Captive Management Plan for Southern White Rhinoceros, *Ceratotherium simum simum*

1. Introduction

1.1. Taxon

Taxon (*scientific name*)	*Ceratotherium simum simum*
Common name	Southern White Rhino
TAG	Perissodactyl and Proboscid
Taxonomy:	*Ceratotherium simum* exists today as two subspecies. *C. s cottoni*, the Northern White Rhinoceros, and *C s simum*, the Southern White Rhinoceros. The latter is confined, as a continuously naturally occurring population, to a small part of the province of Natal in the east of South Africa; chiefly the Umfolozi–Hluhluwe Game Reserve (Player, 1972).
Captive management unit:	Subspecies – *Ceratotherium simum simum*
Scope of managed population	Captive population in ARAZPA institutions
Author	Samantha Stephens, much of introductory text by Peter Stroud
Document dated	April 2005 (final TAG approval 21/6/05)

1.2. Statement of purpose

The captive program aims to ensure the persistence of a captive population in ARAZPA institutions that:

- can act as an insurance population in case of catastrophic declines in the wild;
- conserves high levels of the genetic variability found in wild populations;
- can provide animals for zoo-based research;
- can support the development and documentation of husbandry techniques for the species;
- supports the illustration of biodiversity.

1.3. History in captivity

White rhinos are a recent addition to captivity, the first arriving in a zoo as late as 1946, and perhaps only 13 being held in zoos up until 1960. This can be explained by the rarity of this species (especially the Southern white rhino which potentially was reduced to five breeding females and five breeding males in the 1900'-s) and the subsequent reluctance of authorities to disturb wild populations (Rookmaaker, 1999).

Recent analysis has revealed that the populations held outside of South Africa are not viable in the medium to long term (50-100 years). The reasons for this are complex but chiefly relate to inappropriate social groupings - pairs as opposed to larger groups - established in the 1960's and 70's before the implications of natural social behaviour were apparent. Indeed a list of animals moved from South Africa to zoos during the period January 1, 1961 to March 31, 1972 (Player, 1972) reveals that of 259 specimens sent to known locations in 17 countries, 78 were sent as pairs. If just 4 recipients are excluded from the list - Whipsnade, San Diego, Lion Country Safari and the International Animal Exchange - the figures are more revealing with 78 animals of a total of 104 sent as pairs. Pairs very rarely produce young in the absence of stimulation from conspecifics. In 1995 and 1996, of 94 locations registered with the European Association of Zoos and Aquariums (EAZA) EEP program and the American Association of Zoos (AZA) SSP program, only six recorded breeding. All of these six locations held more than two female white rhinos and five of the six held more than one male. (Goltenboth and Ochs, 1997).

The lessons learned from this situation are reflected in current zoo management plans. Zoos working in cooperation with each other are developing programs seeking to establish viable populations. White rhinos are being placed in social groups of a male with multiple females where conditions make this possible. Guidelines have been established for rhino husbandry (Fouraker and Wagener, 1996).

Southern white rhino were first imported into Australasia in 1980, with Western Plains Zoo receiving 1.2 from Europe and Auckland 1.1 from San Diego Wild Animal Park, USA. More institutions imported small numbers from other captive populations throughout the 80's and 90's. In 1999 the first large import into Australasia from wild populations was completed, with 12 animals coming from the Kruger National Park in South Africa and sent to four institutions. This heralded a regional move away from keeping the species in small groups or pairs, towards a more natural grouping of multiple females with potentially more than one male to rotate through the female herd.

1.4. Programs in other regions

Region	*Program type*	*Population size (date)*	*Coordinator, institution*
Europe	EEP	85.112 (31.12.2002)	Dr Kristina Tomasova, Dvurkralv
N. America	SSP	508 (8/2/03)	Dr Tom Foose, Whiteoaks Conservation Center (studbook keeper) Mr Michael Fouraker, Fort Worth (species coordinator)
WAZA	International studbook	761 (Dec 01)	Dr Andreas Ochs, Berlin Zoo
JAZGA	SSP	55 (Feb 04)	Hideo Takechi, Sendaishi

1.5. Data compilation and analysis

Software used:	*Package*	*Version*	*Author, date*
	SPARKS	1.52	ISIS, 26/8/2002
	PM2000	1.175	J.P Pollak, R.C. Lacy, J.D. Ballou. 2000. Chicago Zoological Society

1.6. Studbook data

Studbook compiled by:	*Samantha Stephens*
Scope of data:	Australasia
Date first compiled:	19 May 1999 (Peter Stroud, Melbourne Zoo)
Data now current to:	February 1, 2005

Table 1: Overview of studbook data

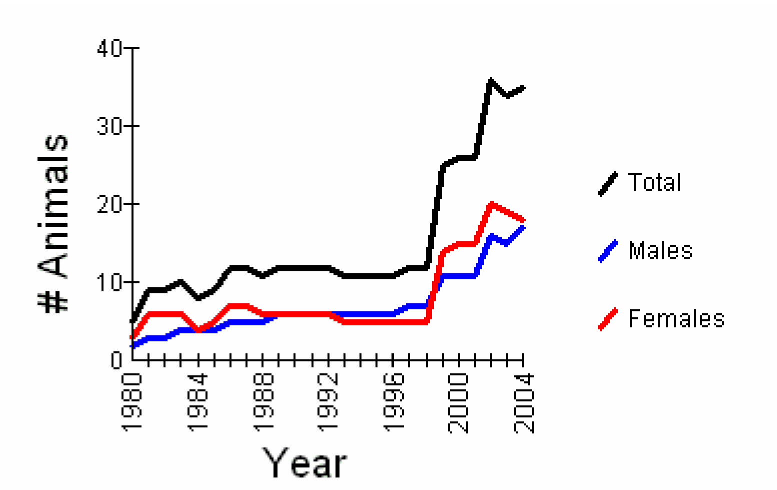
		No. of specimens	% of total
Totals	Specimens in studbook	77	100
	Living specimens	39	50.65
Sex	Females	46	59.7
	Males	31	40.3
	Unknown	0	0
Origins	Captive born	33	42.8
	Wild born	44	57.2
	Unknown origin	0	0
Parentage	Parents known (identified by studbook no. or as 'WILD')	154	100
	Multiple possible parents (listed as 'MULT...')	0	0
	Parents unknown (listed as 'UNK')	0	0
Birth dates	Known or Estimated studbook	77	100
	Unknown	0	0

2. Demographic Review

2.1. Annual census

Data restricted to: *Australasia, living as at 1st February 2005*

Graph 1: Annual census of the captive population of *Ceratotherium simum simum.*



2.2. Recent developments in the captive population

Data restricted to: *Australasia*

Table 2: Developments in the captive population of Ceratotherium simum simum, (2001 - 2005)

	Year1 2001	Year2 2002	Year3 2003	Year4 2004	Year5 2005	Totals
Population size at 1st Jan	26	26	36	34	35	
Acquisitions:						
Births	0	4	1	2	2	
Captures from wild	0	7	0	0	0	
Imports	0	0	0	0	0	
Total acquisitions	**0**	**11**	**1**	**2**	**2**	
Dispositions:						
Deaths (total no.)	0	1	3	1	0	
(Neonatal deaths)	*(0)*	*(1)*	*(0)*	*(0)*	*(0)*	
Exports	0	0	0	0	0	
Releases	0	0	0	0	0	
Lost-to-follow-up	0	0	0	0	0	
Total dispositions	**0**	**1**	**3**	**1**	**0**	
Population size at 31st Dec.	26	36	34	35	37	

*Year 5 end of period 1st February 2005

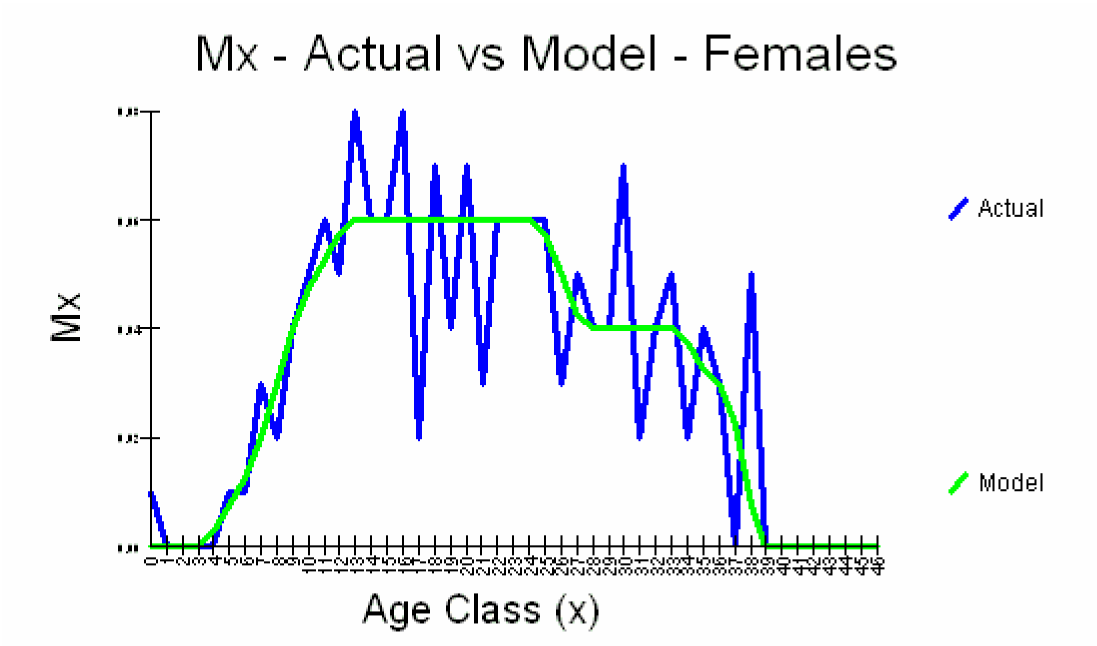
2.3. Reproduction

Reproductive cycle:	*Can reproduce at any time of the year; in wild tend to have birth peaks during rainy seasons (Smithers, 1996; Kingdon, 1997).*
Social structure:	*Most social of rhino species. Adult males territorial and solitary but may tolerate submissive juvenile males in territory. Females often seen with calves at foot, females and subadults are rarely seen alone. Juveniles pushed off from mothers at birth of next calf find similar aged calves and/or calfless females to associate with (Smithers, 1996; Kingdon, 1997; Estes, 1999).*
Mating behaviour:	*Territorial males check oestrus status of females moving through their territory and attempt to keep them in territory and mate them (Smithers, 1996; Kingdon, 1997; Estes, 1999).*
Litter/clutch size	*1*

DEMOGRAPHIC ANALYSIS IS BASED ON DATA FROM THE NORTH AMERICAN STUDBOOK (AS IT CONTAINS 508 SPECIMENS AND THEREFORE PROVIDES MORE ACCURATE

ESTIMATES OF DEMOGRAPHIC PARAMETERS THAN THE AUSTRALASIAN ONE). GENETIC ANALYSIS USES AUSTRALASIAN STUDBOOK DATA.

<u>Graph 2: Age-specific fecundity in the captive population of female southern white rhinoceros</u>



<u>Graph 3: Age-specific fecundity in the captive population of male southern white rhinoceros</u>

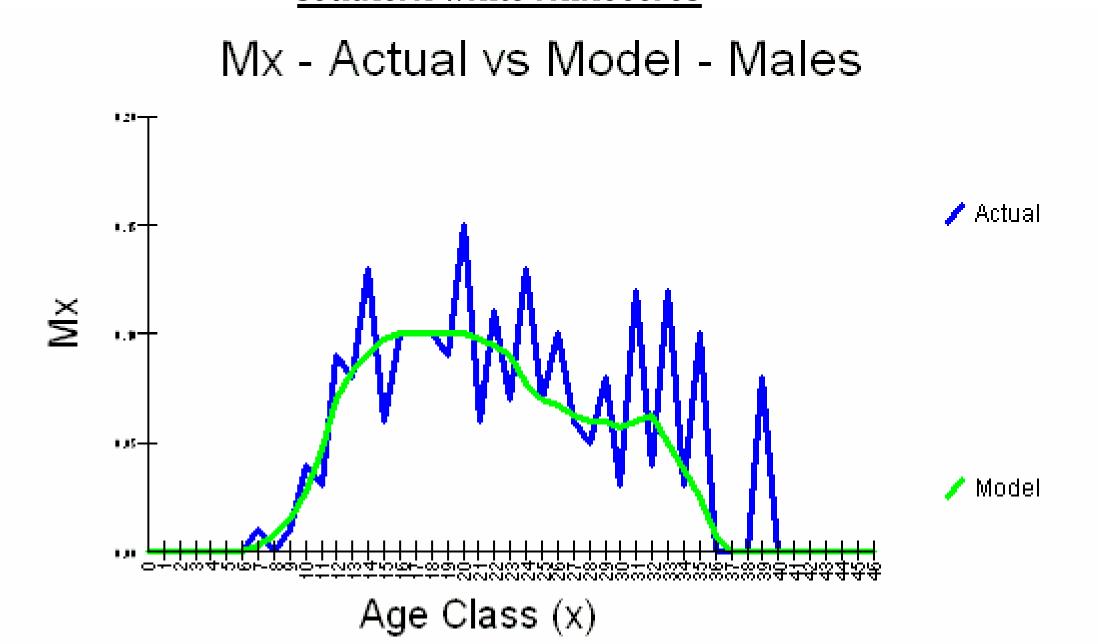
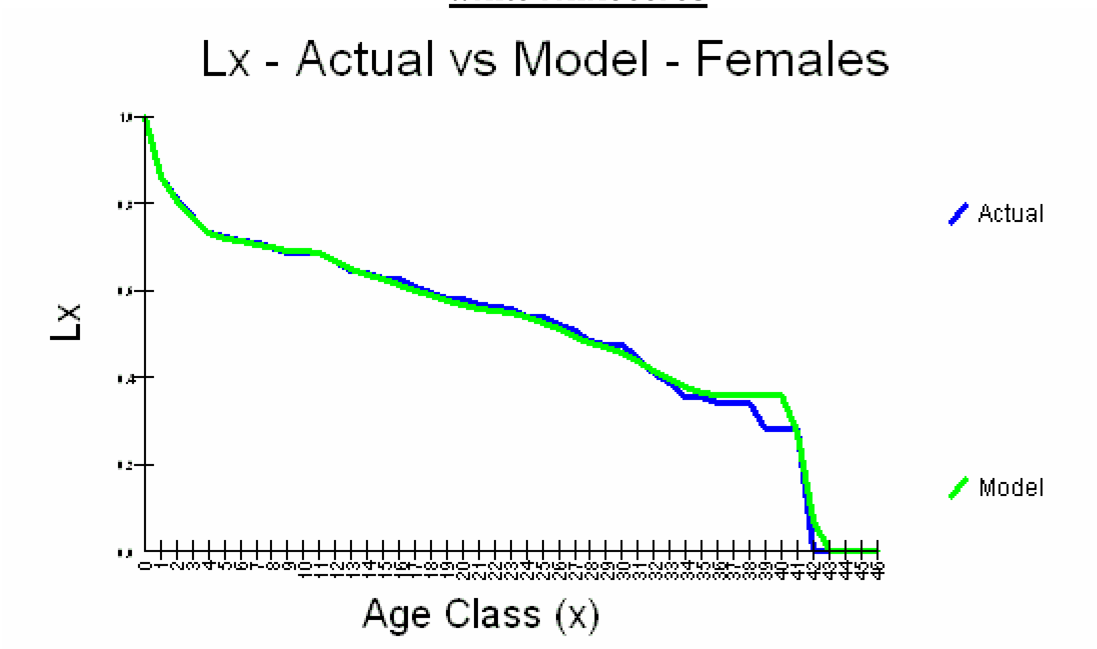


Table 3: Reproductive parameters from studbook data

Females	
Age range of possible reproduction (age of youngest and oldest animals recorded breeding)	4y 5d to 38y 7m 27d
Age range of peak reproduction (age classes for which average (median) Mx value is exceeded)	18y – 35y
Males	
Age range of possible reproduction (age of youngest and oldest animals recorded breeding)	6y 3m 26d to 37y 9m 15d
Age range of peak reproduction (age classes for which average (median) Mx value is exceeded)	16y – 30y

2.4. Mortality

<u>Graph 4: Survivorship in the captive population of female southern white rhinoceros</u>



Graph 5: Survivorship in the captive population of male southern white rhinoceros

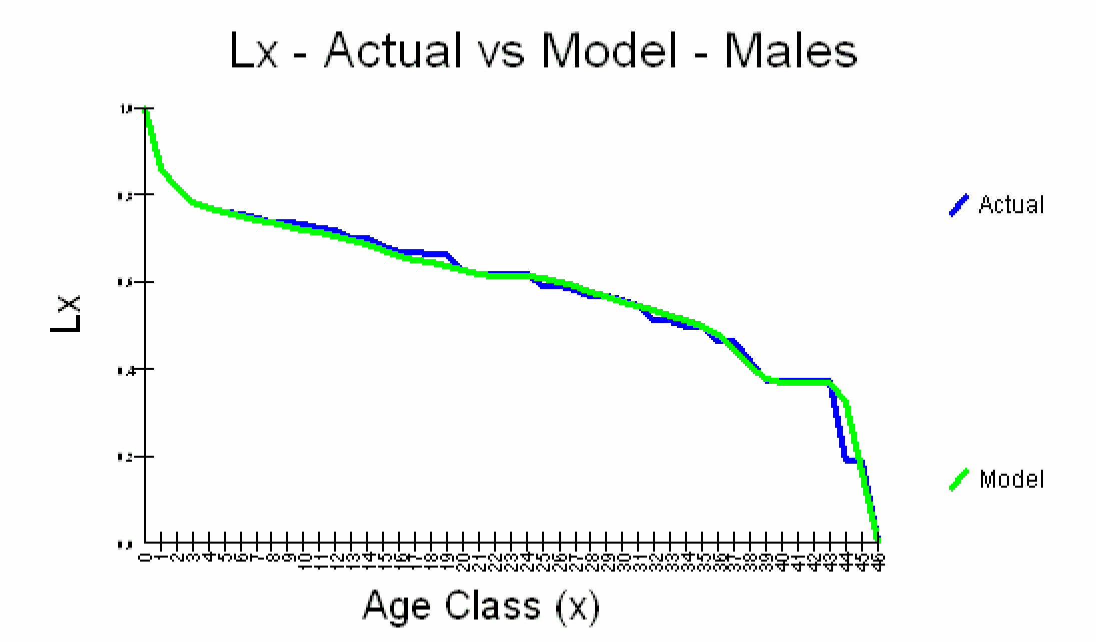


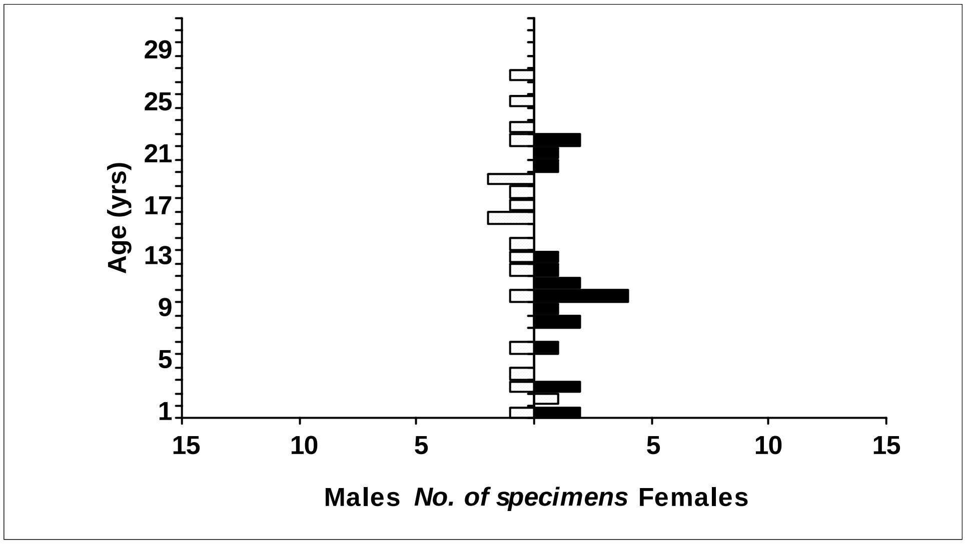
Table 4: Summary of mortality data from studbook

Females	
% juvenile mortality (dying in first 4 years)	30%
Average life expectancy of adults *(median age at death of animals surviving juvenile age classes)*	31.6
Maximum longevity *(age at death of oldest animal in studbook*	~ 41 Oldest animals have estimated birth dates
Males	
% juvenile mortality (dying in first 7 years)	28 %
Average life expectancy of adults *(median age at death of animals surviving juvenile age classes)*	35.3
Maximum longevity *(age at death of oldest animal in studbook)*	~ 45 Oldest animals have estimated birth dates

2.5. Age structure and sex ratio

Data restricted to: *Australasia, living as at 28 March 2004*

Graph 4: Age pyramid of the captive population of southern white rhinoceros



3. Genetic status

3.1. Pedigree assumptions

Table 5: Pedigree assumptions for genetic analysis of the Australasian captive population of southern white rhinoceros

No of specimens requiring assumed sires and/or dams *(only include animals impacting on the living population; include all UNKs treated as founders)*:	0
Proportion of ancestry traced to founders in studbook *(i.e. before pedigree assumptions are factored in*	100 %
Proportion of ancestry traced to founders in analytical data set *(i.e. after pedigree assumptions are factored in*	Not applicable

[see appendix for details]

3.2. Summary of results

No. of gene drop iterations:	1000
Data restricted to: *Australasia*	01/02/2005

Table 6: Genetic status of the captive population of southern white rhinoceros at 28/03/04

Founders	
Number of known founders	33
Known potential no. of founders *(i.e. including known wild caught animals yet to breed)*	40
Gene diversity	
Fraction of source gene diversity retained	0.9663
Founder Genome Equivalents (FGE)	14.85
Potential fraction of source gene diversity retained (if founder skew was adjusted)	0.9825
Inbreeding	
Mean inbreeding coefficient	0
Range of inbreeding coefficients	0
Mean Kinship	
Descendant population mean kinship	0.337

4. Current Population Projections

4.1. Planned regional population size

	Current			**Planned**		
	Males	**Females**	**Unk.**	**Males**	**Females**	**Undet.**
Auckland	2	1	0	2	3	1
Beerwah	0	0	0	1	4	0
Western Plains	2	6	0	4	7	3
Hamilton	2	2	0	4	3	2
Mogo	0	0	0	2	0	0
Monarto	2	2	0	2	4	0
Orana	3	2	0	2	5	0
Perth	1	3	0	1	2	2
Werribee	4	4	0	3	4	4
Yarraluml	0	0	0	1	2	0
TOTALS	15	19	0	22	34	12

4.2. Implications of planned population size

Population growth	
Estimated time to achieve planned population size through breeding from current population	Not possible at current growth rate – if husbandry changes achieve growth rate of 1.04 it will take approx. 15 years to achieve target population size. Increased growth rate is expected due to import of wild caught animals
Viability	
Expected length of time over which the population will retain 90% of the gene diversity within the	22 years

(wild) source population without further immigration.	

5. Management Strategy

5.1. Target population characteristics

Goals for population management:	Move population growth rate to 1.05 and maintain 90% GD at the end of 50 years
Population size needed *(if calculated)*:	69
Available captive space:	68
Rate of immigration required:	None if population growth rate is 1.05
Source of additional founders:	To be determined if required – see above
Number of births required per year to attain zero population growth once planned population size is reached	0.6

5.2. Demographic management strategy

The number of breeding pairs each year/season will be determined with the aim of maintaining planned numbers and avoiding the production of surplus. The number of breeding pairs recommended each (year/season) will be selected with reference to:

1. Available space (if population is not at capacity)
2. PM2000 analysis of reproductive rate required to maintain zero population growth (if population at capacity)

5.3. Genetic management strategy

Selection of breeding groups is to be aimed at reducing the rate at which gene diversity is lost and inbreeding is accumulated within the population. Recent research has suggested that females should be bred early to reduce the chance of asymmetrical reproductive aging, which can compromise breeding later in their lives. Optimal breeding pairs will be selected based on the following criteria (in order of importance), and taking into consideration the social and physiological constraints of the species:

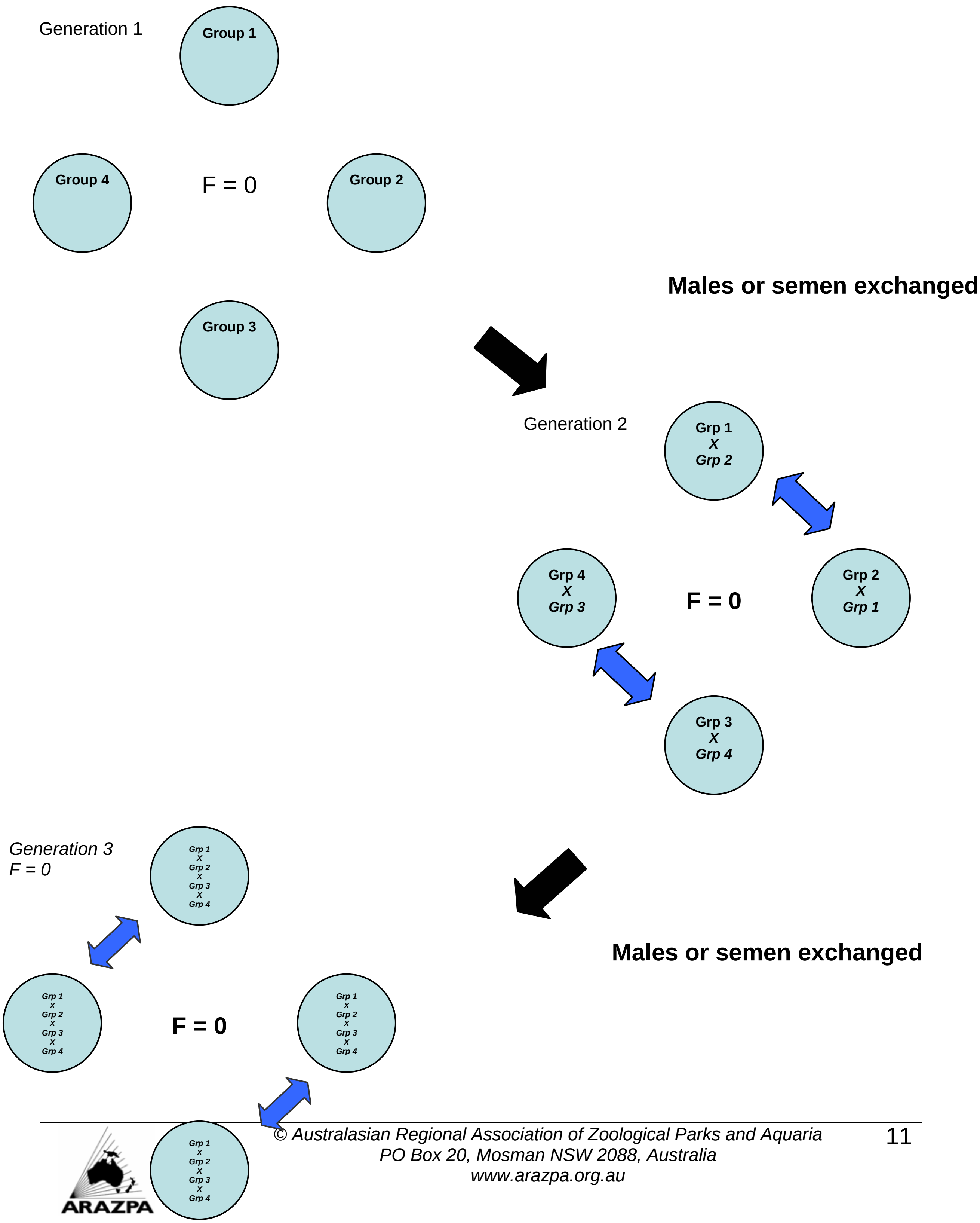
- **Males aged at least 7 yrs; females aged at least 6 yrs**
- **Low mean kinship values relative to the population average**
- **Like mean kinship values between prospective pairs**
- **Avoiding inbreeding levels equal to or above 0.125**
- **Young females put into breeding situations whenever possible.**

To maximise gene diversity and minimise inbreeding, a MAXIMUM AVOIDANCE OF INBREEDING scheme (modified from Princée, unpubl.) will be adopted. This is shown on the following page. Though ideally this scheme is applied to species with non-overlapping generations, with careful management, it should allow for several year of breeding in the region, with no inbreeding and high levels of gene diversity maintained. The scheme works as follows:

- Each group begins with at least one male and a number of females. All males should be unrelated, and cows in one group should be unrelated to those in the other five groups.
- Breeding occurs within each group, to produce a new generation of half-sibs.
- Paired groups (i.e. 1 & 2; 3 & 4) swap males (or semen).
- Breeding continues. This time stocks in each group are related to those at one other group in the region.

- In the following generation, males (or semen) are exchanged again, to provide for another

Maximum Avoidance of Inbreeding Scheme



The current Regional situation is organised as follows;

Group A: ***Auckland, Hamilton and Orana Park – the New Zealand zoos will be treated as one group, and animals swapped between the two breeding groups (Hamilton and Orana) until all options without inbreeding are used.***

Group 1: ***Western Plains Zoo***
Group 2: ***Monarto Zoo***
Group 3: ***Perth Zoo***
Group 4: ***Werribee***

The four Australian zoos are managed with a 4 way MAI scheme.
Generation 1
All breeding possibilities WITHIN groups to be attempted with no swapping of animals between groups. Only F1 generation animals to breed this generation.

Generation 2
Monarto/Perth and Werribee/Dubbo exchange males. Exhaust all possibilities there, eg swap all breeding males available.

Generation 3
Monarto/Perth and Werribee/Dubbo exchange males. Last of opportunities for no inbreeding.

Specifics

Group A

Auckland/Hamilton

- Auckland's young female ***SB 1353*** has moved to Hamilton to join the two females ***SB 1357 and 1358.*** This will form a herd of three unrelated females, all founders, with a juvenile male calf ***SB 1409***.
- This grouping has three adult males;
    - ***SB 1356*** a wild caught male (sire to the calf) currently in a breeding situation at Hamilton
    - ***SB 1273*** at Auckland - an as yet unrepresented wild caught founder male important to put into a breeding situation eventually
    - ***SB 541*** a captive born male related to the international population and to the two females at Orana Park. This animal has not yet bred although he has been in a breeding situation recently and has mounted a female several times unsuccessfully. He is less important to breed than the wild caught founders.

Orana Park

- All Orana Parks animals are captive bred, and have a mean kinship values ranging from 0.0365 to 0.0660 relative to the current population.
- The two females ***SB's 820 and 821*** are related to each other
- The two males are ***SB's 921 and 801***

SB 921 and 820 *have bred a male, who has been transferred to Monarto*
**If SB541 does not breed this grouping is unrelated to the others*
**SB1409 is F2 generation and shouldn't breed until the second round*

Western Plains Zoo

- Dubbo has a female herd of three unrelated female founders ***SB's 1438, 1430 and 1431.*** There is a juvenile female calf ***SB 1434*** in this female herd, conceived to a wild sire, born to ***SB 1430,*** and two newborn female calves. The new female calf born to *SB 1431* is being hand raised due to her mother having some sort of neurological problems. The now dead captive born male 'Tom' **SB195** sired the two newborns
- The two males in this group **SB 1429 and 1432** are both unrelated wild caught founders, equally important to breed.

**SB 1434 is F2 generation and should not breed until the second cycle*
**Once first male has bred swap with alternate.*

Monarto

- This institution has two young females – a wild caught founder ***SB 1426*** and a captive born female ***SB 1100*** who is unrelated to the current living regional population. April 2005 – *SB 1100* has had a male calf to *SB 1426*
- The breeding male is an unrepresented wild caught founder ***SB 1427.*** A young male from Orana Park ***SB 1281*** has just been transferred to Monarto.

**Breeding male is SB 1427. SB 1281 is an F2 generation which has been 'prematurely' moved, should not be bred til second cycle*

Perth

- Perth has two 7-year-old wild caught founder females ***SB's 1282 and 1283***, and a juvenile female calf ***SB 1436*** to ***SB 1283*** and 914.
- The male ***SB 914*** is a captive born animal unrelated to the current living population (except his calf).

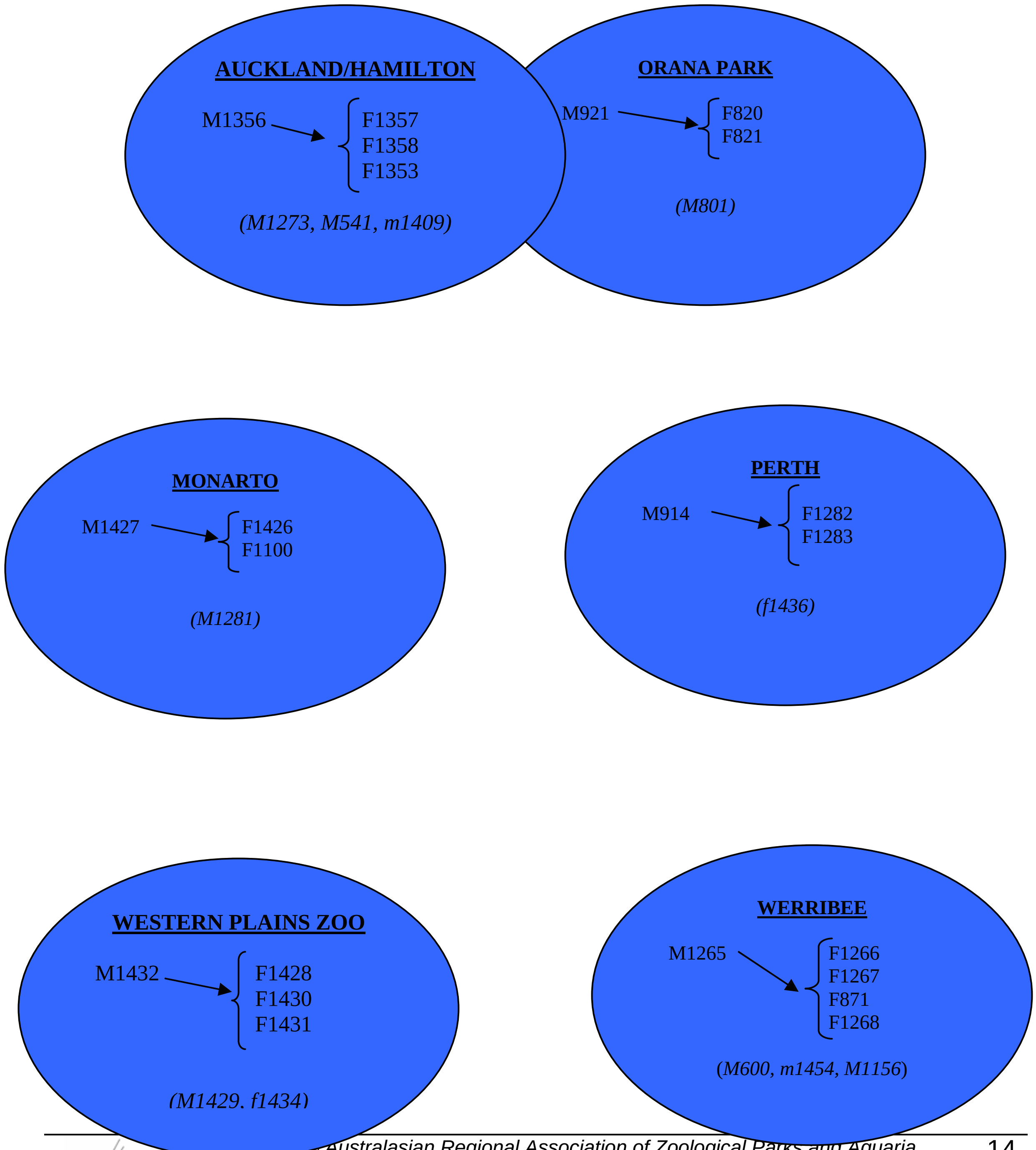
**SB 1283 is pregnant again to 914. SB 1282 is not cycling, Perth is investigating ways to induce ovulation*

Werribee

- The female herd consists of two wild caught founders ***SB's 1266 and 1267***; the wild sired daughter of 1266 ***SB 1268*** who is F2 generation and ***SB 871***, a captive born female kept historically in a pair situation. Ultrasound has detected uterine cysts in this animal and she has not bred although she has been in breeding situations. ***SB 1267*** has a juvenile male calf to male 1265, and now a newborn male calf to 1265.
- Males are
    - **SB 1265**; a wild caught founder who has bred with 1267.
    - **SB 1156**; a captive born young male. This animal is related to SB801 at Orana.
    - **SB 600**; a captive born male kept historically in a pair situation, who has not bred. He is the last male in importance to breed at Werribee.

Australasian <u>Ceratotherium simum simum</u> breeding groups – as per Maximum Avoidance of Inbreeding (MAI) scheme

<u>Generation One</u>



5.4. Program administration

Planned frequency of recommendations:	Annually
Progress reported:	Annually
Program review:	Every 5 years

Management team (if needed - TAG to determine)

Name	Institution	Email
Samantha Stephens	Melbourne Zoo	mojodog@ozemail.com.au

6. Recommendations for 2004/2005

6.1. General recommendations

Recommendation	Deadline
Auckland to review current status, consider importing companion females(s), or loaning current female to Hamilton	Completed – loaned to Hamilton 2004
Hamilton, Werribee and Mogo to discuss with Species coordinator pairing SB1409 and SB1454 to hold as display pair at Mogo. There is a need to ensure back up solo housing is available should attempt to integrate fail. Mogo to build rhino facility as soon as possible for these two animals.	2005
New Zealand zoos to discuss moving males between institutions; Hamilton to send 'Zambese' to Orana Park, Auckland to send 'Kruger' to Hamilton. 'Cyrano' to be housed solo at Hamilton or Orana. Hamilton to investigate feasibility of holding 2 adult males, will require building a new facility.	2005 2005

6.2. Specimen transfer recommendations

No.	Sbk #	Sex	ARKS #	Current location	Transfer to (Location)
1.	1281	M	90023	Orana	Monarto (completeted)

6.3. Breeding recommendations

	Males		Females		Status Jan 2005
	Sbk #	ARKS #	Sbk #	ARKS #	
Western Plains Zoo *Breed females as available to 'Khulu'*	1432	A20086 Khulu	1430	A20084 Umqali	Poss in calf to 'Khulu'
			1428	A20082 Aluka	Has newborn female calf to 'Tom'
			1431	A20085 Intombi	Has newborn female calf to 'Tom'
Orana *Breed 'Cyrano' over females once more.*	921	531 Cyrano	609	279 Mapenzi	Faecal test not pregnant
			820	280 Utani	Faecal test not pregnant
Perth *Stop breeding Memphis over Sabie after this calf. Attempt AI procedure with Katala late 2005.If AI unsuccessful, send Katala to open range zoo on breeding loan.*	914	900013 Memphis	1282	990647 Katala	Not cycling, using drugs to attempt to stimulate cycle
			1283	990646 Sabie	Due in May to 'Memphis'
Werribee *Genetically it would be best to not breed Sisi until later as she is F2, however from a husbandry aspect she needs to breed as soon as possible.*	1156	970061 Kapamba	1266	990034 Make	No male in with females
			1267	990035 Letaba	Has 2mo old male calf to 'Umgana"
			T124	990036 Sisi	No male in with females
			871	890109 Likwezi	Highly unlikely to breed
Monarto	1427	A29072 Satara	1100	A09118 Uhura	New male calf born April 2005
			1426	A29071 Mopani	Probably not pregnant
Hamilton *Stop breeding Zambese over Caballe after next calf*	1356	A29072 Zambese	1357	990083 Moesha	No signs of cycling
			1358	990084 Caballe	Still born calf early 2005
			1353	100047 Kito	Still juvenile

6.4 Management issue

- Recent research (*Hermes et al*) has shown that periods of non breeding in this species leads to asymmetric reproductive aging, resulting in problems of reduced fertility, a shortened reproductive life-span and ultimately irreversible acyclicity. Early pregnancy appears to confer some degree of protection against this, so it is recommended that female white rhino become pregnant as soon as possible.

- We are now at a stage where three bulls in the region have sired two calves each over the same cows, with the danger that if this continues we may dominate the region with the genes of these six animals. Werribee has an alternate male (Kapamba) to start breeding with. The young male ‘Kruger’ currently at Auckland should be put into a breeding situation, probably at Hamilton so that Hamilton’s current male ’Zambese’ can move to Orana to breed the females there. This combination would leave 3 solo adult males in New Zealand. ‘Mandhla’ at Auckland is a captive born male who is unlikely to breed as he has had opportunity to do so, and is also related to the international population. ‘Stumpy’ at Orana Park is also unlikely to breed, however ‘Cyrano’ is a proven breeder and may be required later in the program. If space allows at Hamilton, he could be housed solo there (giving them two bulls), and bred there eventually.

- Three regional institutions wish to acquire this species; two long term wanting breeding herds, and one willing to hold what is required by the CMP. It is not foreseen that there will be enough surplus females produced by this region to form two new herds for at least 10 years, however the region will probably be able to supply males when required. Institutions wanting females will probably have to import. Any proposed imports should be checked with species coordinator to ensure they are unrelated to current stock and to get the best fit for the age pyramid. Imports will ideally be older animals as we currently have an age pyramid with many young animals.

- Auckland has expressed concern over holding 2 solo males due to limited facilities, and would prefer to hold a solo male for display. Males can potentially be swapped as required for breeding.

- Orana Park has expressed interest in acquiring more females for their herd. Long term those institutions with the space should be encouraged to move to large multispecies paddocks for breeding herds, and urban zoos towards holding males for display until required for breeding. A good conditioning program can ensure problem free transfers between institutions when animals are required to be moved.

- Juveniles should not be removed from the natal group before the natural age they would be pushed away by the dam at the birth of her next calf (around 2.5). Ideally they would stay with the herd to sexual maturity (about 4.5 years).
- Current management of surplus/extra males in this region is to hold them solo and/or rotate them through a female group. There are some institutions in America and possibly Europe who successfully hold groups (pairs or trios) of male white rhino – This could be an option for this region. The similar aged young males at Hamilton and Werribee (SB1409 b Jan 2002; SB1454 b Sep 2002) could be paired and held as display at Mogo, until such time in the future either was needed for breeding. The younger male at Hamilton (SBt150 b Feb 2004) may also be attempted to include in this group; alternatively he and the new male calf at Werribee could be paired eventually and displayed at one of the other institutions wishing to acquire this species. Young males need to be put together before sexual maturity, and when adults, housed away from females.

6.5 Institutions wishing to acquire this species

Institutions are listed in priority order for receiving available animals (priority selected on basis of date of first listing in regional census and plan).

	Planned holding (2004 Census)	Approx. year animals* available	Comment
Mogo	0.0.2	2006	Willing to hold whatever grouping recommended
Beerwah	1.4	2010	Could house sooner but currently happy to wait for available animals
Yarraluml	1.2	2015?	Cannot hold this species until institution acquires adjoining land. Could initially hold surplus male(s), later breeding herd.

*animals captive bred within ARAZPA institutions

6.6 Recommended herd size

The AZA recommends a breeding herd size of five (one male with four females) with a back up male held separately. As the most social of the rhino species it is recommended institutions hold at least 2 females, and a breeding herd would consist of at minimum 1.2 animals. Current understanding is that males are stimulated to breed by the presence or evidence of rivals, therefore it is recommended institutions wishing to breed hold two males, although institutions with one male having problems breeding could experiment with using urine and faeces from other zoos.

If unable to house a minimum herd institutions are encouraged to house surplus animals (probably males) as display, or until required for breeding.

6.7 References

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Appendices (***Demographic data is from North American studbook, Genetic data is from Australasian studbook)***

7.1. Life tables

Males Actual Life table

"Age		"Qx"		Px	""	lx	""	Mx"	"	Risk Qx	"	Risk(Mx)"
0		0.140		0.860		1.000		0.000		143.000		123.700
1		0.050		0.950		0.860		0.000		110.600		107.000
2		0.040		0.960		0.817		0.000		101.100		98.500
3		0.020		0.980		0.784		0.000		109.400		108.400
4		0.010		0.990		0.769		0.000		120.000		119.000
5		0.010		0.990		0.761		0.000		123.500		123.400
6		0.010		0.990		0.753		0.000		122.400		121.400
7		0.010		0.990		0.746		0.010		122.400		122.300
8		0.000		1.000		0.738		0.000		121.700		121.700
9		0.010		0.990		0.738		0.010		117.700		116.900
10		0.010		0.990		0.731		0.030		115.700		115.100
11		0.010		0.990		0.724		0.030		108.400		107.800
12		0.020		0.980		0.716		0.070		104.600		103.800
13		0.000		1.000		0.702		0.060		97.300		97.300
14		0.030		0.970		0.702		0.100		92.400		91.500
15		0.020		0.980		0.681		0.050		86.800		85.900
16		0.000		1.000		0.667		0.080		82.000		82.000
17		0.010		0.990		0.667		0.080		76.700		75.700
18		0.000		1.000		0.661		0.080		70.800		70.800
19		0.040		0.960		0.661		0.070		67.500		66.700
20		0.020		0.980		0.634		0.130		62.700		61.800
21		0.000		1.000		0.622		0.050		59.700		59.700
22		0.000		1.000		0.622		0.100		57.400		57.400
23		0.000		1.000		0.622		0.050		55.400		55.400
24		0.040		0.960		0.622		0.110		53.000		52.100
25		0.000		1.000		0.597		0.060		48.900		48.900
26		0.020		0.980		0.597		0.080		48.000		47.500
27		0.020		0.980		0.585		0.050		47.000		46.100
28		0.000		1.000		0.573		0.040		45.100		45.100
29		0.020		0.980		0.573		0.070		45.000		44.400
30		0.020		0.980		0.562		0.020		42.600		42.300
31		0.050		0.950		0.550		0.090		39.700		38.400
32		0.000		1.000		0.523		0.030		32.800		32.800
33		0.030		0.970		0.523		0.100		31.400		30.700

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34	0.000	1.000	0.507	0.020	27.200	27.200
35	0.050	0.950	0.507	0.070	21.200	21.100
36	0.000	1.000	0.482	0.000	14.800	14.800
37	0.090	0.910	0.482	0.000	11.400	11.100
38	0.110	0.890	0.438	0.000	9.000	8.100
39	0.000	1.000	0.390	0.060	7.700	7.700
40	0.000	1.000	0.390	0.000	7.000	7.000
41	0.000	1.000	0.390	0.000	6.400	6.400
42	0.000	1.000	0.390	0.000	5.000	5.000
43	0.240	0.760	0.390	0.000	4.100	3.100
44	0.000	1.000	0.297	0.000	1.000	1.000
45	0.000	1.000	0.297	0.000	0.700	0.700
46	1.000	0.000	0.297	0.000	0.000	0.000
47	1.000	0.000	0.000	0.000	0.000	0.000

30-day mortality (both sexes): 12.1% (4 of 33 neonates)

r = 0.0044
lambda = 1.0044
T = 21.98
N = 19.00
N(at 20 yrs) = 20.75

Males Model Life table

"Age	Qx	Px	lx	Mx	Vx	Ex	Risk Qx	Risk Mx
0	0.140	0.860	1.000	0.000	1.075	30.483	143.000	123.700
1	0.053	0.948	0.860	0.000	1.192	32.742	110.600	107.000
2	0.038	0.963	0.815	0.000	1.246	33.245	101.100	98.500
3	0.022	0.978	0.784	0.000	1.282	33.247	109.400	108.400
4	0.012	0.988	0.767	0.000	1.302	32.824	120.000	119.000
5	0.010	0.990	0.757	0.000	1.314	32.186	123.500	123.400
6	0.010	0.990	0.749	0.000	1.325	31.501	122.400	121.400
7	0.010	0.990	0.742	0.003	1.335	30.809	122.400	122.300
8	0.010	0.990	0.735	0.008	1.344	30.110	121.700	121.700
9	0.010	0.990	0.727	0.015	1.347	29.404	117.700	116.900
10	0.010	0.990	0.720	0.025	1.342	28.691	115.700	115.100
11	0.010	0.990	0.713	0.038	1.328	27.971	108.400	107.800
12	0.012	0.988	0.706	0.053	1.303	27.277	104.600	103.800
13	0.017	0.983	0.697	0.063	1.267	26.677	97.300	97.300
14	0.020	0.980	0.685	0.070	1.224	26.168	92.400	91.500
15	0.017	0.983	0.671	0.078	1.174	25.649	86.800	85.900

16	0.012	0.988	0.659	0.080	1.111	25.025	82.000	82.000
17	0.010	0.990	0.651	0.080	1.041	24.298	76.700	75.700
18	0.012	0.988	0.644	0.080	0.970	23.563	70.800	70.800
19	0.017	0.983	0.636	0.080	0.901	22.906	67.500	66.700
20	0.015	0.985	0.625	0.080	0.833	22.268	62.700	61.800
21	0.005	0.995	0.616	0.078	0.759	21.484	59.700	59.700
22	0.000	1.000	0.613	0.075	0.682	20.536	57.400	57.400
23	0.000	1.000	0.613	0.073	0.606	19.536	55.400	55.400
24	0.005	0.995	0.613	0.065	0.534	18.582	53.000	52.100
25	0.015	0.985	0.610	0.060	0.472	17.759	48.900	48.900
26	0.020	0.980	0.601	0.058	0.419	17.058	48.000	47.500
27	0.020	0.980	0.589	0.053	0.368	16.385	47.000	46.100
28	0.020	0.980	0.577	0.050	0.321	15.699	45.100	45.100
29	0.020	0.980	0.565	0.050	0.276	14.999	45.000	44.400
30	0.020	0.980	0.554	0.048	0.230	14.285	42.600	42.300
31	0.020	0.980	0.543	0.050	0.186	13.556	39.700	38.400
32	0.020	0.980	0.532	0.053	0.139	12.812	32.800	32.800
33	0.022	0.978	0.521	0.040	0.088	12.069	31.400	30.700
34	0.027	0.973	0.510	0.028	0.049	11.352	27.200	27.200
35	0.035	0.965	0.496	0.018	0.022	10.686	21.200	21.100
36	0.055	0.945	0.478	0.005	0.005	10.140	14.800	14.800
37	0.080	0.920	0.452	0.000	0.000	9.798	11.400	11.100
38	0.068	0.933	0.416	0.000	0.000	9.501	9.000	8.100
39	0.022	0.978	0.388	0.000	0.000	8.909	7.700	7.700
40	0.000	1.000	0.379	0.000	0.000	8.000	7.000	7.000
41	0.000	1.000	0.379	0.000	0.000	7.000	6.400	6.400
42	0.000	1.000	0.379	0.000	0.000	6.000	5.000	5.000
43	0.000	1.000	0.379	0.000	0.000	5.000	4.100	3.100
44	0.000	1.000	0.379	0.000	0.000	4.000	1.000	1.000
45	0.000	1.000	0.379	0.000	0.000	3.000	0.700	0.700
46	0.000	1.000	0.379	0.000	0.000	2.000	0.000	0.000
47	0.250	0.750	0.379	0.000	0.000	1.000	0.000	0.000

r = -0.0020
lambda = 0.9980
T = 21.39
N = 19.00
N(at 20 yrs) = 18.24

Females Actual Life table

"Age	Qx	Px	lx	Mx	Risk Qx	Risk Mx
0	0.140	0.860	1.000	0.000	122.800	107.100
1	0.060	0.940	0.860	0.000	101.600	97.400
2	0.040	0.960	0.808	0.000	113.900	111.600
3	0.040	0.960	0.776	0.000	135.000	132.000
4	0.010	0.990	0.745	0.000	151.400	151.400
5	0.010	0.990	0.738	0.010	153.800	153.000
6	0.010	0.990	0.730	0.010	158.600	157.600
7	0.010	0.990	0.723	0.030	161.700	160.700
8	0.020	0.980	0.716	0.020	166.300	165.700
9	0.000	1.000	0.701	0.040	159.800	159.800
10	0.000	1.000	0.701	0.040	148.000	148.000
11	0.030	0.970	0.701	0.050	140.600	138.600
12	0.030	0.970	0.680	0.050	129.700	128.000
13	0.010	0.990	0.660	0.070	120.900	120.600
14	0.020	0.980	0.653	0.050	114.500	114.100
15	0.000	1.000	0.640	0.050	110.900	110.900
16	0.030	0.970	0.640	0.070	109.300	107.500
17	0.020	0.980	0.621	0.020	101.300	101.000
18	0.030	0.970	0.609	0.060	97.000	95.500
19	0.000	1.000	0.590	0.030	90.300	90.300
20	0.020	0.980	0.590	0.060	88.300	86.800
21	0.010	0.990	0.579	0.030	83.500	82.700
22	0.010	0.990	0.573	0.050	82.000	81.600
23	0.030	0.970	0.567	0.050	79.900	79.300
24	0.000	1.000	0.550	0.050	74.100	74.100
25	0.030	0.970	0.550	0.050	69.600	68.500
26	0.030	0.970	0.534	0.020	66.800	64.900
27	0.050	0.950	0.518	0.040	62.100	59.900
28	0.020	0.980	0.492	0.030	59.000	58.600
29	0.000	1.000	0.482	0.030	58.000	58.000
30	0.050	0.950	0.482	0.060	58.500	56.100
31	0.090	0.910	0.458	0.020	54.800	52.000
32	0.040	0.960	0.417	0.030	47.500	47.300
33	0.070	0.930	0.400	0.040	40.400	39.600

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34	0.000	1.000	0.372	0.020	31.800	31.800
35	0.030	0.970	0.372	0.030	28.700	28.700
36	0.000	1.000	0.361	0.020	23.700	23.700
37	0.000	1.000	0.361	0.000	16.200	16.200
38	0.140	0.860	0.361	0.030	14.500	14.300
39	0.000	1.000	0.310	0.000	8.700	8.700
40	0.000	1.000	0.310	0.000	7.400	7.400
41	0.000	1.000	0.310	0.000	4.200	4.200
42	1.000	0.000	0.310	0.000	0.000	0.000
43	1.000	0.000	0.000	0.000	0.000	0.000
44	1.000	0.000	0.000	0.000	0.000	0.000
45	1.000	0.000	0.000	0.000	0.000	0.000
46	1.000	0.000	0.000	0.000	0.000	0.000
47	1.000	0.000	0.000	0.000	0.000	0.000

30-day mortality (both sexes): 12.1% (4 of 33 neonates)

r = 0.0044
lambda = 0.9833
T = 20.87
N = 20.00
N(at 20 yrs) = 14.28

"Age	Qx	Px	lx	Mx	Vx	Ex	Risk Qx	Risk Mx
0	0.140	0.860	1.000	0.000	1.075	25.914	122.800	107.100
1	0.065	0.935	0.860	0.000	1.180	27.847	101.600	97.400
2	0.045	0.955	0.804	0.000	1.227	28.420	113.900	111.600
3	0.033	0.968	0.768	0.000	1.254	28.529	135.000	132.000
4	0.017	0.983	0.743	0.003	1.264	28.239	151.400	151.400
5	0.010	0.990	0.730	0.008	1.256	27.620	153.800	153.000
6	0.010	0.990	0.723	0.013	1.238	26.888	158.600	157.600
7	0.010	0.990	0.715	0.020	1.216	26.150	161.700	160.700
8	0.007	0.993	0.708	0.030	1.185	25.372	166.300	165.700
9	0.002	0.998	0.703	0.038	1.140	24.495	159.800	159.800
10	0.007	0.993	0.701	0.043	1.089	23.613	148.000	148.000
11	0.022	0.978	0.696	0.048	1.043	22.957	140.600	138.600
12	0.027	0.973	0.680	0.050	1.003	22.519	129.700	128.000
13	0.022	0.978	0.662	0.050	0.960	22.071	120.900	120.600
14	0.020	0.980	0.647	0.050	0.913	21.529	114.500	114.100
15	0.020	0.980	0.634	0.050	0.865	20.948	110.900	110.900
16	0.020	0.980	0.621	0.050	0.817	20.355	109.300	107.500

17	0.020	0.980	0.609	0.050	0.768	19.750	101.300	101.000
18	0.020	0.980	0.596	0.050	0.720	19.133	97.000	95.500
19	0.017	0.983	0.585	0.050	0.671	18.480	90.300	90.300
20	0.012	0.988	0.574	0.050	0.619	17.746	88.300	86.800
21	0.010	0.990	0.567	0.050	0.565	16.937	83.500	82.700
22	0.010	0.990	0.561	0.050	0.511	16.098	82.000	81.600
23	0.015	0.985	0.556	0.050	0.459	15.289	79.900	79.300
24	0.025	0.975	0.548	0.050	0.409	14.580	74.100	74.100
25	0.030	0.970	0.534	0.048	0.363	13.963	69.600	68.500
26	0.030	0.970	0.518	0.040	0.319	13.364	66.800	64.900
27	0.027	0.973	0.502	0.033	0.283	12.731	62.100	59.900
28	0.022	0.978	0.488	0.030	0.252	12.032	59.000	58.600
29	0.027	0.973	0.477	0.030	0.224	11.314	58.000	58.000
30	0.043	0.958	0.464	0.030	0.197	10.687	58.500	56.100
31	0.050	0.950	0.445	0.030	0.172	10.156	54.800	52.000
32	0.048	0.953	0.422	0.030	0.147	9.626	47.500	47.300
33	0.040	0.960	0.402	0.030	0.120	9.021	40.400	39.600
34	0.025	0.975	0.386	0.028	0.091	8.292	31.800	31.800
35	0.007	0.993	0.377	0.023	0.064	7.413	28.700	28.700
36	0.000	1.000	0.374	0.020	0.040	6.438	23.700	23.700
37	0.000	1.000	0.374	0.015	0.020	5.438	16.200	16.200
38	0.000	1.000	0.374	0.005	0.005	4.438	14.500	14.300
39	0.000	1.000	0.374	0.000	0.000	3.438	8.700	8.700
40	0.000	1.000	0.374	0.000	0.000	2.438	7.400	7.400
41	0.250	0.750	0.374	0.000	0.000	1.643	4.200	4.200
42	0.750	0.250	0.280	0.000	0.000	1.200	0.000	0.000
43	1.000	0.000	0.070	0.000	0.000	1.000	0.000	0.000
44	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
45	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
46	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
47	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

r = -0.0180
lambda = 0.9822
T = 20.80
N = 20.00
N(at 20 yrs) = 13.95

7.2. Genetic Analysis

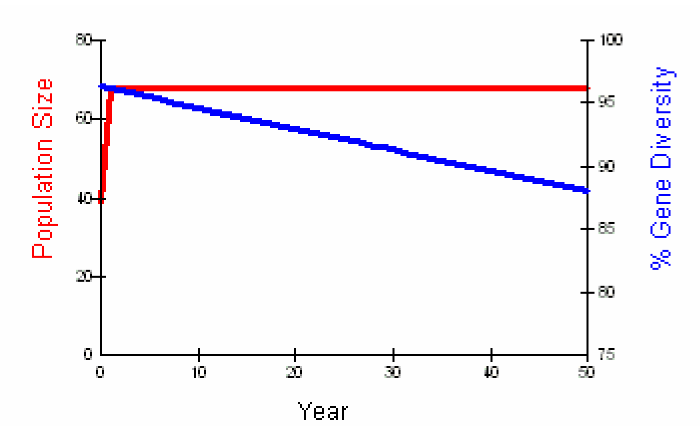
Founders = 33
Potential Founders = 7 additional

Living Descendants = 23.00
Percent Known = 100.0
GD = 0.9663
Potential GD = 0.9825
GV = 0.9669
fge = 14.85
Potential fge = 28.56
Founder Genomes Surviving = 18.06
Potential Founder Genomes Surviving = 28.56
Mean F = 0.0000

Genetic goals

Program Objectives: 90% Gene Diversity at the end of 50 years
Can maintain 90% Gene Diversity for 22 years
Goal Not Possible - Can Only Maintain 83.66%

Other variables:
Generation Length = 15.0000
Current Population Size = 39.0000
Current Effective Size = 10.9000
Ratio of Ne/N = 0.2800
Current Gene Diversity = 0.9663
Maximum Allowable Population Size = 68.0000
Population Size Needed to Meet Goals = 68.0000



7.4. Individuals used in analysis

Studbook #" "Sex" "Sire" "Dam" "Age" "Location" "Vx" "% Known" "F" "MK" "KV" "GU - All" "GU - Descend" "Prob Lost" "FOKE" "# Offspring" "Local ID" "Additional Identifiers"	
1266 "F" "WILD" "WILD" 20 "WERRIBEE " 0.62 100.0 0.0000 0.0109 0.0121 0.5000 -1.0000 0.2540 1.00 1 990034 "Make"	
1265 "M" "WILD" "WILD" 16 "WERRIBEE " 1.22 100.0 0.0000 0.0217 0.0245 0.2475 -1.0000 0.0657 2.00 3 990033 "Umgana"	
1273 "M" "WILD" "WILD" 15 "AUCKLAND " 1.26 100.0 0.0000 0.0000 0.0000 1.0000 -1.0000 0.1754 0.00 0 990099 "Kruger"	
1432 "M" "WILD" "WILD" 15 "DUBBO " 1.26 100.0 0.0000 0.0000 0.0000 1.0000 -1.0000 0.1754 0.00 0 "A20086" "Khulu 43-2678-7D4F 41 R"	
1427 "M" "WILD" "WILD" 13 "MONARTO " 1.35 100.0 0.0000 0.0000 0.0000 1.0000 -1.0000 0.1532 0.00 0 "A29072" "Satara Et33 434C40604A"	
1267 "F" "WILD" "WILD" 12 "WERRIBEE " 1.02 100.0 0.0000 0.0217 0.0245 0.2605 -1.0000 0.0892 2.00 2 990035 "Letaba"	
1356 "M" "WILD" "WILD" 12 "HAMILTON " 1.40 100.0 0.0000 0.0217 0.0263 0.2455 -1.0000 0.0490 2.00 2 990082 "Zambese"	
1429 "M" "WILD" "WILD" 11 "DUBBO " 1.41 100.0 0.0000 0.0000 0.0000 1.0000 -1.0000 0.1423 0.00 0 "A20083" "Umfana 31 R 43-2715-7B3C"	
1430 "F" "WILD" "WILD" 11 "DUBBO " 1.06 100.0 0.0000 0.0109 0.0128 0.5000 -1.0000 0.1371 1.00 1 "A20084" "Umqali 36 R 43-2700-376D"	
1357 "F" "WILD" "WILD" 10 "HAMILTON " 1.10 100.0 0.0000 0.0000 0.0000 1.0000 -1.0000 0.2184 0.00 0 990083 "Moesha"	
1428 "F" "WILD" "WILD" 10 "DUBBO " 1.10 100.0 0.0000 0.0109 0.0113 0.5000 -1.0000 0.1338 1.00 1 "A20082" "Aluka 32 R 43-273B-6038"	
1358 "F" "WILD" "WILD" 9 "HAMILTON " 1.16 100.0 0.0000 0.0217 0.0263 0.2490 -1.0000 0.0696 2.00 2 990084 "Caballe"	
1426 "F" "WILD" "WILD" 9 "MONARTO " 1.16 100.0 0.0000 0.0000 0.0000 1.0000 -1.0000 0.2014 0.00 0 "A29071" "Mopani Et 18 43262E2F1A"	

1431 "F" "WILD" "WILD" 8 "DUBBO " 1.18 100.0 0.0000 0.0109 0.0113 0.5000 -1.0000 0.1187 1.00 1 "A20085" "Intombi 40 R 43-2469-1352"	
1282 "F" "WILD" "WILD" 7 "PERTH " 1.22 100.0 0.0000 0.0000 0.0000 1.0000 -1.0000 0.1854 0.00 0 990647 "Katala"	
1283 "F" "WILD" "WILD" 7 "PERTH " 1.22 100.0 0.0000 0.0109 0.0128 0.5000 -1.0000 0.1097 1.00 1 990646 "Sabie"	
541 "M" 52 159 26 "AUCKLAND " 0.55 100.0 0.0000 0.0489 0.0321 0.3050 0.3050 0.2121 4.50 0 "ME3279" "Mandhla"	
600 "M" 70 106 24 "WERRIBEE " 0.70 100.0 0.0000 0.0217 0.0147 1.0000 1.0000 0.3790 2.00 0 810003 "Lee"	
801 "M" 195 342 22 "ORANA " 0.83 100.0 0.0000 0.0394 0.0340 0.4915 0.4915 0.1815 3.62 0 531 "Nyasa Stumpy"	
820 "F" 52 159 21 "ORANA " 0.56 100.0 0.0000 0.0544 0.0393 0.1580 0.1580 0.1434 5.00 1 280 "Utani"	
821 "F" 52 147 21 "ORANA " 0.56 100.0 0.0000 0.0408 0.0258 0.5675 0.5675 0.3013 3.75 0 279 "Mapenzi"	
823 "M" 52 277 21 "TIPP STAT" 0.88 100.0 0.0000 0.0408 0.0307 0.5610 0.5610 0.1984 3.75 0 840002 "Nakili"	
871 "F" 195 121 19 "WERRIBEE " 0.66 100.0 0.0000 0.0380 0.0294 0.5610 0.5610 0.2519 3.50 0 890109 "Likwezi"	
921 "M" 390 391 18 "ORANA " 1.08 100.0 0.0000 0.0326 0.0370 0.5000 0.5000 0.1284 3.00 1 609 "Cyrano"	
897 "M" 180 182 18 "TIPP STAT" 1.08 100.0 0.0000 0.0217 0.0228 1.0000 1.0000 0.2225 2.00 0 870001 "Star"	
914 "M" 40 397 17 "PERTH " 1.15 100.0 0.0000 0.0326 0.0371 0.5000 0.5000 0.1196 3.00 1 900013 "Memphis"	
1268 "F" "P1266" 1266 9 "WERRIBEE " 1.16 100.0 0.0000 0.0217 0.0243 0.5000 1.0000 0.1433 2.00 1 990036 "Sisi Cee Cee"	
1156 "M" 343 907 9 "WERRIBEE " 1.41 100.0 0.0000 0.0231 0.0306 0.9365 0.9365 0.1362 2.13 0 970061 "Kapamba"	
1100 "F" 0319 1097 9 "MONARTO " 1.16 100.0 0.0000 0.0217 0.0243 1.0000 1.0000 0.2014 2.00 0 "A09118" "Uhura"	
1281 "M" 921 820 5 "ORANA " 1.35 100.0 0.0000 0.0544 0.0523 0.0000 0.0000 0.0362 5.00 0 990023 "Ibutho"	
1353 "F" "P1274" 1274 5 "AUCKLAND " 1.25 100.0 0.0000 0.0217 0.0263 1.0000 1.0000 0.1762 2.00 0 100047 "Kito"	
1409 "M" 1356 1358 3 "HAMILTON " 1.30 100.0 0.0000 0.0326 0.0400 0.0000 0.5055 0.0169 3.00 0 100262 "Inkosi"	
1454 "M" 1265 1267 2 "WERRIBEE " 1.26 100.0 0.0000 0.0326 0.0378 0.0000 0.4920 0.0225 3.00 0 "A20060" "Ganini Public Darcyjr In House"	
1436 "F" 914 1283 2 "PERTH " 1.22 100.0 0.0000 0.0326 0.0378	

0.0000 0.5000 0.0357 3.00 0 "A20623" "Storm (in House) Tamu (public)"	
1434 "F" "P1430" 1430 2 "DUBBO " 1.22 100.0 0.0000 0.0217 0.0256 0.5000 1.0000 0.1134 2.00 0 "A30052" "Azizi"	
"T150" "M" 1356 1358 1 "HAMILTON " 1.20 100.0 0.0000 0.0326 0.0389 0.0000 0.5055 0.0192 3.00 0 "______" "Mtoto"	
"T152" "M" 1265 1267 0 "WERRIBEE " 1.08 100.0 0.0000 0.0326 0.0358 0.0000 0.4920 0.0278 3.00 0 "A40044" "Swazi"	
"T151" "F" 195 1431 0 "DUBBO " 1.08 100.0 0.0000 0.0380 0.0360 0.0575 0.5575 0.0532 3.50 0 "A50007" ""	
"T153" "F" 195 1428 0 "DUBBO " 1.08 100.0 0.0000 0.0380 0.0360 0.0650 0.5650 0.0575 3.50 0 "A50013" ""	