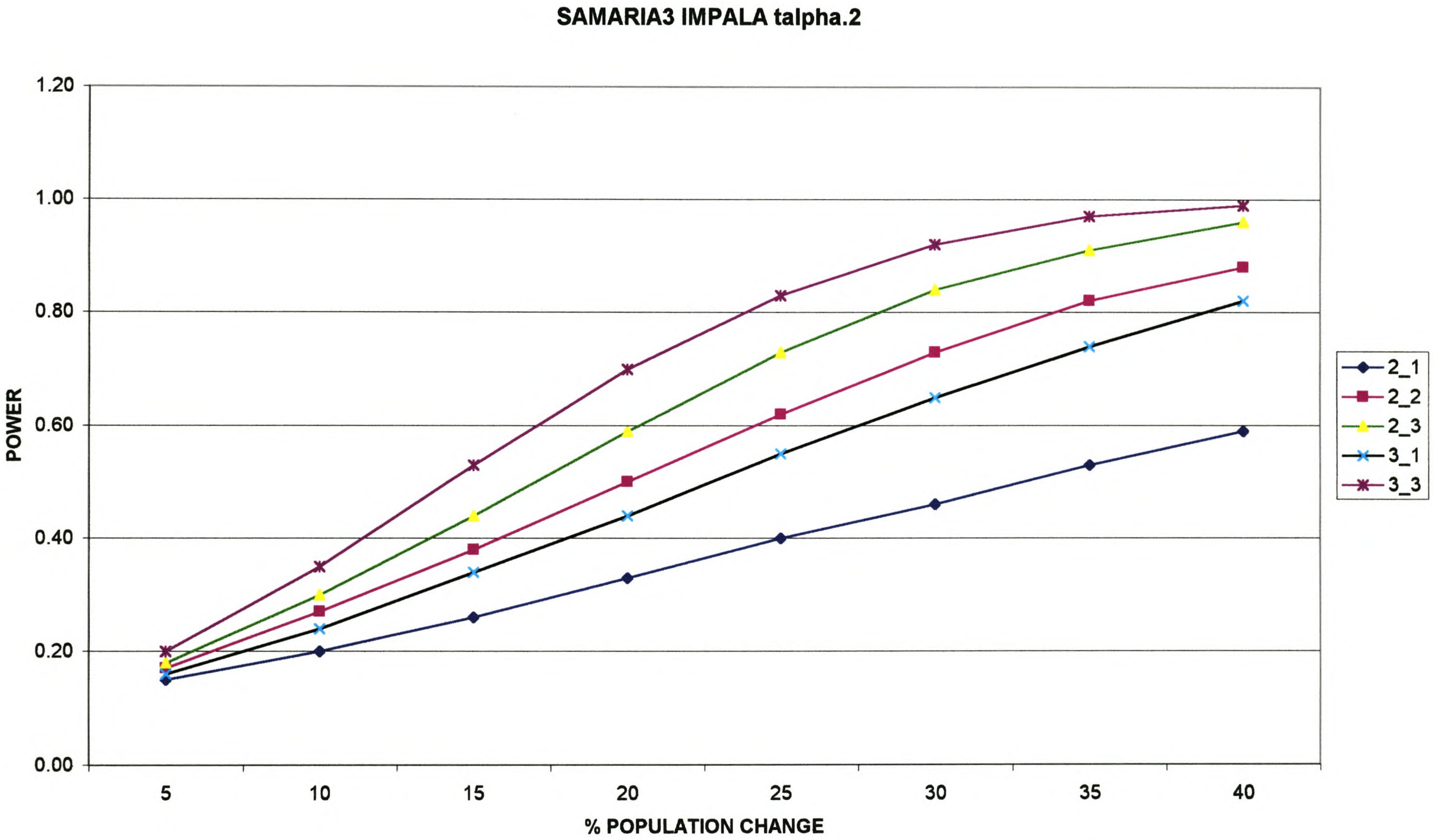


Figure 160: Power curves for various count replicate options at 20% significance for impala on the farm Samaria 3, northern mopane veld.